



February 23, 2021

Town of North Haven
Inland Wetlands Commission
Memorial Town Hall
18 Church St.
North Haven, Conn.06473

RE: Inland Wetlands Application # 120-06
The Slate School-5100 Ridge Road-Nitrogen Dilution Analysis

Dear Commission Members:

This letter and attached information will serve to follow-up to and expand upon concerns raised in our January 25, 2021 letter to you on this matter. In particular, these concerns relate to the unrenovated sewage plume reaching the nearby wetland and introducing nitrogen and other pollutants to the wetlands. We suggested that there was a way to model these conditions using an established, well accepted technique that is contained in the referenced 2006 DEEP guidance document. Excerpts from pertinent sections of the document are attached and we have highlighted particular provisions that are on point. As we did in our prior letter, we call your attention to the applicability of the principles contained in the document which are clearly expressed in Section 1-p. 2 of 12 as follows “...**the underlying principles involved apply to all on-site systems, regardless of size.**” (Bold added)

We understand that the applicant has submitted revised documents and a response to our comments that attempt to sidestep this matter by suggesting that the principles do not apply because of the size of the sewage disposal system which is clearly contrary to the statement contained in the document as quoted above. In light of this, the neighbors have requested that this office prepare a nitrogen dilution analysis and we have done so. The analysis follows the methodology recommended by DEEP and relies on the maps and other documents provided by the applicant. It is interesting to note that the example provided in the DEEP document uses a school as the land use further supporting the appropriateness of this method of analysis to this matter. Copies of the applicable sections of the DEEP methodology are attached along with our calculations.

Our calculations indicate that the concentration of nitrate at the wetland is 32.4 mg/L which exceeds the DEEP target of 10 mg/L and, as in the DEEP example, indicates that there is insufficient dilution from infiltrated precipitation. Equally important in this instance is the concentration of the ammonium byproduct which can be toxic to aquatic life at concentrations as low as 1 mg/L.

Loureiro Engineering Associates, Inc.

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We have shared this information with the Environmental Scientist, George Logan, who will provide an opinion of the significance of these concentrations relative to wetland impact.

We appreciate the opportunity to present the neighbors' concerns to you and trust that you will give them the consideration that they deserve.

Sincerely,

LOUREIRO ENGINEERING ASSOCIATES, INC.

A handwritten signature in blue ink, appearing to read "Clinton S. Brown II".

Clinton S. Brown II PE AICP
Director

Attachments

Pc.Att'y. John Acampora w/att.
Att'y. John Parise w/att.
George Logan REMA w/att.

Nitrogen Dilution Analysis

Source:

Connecticut Department of Environmental Protection
Bureau of Materials Management and Compliance Assurance
Guidance for Design of Large-Scale On-Site Wastewater Renovation Systems
February 2006

Nitrogen Dilution Model

$$N_{gw} = [(Q_{ww} \times N_{ww}) / (Q_{ww} + Q_{ip})]$$

where:

- N_{gw} = nitrogen concentration in ground water at the point of concern, [M/V]
 Q_{ww} = daily design volume of wastewater, [L³]
 N_{ww} = nitrogen concentration in the wastewater reaching the ground water
= 60% of the raw wastewater total nitrogen concentration, [M/V]
 Q_{ip} = daily volume of infiltrated precipitation, [L³]

Also,

$$Q_{ip} = \%I \times A_e / 100$$

where:

$\%I$ = percent infiltration, from Figure N-1

A_e = effective infiltration area, = $(X_d + X_u + X_{SWAS})(2y)$, [L²]

As shown on Figure N-2,

- X_d = longitudinal horizontal distance from the downgradient side of the SWAS to the down gradient point of concern, measured parallel to the local direction of ground water flow [L]
 X_u = longitudinal horizontal distance from the up-gradient side of the SWAS to the up gradient property line, measured parallel to the local direction of ground water flow [L]
 X_{SWAS} = horizontal width of SWAS, measured parallel to the local direction of ground water flow [L]
 y = horizontal transverse distance from the point of concern on the longitudinal centerline of nitrogen plume to the plume concentration contour = 10 mg/l nitrogen, measured perpendicular to direction of local ground water flow, obtained from Tables No. N-1A or Table N- 1B (by interpolation if necessary) [L]
 Y = horizontal transverse width of SWAS, measured perpendicular to direction of local ground water flow [L]

Assumptions:

- a. Raw Wastewater has a total nitrogen concentration of 80mg/L
- b. Annual precipitation = 48 inches (equivalent to 0.13 inches/day)

Calculations:

- a. From Fig N-1 (attached):
CN = 70 (per MMI report and TR-55 manual for woods (good) with a hydrologic soil group C)
Therefore, %I = 44%, or 0.44
- b. $N_{ww} = 0.60 \times 80\text{mg/L} = 48 \text{ mg/L}$
- c. From Table No. N-1A (attached): $y = 70'$

$$A_e = (X_d + X_u + X_{SWAS})(2y)$$

$X_d = 69'$ (closest downgradient point of concern – wetland)

$X_u = 32'$ (average distance to nearest upgradient edge of contributing drainage area)

$X_{SWAS} = 4'$ (system width)

$y = 70'$

$$A_e = (69' + 32' + 4')(2 \times 70') = 14,700 \text{ ft}^2 = 1,366 \text{ m}^2$$

- d. $Q_{ip} = \%I \times A_e / 100$
 $= (0.44)(0.13 \text{ in/day})(2.54 \text{ cm/in})(1\text{m}/100\text{cm})(1,366 \text{ m}^2)$
 $= (0.44)(0.003 \text{ m/day})(1,366 \text{ m}^2) = 1.803 \text{ m}^3/\text{day}$
 $= (1.803 \text{ m}^3/\text{day})(1000 \text{ L/m}^3) = 1,803 \text{ L/day}$
- e. $Q_{ww} = 990 \text{ GPD} \times 3.785 \text{ L/gal.} = 3,747 \text{ L/day}$
- f. $Q_{ww} \times N_{ww} = (3,747 \text{ L/day})(48 \text{ mg/L}) = 179,856 \text{ mg/day}$
- g. $Q_{ww} + Q_{ip} = (3,747 \text{ L/day}) + (1,803 \text{ L/day}) = 5,550 \text{ L/day}$
- h. $N_{gw} = [(Q_{ww} \times N_{ww}) / (Q_{ww} + Q_{ip})]$
 $= (179,856 \text{ mg/day}) / (5,550 \text{ L/day}) = \mathbf{32.4 \text{ mg/L}}$

