Database Development, Hydrologic Budget and Nutrient Loading Assumptions for the "Method for Assessment, Nutrient-loading, And Geographic Evaluation of Nonpoint Pollution" (MANAGE) Including the GIS-Based Pollution Risk Assessment Method

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Outline of the functions of the MANAGE AML

The AML automates the data collection process for the MANAGE Excel Model. Data exported by the AML may be directly imported into the MANAGE Model.

Input coverages utilized by the MANAGE AML:

WATERSHED BOUNDARY COVERAGE – study area boundary outline (watershed, subwatershed, wellhead protection area, or aquifer recharge area).
LAND USE COVERAGE
SOILS COVERAGE
SEWER LINE COVERAGE
HYDRO_LINE COVERAGE (streams and small rivers)
HYDRO_POLY COVERAGE (lakes and large rivers)

Coverages produced and used by the MANAGE AML:

LU = Land use coverage
SLS = Soils coverage
SEW = Sewer line coverage
BASIN = Watershed boundary coverage
HP = Hydro_poly coverage
HL = Hydro_line coverage
SHEDLU = Land use clipped by watershed/study area boundary.
SHEDSLS = Soils clipped by watershed/study area boundary.
LUSL = Land use and soils intersected.
SHEDHL = Hydrolines (rivers and streams) clipped by watershed/study area boundary.
SHEDHP = Hydropolys (pond and large rivers) clipped by watershed/ study area boundary.
SHEDHYDRO = Data from hydrolines and hydropolys joined (appended) together to create a coverage of all surface water features.
SHEDSEW = Sewer Lines (if specified) clipped by watershed/study area boundary.
SHEDSEW_AREA = Buffered sewer lines.
SHED_UNSEW = Land use and soils in watershed/study area that is unsewered.
SHEDRA1 = Buffer of shedhydro coverage (all surface waters). The value used to buffer the coverage (in feet) is provided by the user.

Coverages produced and used by the MANAGE AML (continued):

SHEDRA = Buffered shedhydro coverage (all surface waters) with area of surface waters removed. The value used to buffer the coverage (in feet) is provided by the user. This coverage defines the riparian area.
SHEDRA_LUSL = Land use and soils in riparian areas.
SHEDRA_UNSEW = Land use and soils in riparian areas that are unsewered.

Files created by the MANAGE AML that are utilized by the MANAGE excel spreadsheet:

SW_ALL.CSV = Land use and soils data for watershed/study area
SW_UNSEW.CSV = Land use and soils for the unsewered portion of the watershed/study area
SWRA_ALL.CSV = Land use and soils in riparian areas
SWRA_UNS.CSV = Land use and soils in riparian areas in the unsewered portion of the watershed/study area.

Steps completed by the MANAGE AML:

1. User enters the location of the LAND USE COVERAGE and the file is re-named LU.
2. User enters the location of the SOILS COVERAGE and the file is re-named SLS.
3. User enters the location of the SEWER LINE COVERAGE (if there is one) and the file is re-named SEW.
4. User enters the SEWER LINE BUFFER WIDTH (default value = 500 ft).
5. User enters the location of the WATERSHED BOUNDARY COVERAGE and the file is re-named BASIN.
6. User enters the location of the HYDRO-POLY COVERAGE and the file is re-named HP.
7. User enters the location of the HYDRO-LINE COVERAGE and the file is re-named HL.
8. User enters the WIDTH OF THE RIPARIAN AREA (default value = 200 feet)
9. The coverages listed below are clipped with the BASIN coverage.
    a. LU clipped and new coverage is named: SHEDLU.
    b. SLS clipped and new coverage is named: SHEDSLS.
    c. SEW clipped and new coverage is named: SHEDSEW.
    d. HL clipped and new coverage is named: SHEDHL.
    e. HP clipped and new coverage is named SHEDHP.
10. SHEDLU and SHEDSLS are intersected to create a new coverage: LUSL.
11. The following fields are added to LUSL:
    i. "ACRES" – Area of polygon in acres
    ii. "CE-ID" – Cooperative Extension Land Use Codes used in MANAGE (see Appendix A).
    iii. "IMPERV" – % Impervious surface based on CE-ID field (See Appendix H)
    iv. "CE_SHWT" – Seasonal High Water Table (SHWT) code based on soil type (see Appendix A).
    v. "ERODIBLE" – Erosion potential of soil based on soil type (see Appendix A).
    vi. "EXCESS_PERM" – Excessively permeable soils are identified based on soil type (see Appendix A)
    vii. "PARENT_MATERIAL" – Parent material of the soils are identified based on soil type (organic, outwash, ablation till, etc.) (refer to Appendix A).
    viii. "RESTLAY" – Identify restrictive layers based on soil type (refer to Appendix G).
12. Calculates ACRES of each polygon in LUSL.

13. Selects LULS and loads data into fields just added:
    i. Field CE-SHWT = “U”
    ii. Field ERODIBLE = “N”
    iii. Field EXCESS_PERM = ‘N”
    iv. Field PARENT_MATERIAL = “other”
    v. Field RESTLAY = “N”
    vi. Field IMPERV = 0
14. Aggregates land use codes (CODE95) into CE-ID categories. This reduces the number of land use categories (see Appendix A for the aggregate categories).
15. Selects the field SOIL-NAME and adds the appropriate information to the following fields based on soil type: CE_SHWT, EXCESS_PERM, PARENT_MATERIAL, RESTLAY, ERODIBLE (see Appendix A). This action modifies the data input under step 13 for the given fields. Any soils within the soils coverage that are not listed in Appendix A retain the value loaded under step 13.
16. Loads values into field IMPERV based on CE-ID (see Appendix H).
17. Appends HYDROPOLY and HYDROLINES into one coverage (SHEDHYDRO).
18. SHEDHYDRO is buffered by the value input by the user and the buffer saved to file SHEDRA1
19. Adds the field “RADONUT” to SHEDRA1.
20. Removes the areas of surface waters found in SHEDHP from the buffer file SHEDRA1 creating a new file SHEDRA.
21. Deletes SHEDRA1.
22. Selects SHEDRA and adds the field “RADONUT” and makes it equal to “inside”.
23. Intersects SHEDRA and LUSL to create the file SHEDRA_LUSL.
24. If there isn’t a sewer coverage: Then
    i. Copies LUSL to SHED_UNSEW.
    ii. Copies SHEDRA_LUSL to SHEDRA_UNSEW.
    iii. Adds the field “SEWDONUT” to SHED_UNSEW.
    iv. Adds the field “SEWDONUT” to SHEDRA_UNSEW.
    v. Selects SHED_UNSEW and sets “SEWDONUT” equal to 1.
    vi. Selects SHEDRA_UNSEW and sets “SEWDONUT “equal to 1.
25. If there is a sewer coverage then:
    i. Buffers the sewer coverage by the user specified value creating the file SHEDSEW_AREA.
    ii. Adds a field to SHEDSEW_AREA called “SEWDONUT”.
    iii. Sets the field “SEWDONUT” equal to “inside”
26. Intersects (identity) SHEDRA_LUSL and SHEDSEW_AREA to create SHEDRA_UNSEW
27. Intersects LUSL and SHEDSEW_AREA to create SHED_UNSEW
28. Recalculates polygon areas in acres for SHED_UNSEW, SHEDRA_UNSEW and SHEDRA_LUSL.
29. The data is then run through the frequency command to compile the data according to land use/soils and then converted into a .csv format

Documentation of MANAGE Excel Model

The MANAGE Excel Model is organized into five sections:

1) Data Input. The model requires the data listed below. Data may be input from the MANAGE AML export files or from another database.
    a. Land use and soils data for watershed/study area
    b. Land use and soils for the unsewered portion of the watershed/study area
    c. Land use and soils in riparian areas
    d. Land use and soils in riparian areas in the unsewered portion of the watershed/study area.
2) Best Management Practices (BMP's). This section allows the user to specify various existing or proposed BMP's. Possible BMP's include stormwater management options, alternatives to standard septic systems, reduced imperviousness through creative design and methods to improve lawn and agricultural management.

