

**MANAGE: a Method for Assessment, Nutrient-loading, And Geographic Evaluation  
of Nonpoint Pollution**

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GIS Coverages: BOUNDARY OUTLINE (Surface Watershed, Wellhead Zone Of Contribution, WHPA,  
or Aquifer)

LAND USE

SOILS

SEWERS

COMMUNITY WATER SUPPLY WELLS

PUBLIC WATER SYSTEMS

POLITICAL BOUNDARIES

ROADS

BUFFERED SURFACE WATERS (100 ft. buffer for surface contribution, 150 ft. buffer in  
areas prescribed by planners for BMP's, call them BUFFERP and BUFFERB).

A. Prepare coverages for analysis, using ARC/INFO:

(Note: Much of this can be done with an ARC/INFO command file which is currently  
being developed).

1. CLIP with BOUNDARY OUTLINE (and sub-watershed boundaries)

LAND USE

SOILS

SEWERS

PUBLIC WATER SYSTEMS

COMMUNITY WATER SUPPLY WELLS

POLITICAL BOUNDARIES

ROADS

Create BUFFERP (100 ft. buffer on surface water), BUFFERB (150 ft. for BMP's) by  
buffering HYDROGRAPHY coverage (surface water).

2. Aggregate LAND USE to selected land use categories (SUBAPPENDIX A).

3. Aggregate SOILS to selected soil hydrologic groups (A, B, C, D). -- SOILHG

4. Aggregate SOILS to "Restrictive", "Non-restrictive": A+B, C, D (SUBAPPENDIX G). -- SOILPS

5. INTERSECT newly created SOILHG and LAND USE coverages.

6. INTERSECT newly created SOILPS and LAND USE coverages.

7. CLIP SOILPS/LAND USE with BUFFERP -- create RIPARPS.

8. CLIP SOILHG/LAND USE with BUFFERB -- create LUBMP.

9. BUFFER SEWERS coverage (line coverage) with 100 ft. to create a polygon coverage, SEWERP.

10. CLIP SOILPS/LAND USE and RIPARPS with SEWERP.

11. Use PUBLIC WATER SYSTEMS to determine areas using private wells.

12. Use COMMUNITY WATER SUPPLY WELLS to assess extent of possible hydrologic interaction  
with receiving water of interest.

13. Use TOWN BOUNDARIES, ROADS when creating maps as visual aids.

B. Create maps and tables of current status of watershed using ARC/VIEW.

1. INVENTORY existing land uses which serve as nutrient load reducers (e.g. existing forested  
buffers). Give user positive feedback for currently existing valuable resources. Treat  
existing forested buffers as BMP's when calculating loading.

2a. QUERY user for more information on ambiguous or high risk land uses:

Agriculture (Cropland/Pasture/Orchard) - does the breakdown shown by RIGIS reflect  
current usage? Are large animals present (dairy farms, horses)?

Pasture - grazing? If so, what seasons? Manure applied? If so, when?

Show photos illustrating high and low ranges.

Orchards and Groves vs. Nurseries -- growing fruit vs. growing trees (diff. fert.  
practices)

Are there any turf farms? These should be treated differently from row crops.

Institutional (e.g., approximate # of people, type of institution)

Commercial

Industrial

Waste Disposal

Sewage Treatment Plants - leaks?

Number of aging septic systems (> 20 years old), and any known failures or failure rates? Assign proportion of septic systems which malfunction based on hydrologic soil group ("restrictive", "non-restrictive: A+B, C, D; see SUBAPPENDIX G for definitions).

Point Sources of P

Point Sources of N

Possibly include contributions from the process of developing land (one year pulse): Novotny and Olem (1994) give 23 kg P/ha/yr and 63 kg N/ha/yr exported by runoff from developing urban land (p. 450). I'm in the process of looking at other sources as well.

Other nonpoint sources of P and N(e.g. large flock of ducks or geese (>100 birds); if so, where?; other?)

Any camps, nursing homes? Within 100 feet of surface water?

Average occupancy rate; seasonal; single family dwelling vs. apartment?

(as # homes goes down, so does likelihood of actually representing the mean)

Any BMP's currently in place, such as storm water basins, conservation tillage?

Golf courses should be treated separately from other recreation.