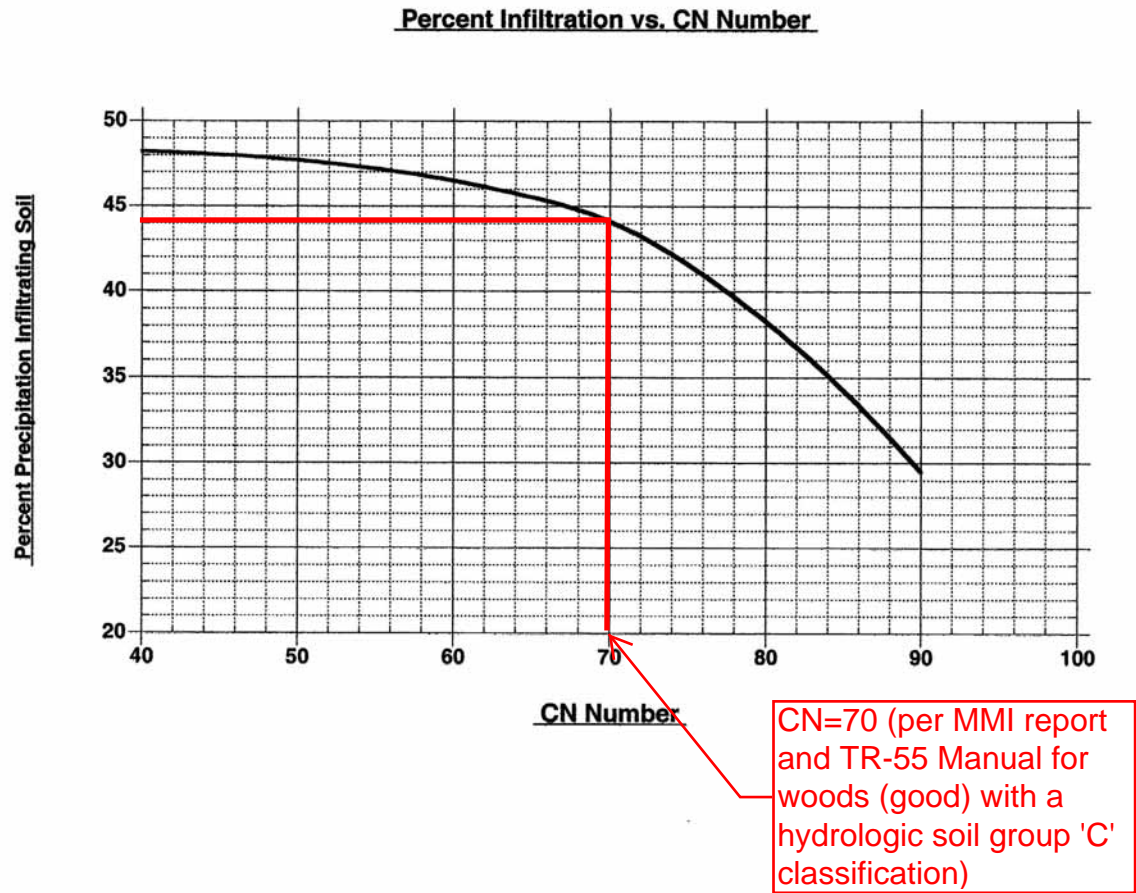


Figure N-1

TABLE N-1A

Lateral Extent of 10 mg/L Nitrogen Plume in Glacial Till

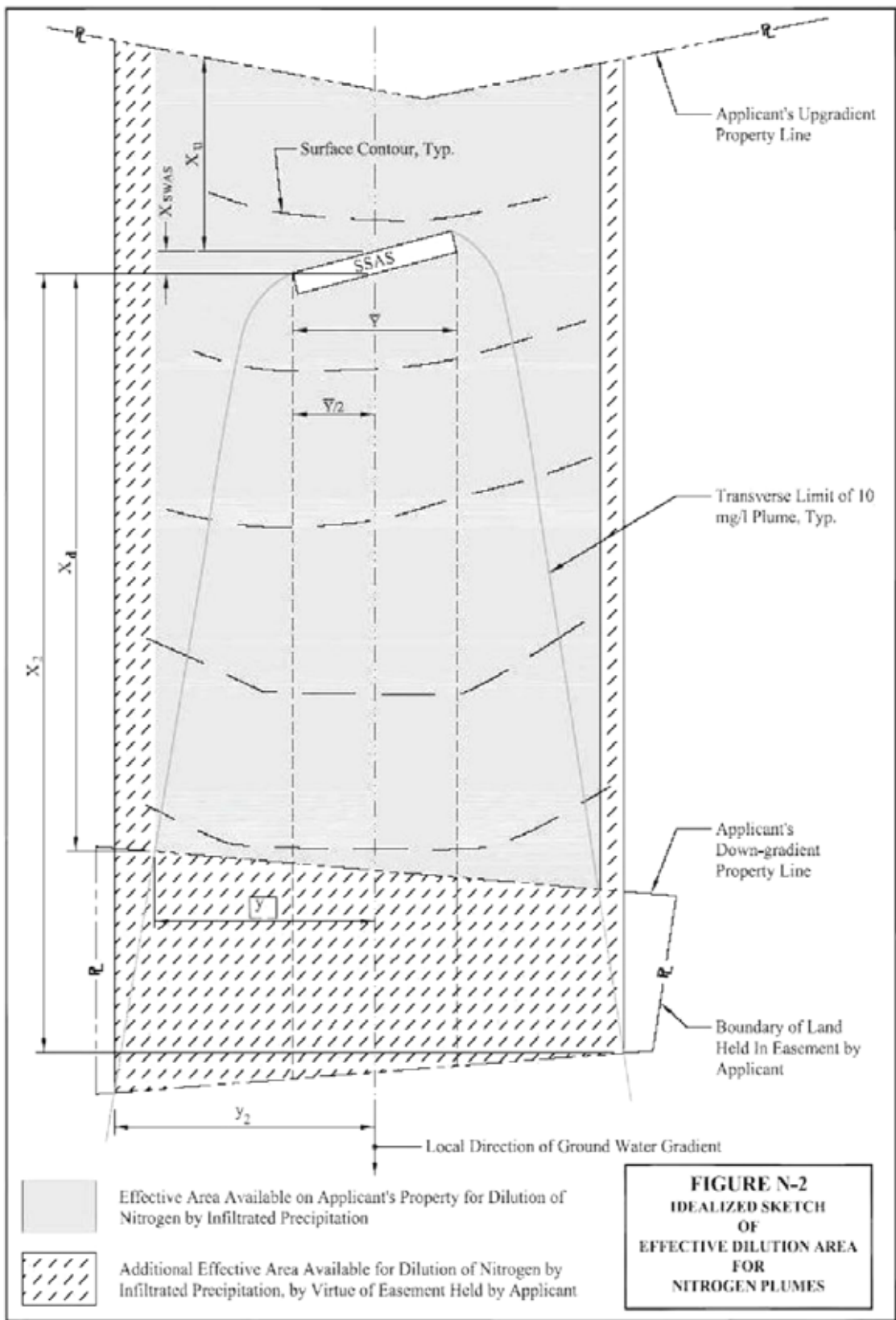
y=Distance perpendicular to direction of ground water flow, from centerline of plume to plume C = 10 mg/L												
Co, mg/L	Y=100 Ft.						Y=200 Ft.					
	x=0	x=100	x=200	x=300	x=400	x=500	x=0	x=100	x=200	x=300	x=400	x=500
	y=	y=	y=	y=	y=	y=	y=	y=	y=	y=	y=	y=
24	50	54	58	58	58	58	100	104	108	113	116	117
30	50	59	67	73	73	73	100	109	117	126	134	141
36	50	62	74	83	87	87	100	112	124	135	147	158
42	50	64	78	91	99	102	100	114	129	143	159	170
48	50	66	82	97	109	115	100	116	133	149	165	180
54	50	68	86	103	118	126	100	118	136	154	172	189
60	50	69	89	107	123	134	100	119	139	158	177	196
66	50	71	91	111	128	142	100	121	141	162	182	203
72	50	72	93	114	133	148	100	122	143	165	187	208