3) Data Processing and Refinement. These sections process the input data and allows the user to add site-specific information, if it is available. Also in this section, model assumptions are stated (such as runoff coefficient values) and the user is given the opportunity to change them. Care should be taken when modifying assumptions to be sure that the selected values are realistic.
4) Calculations. Runoff, nutrient loading, and recharge calculations are completed in this section.
5) Summary. Results are summarized and graphs are generated.

Basic Calculations Completed by MANAGE Excel Model:

1. Calculate runoff from study area based on the lumped sum method

   Volume of runoff from study area to surface receiving water = Total volume
   Total Volume = Σ Runoff from all soil and land use types = (Precipitation) X (Area of Soil/Land use Combination) X (Runoff coefficient for soil/Land use combination) X (Conversion factor)

   BMPs are applied where appropriate

2. Calculate infiltration to groundwater

   V(infil) = V(PPT) - V(surface RO) - V(ET)

   V(infil) = Volume of infiltration
   V (PPT) = Volume of precipitation
   V (surface RO) = Volume of surface runoff
   V(ET) = Volume of evapotranspiration (defined previously)

3. Calculate the Phosphorus and Nitrogen Loading to surface water using the lumped sum method

   Total P load from watershed = Σ over all soil and Land Use combinations =
   = (Area of each soil/land use combination) X ((Loading factor for each soil/land use combination)

   BMPs are applied where appropriate as well as contributions from malfunctioning septic systems via overland flow, with a higher loading from those within riparian areas and point sources.

4. Calculate Nitrogen loading to groundwater reservoir by taking the sum of nitrogen sources listed below:

   a. Approximate number of unsewered dwellings in watershed.
   b. Approximate number of occupants/dwelling, adjusted for seasonal occupancy. (Weiskel and Howes (1991) found water use records better reflected occupancy than did assuming an average number of people/dwelling unit. However, summer water use can go up as a result of several factors, not just population increase. These include filling swimming pools and watering lawns. Garbage collection might be a better indicator. Currently 1990 RI Census data (see Appendix F) and input from local government officials is used to estimate occupancy rates.
   c. Approximate contribution from all septic systems.
   d. Approximate total fertilized lawn area and fertilized agricultural areas in watershed.
   e. Approximate contribution from pets in residential areas.
   f. Approximate contribution from stormwater runoff infiltration from unfertilized pervious areas.
   g. Applying BMPs where appropriate.

5. Review results.

   Generally, after completing the model for current conditions in a study are the inputs are modified to reflect several future build-out scenarios chosen by the community, based on such factors as zoning. This may include BMP’s, as well as projected point sources.

APPENDIX A: LAND USE AND SOILS DESIGNATIONS

TABLE A1: RIGIS code and corresponding MANAGE Nutrient Loading Model Land Use Designations

RIGIS Code	RIGIS Category	Explanation	MANAGE Category
111	High Density Residential	> 8 dwelling units/acre (1/8 acre lot)	HDR
112	Medium High Density Residential	4 to 7.9 units/acre (1/4 acre lot)	MHDR
113	Medium Density Residential	1 to 3.9 units/acre (1 acre lot)	MDR
114	Medium Low Density Residential	0.5 to 0.9 units/acre (2 acre lot)	MLDR
115	Low Density Residential	< 0.5 units/acre (> 2 acre lot)	LDR
120	Commercial & Services	Sale of products and services	COMMERCIAL
130	Industrial	Manufacturing, design and assembly, finishing, etc. industrial parks	INDUSTRIAL
141	Roads	Divided Highways	ROADS
142	Airports	Runways, terminals, parking	AIRPORTS
143	Railroads	Terminals, parking repair areas	RAILROADS
144	Water and Sewage Treatment Facilities	Land and associated buildings	INSTITUTION
145	Waste Disposal Areas	Active landfills and junkyards	JUNKYARDS
146	Power Lines	Rights-of-way of 100 feet or more	PASTURE
147	Other	Water-based transportation facilities, commercial docks	COMMERCIAL
150	Mixed Urban	Light industrial/commercial uses that cannot be separated	COMMERCIAL
161	Developed Recreation	Urban parks, zoos, stadiums, golf courses, playfields, marinas	RECREATION
162	Urban Open Space	Vacant land	RECREATION
163	Cemeteries		RECREATION
170	Institutional	Educational, health, correctional, religious, military, etc.	INSTITUTION
210	Pasture	Hay fields, land not suitable for tillage	PASTURE
220	Cropland	Intensively farmed and tillable lands	CROPLAND
230	Orchards, Groves, Nurseries		ORCHARDS
240	Confined Feeding Operations	Animal raising in confined areas	CROPLAND
250	Idle Agriculture	Abandoned fields and orchards, etc.	BRUSH
310	Deciduous Forest	80% or greater deciduous species	FOREST

RIGIS Code	RIGIS Category	Explanation	MANAGE Category
320	Evergreen Forest	80% or greater evergreen species	FOREST
330	Mixed-Deciduous	50-80% deciduous dominant	FOREST
340	Mixed-Evergreen	50-80% evergreen dominant	FOREST
400	Brushland	Shrub and brush areas, cut over areas undergoing reforestation	BRUSH
500	Water	Reservoirs, lakes, ponds	WATER
600	Wetland	Forested and non-forested areas	WETLAND
710	Beaches		BARREN
720	Sandy Areas other than Beaches		BARREN
730	Rock Outcrop		BARREN
740	Strip Mines, Quarries, Gravel Pits		BARREN
750	Transitional Areas		Assigned to MD Res. Unless otherwise specified
760	Mixed Barren		BARREN

TABLE A2: MANAGE Land Use Aggregations based on RIGIS Codes and High Intensity Land Use Designations

MANAGE Code	MANAGE Category	RIGIS Category and Code	High Intensity Land Use[1]	Land Use Legend Category[2]
1	HDR	High Density Residential (111)	X	High – Medium High Density Residential
2	MHDR	Medium High Density Residential (112)	X	High – Medium High Density Residential
3	MDR	Medium Density Residential (113)		Medium – Medium Low Density Residential
4	MLDR	Medium Low Density Residential (114)		Medium – Medium Low Density Residential
5	LDR	Low Density Residential (115)		Low Density Residential
6	COMMERCIAL	Commercial & Services (120)	X	Commercial or Industrial
		Other (147)	X	Commercial or Industrial
		Mixed Urban (150)	X	Commercial or Industrial
7	INDUSTRIAL	Industrial (130)	X	Commercial or Industrial
8	ROADS	Roads (141)	X	Transportation
9	AIRPORTS	Airports (142)	X	Transportation
10	RAILROADS	Railroads (143)	X	Transportation
11	JUNKYARDS	Waste Disposal Areas (145)	X	Waste Disposal
12	RECREATION	Developed Recreation (161)		Institutional, Developed Recreation, Cemetery
		Urban Open Space (162)		Vacant Land (Urban)
		Cemeteries (163)		Institutional, Developed Recreation, Cemetery
13	INSTITUTION	Water and Sewage Treatment Facilities (144)	X	Water/Sewage Treatment
		Institutional (170)	X	Institutional, Developed Recreation, Cemetery
14	PASTURE	Power Lines (146)		Pasture,Idle Agriculture or Power Lines
		Pasture (210)		Pasture,Idle Agriculture or Power Lines
15	CROPLAND	Cropland (220)	X	Cropland, Orchards and Nurseries
		Confined Feeding Operations (240)	X	Cropland, Orchards and Nurseries