2b. QUERY user for more information on receiving water body:

Surface Water Lake or Reservoir

a. Mean Depth

b. Flushing Rate

c. Water withdrawal near the reservoir or augmentation to the reservoir

d. Is it a river impoundment? (cite Bonnie's work; higher flushing rate would mean it is probably less sensitive to loading).

Area Contributing to Groundwater can be:

Well Head Protection Area (WHPA)

Groundwater Drainage Area

Groundwater Reservoir

Coastal Embayment:

a. Mean Depth

b. Any other necessary data as defined by Coastal Resources Center.

C. Estimate nutrient loading to receiving water body, and receiving water body response.

Use range of loading factors: high, low; combine with hydrologic soil group to get most likely loading factor for a given land use on a particular soil.

What about wet year, average year, dry year for precipitation? How would loading factors change?

1. CALCULATE:

a. Runoff Coefficients for each SOILHG/LAND USE combination.  
(see SUBAPPENDIX B)

b. Volume of Runoff from Watershed to Surface Receiving Water.

Total Volume =  $\Sigma$  over all S/LU types:

(45 inches ppt)X(area of S/LU type)X(runoff coeff. of S/LU type)X (conversion factor)

c. Volume of Infiltration to Groundwater Reservoir.

$V(\text{infil}) = V(\text{ppt}) - V(\text{surface ro}) - V(\text{et})$

## 2. CALCULATE P and N Loading to Surface Water via Lumped Sum Method:

Total P load from watershed =  $\Sigma$  over all Land Uses

(Area of Land Use k) X (Loading factor for LU k),

applying BMP's where appropriate, PLUS:

- a. Contributions from malfunctioning septic systems via overland flow, with a higher loading from those within riparian areas.
  - b. Point sources
3. CALCULATE N Loading to Groundwater Reservoir:
- 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 we're using 1990 RI Census data, SUBAPPENDIX F.
  - 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.
4. CALCULATE N Loading to Coastal Embayment:
- a. Calculate Groundwater contribution to bay.
  - b. Calculate Surface Runoff contribution using step 2.
5. ESTIMATE receiving water response in the form of concentration of nutrient, trophic state.
6. ANALYSE several future buildout scenarios (include all-forest scenario, at least during development of the program) chosen by the community, based on such factors as zoning. This may include BMP's, as well as projected point sources.
7. During program development, use data collected by Watershed Watch or other sources to compare with program predictions.

## D. ASSIGN RISK using:

1. Current and future unknowns.
2. Current and future loading, nutrient concentrations, trophic state.
3. Flag C and D soils with steep slopes, high water tables, small lots, old septic systems as high risk.
4. Include risk evaluation of different land uses (RIDEM (1993a) classifies land use by risk).
5. Consider possible internal P loading from shallow lakes with anoxic bottoms.
6. Consider areas where private wells are in use.

## SUBAPPENDIX A: LAND USE AND SOILS DESIGNATIONS

TABLE A1: RIGIS and corresponding *MANAGE*: Nutrient Loading Model Land Use Designations  
(\* designates high-risk point source and should be flagged)

<u>CODE</u>	<u>RIGIS CATEGORY</u>	<u>EXPLANATION</u>	<u>MANAGE</u>
111	High Density Residential	> 8 dwelling units/acre	HD Res.
112	Medium High Density Resid.	4 to 7.9 units/acre	MHD Res.
113	Medium Density Residential	1 to 3.9 units/acre	MD Res.
114	Medium Low Density Resid.	0.5 to 0.9 units/acre	MLD Res.
115	Low Density Residential	< 0.5 units/acre	LD Res.
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 & 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
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

TABLE A1 continued: RIGIS and corresponding *MANAGE*: Nutrient Loading Model Land Use Designations  
 (\* designates high-risk point source and should be flagged)

<u>CODE</u>	<u>RIGIS CATEGORY</u>	<u>EXPLANATION</u>	<u>MANAGE</u>
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 from RIGIS Designations