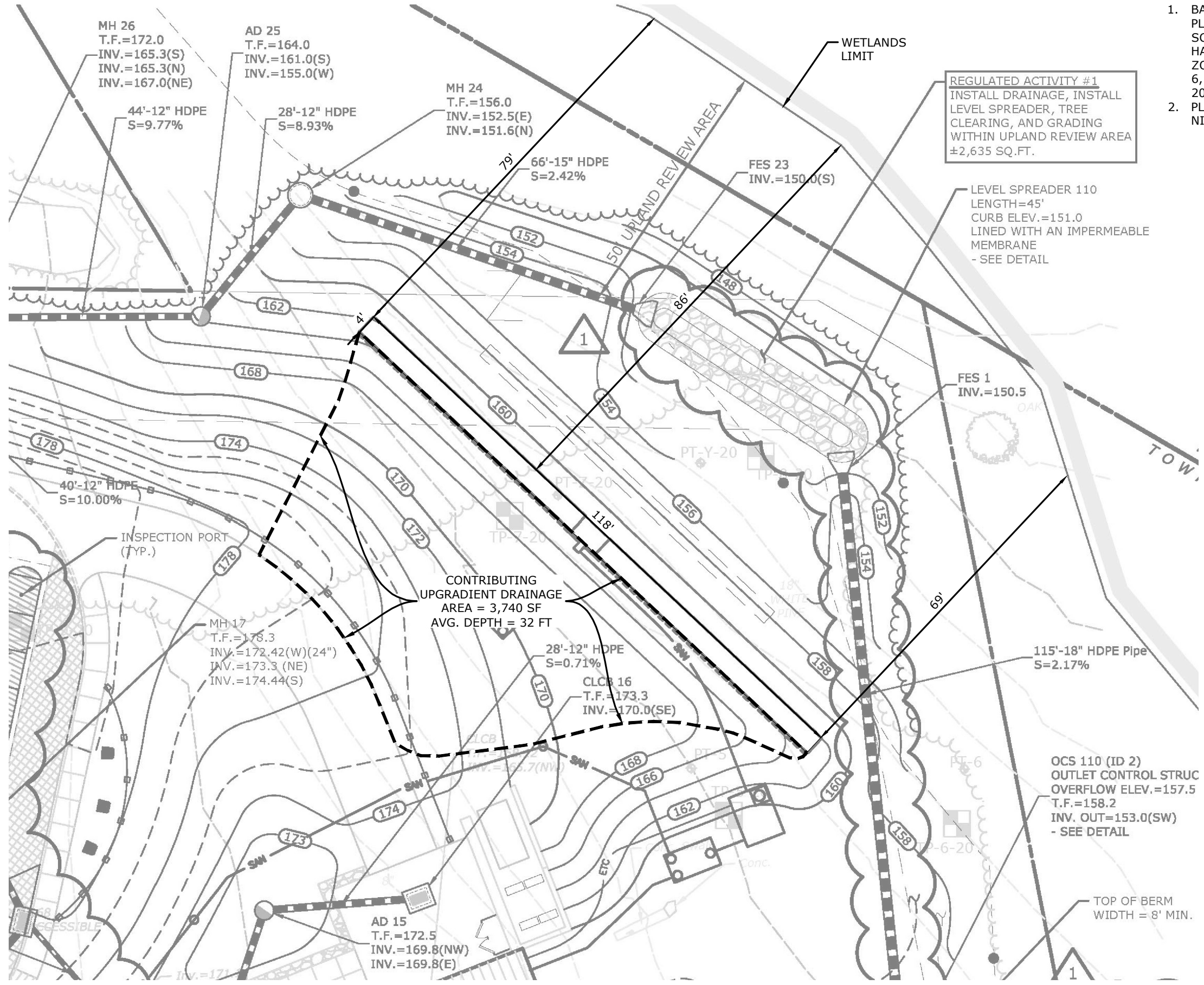
Input values:
 Co = 48 mg/L
 Y = 118' (length of system spread)
 x = 69' (closest downgradient point of concern)

Averages:
 when Y = 100', x = 0' to 100':
 $y = 50' + ((66' - 50') \times 0.69) = 50' + 11' = 61'$
 when Y = 200', x = 0' to 100':
 $y = 100' + ((116' - 100') \times 0.69) = 100' + 11' = 111'$
 when Y = 118', y = 61' and y = 111':
 $y = 61' + ((111' - 61') \times 0.18) = 61' + 9' = 70'$

Notes:

1. Co = Nitrogen concentration in discharge from SWAS.
2. x = longitudinal horizontal distance from SWAS to point of concern, measured parallel to the local direction of ground water flow.
3. Y = horizontal dimension of SWAS measured perpendicular to the local direction of ground water flow.
4. For intermediate values of Co, Y and y, interpolate from tables.
5. Refer to Figure N-2 for depiction of x, Y, and y.



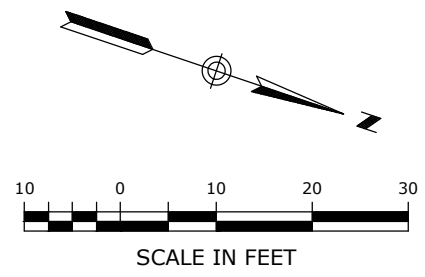


- NOTES:**
1. BASE MAPPING IS PROVIDED PER THE SITE PLAN SET ENTITLED, "SLATE UPPER SCHOOL, 5100 RIDGE ROAD, NORTH HAVEN, CONNECTICUT, PLANNING AND ZONING SUBMISSIONS", DATED NOVEMBER 6, 2020, LAST REVISED FEBRUARY 17, 2021, PREPARED BY MILONE & MACBROOM.
 2. PLAN HAS BEEN PREPARED TO SUPPORT NITROGEN DILUTION ANALYSIS ONLY.

SCALE 1" = 20'	COMM. NO.	DATE 2020-02-22
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NITROGEN DILUTION ANALYSIS

THE SLATE SCHOOL
5100 RIDGE ROAD
NORTH HAVEN, CONNECTICUT



CONNECTICUT DEPARTMENT OF ENVIRONMENTAL PROTECTION

BUREAU OF MATERIALS MANAGEMENT AND COMPLIANCE ASSURANCE



**GUIDANCE FOR DESIGN
OF
LARGE-SCALE
ON-SITE WASTEWATER RENOVATION SYSTEMS**

February 2006

**Funded in part by the CT DEP through a US EPA
Nonpoint Source Grant under § 319 Clean Water Act**



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When the pretreated wastewater is discharged to the subsurface via a properly designed SWAS it is further renovated as it travels through the subsurface soils and eventually reaches and commingles with the ground water. The ground water in turn is eventually extracted via wells for various water supply purposes, including drinking water, or discharges to surface waters that are used for many purposes.

Therefore, the chief objective for design, construction, operation and maintenance of a SWAS and the associated pretreatment facilities must be to renovate the wastewater so as to protect the public health and the environment. Most soils have substantial but finite capacities to accomplish the renovation of pretreated domestic wastewater by providing an environment that causes the death or inactivation of pathogens and removal or attenuation of chemical pollutants. It is axiomatic that the pretreated wastewater must remain in the soil for a suitable time to permit such renovation to take place. A corollary objective is to ensure that the wastewater makes intimate contact with the soil particles under suitable environmental conditions so as to effect such renovation. This requires that the soils in which a SWAS are installed have ample hydraulic and renovative capacities and that there are adequate vertical and horizontal separating distances between the SWAS and any point of concern to provide the necessary time and adequate soil contact for the renovation to take place.

While this document is directed toward design, construction, operation and maintenance of large-scale OWRS having design flows greater than 5,000 gpd, including associated wastewater collection systems, the underlying principles involved apply to all on-site systems, regardless of size. The size of a system is a function of the daily rate of wastewater discharge and its bio-chemical characteristics, and the physical characteristics of the site, including: area, shape, topography, depth to the controlling ground water table and soil characteristics. The two basic criteria for judging the adequacy of an OWRS are: "Will the discharge cause pollution?" and "Will the system work?"

The basic concerns that must be addressed to judge the adequacy of an OWRS are:

- Does the proposed site of a subsurface wastewater absorption system (SWAS) have sufficient land area to accept the size of the system necessary to meet the requirements of the Department?
- Does the soil-ground water regime in which the SWAS is proposed to be located have sufficient renovative capacity to bring the pretreated wastewater into compliance with the required ground water quality standards of the Department before it reaches a point of concern, such as: a potable water supply well, wetland, surface water body or the applicant's property boundary?
- Does the soil-ground water regime in which the SWAS is proposed to be located have sufficient hydraulic capacity to accept and transport the pretreated wastewater for an adequate distance without surfacing or breakout?
- Is or will there be a responsible entity, with adequate and continual authority and assured financial means, to properly construct, operate and maintain the OWRS to the satisfaction of the Department?

To address these concerns, many factors must be thoroughly and methodically evaluated, using the best engineering practice in applying fundamental scientific and engineering principles, and the best information currently available or reasonably obtainable.

The basic purpose of this document is to present information and methodologies that can be used in evaluating these factors and addressing these concerns.

B. Units Of Measure

The U.S. ("English") system of measurement units is utilized in this document, with few exceptions (e.g. mg/L, meters). For those persons who need, or prefer, to work in metric units, a table of U.S. to Metric conversion factors is provided in Appendix D.