MANAGE Code	MANAGE Category	RIGIS Category and Code	High Intensity Land Use[1]	Land Use Legend Category[2]
16	ORCHARDS	Orchards, Groves, Nurseries (230)	X	Cropland, Orchards and Nurseries
17	BRUSH	Idle Agriculture (250)		Pasture,Idle Agriculture or Power Lines
		Brushland (400)		Forest and Brushland
18	FOREST	Deciduous Forest (310)		Forest and Brushland
		Evergreen Forest (320)		Forest and Brushland
		Mixed-Deciduous (330)		Forest and Brushland
		Mixed-Evergreen (340)		Forest and Brushland
19	BARREN	Beaches (710)		Sandy/Beaches
		Sandy Areas other than Beaches (720)		Sandy/Beaches
		Rock Outcrop (730)		Quarries and Outcrop
		Strip Mines, Quarries, Gravel Pits (740)		Quarries and Outcrop
		Mixed Barren (760)		Quarries and Outcrop
20	WETLAND	Wetland (600)		Wetland or Water
21	WATER	Water (500)		Wetland or Water
22	Assigned to MD Res. Unless otherwise specified	Transitional Areas (750)		Transitional (Manage assigns to Med Density Res.)

Notes:
[1]The high intensity land use designation is utilized in MANAGE to designate land use types that have a greater potential pollution load. The designations as presented above were used in the SWAP reports.

[2]Land use aggregates generally utilized in legend for mapping land use data. Color scheme is provided below. The legend and instructions for use are provided for download on the RI NEMO web-site (http://www.uri.edu/ce/wq/NEMO/Tools/mapping.htm). Note that high intensity land use designation does not correspond directly to the land use legend categories.

Legend

High-Medium High Density Residential	Cropland, Orchards and Nurseries
Medium - Medium Low Density Residential	Forest and Brushland
Low Density Residential	Sandy/Beaches
Commercial or Industrial	Quarries and Outcrop
Transportation	Water/Sewage Treatment
Waste Disposal	Vacant Land (Urban)
Institutional, Developed Recreation, Cemetary	Transitional (Manage assigns to Med Density Res.)
Pasture,Idle Agriculture or Power Lines	Wetland or Water

TABLE A3: Hydrologic Soil Groups of Rhode Island Soils Used in MANAGE
(Source: MANAGE AML and RIGIS Attribute Tables)

Abbreviation	Soil Name	Parent Material	SHWT	Excessive Permeable	Restrictive Layer	Erodible	RIGIS – Soil Hydro Group
Aa	Adrian	Organic	S				D
Af	Agawam	Outwash	D	Y			B
Bc	Birchwood	Lodgement Till	M		Y		C
Bh	Bridgehampton	Outwash	D	Y			B
Bm, Bn, Bo	Bridgehampton-Charlton Complex	Ablation Till	D				B
Br, Bs	Broadbrook	Lodgement Till with Eolian Mantle	D		Y		C
CB, CC, Ca	Canton and Canton-Charlton Complex	Ablation Till	D			Y	B
Cd, Ce, Ch, Ck	Canton-Charlton Complex	Ablation Till	D			Y	B
Co	Carlisle	Organic	S				D
Dc	Deerfield	Outwash	M	Y			B
Ef	Enfield	Outwash with an Eolian Mantle	D	Y			B
GB, Gh	Gloucester Complexes	Ablation Till	D	Y		Y	GB =B Gh = A
Hk, Hn	Hinckley & Hinckley Enfield Complex	Outwash	D	Y		Y	Hk =A Hn = B
Ip	Ipswich	Organic	S				D
Lg	Lippitt	Ablation Till	D	Y	Y		C
Ma, Mc	Mansfield	Lodgement Till	S		Y		D
Mk	Matunuck	Organic	S				D
Mm, MU	Merrimac	Outwash	D	Y			A
Na, Nb, Nc	Narragansett	Ablation Till	D				B
Ne, Nf, No	Newport	Lodgement Till	D		Y	Y	C
NP	Newport		D		Y		C
Nt	Ninigret	Outwash	M	Y			B
Pa, Pb, Pc	Paxton	Lodgement Till	D		Y		C
PD	Paxton		D		Y		C
Pm, Pn	Pittstown	Lodgement Till	M		Y		C
Pp	Pootatuck	Alluvial	M				B
Ps	Poquonock	Lodgement till with Sandy mantle	D		Y		C
Qo	Quonset	Outwash	D	Y			A
Ra, Rb	Rainbow	Lodgement till with eolian mantle	M		Y		C

Abbreviation	Soil Name	Parent Material	SHWT	Excessive Permeable	Restrictive Layer	Erodible	RIGIS – Soil Hydro Group
Rc	Raypol	Outwash with Eolian Mantle	S	Y			C
Re, Rf	Ridgebury	Lodgement Till	S		Y		C
Ru	Rippowam	Alluvial	S				C
Sb	Scarboro	Outwash	S	Y			D
Sc, Sd	Scio	Ablation Till with Eolian Mantle	M				B
Se, Sf	Stissing	Lodgement Till	S		Y		C
Ss	Sudbury	Outwash	M				B
St, Su, Sv	Sutton	Ablation Till	M				B
Tb	Tisbury	Outwash	M	Y			B
Wa	Walpole	Outwash	S				C
Wb, Wc, Wd	Wapping	Ablation Till with Eolian Mantle	M				B
Wg	Windsor	Outwash	D	Y			A
Wh, Wo, Wr	Woodbridge	Lodgement Till	M		Y		C

Notes:

1. If a soil type is present but not listed in this table then MANAGE assigns the following default values to the soil type: SHWT = U, Erodible = N, Excessively Permeable = N, Parent Material = Other and Restrictive Layer = N

2. All soils data in Table A3 are coded into the MANAGE AML, except for Hydro-Group. Hydro-group is defined in the imported RIGIS soils data. The Hydro-Group data listed in the above table is for the RIGIS 1996 soils data layer.

3. SHWT depth, Excessive Permeable, Restrictive Layer and Erodible data from Tables 25 and 26, Soil Survey of Rhode Island, Rector 1981. Restrictive soils are considered those with a permeability of <0.2 in/hr at approximately 20 to 60 inches in depth.

4. Seasonal High Water Table (SHWT) Terms Definition

SHWT	Depth to SHWT	
S	Shallow	0-1.5 ft.
M	Moderate	1.5 – 3.5 ft.
D	Deep	> 6 ft.
U	Unknown	

5. Often in the MANAGE analysis soil hydrogroup is combined with Seasonal High Water Table (SHWT) to produce graphics depicting areas with poor drainage and high water table. Soil hydrogroup is a term that defines soil permeability. Hydrogroup A soils are rapidly permeable and hydrogroup D soils are wetland soils that are very slow to drain. SHWT is defined in note 3 (above).