<u>MANAGE CODE</u>	<u>MANAGE CATEGORY</u>	<u>RIGIS CATEGORY (CODE)</u>
1	HD Res.	High Density Residential (111)
2	MHD Res.	Medium High Density Residential (112)
3	MD Res.	Medium Density Residential (113)
4	MLD Res.	Medium Low Density Residential (114)
5	LD Res.	Low Density Residential (115)
6	COMMERCIAL	Commercial & Services (120) Other (147) Mixed Urban (150)
7	INDUSTRIAL	Industrial (130)
8	ROADS	Roads (141)
9	AIRPORTS	Airports (142)
10	RAILROADS	Railroads (143)
11	JUNKYARDS	Waste Disposal Areas (145)
12	RECREATION	Developed Recreation (161) Urban Open Space (162) Cemeteries (163)
13	INSTITUTION	Water & Sewage Treatment (144) Institutional (170)
14	PASTURE	Power Lines (146) Pasture (210)
15	CROPLAND	Cropland (220) Confined Feeding Operations (240)
16	ORCHARDS	Orchards, Groves, Nurseries (230)
17	BRUSH	Idle Agriculture (250) Brushland (400)
18	FOREST	Deciduous Forest (310) Evergreen Forest (320) Mixed-Deciduous (330) Mixed-Evergreen (340)
19	BARREN	Beaches (710) Sandy Areas other than Beaches (720) Rock Outcrop (730) Strip Mines, Quarries, Gravel Pits (740) Mixed Barren (760)
20	WETLAND	Wetland (600)
21	WATER	Water (500)
22	TRANSITIONAL	Transitional Areas (750)

TABLE A3: Hydrologic Soil Groups of Rhode Island Soils  
(Source: Rector, 1981)

<u>SOIL NAME</u>	<u>HYDROLOGIC SOIL GROUP</u>
Adrian	A/D (Designated as D for <i>MANAGE</i> )
Agawam	B
Birchwood	C
Bridgehampton	B
Broadbrook	C
Canton	B
Carlisle	A/D (Designated as D for <i>MANAGE</i> )
Charlton	B
Deerfield	B
Enfield	B
Gloucester	A
Hinckley	A
Ipswich	D
Leicester	C
Lippitt	C
Mansfield	D
Matunuck	D
Merrimac	A
Narragansett	B
Newport	C
Ninigret	B
Paxton	C
Pittstown	C
Podunk	B
Poquonock	C
Quonset	A
Rainbow	C
Raypol	C
Ridgebury	C
Rumney	C
Scarboro	D
Scio	B
Stissing	C
Sudbury	B
Sutton	B
Tisbury	B
Walpole	C
Wapping	B
Whitman	D
Windsor	A
Woodbridge	C

## SUBAPPENDIX B: SURFACE RUNOFF COEFFICIENTS

Using the formula presented by Adamus and Bergman (1993), the runoff coefficient for each SOIL/LAND USE combination is estimated by:

$$C = LLC + (ULC - LLC) * X$$

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 Land Use

LAND USE	LLC	ULC
HDR <sup>a</sup>	0.64	0.77
MHDR <sup>a</sup>	0.39	0.64
MDR <sup>a</sup>	0.23	0.39
MLDR <sup>a</sup>	0.16	0.23
LDR <sup>a</sup>	0.10	0.16
COMMERCIAL <sup>b</sup>	0.50	0.90
INDUSTRIAL <sup>b</sup>	0.50	0.90
ROADS <sup>c</sup>	0.70	0.82
AIRPORTS <sup>c</sup>	0.70	0.82
RAILROADS <sup>c</sup>	0.70	0.82
JUNKYARDS <sup>c</sup>	0.70	0.82
RECREATION <sup>b</sup>	0.10	0.30
INSTITUTION <sup>d</sup>	0.39	0.64
PASTURE <sup>e</sup>	0.05	0.25
CROPLAND <sup>e</sup>	0.15	0.50
ORCHARDS <sup>e</sup>	0.05	0.25
BRUSH <sup>b</sup>	0.0	0.10
FOREST <sup>e</sup>	0.0	0.10
BARREN <sup>b</sup>	0.05	0.80
WETLAND <sup>f</sup>	0.0	0.10
WATER	1.0	1.0

<sup>a</sup> Calculation of ULC and LLC for Residential (HDR, MHDR, MDR, MLDR, LDR) 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 degree of imperviousness for developed areas is taken from TR55 (1975):

<u>Land Use</u>	<u>% Impervious</u>
RESIDENTIAL	
1/8 acre	65
1/4 acre	38
1/3 acre	30
1/2 acre	25
1 acre	20
2 acre	12
COMMERCIAL	85
INDUSTRIAL	72

For example, MHDR is defined as 4 to 7.9 dwelling units/acre (= 1/4 to 1/8 acre density). The ULC will apply to C calculated for 1/8 acre density, while LLC will apply to C calculated for 1/4 acre density.

$$\text{ULC (MHDR)} = 0.05 + 0.9 (0.65) = 0.64$$

$$\text{LLC (MHDR)} = 0.05 + 0.9 (0.38) = 0.39$$

<sup>b</sup> From Novotny and Olem (1994), p. 146.