C. Terminology

As previously stated, this document stresses the renovation of domestic wastewater. However, at the time this document was written, the governing State Statutes and the Department's Water Quality Standards, Water Discharge Regulations, Rules of Practice and Environmental Permit Application Package all refer to "Sewage", "Domestic Sewage", "Sewage Disposal", "Subsurface Sewage Disposal System", "Leaching System" and like terms. In this document, the following words and terms are equivalent:

<u>This Document</u>	<u>Existing Terminology</u>
Wastewater	Sewage
Domestic Wastewater	Domestic Sewage
Wastewater Renovation	Sewage Disposal
Subsurface Wastewater Absorption System (SWAS)	Subsurface Sewage Disposal System, or Leaching System
On-site Wastewater Renovation System (OWRS)	Land Treatment System, Subsurface Sewage Disposal System

D. Disclaimer

Throughout this document, proprietary commercial products and processes have been mentioned by trade name in order to illustrate a point or to provide a general indication as to what products or processes may be available for use in on-site wastewater renovation facilities. Mention of trade names, proprietary commercial products and processes does not constitute endorsement or recommendation for use by the Department.

E. Departments' Jurisdiction over OWRS

The Department has jurisdiction over the design, construction and operation of: OWRS facilities having a design capacity in excess of 5,000 gallons per day that discharge to any one property, regardless of the number of systems; systems including advanced pretreatment regardless of capacity; and Community Sewerage Systems (those serving more than one residential structure). Under $\text{t } 22a-430$ of the Connecticut General Statutes (CGS), the Department is responsible for issuing State Discharge Permits for operation and monitoring of such systems.

Nitrogen is essential to the growth and reproduction of phytoplankton. In saline bays and estuaries, nitrogen is the limiting nutrient. In the presence of an over abundance of nitrogen, organisms such as algae (phytoplankton) and floating, submerged or emergent aquatic vegetation (macrophytes) can proliferate in these water bodies. This can accelerate the natural processes of eutrophication.

The death and decay of excessive algae results in oxygen depletion, a condition that is inimical to fish and other aquatic life that require oxygen to survive. The decay of organic sediment under anoxic conditions can also result in the release of ammonia, which can have a toxic effect on aquatic life, as discussed elsewhere herein. The adverse ecological effects of high nitrogen loads to The Long Island Sound, which stimulate phytoplankton blooms, leading to hypoxia (dissolved oxygen (DO) concentration of 3 mg/l or less), have been well documented (LISS-1990, CT DEP-1998).

Health problems can occur when water that contains nitrates in excess of 10 mg/l, (expressed as nitrate-nitrogen, or $\text{NO}_3\text{-N}$), is consumed by infants, either by direct ingestion, as a result of its use in preparing baby formulas, or to a fetus in a pregnant woman. Nitrate is reduced in the baby's body to nitrite. Nitrite is able to oxidize ferrous iron in hemoglobin to ferric iron and convert hemoglobin (the blood pigment that carries oxygen from the lungs to tissue) to methemoglobin that is incapable of carrying molecular oxygen to tissue. This condition, known as methemoglobinemia (infant cyanosis, or "blue baby disease"), can result in suffocation and is particularly toxic to infants less than three months old.

Methemoglobinemia can also occur in older children and adults if sufficient nitrate is ingested (Bitton and Gerba, 1994; Ammann-1995). Nitrite is also reputed to induce human gastric cancer (Lee, et al.- 1995). The U.S. EPA has established a maximum pollutant level (MCL) of 10 mg/l of nitrate, expressed as $\text{NO}_3\text{-N}$, for drinking water supplies.

2. Nitrogen

Nitrogen is one of two most prominent nutrients in pretreated wastewater discharged to the ground water (the other being phosphorus), and its fate and transport in the soil/ground water regime is of considerable concern when designing OWRS. Concentrations of total nitrogen (TN) in septic tank effluent (STE) typically range from 40-80 mg/l or more, depending upon the source of the wastewater. Sources of wastewater containing higher percentages of toilet/urinal wastes (blackwater) than typical residential septic tank effluent can have much higher TN concentrations.

Most of the nitrogen in wastewater receiving pretreatment in a septic tank is in the form of the ammonium ion (NH_4), with some organic nitrogen, and sometimes trace-to-small amounts of nitrite (NO_2) and nitrate (NO_3) also present. In a conventional OWRS that has an aerobic soil zone beneath the SWAS, ammonium and organic nitrogen are rapidly converted to nitrate. Organic nitrogen must first be mineralized (converted to the inorganic form) by microbial action to ammonium, which takes place in the septic tank and in the biomat, before it is oxidized to nitrate by autotrophic bacteria in the aerobic unsaturated zone.

Where conditions are favorable, various processes remove some of the nitrate. The most significant of these processes is biological denitrification, the reduction of nitrates to nitrogen gas by the metabolic processes of facultative microbes under anoxic conditions. The gaseous nitrogen is then released into the atmosphere via the unsaturated soil pores in the unsaturated zone. However, where conditions are not favorable for the denitrification process (the usual case), nitrate, being very soluble and chemically inactive, may easily percolate down to, mingle, and move with the ground water to points of concern such as drinking water wells and surface waters. The presence of nitrates in both ground water and surface water in concentrations significantly greater than natural background levels can lead to environmental problems.

Up to 20 percent or more of the total nitrogen in raw domestic wastewater can be removed in the septic tank by sedimentation and microbial assimilation (Hardesty, 1974; Laak-1986; Pell and Nyberg-1989, Long-1995). However, where most of the nitrogen enters the septic tank in dissolved forms, as may be the case for wastewaters from schools and domestic wastewater from commercial establishments and industrial facilities (where urine may be the main contribution), the amount removed will be much lower, as sedimentation will not be a significant factor. The remaining nitrogen is discharged with the septic tank effluent to the SWAS.

The fate of the remaining nitrogen depends upon a number of mechanisms and processes, including mineralization, adsorption, plant uptake, volatilization, fixation, immobilization, nitrification and denitrification. These processes in turn depend upon such factors as; soil pH, temperature, moisture, oxidation-reduction (redox) potential, oxygen present in the soil gases, presence and type of organic matter in the soil, soil cation exchange capacity, and microbial populations. In a properly functioning SWAS, 15 to 25 percent of the nitrogen remaining in the septic tank effluent may be removed (Laak – 1986; Long, 1995; Wilhelm et al. – 1996; Crites & Tchobanoglous - 1998).

Mineralization of nitrogen, the conversion of organic nitrogen to inorganic nitrogen (predominantly ammonium) by biological action occurs both in the septic tank and at the biomat in the SWAS, and very little organic nitrogen is found in the wastewater after it flows through the biomat.

Adsorption of ammonium via soil cation exchange may play a role in nitrogen removal, but nitrogen so adsorbed is subject to subsequent desorption and leaching. In addition, eventually a state of equilibrium may become established as all of the cation exchange sites are occupied. When this occurs, desorbed ammonium is replaced with new ammonium cations, and no net removal of ammonium occurs (Magdoff et. al.-1974; Sikora and Corey-1976; Brown, et al.-1978; Brown et al.-1984). Thus, ammonia-nitrogen may remain in ground water that discharges to surface water bodies.

Ammonia is reported to be toxic to aquatic life at very low concentrations of less than 1 mg/L (Laak-1986; U.S.EPA-1993). The EPA criteria for ambient water quality, as well as modified-state criteria, give both maximum total and unionized (free) ammonia levels as a function of pH and temperature. The maximum one-hour average in-stream concentrations of un-ionized ammonia-nitrogen (NH_3) permissible in a three-year period are all under 1 mg/L. The maximum four-day average concentrations for the same are all under 0.1 mg/L (USEPA-1985; USEPA-1993).

The acute toxicity of NH_3 has been shown to increase as pH and temperature decrease. Thus, if nitrification does not occur due to the existence of anaerobic conditions beneath the SWAS, and small amounts of free ammonia persist in the ground water, an adverse effect on aquatic life could result where the ground water discharges to nearby surface waters.