   The poor drainage/high water table graphic is created by combining soil hydrogroup and SHWT based on the table and legend pallet below. Soil hydrogroup information is contained in the RIGIS soils shapefile or coverage. An additional table is available from RI NEMO that contains the needed data on SHWT for each soil type. A complete description of the procedure to produce the poor drainage/high water table graphic is provided here:

i. Obtain the RIGIS soils shapefile or coverage. This shapefile contains a field "Hydro_group", which contains the soils hydrogroup information. If you have run the MANAGE aml, the output file "lusl" contains the proper data to create the drainage/high water table graphic, skip to step 3.

ii. Information on SHWT must be added to the RIGIS soils shapefile. If you have run the MANAGE aml, this information will already be present in the file "lusl", and you can skip this step. If you have not run the MANAGE aml either:
   a. Add a text field to the RIGIS soils shapefile, name the field CE_SHWT and then populate the field with SHWT data located in Table A3 (Hydrologic soil groups of Rhode Island soils used in MANAGE) or,
   b. Obtain the soils join table from RI NEMO and join this table to the RIGIS soils shapefile based on soil abbreviation. This data is available from the RI NEMO website at: http://www.uri.edu/ce/wq/NEMO/Tools/mapping.htm

iii. Add a field to the RIGIS soils shapefile or the file "lusl" and name it "CE_Soils". The added field should be designated for text. Using the "calculate values" function (right click on the new field) add Hydro_group to CE_SHWT. The resulting values should look like: AD, DS, etc. The first letter should indicate Hydro_group and the second letter CE_SHWT.

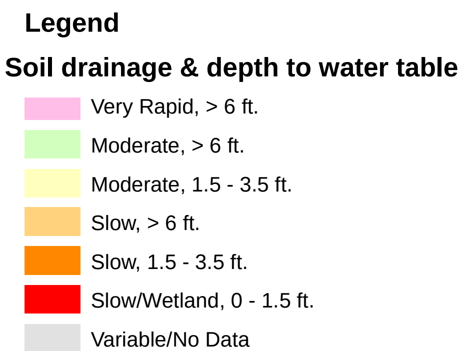
iv. Once the new field "CE_Soils" has been calculated, either code the shapefile legend based on the information below in step 5 or obtain the layer file from RI NEMO that already contains the legend information (ManageSoilsLegend.lyr). With the ESRI upgrade from ArcView 3 to ArcView 9 avl files were no longer supported, therefore all legend information is contained in layer files. If you use the RI NEMO layer file, simply change the data reference in the layer file to your file and the layer should update automatically.

v. Otherwise, in the attribute table properties under symbology click on "unique value" then group each of the Hydro_group + CE_SHWT combinations as shown in the table below:

Hydro_group + CE_SHWT	**Category/Description**
AD, AU	Very rapid, >6 ft.
BD	Moderate, > 6 ft.
BM	Moderate, 1.5-3.5 ft.
CD	Slow, > 6 ft.*
CM	Slow, 1.5-3.5 ft.
CS, DS	Slow/Wetland, 0-1.5 ft.
0U, CU, DU, VariableU	Variable/No Data

*Note: Many soils mapped as hydrogroup C with a SHWT greater than 6 feet are likely to have a higher SHWT when located in lodgement till parent material.

vi. The soil drainage and depth to watertable groups are displayed using the legend as shown below.



APPENDIX B: SURFACE RUNOFF COEFFICIENTS

The runoff coefficient for each Soil/Land use combination is estimated using the formula presented by Adamus and Bergman (1993). This calculation is presented below.

C = LLC + (ULC - LLC) * X

C = runoff coefficient
LLC = lower limit runoff coefficient for a particular land use
ULC = upper limit runoff coefficient for a particular land use
X = 0 for soil type A; 1/3 for soil type B; 2/3 for soil type C; 1 for soil type D.

TABLE B1: Upper and Lower Limit Runoff Coefficients for each Soil/Land use combination

	Reference Values		Calculated Runoff Coefficient (C) Based on Soil Hydrogroup			
Land Use	**LLC**	**ULC**	**A**	**B**	**C**	**D**
HDR[a]	0.37	0.55	0.37	0.43	0.49	0.55
MHDR[a]	0.18	0.37	0.18	0.24	0.31	0.37
MDR[a]	0.15	0.18	0.15	0.16	0.17	0.18
MLDR[a]	0.12	0.15	0.12	0.13	0.14	0.15
LDR[a]	0.11	0.12	0.11	0.11	0.12	0.12
COMMERCIAL[b]	0.5	0.85	0.50	0.62	0.73	0.85
INDUSTRIAL[b]	0.5	0.85	0.50	0.62	0.73	0.85
ROADS[a]	0.7	0.82	0.70	0.74	0.78	0.82
AIRPORTS[a]	0.7	0.82	0.70	0.74	0.78	0.82
RAILROADS[a]	0.7	0.82	0.70	0.74	0.78	0.82
JUNKYARDS[a]	0.7	0.82	0.70	0.74	0.78	0.82
RECREATION[b]	0.1	0.3	0.10	0.17	0.23	0.30
INSTITUTION[c]	0.33	0.39	0.33	0.35	0.37	0.39
PASTURE[d]	0.05	0.25	0.05	0.12	0.18	0.25
CROPLAND[d]	0.15	0.5	0.15	0.27	0.38	0.50
ORCHARDS[d]	0.05	0.25	0.05	0.12	0.18	0.25
BRUSH[b]	0	0.1	0.00	0.03	0.07	0.10
FOREST[d]	0	0.1	0.00	0.03	0.07	0.10
BARREN[b]	0.05	0.8	0.05	0.30	0.55	0.80
WETLAND[e]	0	0.1	0.00	0.03	0.07	0.10
WATER	1	1	1.00	1.00	1.00	1.00

Notes:

[a] Calculation of ULC and LLC for Residential is based on Schueler's (1987) Simple Method:
C = 0.05 + 0.9 I
I = fraction of site imperviousness (e.g. 30% impervious would have I = 0.3)

The percentage of site imperviousness for each land use is provided in Appendix H. The fraction of site imperviousness (I) for the calculation of residential ULC and LLC was set at the updated MANAGE values (2003) for site impervious surface. The ULC for each residential land use was set as the residential LLC of the more intense residential development (ie: the ULC for MHDR is set as the LLC for HDR). The fraction of impervious surface for roads, airports, railroads and junkyards was set at theTR55 value for industrial to determine the ULC and commercial to determine the LLC.

[b] Based on data presented by Novotny and Olem (1994), p. 146.

[c] Assuming INSTITUTION is hydrologically similar to MHDR, unless otherwise specified by the user.

[d] Based on best professional judgement, using Curve Number Method as a guide.

[e] Generally WETLANDS will occur on D soils. It is assumed that wetlands are similar to forests on D soils, and for this reason wetlands are set using the same coefficients as the FOREST category.

[f] It is assumed that Evapotranspiration and surface runoff will vary through the year.

APPENDIX C: TOTAL PHOSPHORUS EXPORT COEFFICIENTS TO SURFACE WATER

Because phosphorus tends to adsorb to soil particles, little phosphorus reaches surface waters via groundwater seepage. Instead, the majority of phosphorus is transported to a receiving water body by runoff from rainfall events (some adsorbed to eroding soil, some in dissolved form). Additional phosphorus reaches surface water through overland flow of septic system effluent from malfunctioning septic systems throughout the watershed. The load from those malfunctioning septic systems located immediately adjacent (the riparian areas, assumed to be within 200 feet in this model or a user specified value) to the receiving water body is assumed to be higher than from those located farther away from surface waters. The relatively short distance and travel time from the riparian area septic systems to the surface water provides little or no opportunity for infiltration and adsorption of phosphorus to occur. Phosphorus loading from malfunctioning septic systems is calculated separately (Appendix G). The phosphorus loading factors listed below include contributions from diverse sources such as atmospheric deposition, fertilizers, and small animal waste. The loading factors on surface water reflect direct atmospheric deposition only.