<sup>c</sup> Using the COMMERCIAL and INDUSTRIAL land use imperviousness figures in (a) for the high and low.

<sup>d</sup> Assuming INSTITUTION is hydrologically similar to MHD residential, unless otherwise specified by the user.

<sup>e</sup> Based on best professional judgement, using Curve Number Method as a guide.

<sup>f</sup> Generally WETLANDS will occur on D soils. We are assuming that wetlands are similar to forests on D soils, and for this reason are using the same coefficients as the FOREST category.

However, it is true for all land use types that ET and SRO will vary through the year.

## SUBAPPENDIX 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 100 feet in this model) 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 (SUBAPPENDIX 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)

LAND USE CATEGORY	LPC <sup>a</sup>	HPC <sup>a</sup>
HDR <sup>b</sup>	3.6	4.4
MHDR <sup>b</sup>	2.3	3.6
MDR <sup>b</sup>	1.3	2.3
MLDR <sup>b</sup>	0.9	1.3
LDR <sup>b</sup>	0.6	0.9
COMMERCIAL	1.0	2.5
INDUSTRIAL	1.0	3.5
ROADS <sup>c</sup>	1.0	3.5
AIRPORTS <sup>c</sup>	1.0	3.5
RAILROADS <sup>c</sup>	1.0	3.5
JUNKYARDS <sup>c</sup>	1.0	3.5
RECREATION	0.5	1.5
INSTITUTION <sup>d</sup>	2.2	3.5
PASTURE <sup>e</sup>	0.3	1.0
CROPLAND <sup>f</sup>	0.5	4.5
ORCHARDS	0.4	2.0
BRUSH	0.05	0.2
FOREST	0.05	0.2
BARREN	0.05	0.2
WETLAND	0.0	0.0
WATER <sup>g</sup>	0.3	0.3

From the **unsewered** portion of the Watershed:

Malfunctioning Riparian Septic Systems (within 100 ft of surface water)<sup>h</sup> 2.3 lb/cap/yr (15 mg/l and 50 gcd)

Malfunctioning Septic Systems outside the riparian areas<sup>l</sup> 1.15 lb/cap/yr

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

<sup>a</sup> These phosphorus export coefficients were selected by looking at literature reviews by Rast and Lee (1983), Frink (1991), and Budd and Meals (1994), and by looking at 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

<sup>b</sup> Based on RIDEM (1993b) and assuming 45 inches of precipitation annually (Allen and others, 1966).

<sup>c</sup> Assuming these land uses are similar to COMMERCIAL and INDUSTRIAL.

<sup>d</sup> Assuming INSTITUTION is similar to MHD Residential land use, unless otherwise specified by the user.

<sup>e</sup> 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))

<sup>f</sup> Assuming no conservation tillage or terracing. If BMP's are in place, they will be applied.

<sup>g</sup> Atmospheric deposition only. This is a best guess. I have a call in to Dr. Ken Rahn at the GSO, who is supposed to have figures for RI. 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, ag/rural, urban.

<sup>h</sup> See SUBAPPENDIX G for proportion of total number of septic systems which malfunction. If we assume 2.6 cap/residential septic system (1990 RI Census), this comes to 6 lb P/malfunctioning residential septic system within the 100 ft. buffer.

<sup>j</sup> See SUBAPPENDIX G for proportion of total number of septic systems which malfunction. If we assume 2.6 cap/residential septic system (1990 RI Census), this comes to 3 lb P/malfunctioning residential septic system outside the 100 ft. buffer.