Plant uptake of some of the nitrogen may occur, provided the [SWAS] is within the root zone of the plants, but the amount of nitrogen discharged to a [SWAS] greatly exceeds that which can normally be utilized by nearby plants (Sikora-1976). Plant uptake is usually visually evident from the distinctively greener grass that grows above a SWAS where the effluent can rise into the root zone. This situation may occur when a SWAS malfunctions and floods the surface or near surface, or when a normally operating SWAS has been constructed at a shallow depth below ground surface. However, most of the pretreated wastewater is discharged below the root zone of local vegetation; also, such uptake essentially ceases during the dormant season. Further, unless the vegetation is harvested, it is likely that N will be recycled to the soil as the vegetation decays during the dormant season.

Volatilization of ammonium is only significant at high pH values (≥ 9.5), which seldom exist in and beneath a SWAS. Fixation occurs when ammonium ions become trapped between intercellular layers of clay. Volatilization and fixation are not thought to be significant nitrogen removal processes (Lance-1972).

Immobilization occurs as the microorganisms engaged in removing organic matter incorporate nitrogen in their cells during synthesis reactions. This may account for five to ten percent, or less, of nitrogen removal (Lance -1972). Research has shown that nitrogen incorporated into microbes is held in a rather stable form (Laak-1986).

In a properly functioning SWAS, underlain by an ample depth of unsaturated aerobic soil, almost complete oxidation of ammonium to nitrate usually occurs within 30 - 60 cm (1-2 ft.) of unsaturated soil below the bottom of the leaching system due to the metabolic action of nitrifying bacteria. This usually occurs within a few hours of the exposure of ammonium to an aerobic soil environment (Anderson, et al.-1994; Duncan, et al.-1994; Long -1995). Ammonium is first oxidized to nitrites and the nitrites are subsequently oxidized rapidly to nitrates. If dissolved oxygen is present in the effluent when it reaches the water table, or if the background ground water contains appreciable dissolved oxygen, aerobic oxidation of ammonium may continue in the saturated zone (Wilhelm, et al.-1994).

It should be noted that the necessity for aerobic, unsaturated soil conditions requires that the SWAS not be installed too deeply into the soil, since the oxygen present in the unsaturated soil voids decreases rapidly with depth below ground surface. Below about 40 cm (16 in.) from the surface, the rate of oxygen diffusion decreases exponentially (Otis-1997). Likewise, the placement of a dense layer of soil or pavement above the [SSAS] will severely restrict the transfer of oxygen into the soil (Long-1995).

If conditions are favorable for denitrification (presence of a suitable carbon source, facultative heterotrophic bacteria, and anoxic or anaerobic conditions), some of the nitrate may be denitrified. Very little denitrification will take place in clean sands because of the lack of organic carbon. Some small amount of denitrification may take place in saturated micro-sites between the soil grains (Sextone et al. 1985; Long-1995) where the traces of dissolved organic carbon in the ground water may be sufficient to support the denitrification process. Crites and Tchobanoglous (1998) indicated that about 15% of the nitrate is denitrified in sandy, well-drained soils and 25% in heavier soils.

Nitrate removal from wastewater by denitrification is considered to be rare in aquifers below SWAS (Wilhelm et al.-1994) and most investigators have presumed that dilution by ground water is the predominant mechanism that significantly lowers the nitrate-nitrogen concentration in the ground water. Recent studies have indicated that, in some cases, dilution of nitrates (and other constituents of wastewater) below a SWAS may be much less than posited in previous decades (ibid.) Most investigators have indicated that, generally, any remaining nitrate in the percolate from a SWAS that has not been denitrified before it reaches the ground water will remain unaltered in chemical composition or concentration other than by dilution. In general, nitrate is found to be more mobile in soils with greater moisture content, greater hydraulic conductivity, coarser texture and greater structure.

On the other hand, there is evidence that substantial denitrification may take place where nitrate laden ground water flows through saturated soils with significant readily assimilable (labile) organic carbon content, such as those that exist in wetlands and beneath some water bodies (Robertson, et al. 1991; Korom-1992; Long-1995). Denitrification can also be caused by the action of certain autotrophic bacteria using reduced iron and sulfide as electron donors in the absence of organic carbon (Korom, ibid). However, current capabilities to predict an aquifer's denitrification characteristics are site specific at best (Korom-ibid.).

Nitrogen also reaches the ground water from other sources such as decomposing plants and animals, animal wastes, application of fertilizers for lawn care and agricultural purposes, bacterial action in soil, and direct deposition from the atmosphere.

3. Phosphorus

Phosphorus (P) is the other prominent nutrient in wastewater discharged to the ground water. Phosphorus occurs in natural waters and in wastewaters almost solely as phosphates ($\text{PO}_4\text{-P}$) (Standard Methods-1995). The principal sources of $\text{PO}_4\text{-P}$ in domestic wastewater are human waste, food wastes, toothpaste, pharmaceuticals, detergents (particularly dishwashing detergents), and food-treating compounds. Phosphates in wastewater may include orthophosphates, condensed phosphates (polyphosphates) and organically bound phosphates.

Since in most cases ground water will eventually reach a surface water body, it is important that the phosphorus concentration in the percolate from a SWAS be reduced to background levels in the ground water prior to the ground water reaching a point of concern. Laak (1986) reported that natural ground waters contain 0.01-0.06 mg/l of $\text{PO}_4\text{-P}$, while Reneau, et al (1989) reported that $\text{PO}_4\text{-P}$ concentrations in shallow groundwater are

2. Exact specified materials are difficult to acquire and may be drastically altered by placement methods.
3. The cost of such an installation, particularly engineering inspection and testing, is very high. If an error is made, the cost of correction may become prohibitive.

G. Nutrient Reduction (Nitrogen and Phosphorus)

1. General

A discussion on the importance of reduction of the amount nitrogen and phosphorus discharged to the environment via an OWRS is given in Section II. In the following, where computations of nitrogen dilution or phosphorus immobilization in the soil are made, the wastewater flow used in such computations should be the design average daily flow, rather than the design maximum day flow.

2. Nitrogen Dilution by Infiltrated Precipitation

The model used by the Department for nitrogen dilution by infiltrated precipitation, as presented in Healy and May (1982, rev. 1997) is retained in this document. However the methodologies for determining the amount of rainfall that infiltrates to the ground water, and the effective infiltration area, have been revised.

A study of available publications on water resources in Connecticut and rainfall-runoff relationships lead to adoption of a method for defining the percent of precipitation that infiltrates to the ground water under various soil conditions (Jacobson-2001). The results, given in graphical form in Figure No. N-1, permits determination of the percentage of infiltration based on the Runoff Curve Number (CN) method developed by the US S.C.S.(U.S.D.A.-1986).

The curve shown in Figure No. N-1 is intended to be used with a composite CN value computed for that portion of a project site that can logically be assumed to contribute infiltration for dilution of nitrogen discharged from a SWAS. The soil types and Hydrologic Soil Group classifications for soils at a project site can be obtained from maps and tables contained in the S.C.S. Soil Surveys for the various counties in Connecticut. The corresponding CN values can be obtained from Tables 2a-2c in the S.C.S./N.R.C.S. publication TR-55 (U.S.D.A.-1986). The procedures for computing a composite CN value for a project site are explained in TR-55, are familiar to most consulting engineers, and need not be given here.

Using the total lot area as the effective infiltration area, where the SWAS occupies only a small portion of the lot width, results in overestimating the affect of nitrogen dilution by infiltrated precipitation. After wastewater percolates downward from a SWAS to the ground water table, it generally flows as a plume in the local direction of ground water flow and gradually spreads transverse to the direction of the local ground water flow. The spreading of the nitrogen plume depends on the characteristics of the aquifer. When the lot width is substantially greater than the width of the SWAS, the spread may not be such that the plume covers the entire lot area, and therefore the total lot area should not be used as the effective infiltration area.