Using a similar formula to that used to calculate the runoff coefficient, a "most likely" phosphorus export coefficient for a particular land use is calculated for each SOIL/LAND USE combination as:

$$PC = LPC + (HPC - LPC)*X$$

PC = "most likely" phosphorus export coefficient
LPC = low phosphorus export coefficient for a particular land use
HPC = high phosphorus export coefficient for a particular land use
X = 0 for soil type A; 1/3 for soil type B; 2/3 for soil type C; 1 for soil type D.

TABLE C1: Total Phosphorus Export Loading Coefficients (lb/acre/yr) for Each Soil/Land use Combination

	Reference Values		**Calculated Runoff Coefficient (C) Based on Soil Hydro Group**			
LAND USE CATEGORY	**LPC[a]**	**HPC[a]**	**A**	**B**	**C**	**D**
HDR[b]	2.1	3.1	2.1	2.4	2.8	3.1
MHDR[b]	1.0	2.1	1.0	1.4	1.7	2.1
MDR[b]	0.8	1.0	0.8	0.9	0.9	1.0
MLDR[b]	0.7	0.8	0.7	0.7	0.8	0.8
LDR[b]	0.6	0.7	0.6	0.6	0.7	0.7
COMMERCIAL	1	2.5	1.0	1.5	2.0	2.5
INDUSTRIAL	1	3.5	1.0	1.8	2.7	3.5
ROADS[c]	1	3.5	1.0	1.8	2.7	3.5
AIRPORTS[c]	1	3.5	1.0	1.8	2.7	3.5
RAILROADS[c]	1	3.5	1.0	1.8	2.7	3.5
JUNKYARDS[c]	1	3.5	1.0	1.8	2.7	3.5
RECREATION	0.5	1.5	0.5	0.8	1.2	1.5
INSTITUTION[d]	1.0	2.1	1.0	1.4	1.7	2.1
PASTURE[e]	0.3	1	0.3	0.5	0.8	1.0
CROPLAND[f]	0.5	4.5	0.5	1.8	3.2	4.5

	Reference Values		**Calculated Runoff Coefficient (C) Based on Soil Hydro Group**			
LAND USE CATEGORY	**LPC[a]**	**HPC[a]**	**A**	**B**	**C**	**D**
ORCHARDS	0.4	2	0.4	0.9	1.5	2.0
BRUSH	0.1	0.2	0.1	0.1	0.2	0.2
FOREST	0.1	0.2	0.1	0.1	0.2	0.2
BARREN	0.1	0.2	0.1	0.1	0.2	0.2
WETLAND	0	0	0.0	0.0	0.0	0.0
WATER[g]	0.3	0.3	0.3	0.3	0.3	0.3

[a] These phosphorus export coefficients were selected based on literature reviews by Rast and Lee (1983), Frink (1991), and Budd and Meals (1994), and by considering values given by RIDEM(1993b), Novotny and Olem (1994), and Stigall and others (1993), followed by discussions with Arthur J. Gold at the University of Rhode Island and with Kris Stewart at the Natural Resources Conservation Service of the United States Department of Agriculture

[b] Based on RIDEM (1993b) and assuming 45 inches of precipitation annually (Allen and others, 1966).

[c] Assuming these land uses are similar to INDUSTRIAL land use.

[d] Assuming INSTITUTION is similar to MHDR land use, unless otherwise specified by the user.

[e] If pasture is grazed, or if manure is applied, values will be higher (Reckhow and others (1980) show rotational grazing 0.9 lb/ac/yr; continuous grazing or forage fertilized 3.5 lb/ac/yr (p. 60, 97))

[f] Assuming no conservation tillage or terracing. If BMP's are in place, they will be applied.

[g] Atmospheric deposition only. Some authors (e.g., Reckhow and others (1980) and Horsley & Witten (1994)) suggest 3 different loading rates to the surface of a water body, depending upon the dominant land use in the watershed: forest, agricultural/rural, urban.

Loading from malfunctioning residential septic systems in the unsewered portion of the watershed is calculated as follows:

Septic systems within the 200 ft riparian buffer:

> See Appendix G for the proportion of total number of septic systems which malfunction. The total phosphorus loading from malfunctioning riparian septic systems (within 200 ft of surface water) is set at 2.3 lb/cap/yr (15 mg/l and 50 gpd). If it assumed that there is 2.4 cap/residential septic system (1990 RI Census) then there is 5.5 lb P/malfunctioning residential septic system within the 200 ft. buffer.

Septic systems outside the riparian areas:

> See Appendix G for proportion of total number of septic systems which malfunction. The total phosphorus loading from malfunctioning septic systems outside the riparian area is set at 1.15 lb/cap/yr. If it is assumed that there is a 2.4 cap/residential septic system (1990 RI Census), this comes to 2.8 lb P/malfunctioning residential septic system outside the 200 ft. buffer.

Note: Background concentration of P in RI Surface Water (no human influence) is ~ 5-10 ppb per Linda Green, URI Watershed Watch.

APPENDIX D: TOTAL NITROGEN EXPORT COEFFICIENTS TO SURFACE WATER

Although nitrogen is generally not considered to be the limiting nutrient in fresh water systems, it has been found to be the nutrient promoting growth of algae and aquatic plants in coastal waters. In order to estimate the total load of nitrogen reaching a coastal embayment, both contributions from surface runoff, as well as from groundwater seepage must be estimated. The surface runoff contribution of nitrogen can be calculated the same way as the phosphorus contribution (Appendix C). Like phosphorus, nitrogen can be transported from malfunctioning septic systems via overland flow to the receiving surface water. Estimation of the nitrogen load from malfunctioning septic systems is done in the same way as estimation of the phosphorus load, using soil properties and increasing the nitrogen loading for systems located within the riparian areas. The nitrogen loading factors listed below include contributions from diverse sources such as atmospheric deposition, fertilizers, and small animal waste. The loading factors on surface water reflect direct atmospheric deposition only. Using a similar formula to that used to calculate the runoff coefficient, a "most likely" nitrogen export coefficient for a particular land use is calculated for each SOIL/LAND USE combination as:

$$NC = LNC + (HNC - LNC) * X$$

NC = "most likely" nitrogen export coefficient
LNC = low nitrogen export coefficient for a particular land use
HNC = high nitrogen export coefficient for a particular land use
X = 0 for soil type A; 1/3 for soil type B; 2/3 for soil type C; 1 for soil type D.

TABLE D1: Total Nitrogen Export Loading Coefficients (lb/acre/yr) for each Soil/Land use Combination

	Reference Values		Calculated Runoff Coefficient (C) Based on Soil Hydro Group			
LAND USE CATEGORY	**LNC[a]**	**HNC[a]**	**A**	**B**	**C**	**D**
HDR[b]	7	10.2	7.0	8.1	9.1	10.2
MHDR[b]	3.3	7	3.3	4.5	5.8	7.0
MDR[b]	2.8	3.3	2.8	3.0	3.1	3.3
MLDR[b]	2.3	2.8	2.3	2.5	2.6	2.8
LDR[b]	2.1	2.3	2.1	2.2	2.2	2.3
COMMERCIAL	2	20	2.0	8.0	14.0	20.0
INDUSTRIAL	2	15	2.0	6.3	10.7	15.0
ROADS[c]	2	20	2.0	8.0	14.0	20.0
AIRPORTS[c]	2	20	2.0	8.0	14.0	20.0
RAILROADS[c]	2	20	2.0	8.0	14.0	20.0
JUNKYARDS[c]	2	20	2.0	8.0	14.0	20.0
RECREATION	1.5	4	1.5	2.3	3.2	4.0
INSTITUTION[d]	3.3	7	3.3	4.5	5.8	7.0
PASTURE[e]	2	5.5	2.0	3.2	4.3	5.5
CROPLAND[f]	4	50	4.0	19.3	34.7	50.0
ORCHARDS	4	35	4.0	14.3	24.7	35.0

	Reference Values		Calculated Runoff Coefficient (C) Based on Soil Hydro Group			
LAND USE CATEGORY	**LNC[a]**	**HNC[a]**	**A**	**B**	**C**	**D**
BRUSH	0.9	2.9	0.9	1.6	2.2	2.9
FOREST	0.9	2.9	0.9	1.6	2.2	2.9
BARREN	0.9	2.9	0.9	1.6	2.2	2.9
WETLAND	0	0	0.0	0.0	0.0	0.0
WATER[g]	8	8	8.0	8.0	8.0	8.0

[a] These nitrogen export coefficients were selected based on literature reviews by Rast and Lee (1983), Frink (1991), and Budd and Meals (1994), and by considering values given by RIDEM(1993b), Novotny and Olem (1994), and Stigall and others (1993), followed by discussions with Arthur J. Gold at the University of Rhode Island

[b] Based on RIDEM (1993b) and assuming 45 inches of precipitation annually (Allen and others, 1966).