## SUBAPPENDIX 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 limiting in coastal waters (REF?). 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 (SUBAPPENDIX 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 whether the septic system is located within a riparian area as factors. 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)

LAND USE CATEGORY	LNC <sup>a</sup>	HNC <sup>a</sup>
HDR <sup>b</sup>	11.9	14.3
MHDR <sup>b</sup>	7.3	11.9
MDR <sup>b</sup>	4.3	7.3
MLDR <sup>b</sup>	3.0	4.3
LDR <sup>b</sup>	1.8	3.0
COMMERCIAL	2.0	20.0
INDUSTRIAL	2.0	15.0
ROADS <sup>c</sup>	2.0	20.0
AIRPORTS <sup>c</sup>	2.0	20.0
RAILROADS <sup>c</sup>	2.0	20.0
JUNKYARDS <sup>c</sup>	2.0	20.0
RECREATION	1.5	4.0
INSTITUTION <sup>d</sup>	7.1	11.6
PASTURE <sup>e</sup>	2.0	5.5
CROPLAND <sup>f</sup>	4.0	50.0
ORCHARDS	4.0	35.0
BRUSH	0.9	2.9
FOREST	0.9	2.9
BARREN	0.9	2.9
WETLAND	0.0	0.0
WATER <sup>g</sup>	8.0	8.0

From the **unsewered** portion of the Watershed:

Failing Riparian Septic Systems (within 100 ft of surface water)<sup>h</sup> 7.0 lb/cap/yr

Failing Septic Systems outside the riparian areas<sup>j</sup> 5.6 lb/cap/yr

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 says 0.2 to 0.35 mg/l ]

- <sup>a</sup> These nitrogen export coefficients were selected by looking at literature reviews by Rast and Lee (1983), Frink (1991), and Budd and Meals (1994), and by looking at 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
- <sup>b</sup> Based on RIDEM (1993b) and assuming 45 inches of precipitation annually (Allen and others, 1966).
- <sup>c</sup> Assuming these land uses are similar to COMMERCIAL and INDUSTRIAL.
- <sup>d</sup> Assuming INSTITUTION is similar to MHD Residential land use, unless otherwise specified by the user.
- <sup>e</sup> 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))
- <sup>f</sup> Assuming no conservation tillage or terracing. If BMP's are in place, they will be applied.
- <sup>g</sup> Atmospheric deposition only. This is a best guess. I have a call in to Dr. Ken Rahn at the GSO, who is supposed to have figures for RI. 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, ag/rural, urban.
- <sup>h</sup> See SUBAPPENDIX G for proportion of total number of septic systems which malfunction. If we assume 2.6 cap/residential septic system (1990 RI Census), this comes to 18.2 lb N/malfunctioning residential septic system within the 100 ft. buffer.
- <sup>j</sup> See SUBAPPENDIX G for proportion of total number of septic systems which malfunction. If we assume 2.6 cap/residential septic system (1990 RI Census), this comes to 14.6 lb N/malfunctioning residential septic system outside the 100 ft. buffer.

SUBAPPENDIX 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 percolating recharge water can be estimated by dividing the total N loading from various and diverse land use above the aquifer by the dilution by recharge 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:

- Septic systems
- Lawn fertilizers
- Agricultural fertilizers
- Large animals (cows, horses)
- Pet waste
- Stormwater infiltration

Sources of recharge include:

- Precipitation
- 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, based on housing density. Commercial, Industrial, and Institution areas are all treated as MD Residential.

- Assume: 2.6 cap/dwelling unit (SUBAPPENDIX F).
- 7 lb N/person/yr leaves the septic tank (SUBAPPENDIX H).
- 50 gal/person/day (SUBAPPENDIX H).
- 90% of N leaches to the groundwater (Siegrist and Jenssen, 1989 give 80%, but in Rhode Island where conventional OSDS are typically buried deeper, and gravel fill is brought in, 90% is 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. For the moment, we will assume 100% occupancy rate, to determine the worst potential impact (this may not be appropriate for all watersheds). For example, MD Res. is defined as 1 to 3.9 units per acre.