Percent Infiltration vs. CN Number

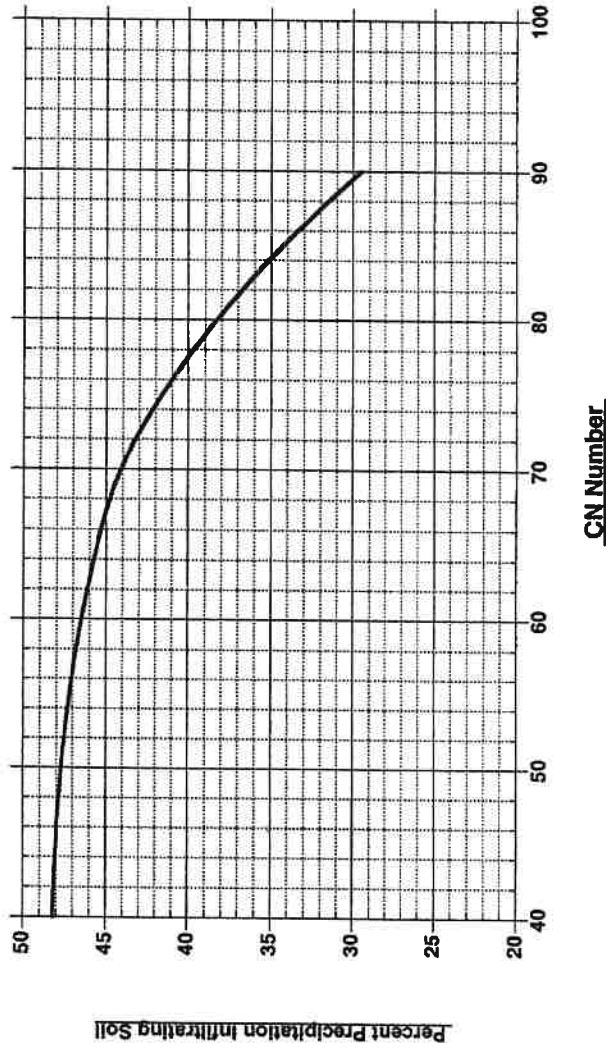


Figure N-1

Mass transport processes determine the extent of plume spread and the geometric character of the contaminant concentration distribution (Domenico and Schwartz-1990). The principal processes responsible for the mass transport of chemicals dissolved in the ground water include advection, dispersion, and retardation. For non-reactive (conservative) chemicals, only the advection and dispersion processes are of concern. Based on the information previously discussed concerning the fate and transport of nitrogen (specifically, nitrates) in ground water, it can be considered as a non-reactive contaminant.

An elementary approach for modeling the effective dilution area was developed based on the concepts of hydrodynamic dispersion discussed in Freeze and Cherry (1979) and of contaminant transport in Domenico and Schwartz (1990). Domenico and Schwartz (1990) provide an analytical equation developed by Domenico and Robbins (1985) for advective and dispersive mass transport of a contaminant from a continuous finite planar source. A two-dimensional solution (vertical dispersion assumed negligible) was deemed reasonable for delineating the horizontal extent (boundary) of a nitrogen plume.

Therefore, the Domenico and Robbins equation was adjusted for a two-dimensional plume analysis (horizontal x and y directions) by eliminating the term for dispersion in the vertical direction as suggested in Domenico and Schwartz (1990). The analytical equation was solved for values of the horizontal perpendicular offset (y) from the plume centerline to the point on the plume boundary where the N concentration in the ground water is reduced from the initial concentration (C_0) in the percolating wastewater to a concentration (C)=10 mg/l (Jacobson-2001). Thus, within the plume boundary, the N concentrations vary from the initial concentration C_0 to a concentration of 10 mg/L, while outside of the plume boundary the concentration of N is less than 10 mg/L.

Tables were prepared to provide values of y, at various distances (designated as x) down-gradient from the SWAS, for various values of the initial concentration (C_0) of N in the wastewater percolating downward from a SWAS and for various lateral dimensions of the SWAS. Separate tables are provided for glacial till (Table No. N-1A) and stratified drift aquifers (Table No. N-1B). These tables can be used to determine the lateral extent of the effective infiltration area.

Figure No. N-2 presents an idealized view of the lateral extent of the plume concentration contour of 10 mg/l at a distance of x meters down-gradient of a SWAS, and indicates how the information obtained from Tables N-1A and N-1B can be used to determine the effective infiltration area.

It should be noted that, when the horizontal perpendicular offset (y) from the plume centerline to the point on the plume boundary where the N concentration is 10 mg/l, (for a given value of x from the SWAS to the Applicant's downgradient property line), indicates the plume boundary extends beyond a side boundary of the Applicant's property, it will be necessary to enter either Table N-1A or Table N-1B with the value of the shortest horizontal perpendicular offset (y) from the plume centerline to the nearest side boundary and solve for a revised distance x. It is this revised distance that should be used, together with the values for X_{swas} and X_u to determine the length of the effective infiltration area (See Figure N-2 for depiction of (y), (x), X_{swas} and X_u).

TABLE N-1A

Lateral Extent of 10 mg/L Nitrogen Plume in Glacial Till

y=Distance perpendicular to direction of ground water flow, from centerline of plume to plume C = 10 mg/L

Co, mg/L	Y=100 Ft.						Y=200 Ft.					
	x=0	x=100	x=200	x=300	x=400	x=500	x=0	x=100	x=200	x=300	x=400	x=500
	y=	y=	y=	y=	y=	y=	y=	y=	y=	y=	y=	y=
24	50	54	58	58	58	58	100	104	108	113	116	117
30	50	59	67	73	73	73	100	109	117	126	134	141
36	50	62	74	83	87	87	100	112	124	135	147	158
42	50	64	78	91	99	102	100	114	129	143	159	170
48	50	66	82	97	109	115	100	116	133	149	165	180
54	50	68	86	103	118	126	100	118	136	154	172	189
60	50	69	89	107	123	134	100	119	139	158	177	196
66	50	71	91	111	128	142	100	121	141	162	182	203
72	50	72	93	114	133	148	100	122	143	165	187	208

Co, mg/L	Y=300 Ft.						Y=400 Ft.					
	x=0	x=100	x=200	x=300	x=400	x=500	x=0	x=100	x=200	x=300	x=400	x=500
	y=	y=	y=	y=	y=	y=	y=	y=	y=	y=	y=	y=
24	150	154	158	163	167	171	200	204	208	213	217	221
30	150	159	167	176	185	193	200	209	217	226	236	243
36	150	162	174	185	197	209	200	212	224	236	247	259
42	150	164	179	193	207	227	200	214	229	243	257	271
48	150	166	183	199	215	231	200	216	233	249	265	281
54	150	168	186	204	222	240	200	218	236	254	272	290
60	150	169	189	208	227	247	200	219	23	258	277	297
66	150	171	191	212	232	253	200	221	241	262	282	303
72	150	172	193	215	237	259	200	222	243	265	287	309

Co, mg/L	Y=500 Ft.						Y=600 Ft.					
	x=0	x=100	x=200	x=300	x=400	x=500	x=0	x=100	x=200	x=300	x=400	x=500
	y=	y=	y=	y=	y=	y=	y=	y=	y=	y=	y=	y=
24	250	254	258	262	267	271	300	304	308	313	317	321
30	250	258	267	276	285	293	300	308	317	326	335	343
36	250	262	274	285	297	309	300	312	324	335	347	359
42	250	264	279	293	307	321	300	315	329	343	357	371
48	250	267	283	299	315	331	300	317	333	349	365	381
54	250	268	286	308	322	340	300	318	336	354	372	390
60	250	269	289	308	327	347	300	319	339	358	377	397
66	250	270	291	312	332	353	300	320	341	362	382	403
72	250	271	293	315	337	359	300	321	343	365	387	409

Notes:

1. C_o = Nitrogen concentration in discharge from SWAS.
2. x = longitudinal horizontal distance from SWAS to point of concern, measured parallel to the local direction of ground water flow.
3. Y = horizontal dimension of SWAS measured perpendicular to the local direction of ground water flow.
4. For intermediate values of C_o , Y and y , interpolate from tables.
5. Refer to Figure N-2 for depiction of x , Y , and y .