[c] Assuming these land uses are similar to COMMERCIAL land uses.

[d] Assuming INSTITUTION is similar to MHDR land use, unless otherwise specified by the user.

[e] If pasture is grazed, or if manure is applied, values will be higher (Reckhow and others (1980) show rotational grazing 7.0 lb/ac/yr; continuous grazing or forage fertilized 27.0 lb/ac/yr (p. 60, 97))

[f] Assuming no conservation tillage or terracing. If BMP's are in place, they will be applied.

[g] Atmospheric deposition only based on northeastern U.S. (Ollinger et al. 1993 and Yang 1996). Some authors (e.g., Reckhow and others (1980) and Horsley & Witten (1994)) suggest 3 different loading rates to the surface of a water body, depending upon the dominant land use in the watershed: forest, agricultural/rural, urban.

Loading from malfunctioning residential septic systems in the unsewered portion of the watershed is calculated as follows:

Septic systems within the 200 ft riparian buffer:

> See Appendix G for the proportion of total number of septic systems which malfunction. The total nitrogen loading from malfunctioning riparian septic systems (within 200 ft of surface water) is set at 7.0 lb/cap/yr. If it assumed that there is 2.4 cap/residential septic system (1990 RI Census) then there is 16.8 lb N/malfunctioning residential septic system within the 200 ft. buffer.

Septic systems outside the riparian areas:

> See Appendix G for proportion of total number of septic systems which malfunction. The total nitrogen loading from malfunctioning septic systems outside the riparian area is set at 5.6 lb/cap/yr. If it is assumed that there is a 2.4 cap/residential septic system (1990 RI Census), this comes to 13.4 lb N/malfunctioning residential septic system outside the 200 ft. buffer.

Note:
Background concentration of N in RI Surface Water (no human influence) is ~ 0.25 ppm based on sampling from ponds whose watersheds are subject to little human influence (data from Watershed Watch 1994, Linda Green).
[Art Gold suggests 0.2 to 0.35 mg/l].

APPENDIX E: NITRATE-NITROGEN LOADING TO GROUNDWATER

The long-term water quality of an aquifer can be inferred from the quality of the recharge water (Hantzsche and Finnemore, 1992). Using a mass-balance approach, the average concentration of nitrate found in the infiltrating recharge water can be estimated by dividing the total N loading from various and diverse land use above the aquifer by the recharge volume from precipitation and such artificial sources as septic systems (similar to Frimpter and others (1990); Horsley & Witten (1994); and several other models). There are many complex mechanisms in the nitrogen cycle which are not directly accounted for. However, because nitrate-nitrogen generally behaves conservatively once it reaches the water table, some simplifying assumptions can be made.

$$\text{Average N concentration} = \frac{\text{Annual N load from diverse land uses}}{\text{Annual recharge (natural + septic systems)}}$$

Sources of nitrogen to groundwater include:

i. Septic systems
ii. Lawn fertilizers
iii. Agricultural fertilizers
iv. Large animals (cows, horses)
v. Pet waste
vi. Stormwater infiltration

Sources of recharge include:

i. Precipitation
ii. Septic systems

A) LOAD

Calculate total annual nitrogen load to groundwater, based on land use:

1. Septic systems:

Estimate the total number of residential septic systems in unsewered areas based on housing density. Commercial, Industrial, and Institution areas are all treated as MDR.

Assumptions:
2.4 cap/dwelling unit (Appendix F).
7 lb N/person/yr leaves the septic tank.
50 gal/person/day.
90% of N leaches to the groundwater (Siegrist and Jenssen, 1989).

In Rhode Island where conventional ISDS are typically buried deeper, and gravel fill is brought in, 90% may be a more accurate estimate. This is supported by Lamb and others, 1988).

If only RIGIS land use data is available, estimate the number of homes based on the residential land use category, excluding areas served by sewer systems (see table below). MANAGE assumes a 100% occupancy rate, to determine the worst potential impact (this may not be appropriate for all watersheds).

Table E1: Estimation of the Number of Septic Systems per Acre Based on Land Use

Land Use	Mean Dwelling Unit Density (unit/acre) (Number of Septic Systems/acre)	Assumptions
HDR	8.00	
MHDR	3.60	
MDR	1.00	
MLDR	0.50	
LDR	0.20	
Other:		
COMMERCIAL	1.00	Assume these are similar to MD Residential. Also, we
INDUSTRIAL	1.00	Assume that septic system use in recreational areas is
RECREATION	0.50	Seasonal (6 months out of the year).
INSTITUTION	1.00	

2. Lawns

Estimate lawn area in watershed:

Table E2: Estimation of the Fraction of Lawn Area Associated with Each Land use

Land Use	Fraction of Land Use Attributed to Lawn Area
HDR	0.25
MHDR	0.35
MDR	0.50
MLDR	0.35
LDR	0.25
COMMERICAL	0.05
INDUSTRIAL	0.10
RECREATION	0.70
	(golf courses to be estimated separately)
INSTITUTION	0.25

Assumptions: 75% of residents apply lawn fertilizer.
Fertilizer is applied at a rate of 175 lb N/ac/yr (4 lb/1000 sq. ft./yr)
Leaching rate is 6%, yielding a load of 10.5 lb N/ac/yr leached to the groundwater.
(most models use significantly higher leaching rates (30 to 60 %); a lower estimate is used here due to low leaching rates found by Gold and others (1990), and Morton and others (1988) in Rhode Island outwash soils, and assuming some mismanagement, such as over-watering, bare spots, compacted soil, and improper fertilizer application.

3. Agriculture (CROPLAND and ORCHAR land use)

Assume a fertilizer application rate of 215 lb N/ac/yr, 30% of which leaches to the groundwater.

4. Pet Waste in Residential Areas

0.41 lb N/person/yr is assumed to leach to the groundwater from pet waste. (Koppleman, 1978)

5. Forests and Unfertilized Lawns

Gold and others (1990) show a loading of 1.2 lb/ac/yr from forest (FOREST, PASTURE and BRUSH land use) and unfertilized lawn (unfertilized lawn area = 25% of total lawn area).

B) RECHARGE

Calculate total annual groundwater recharge, based on land use:

1) Natural recharge:

Average annual infiltration = Annual precipitation - Annual ET - Annual RO

I. Average annual precipitation = 45 inches (Allen and others, 1966)
II. Average annual evapotranspiration (ET) = 18 inches (Johnston and Dickerman, 1985)
III. Average annual run off (RO) is calculated from runoff coefficients for each land use category.
Annual RO = (Annual PPT)*(RO coefficient (C))

Wetlands represent a complex system of interaction between surface and groundwater. It is assumed that there is no runoff from a wetland area. The equation above then implies that wetlands recharge 27 inches to groundwater, which is almost never the case. It is assumed that groundwater generally flows into wetlands, rather than water from wetlands percolating to groundwater. If this assumption is made the total area of wetlands in the watershed X 27 inches must be subtracted from the total volume of average annual recharge to groundwater.