<u>Residential Land Use</u>	<u>Mean Dwelling Unit Density</u>
HD Res.	10.0 d.u./acre
MHD Res.	5.95 d.u./acre
MD Res.	2.45 d.u./acre
MLD Res.	0.70 d.u./acre
LD Res.	0.35 d.u./acre
Other:	
COMMERCIAL	Assume these are similar to MD Residential. Also, we
INDUSTRIAL	assume that septic system use in recreational areas is
RECREATION	seasonal (6 months out of the year).
INSTITUTION	

## 2. Lawns

Estimate lawn area in watershed:

<u>Land Use Category</u>	<u>Fraction attributed to lawn</u>
HD Res.	0.25
MHD Res.	0.35
MD Res.	0.50
MLD Res.	0.35
LD Res.	0.25
COMMERCIAL	0.05
INDUSTRIAL	0.10
RECREATION	0.70 (we should deal with golf courses separately)
INSTITUTION	0.25

Assume 75% of residents apply lawn fertilizer.

Assume fertilizer applied at a rate of 175 lb N/ac/yr (4 lb/1000 sq. ft./yr)

Assume a leaching rate of 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 %), but we lowered it due to low leaching rates found by Gold and others (1990), and Morton and others (1988), and assuming some mismanagement, such as overwatering, bare spots, compacted soil, and improper fertilizer application).

## 3. Agriculture

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

## 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 and unfertilized lawn. (FOREST, PASTURE, BRUSH, and 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 PPT - Annual ET - Annual RO

I. Average annual PPT = 45 inches (Allen and others, 1966)

II. Average annual ET = 20 inches (Johnston and Dickerman, 1985)

III. Average annual 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. We have assumed that there is no runoff from a wetland area. The equation above then implies that wetlands recharge 25 inches to groundwater, which is almost never the case. We will assume that generally groundwater flows into wetlands, rather than water from wetlands percolating to groundwater. If we do this, we must subtract the total area of wetlands in the watershed X 25 inches, from the total volume of average annual recharge to groundwater.

2) Recharge from septic systems:

= (total # of septic systems) (2.6 cap/dwelling) (50 gal/cap/day) (365 days/yr)

## SUBAPPENDIX F: 1990 RI CENSUS FIGURES

	<u>Number persons/dwelling unit<sup>a</sup></u>	<u>Vacancy Rate<sup>b</sup></u>
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%

<sup>a</sup> Based on number of occupied (vs. vacant) dwelling units. Does not include seasonally occupied dwelling units.

<sup>b</sup> 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 sewerred.

## SUBAPPENDIX G: CALCULATION OF SEPTIC SYSTEM MALFUNCTION

The number of septic systems estimated to malfunction (defined as those systems which produce surface ponding, leakage of septic effluent) throughout the unsewered portion of the watershed, that is the proportion of all septic systems in the watershed which do not perform properly, will be based on the soil on which they are sited.

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. Those soils will be termed "Restrictive" and are:

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

In addition, eight of these soils have a high-water-table at a depth of 3.5 feet or less, with most of these perched. Eleven of the thirteen soils are in hydrologic soil group C, and the other two are in hydrologic soil group D (Mansfield, Whitman) (Tables 25 and 26 in Rector, 1981).

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

<u>Soil Name (Hyd. Group)</u>	<u>Depth (inches) at which Permeability &lt; 0.2 in/hr</u>	<u>HWT depth (ft)</u>	<u>Type</u>	<u>Months</u>
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
Whitman (D)	18-60	0.0-0.5	Perched	Sep-June
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:

"Restrictive"	65%
"Non-restrictive":	
D	50%
C	30%
A, B	10%

The user can change these failure rates if necessary.

These percentages are based on Nizeyimana and others (1996).

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 100 ft. riparian area. Within the riparian area, we will assume that 100% of the P and N leaving the malfunctioning septic system will reach the receiving water. Outside the buffer, 50% of the P and 80% of the N 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 N is used because the typical N 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.

<u>Leaving Septic Tank</u>	<u>Within 100 ft. buffer</u>	<u>Outside 100 ft. buffer</u>
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 SUBAPPENDIX I for a summary of values and their sources on which these numbers are based)

## SUBAPPENDIX H: IMPERVIOUSNESS OF DEVELOPED LAND

LAND USE	Estimated % Impervious		Value Used in MANAGE <sup>c</sup>
	Low	High	
HDR <sup>a</sup>	65	80	72
MHDR <sup>a</sup>	38	65	50
MDR <sup>a</sup>	20	38	30
MLDR <sup>a</sup>	12	20	16
LDR <sup>a</sup>	5	12	8
COMMERCIAL <sup>b</sup>	50	94	72
INDUSTRIAL <sup>b</sup>	50	94	72
ROADS <sup>c</sup>	72	85	72
AIRPORTS <sup>c</sup>	72	85	72
RAILROADS <sup>c</sup>	72	85	72
JUNKYARDS <sup>c</sup>	72	85	72
RECREATION	5	28	10
INSTITUTION <sup>d</sup>	38	65	50

<sup>a</sup> Based on estimate of impervious fraction used in TR55 (1975) for the low and high ends of the density range.