TABLE N -1B

Lateral Extent of 10 mg/L Nitrogen Plume in Stratified Drift

y=Distance perpendicular to direction of ground water flow, from centerline of plume to plume C = 10 mg/L

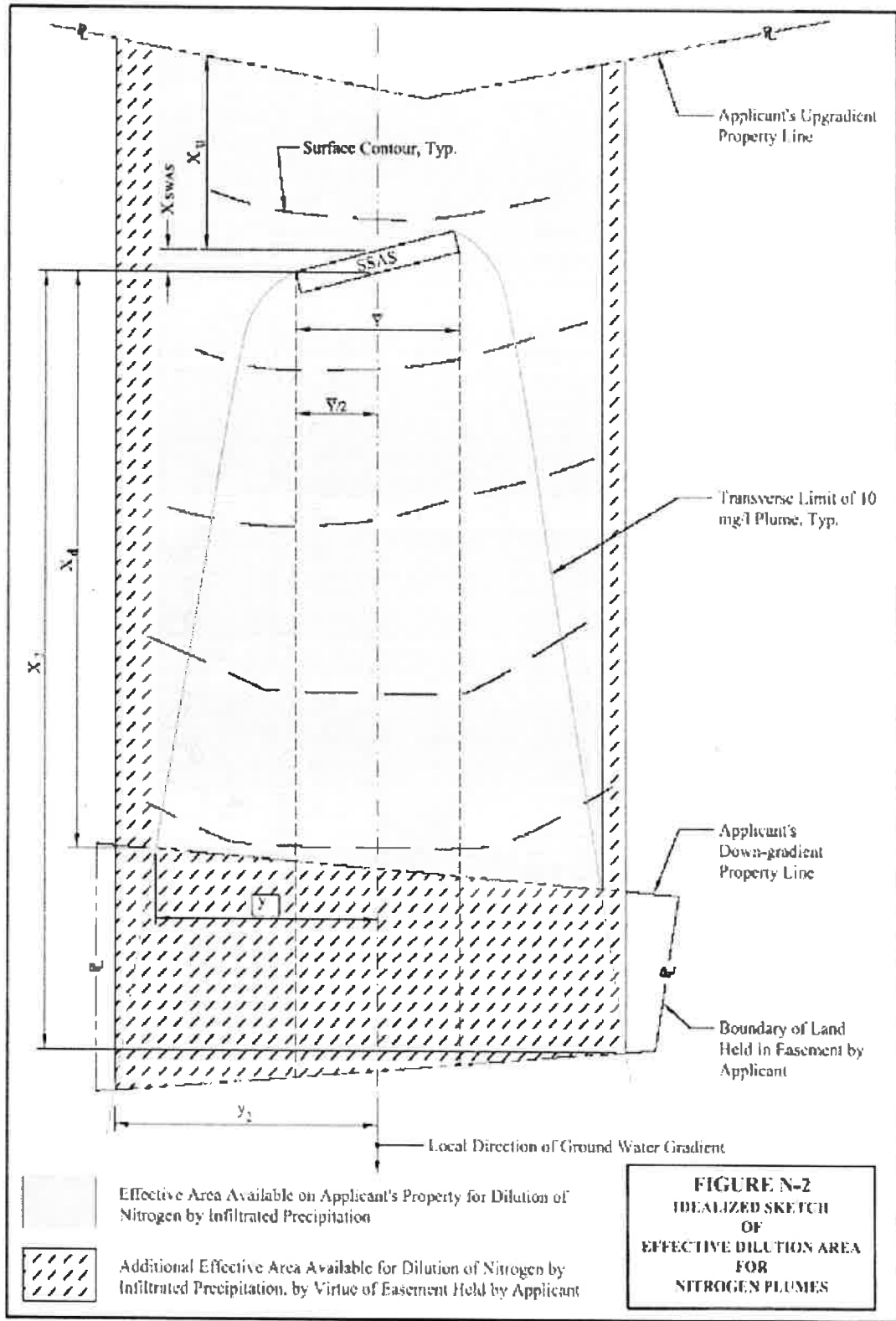
Co, mg/L	Y=100 Ft.						Y=200 Ft.					
	x=0	x=100	x=200	x=300	x=400	x=500	x=0	x=100	x=200	x=300	x=400	x=500
	y=	y=	y=	y=	y=	y=	y=	y=	y=	y=	y=	y=
24	50	52	54	56	58	59	100	102	104	106	108	111
30	50	54	59	63	67	70	100	104	109	113	117	122
36	50	56	62	68	74	79	100	106	112	118	124	130
42	50	57	64	71	78	85	100	107	114	121	129	136
48	50	58	66	74	82	90	100	108	116	124	133	141
54	50	59	68	77	86	94	100	109	118	127	136	145
60	50	60	69	79	89	98	100	110	119	129	139	148
66	50	60	71	81	91	101	100	110	121	131	141	152
72	50	61	72	83	93	104	100	111	122	133	143	154

Co, mg/L	Y=300 Ft.						Y=400 Ft.					
	x=0	x=100	x=200	x=300	x=400	x=500	x=0	x=100	x=200	x=300	x=400	x=500
	y=	y=	y=	y=	y=	y=	y=	y=	y=	y=	y=	y=
24	150	152	154	156	158	161	200	202	204	206	208	211
30	150	154	159	163	167	172	200	204	209	213	217	222
36	150	156	162	168	174	180	200	206	212	218	224	230
42	150	157	164	171	179	186	200	207	214	221	229	236
48	150	158	166	174	183	191	200	208	216	224	233	241
54	150	159	168	177	186	195	200	209	218	227	236	245
60	150	160	169	179	189	198	200	210	219	229	239	248
66	150	160	171	181	191	202	200	210	221	231	241	252
72	150	161	172	183	193	204	200	211	222	233	243	254

Co, mg/L	Y=500 Ft.						Y=600 Ft.					
	x=0	x=100	x=200	x=300	x=400	x=500	x=0	x=100	x=200	x=300	x=400	x=500
	y=	y=	y=	y=	y=	y=	y=	y=	y=	y=	y=	y=
24	250	252	254	256	258	261	300	302	304	306	308	311
30	250	254	259	263	267	272	300	304	309	313	317	322
36	250	256	262	268	274	280	300	306	312	318	324	330
42	250	257	264	271	279	286	300	307	314	321	329	336
48	250	258	266	274	283	291	300	308	316	324	333	341
54	250	259	268	277	286	295	300	309	318	327	336	345
60	250	260	269	279	289	298	300	310	319	329	339	348
66	250	260	271	281	291	302	300	311	321	331	341	351
72	250	261	272	283	293	304	300	311	322	333	343	354

Notes:

1. C_o = Nitrogen Concentration in discharge from SWAS.
2. x = longitudinal horizontal distance from SWAS to point of concern, measured parallel to local direction of ground water flow.
3. Y = horizontal dimension of SWAS measured perpendicular to the local direction of ground water flow.
4. For intermediate values of C_o , Y and y , interpolate from tables.
5. Refer to Figure N-2 for depiction of x , Y , and y .



Nitrogen Dilution Model

The mathematical expression of the nitrogen dilution model used by the Department is as follows:

$$N_{gw} = [(Q_{ww} \times N_{ww}) / (Q_{ww} + Q_{ip})],$$

where:

N_{gw} = nitrogen concentration in ground water at the point of concern, [M/V]

Q_{ww} = daily design volume of wastewater, [L³]

N_{ww} = nitrogen concentration in the wastewater reaching the ground water,
= 60% of the raw wastewater total nitrogen concentration, [M/V]

Q_{ip} = daily volume of infiltrated precipitation, [L³]

Also, $Q_{ip} = \%I \times A_e / 100$ where $\%I$ = percent infiltration, from Figure N-1, and A_e = effective infiltration area, = $(X_d + X_u + X_{SWAS})(2y)$, [L²]

As shown on Figure N-2,

X_d = longitudinal horizontal distance from the downgradient side of the SWAS to the down gradient point of concern, measured parallel to the local direction of ground water flow [L]

X_u = longitudinal horizontal distance from the up-gradient side of the SWAS to the up gradient property line, measured parallel to the local direction of ground water flow [L]

X_{SWAS} = horizontal width of SWAS, measured parallel to the local direction of ground water flow [L]

y = horizontal transverse distance from the point of concern on the longitudinal centerline of nitrogen plume to the plume concentration contour = 10 mg/l nitrogen, measured perpendicular to direction of local ground water flow, obtained from Tables No. N-1A or Table N-1B (by interpolation if necessary) [L]

Y = horizontal transverse width of SWAS, measured perpendicular to direction of local ground water flow [L]

An example of the use of the model equation follows.