2) Recharge from septic systems

Recharge from septic systems = (total # of septic systems) (2.4 cap/dwelling) (50 gal/cap/day) (365 days/yr)

APPENDIX F: 1990 RI CENSUS FIGURES

	Number persons/dwelling unit[a]	Vacancy Rate[b]
State of RI	2.6	8.8%
Bristol County	2.6	5.4%
Kent County	2.6	5.2%
Newport County	2.5	12.8%
Providence County	2.5	6.9%
Washington County	2.6	21.2%

[a] Based on number of occupied (vs. vacant) dwelling units. Does not include seasonally occupied dwelling units.
[b] Vacancy rate includes seasonally occupied dwelling units.
Source: 1990 Census Data from RI Department of Administration, One Capitol Hill, Providence, RI 02908.
Note: We will use 2.6 persons/dwelling unit. The two counties, Newport and Providence, with an average of 2.5 persons/dwelling unit (reflecting a higher number of apartments, which tend to have fewer occupants) are heavily sewered. Occupancy rates may be further refined using US Census block data and building permits.
[c] Values for occupancy rate are often adjusted in the MANAGE model based on the input of local officials and the census figures.

APPENDIX G: CALCULATION OF POTENTIAL SEPTIC SYSTEM MALFUNCTION

The number of septic systems estimated to malfunction throughout the unsewered portion of the watershed will be based on the soil on which they are sited. A malfunctioning system is defined as a system that produces surface ponding, leakage of septic effluent or improper treatment with lack of separation distance to groundwater. Malfunction of conventional septic systems is likely if they are sited in soils with a permeability of < 0.2 in/hr at a depth of about 20 to 60 inches, these soils are termed restrictive. Restrictive Rhode Island soils include:

Birchwood	Poquonock
Broadbrook	Rainbow
Lippitt	Ridgebury
Mansfield	Newport
Stissing	Paxton
Woodbridge	Pittstown

Of the restrictive soils, seven have a high water table (depth to groundwater of 3.5 feet or less) and six of those with high water table have a perched water table. Eleven of the twelve soils are in hydrologic soil group C and one is in hydrologic soil group D (Mansfield).

Table G1: SUMMARY OF PROPERTIES OF "RESTRICTIVE" SOILS (Source: Tables 25 and 26 from Rector, 1981)

Soil Name (Hydro Group)	Depth (inches) at which Permeability < 0.2 in/hr	High Water Table Depth (ft)	Water Table Type	Months with High Water Table
Birchwood (C)	24-60	1.5-3.5	Perched	Nov-Apr
Broadbrook (C)	36-60	>6		
Lippitt (C)	20-40 (BEDROCK)	>6		
Mansfield (D)	15-60	0.0-0.5	Apparent	Nov-Jul
Newport (C)	24-60	>6		
Paxton (C)	23-60	>6		
Pittstown (C)	28-60	1.5-3.0	Perched	Nov-Apr
Poquonock (C)	28-60	>6		
Rainbow (C)	23-60	1.5-3.5	Perched	Nov-Apr
Ridgebury (C)	20-60	0.0-1.5	Perched	Nov-May
Stissing (C)	15-60	0.0-1.5	Perched	Oct-May
Woodbridge (C)	32-60	1.5-3.0	Perched	Nov-Apr

Because of the limitations just described, the proportion of septic systems sited in these soils which are assumed to malfunction will be set at 65%. For septic systems sited in all other soils, the failure rate will be assigned by hydrologic soil group:

Table G2: Septic System Malfunction Rate for Non-restrictive Soils

Soil Hydro Group	Malfunction Rate
A & B	10%
C	30%
D	50%

The user can change these failure rates if necessary. These percentages are based on Nizeyimana and others (1996).

Due to uncertainties in this function it is rarely utilized in MANAGE analysis, mapping is often used instead of this function to determine areas at risk for septic system failure.

The proportion of nutrients present in the septic tank effluent that eventually reach the receiving water body depends upon whether the malfunctioning system is within the 200 ft. riparian area. Within the riparian area, we will assume that 100% of the phosphorus and nitrogen leaving the malfunctioning septic system will reach the receiving water. Outside the buffer, 50% of the phosphorus and 80% of the nitrogen is assumed to reach the surface water. The likelihood of some treatment occurring during percolation after leaving the malfunctioning septic system increases with distance from the surface water. The higher loading rate of 80% for nitrogen is used because the typical nitrogen removal rate for a functioning conventional septic system is 20% (Siegrist and Jenssen, 1989), so this is the best that could realistically be expected from a malfunctioning system.

Table G3: Amount of Nitrogen and Phosphorus Estimated to Reach a Receiving Water Body Based on Location

Nutrient Load Leaving Septic Tank	Nutrient Load Reaching Surface Water Body	
	For Systems in the 200 ft riparian buffer	For Systems outside the 200 ft riparian buffer
7.0 lb N/cap/yr	7.0 lb N/cap/yr (100%)	5.6 lb N/cap/yr (80%)
2.3 lb P/cap/yr	2.3 lb P/cap/yr (100%)	1.15 lb P/cap/yr (50%)

(See Appendix I for a summary of values and their sources on which these numbers are based)

APPENDIX H: IMPERVIOUSNESS OF DEVELOPED LAND

Table H1: Estimated Percent Impervious Surface for Land Use Used in SWAP Report (Original MANAGE Impervious Values)

Land Use	Low	High	Original Values used in MANAGE (and SWAP reports)
	Estimated % Impervious		
HDR[a]	65	80	72
MHDR[a]	38	65	50
MDR[a]	20	38	30
MLDR[a]	12	20	16
LDR[a]	5	12	8
COMMERCIAL[b]	50	94	72
INDUSTRIAL[b]	50	94	72
ROADS[c]	72	85	72
AIRPORTS[c]	72	85	72
RAILROADS[c]	72	85	72
JUNKYARDS[c]	72	85	72
RECREATION	5	28	10
INSTITUTION[d]	38	65	50

Notes:
[a] Based on estimate of impervious fraction used in TR55 (1975).
[b] Calculated from low and high runoff coefficients estimated from Novotny and Olem (1994), p. 146.
[c] Based on TR55. Low is that of Industrial and high is commercial.
[d] Assuming INSTITUTION is hydrologically similar to MHD residential, unless otherwise specified by the user.

Table H2: Updated Estimated Percent Impervious Surface for Land Use Used in MANAGE

Land Use Category	TR 55 USDA	New Jersey DEP[a]	Center for Watershed Protection[b]	Value Used in MANAGE [c] (updated 2003)
	Estimated Site Impervious (%)			
HDR (1/8 acre lot)	65	59	33	55
MHDR (1/4 acre lot)	38	39	28	36
1/3 acre lot	30	34		
1/2 acre lot	25	27	21	
MDR (1 acre lot)	20	18	14	14
MLDR (2 acre lot)	12	12	11	11
LDR (> 2 acre lot)		9.6		9
AGRICULTURE			2	
OPEN URBAN			9	
TOWN HOUSE			41	
MULTIFAMILY			44	
COMMERCIAL	85		72	72
INDUSTRIAL	72		53	54
ROADS			80	72
AIRPORTS				72
RAILROADS				72
JUNKYARDS				72
RECREATION				10
INSTITUTION			34	34

[a] New Jersey DEP
[b] CWP 2002. The Watershed Treatment Model. Ellicott City MD. www.stormwatercenter.net
[c] Values for impervious surface are in the MANAGE code.