<sup>b</sup> Based on estimate of low and high runoff coefficients (see SUBAPPENDIX B).

<sup>c</sup> See SUBAPPENDIX B

<sup>d</sup> Assuming INSTITUTION is hydrologically similar to MHD residential, unless otherwise specified by the user.

<sup>e</sup> **These values are reduced by 20% in areas where the CREATIVE DESIGN BMP is implemented.**

## SUBAPPENDIX I: SEPTIC SYSTEM PARAMETERS

		<u>SOURCE</u>
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 (this is from Weiskel and Howes (1991), though I admit I can't find it in the paper myself. I did find one reference to 3 cap/dwelling in a description of earlier work.)	Frimpter and others (1990)
	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)
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 assumes 10% removal in septic tank; Gold and others (1990) found 21% removal]		USEPA (1980)
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)	Horsley & Witten (1994)
(5.7 lb/cap/yr @ 55 gcd)		
40 mg/l	(Buttermilk Bay)	
(6.7 lb/cap/yr @ 55gcd)		
30 - 80 mg/l		RIDEM (Galen Howard, 1995)
5 - 10 lb/cap/yr		RIDEM (Galen Howard, 1995)
59.3 mg/l		Gold (unpublished?)
(8 lb/cap/yr @ 45 gcd)		

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)

SUBAPPENDIX 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 maintenace (frequent pumping), regular inspection to reduce failure
  - c) Sewering

TABLE 11: REDUCTIONS IN SURFACE RUNOFF, PHOSPHORUS, AND NITROGEN, BY BMP

BMP	Reduction (%) to Surface Water	Reduction (%) to Groundwater	Literature Source
<b>AGRICULTURE</b>			
There is wide variation in the possible reductions due to varying methods, as well as soil type, topography.	20% SRO 20% TP 20% TN	20% TN	Representative value based on data presented in Pennsylvania State University, 1992, and on estimates from USDA NRCS and URI CE.
<u>Methods include:</u> Cover crops Reduced tillage Diversions and swales Terraces Filter Strips Nutrient Management*	* NOTE: You may reduce the amount of fertilizer applied to agricultural areas 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 <u>all</u> cropland and orchards. Applying agricultural BMP's <i>and</i> reducing the fertilizer applied in Section 3 is invalid, because you will be getting reductions in two places for only one BMP.		

**LAWNS**

Methods include:

Reduced fertilizer applications	???	80% TN	Morton and others (1988)
Reduced occurrence of overwatering			
Mower height at 2-3"			LJ's notes say that we should assume 20% to 50% of residents who apply fertilizer could be expected to adopt recommendations with education.
Use of slow release fertilizers			
Leave clippings on the lawn			CITATION?

**STORMWATER MANAGEMENT**

With maintenance	???	45% SRO 45% TP 45% TN	Increased risk of TN leaching to groundwater, depending upon type of management	Representative values, based on data presented in USEPA, 1993.
Without maintenance	???	10% SRO 10% TP 10% TN		

Methods include:

- Wet Basins
- Extended Detention Ponds
- Infiltration Practices
  - Basins, trenches, dry wells
- Vegetated Filter Strips
- Grassed Swales

NOTE: Any chosen method must comply with RI DEM guidelines for water quality enhancement basin design.

**CREATIVE DESIGN**

Creative Landscaping to reduce imperviousness, e.g. shared parking, use of geotextiles, cluster developments	20% reduction in impervious areas		City of Olympia, 1996
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**SEPTIC SYSTEMS**

Denitrification Systems		50% TN	Siegrist and Jenssen, 1989
Improved Maintenance	Eliminate failures		
Sewering	Eliminate failures	leakage	

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