A design average daily flow of 5,000 gallons of wastewater discharged from a school is to be discharged from a SWAS to a glacial till aquifer. The raw wastewater has a total nitrogen concentration of 80 mg/l. There is sufficient depth of unsaturated soil to permit installation of the SWAS in the existing soil while still maintaining the required separating distance between the bottom of the SWAS and the mounded ground water.

The width of the SWAS measured perpendicular to the direction of the local ground water gradient = 256 ft and the SWAS is located 164 ft from the applicant's up-gradient property line. The dimension of the SWAS parallel to the direction of the local ground water gradient = 46 ft The distance from the SWAS to the closest down gradient point of concern, measured parallel to the direction of the local ground water gradient, = 400 ft The composite SCS Curve Number (CN) for the soil in the area of the proposed SWAS = 72. Annual average precipitation = 48 inches (equivalent to 0.13 inches/day).

- a. From Figure No. N-1, for a CN value of 72, the percent of precipitation infiltrating to the ground water = 43%. (Stated another way, the decimal fraction of total precipitation infiltrating to the ground water = 0.43)
- b. The total nitrogen concentration in the wastewater discharged from the SWAS (Co), $N_{ww} = 0.6 \times 80 \text{ mg/l} = 48 \text{ mg/L}$.
- c. From Table No. N-1A (for glacial till aquifers), for $C_o = 48 \text{ mg/l}$, $Y = 256 \text{ ft.}$ and $x = 400 \text{ ft.}$, $y = 193 \text{ ft.}$ (by interpolation between $Y = 200 \text{ ft.}$ and 300 ft.). Therefore, A_e , the effective infiltration area, $= (2 \times 193) \times (164 + 46 + 400) \text{ ft} = 235,400 \text{ sq. ft.}$, or $21,870 \text{ sq. meters}$.
- d. Q_{ip} , the annual daily volume of infiltrated precipitation, $= 0.43 \times 0.13 \text{ in/day} \times 2.54 \text{ cm/inch} \times (1 \text{ m}/100 \text{ cm}) \times 21,870 \text{ sq. meters} = 0.43 \times 0.003 \text{ meters/d} \times 21,870 \text{ sq. meters} = 31.1 \text{ cu. meters} \times 1000 \text{ liters/cu. meter} = 31,100 \text{ liters/d}$.
- e. $Q_{ww} = 5,000 \text{ gal/d} \times 3.785 \text{ liters/gal} = 18,925 \text{ liters/d}$.
- f. $Q_{ww} \times N_{ww} = [18,925 \text{ liters/d} \times 48 \text{ mg/l}] = 908,400 \text{ mg/d}$
- g. $Q_{ww} + Q_{ip} = [18,925 \text{ liters/d} + 31,100 \text{ liters/d}] = 50,025 \text{ liters/d}$.

$N_{gw} = [(Q_{ww} \times N_{ww}) / (Q_{ww} + Q_{ip})] = 908,400 \text{ mg/d} / 50,025 \text{ l/d} = 18.2 \text{ mg/l}$. Since this concentration $> 10 \text{ mg/l}$, additional pretreatment will be necessary as the nitrate nitrogen will not be sufficiently diluted by infiltrated precipitation. As alternatives, the width of the SWAS could be increased to increase the nitrogen dilution area; or, if that was not possible, additional land that would contribute to nitrogen dilution could be acquired by purchase or easement.

The nitrogen dilution model equation can also be re-arranged to solve for the reduction in N_{ww} required to be obtained by additional pretreatment in order to meet the requirement that $N_{gw} \leq 10 \text{ mg/l}$. In this case, the equation takes the following form:

$$\text{Maximum allowable } N_{ww} = 10[(Q_{ww} + Q_{ip}) / Q_{ww}].$$

In the example just given, the maximum allowable $N_{ww} = 10 \times [(18,925 \text{ liters/d} + 31,100 \text{ liters/d}) / 18,925 \text{ liters/d}] = 26.4 \text{ mg/l}$. Thus, additional pretreatment would be required to reduce the total nitrogen in the wastewater discharged to the SSDS from 48 mg/l to 26.4 mg/l .

3. Additional Pretreatment for Nitrogen Removal

Physical/chemical processes and biological processes can be used for nitrogen removal. However, physical/chemical processes are not considered to be suitable for on-site wastewater renovation systems because of the cost of such processes, the operational problems inherent in such processes, and the need for highly skilled operation. In fact, while physical/chemical processes were once considered to be attractive for nitrogen removal at municipal wastewater treatment facilities, they have largely been abandoned in favor of biological processes.

Biological nitrogen removal is a two-step process involving nitrification and de-nitrification. As previously discussed in Section II of this document, nitrification is the biological oxidation of ammonium (NH_4^+) to nitrate (NO_3^-), and de-nitrification is the biological reduction of NO_3^- to nitrogen gas.

There are two basic types of wastewater treatment systems used in the biological nitrogen removal process. One type consists of the suspended growth system, in which the microorganisms that remove the impurities from the wastewater are maintained in suspension in intimate contact with the wastewater to be treated. The other consists of the fixed film system, in which the microorganisms are attached to some type of media, with the wastewater either passing through the media or the media passing through the wastewater. There are also hybrid systems that combine both suspended growth and fixed film processes.

The Department has approved several types of facilities that employ either suspended growth or fixed film processes, or hybrid processes, for pretreatment. Further discussion on enhanced pretreatment for nitrogen removal, including requirements for design, construction, operation, and maintenance, is given in Enhanced Pretreatment, Section XI of this document.

4. Phosphorus Removal

The model used by the Department for removal of phosphorus (P) in the percolate from a SWAS assumes that 30% of the P is removed in the septic tank and in the biomat that forms at the SWAS-soil interface. The remainder must be removed in the soil beneath the SWAS.

Studies have indicated that very limited P transport to ground water occurs in aerobic, water-unsaturated soils of suitable texture and chemical characteristics. In most soils in which Fe, Al and Ca are present in reactive form, aerobic conditions exist, and flow rates are minimal, P movement is minimal and pollution of ground and surface waters from P applied in a SWAS is considered unlikely. In recent extensive field studies, the evidence suggested that P removal in the subsurface is influenced by mineral precipitation reactions in the unsaturated zone which tend to be irreversible.

On the other hand, while some P may be removed in the saturated (ground water) zone beneath and down-gradient of the SWAS there is potential for the migration of P in the saturated zone under certain conditions. P removal in the ground water zone appears to be dominated by sorption reactions that are readily reversible (Robertson and Harman-1999). P has been detected above background levels in ground water adjacent to and down-gradient of subsurface wastewater absorption systems under conditions of saturated flow, high water tables, or high hydraulic loading rates (Reneau-1979).

Therefore, absent any enhanced pretreatment for P removal, it should be demonstrated that the P in the percolate from a SWAS will be removed in the unsaturated soil zone beneath the SWAS.

The Department model assumes that P removed in the unsaturated zone is initially sorbed onto active soil particles, but that over a 6 month period, the sorbed P will combine with Fe, Al or Ca in the soil to form less soluble precipitates. As the precipitates form, the original sorption sites are regenerated. It should be demonstrated that the unsaturated soil beneath a SWAS has the capacity to sorb at least 6 months of the P in the percolate from the SWAS. Therefore, it is necessary to determine the P sorption capacity of the unsaturated soils below the SWAS area and the total mass of soil that the percolate from a SWAS will contact as it moves downward through the unsaturated zone.