APPENDIX I: SEPTIC SYSTEM PARAMETERS

		SOURCE
Residential Wastewater Flow	66 gal/cap/day	Brown and Assoc. (1980)
	45 gal/cap/day	USEPA (1980)
	45 gal/cap/day	Canter and Knox (1985)
	65 gal/cap/day	Frimpter and others (1990)
	33.8 gal/cap/day (=128 liters)	Gold and others (1990)
	45 gal/cap/day (=170 liters)	Postma and others (1992)
	55 gal/cap/day	Horsley & Witten (1994)
	45 - 60 gal/cap/day	RIDEM (Galen Howard, 1995)
Number of people/dwelling	3.5 cap/dwelling	Brown and Assoc. (1980)
	2.7 cap/dwelling	Valiela and Costa (1988)
	3.0 cap/dwelling	Buzzards Bay Project (1990)
	2.7 cap/dwelling	Frimpter and others (1990) (as cited in Weiskel and Howes (1991)
	3.0 cap/dwelling	Horsley & Witten (1994)
Phosphorus in effluent	16.4 mg/l (mean from lit review) (3.3 lb/cap/yr @ 66 gcd)	Brown and Assoc. (1980)
	3 - 5 g/cap/day (in wastewater)	USEPA (1980)
	18 - 29 mg/l (in wastewater)	USEPA (1980)
	15 mg/l (2 lb/cap/yr @ 45 gcd)	Canter and Knox (1985)
	1.4 kg/cap/yr (3.1 lb/cap/yr)	Valiela and Costa (1988)
	1.45 kg/cap/yr (3.2 lb/cap/yr)	Olem and Flock (1990)
	13 mg/l (1.8 lb/cap/yr @ 45 gcd)	Postma and others (1992)
	0.5 - 1.5 kg/system/yr (1.1 - 3.3 lb/system/yr)	Budd and Meals (1994)
	7 - 40 mg/l	Budd and Meals (1994)
	3.2 lb/cap/yr	Horsley & Witten (1994)
Nitrogen in effluent	44.6 mg/l (mean from lit review)	Brown and Assoc. (1980)
	11.2 g/cap/day (9 lb/cap/yr)	Brown and Assoc. (1980)
	6 - 17 g/cap/day (in wastewater)	USEPA (1980)
	35 - 100 mg/l (in wastewater)	USEPA (1980)
	[USEPA assumes 10% removal in septic tank; Gold and others (1990) found up to 21% removal]	
	40 mg/l (5.5 lb/cap/yr @ 45 gcd)	Canter and Knox (1985)
	3.8 kg/cap/yr (8.4 lb/cap/yr)	Valiela and Costa (1988)
	6.72 lb/cap/yr	Buzzards Bay Project (1990)
	40 mg/l (Nitrate-N) (includes 5 mg/l background concentration)	Frimpter and others (1990)
	5 lb/cap/yr	Frimpter and others (1990)
	3.1 kg/cap/yr (7 lb/cap/yr)	Gold and others (1990)
	30 - 60 mg/l	Budd and Meals (1994)
	33.9 mg/l (WHPA) (5.7 lb/cap/yr @ 55 gcd)	Horsley & Witten (1994)

	40 mg/l (6.7 lb/cap/yr @ 55gcd)	(Buttermilk Bay)
	30 - 80 mg/l	RIDEM (Galen Howard, 1995)
	5 - 10 lb/cap/yr	RIDEM (Galen Howard, 1995)
	59.3 mg/l (8 lb/cap/yr @ 45 gcd)	Gold (unpublished?)
Conversion to Nitrate during infiltration		
	50%	RIDEM
	100%	Frimpter and others (1990)

OTHER sources of effluent (e.g. Commercial, Institution, etc.) are described in Tables 4-6 to 4-8 in USEPA (1980)

APPENDIX J: BEST MANAGEMENT PRACTICES (BMP'S)

The MANAGE model assumes that no BMP's are applied unless they are specified by the user. There are many and varied methods which are used to reduce pollutant loadings to water resources. Five general categories of BMP's are available in MANAGE:

1) Agricultural Management: conservation techniques such as cover crops, terracing, reduced tillage, improved nutrient (fertilizer) management.

2) Lawn Management: improved lawn maintenance, including improved fertilizer management, as well as avoiding overwatering, and reducing bare spots and compaction.

3) Stormwater Management: Water quality enhancement basins, which follow Rhode Island Dept. of Environmental Management design guidelines. Basins which were designed only for flood control generally do not meet this specification.

4) Imperviousness Reduction through Creative Design: Landscape design using cluster developments, shared parking, etc.

5) Septic System (On-Site Sewage Disposal System, or OSDS) Alternatives:
    a) On-site denitrification systems (alternative to the conventional OSDS)
    b) Improved maintenance (frequent pumping), regular inspection to reduce failure
    c) Sewering

Agricultural Management

Table J1: Reductions in Surface Runoff, Phosphorus and Nitrogen by Agricultural BMPs

BMPs	Reduction to Surface Water (%)	Reduction to Groundwater (%)	Literature Source
Cover crops Reduced tillage Diversions and swales Terraces Filter strips Nutrient management[a]	20% Surface Runoff 20% TP 20% TN	20% TN	Representative value based on data presented in Pennsylvania State University, 1992, and on estimates from USDA, NRCS and URICE.

There is a wide variation in the possible nutrient loading reductions due to varying methods, as well as soil type, topography, etc.

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[a]The amount of fertilizer applied to agricultural areas may be reduced in Section 3 of the MANAGE model (Data Processing and Refinement), but doing so will give reductions only in nitrogen leaching to groundwater and will apply to all cropland and orchards. Applying agricultural BMP's and reducing the fertilizer applied in Section 3 is invalid, because reductions will be taken in two places for only one BMP.

Lawns

Table J2: Reductions in Surface Runoff, Phosphorus and Nitrogen by Lawn Care BMPs

BMPs	Reduction to Surface Water (%)	Reduction to Groundwater (%)	Literature Source
Reduced fertilizer applications Reduced occurrence of overwatering Mower height at 2-3” Use of slow release fertilizers Leave clippings on the lawn	Unknown	80% TN	Morton and others (1988)

Stormwater Management

Table J3: Reduction in Surface Runoff, Phosphorus and Nitrogen by Stormwater Management BMPs

BMPs	Reduction to Surface Water (%)	Reduction to Groundwater (%)	Literature Source
Wet Basins Extended Detention Ponds Infiltration Practices Basins, trenches, dry wells Vegetated Filter Strips Grassed Swales	With maintenance 80% TSS 45% TP 45% TN Without maintenance Unknown TSS 10% TP 10% TN	Increased risk of TN leaching to groundwater, depending upon type of management	Representative values based on data presented in USEPA, 1993

Note:

Any chosen method must comply with RIDEM guidelines for water quality enhancement basin design.

Creative Land Development Design

Table J4: Reduction in Surface Runoff, Phosphorus and Nitrogen by Creative Land Development Design

BMPs		Literature Source
Creative Landscaping to reduce imperviousness, e.g. shared parking, use of geotextiles, cluster developments	20% reduction in impervious areas (therefore reduction in surface runoff and nutrient loading)	City of Olympia, 1996

Septic Systems

Table J5: Reduction in Surface Runoff, Phosphorus and Nitrogen by Alternative/Innovative Septic Systems

BMPs		Literature Source
Denitrification Systems	50% TN reduction to groundwater	Siegrist and Jenssen, 1989
Improved Maintenance	Eliminate failures	
Sewering	Eliminate leakage failures	

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