REVIEW OF NUTRIENT MANAGEMENT IN THE TOWNSHIP OF ASHFIELD

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The Township of Ashfield
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I) INTRODUCTION

This report is presented in three parts. The first part of this report sets out a framework and proposes policies and actions aimed at significantly improving the Township of Ashfield's ability to plan for and regulate new rural development, including new livestock operations. The complexity of rural development issues demands a completely new approach to planning.

The second part provides a review of Ashfield's nutrient management by-law, By-law Number 11 (and amendments made by By-law Number 17 and 18).

The third part provides a review of the Nutrient Management Plan and Record Keeping System submitted by Country Pork Ltd. (N1/2 Lot 1, Conc. 6 ED, Township of Ashfield) in application for a permit to build a 9000 head nursery barn.

II) BACKGROUND INFORMATION

The following is a brief discussion of several practical scientific issues that have shaped this report

1. Groundwater-Surface Water Interactions

It has been commonplace to divide the impacts of storing and spreading livestock manure into the domain of either groundwater or surface water. At the level of 'first biggest impact', this approach may in fact be valid and even useful. This point is illustrated by the following examples.

Thick layers of heavy, poorly drained soils, coupled with extensive subsurface drainage or significant variation in topography, will result in greater transport of nutrients (nitrate and phosphorus) and microbes (bacteria and protozoa) to surface water (Fetter 1999, Korom 1992).

Conversely, flat, well-drained sandy soils with a shallow water table provide optimum conditions for transport of nitrate and bacteria to groundwater, and in turn enhance the preservation of nitrate once it reaches the groundwater (Exner and Spalding 1994, Steinheimer et al. 1998 et al.).

Nature, however, is a complex system of myriad interconnections. Evidence of strong groundwater-surface water interactions has been gathered over the last two decades and the implications for agriculture are significant. The interactions include the following:

- Contaminants in the shallow groundwater often end up in streams, rivers or lakes, as groundwater discharge (McMahon and Bolke, 1996).
- Contaminants in the rivers, streams and wetlands may enter the groundwater zone as recharge (Mueller et al. 1995).
- Groundwater takings in close proximity to surface water can artificially induce or increase surface water movement into the groundwater zone (Freeze and Cherry 1979).

The implication is that we really do not have the luxury of managing one system or the other, or managing them both as separate entities. Understanding the major pathways helps establish the first line of defense; however, the next generation of controls to manage agricultural parameters of concern must treat the hydrologic cycle as an interconnected entity.

2. Agricultural Parameters of Concern

Within research, extension and regulatory circles, considerable effort has been placed on transforming our perception of manure as a waste product, to manure as a nutrient. In so far as the goal has been to replace the use of commercial fertilizer with manure-derived nitrogen, phosphorus, and potassium, and minimize the loss of manure nutrients to the environment, this has been a very positive evolution.

Manure, however, is not applied like a fertilizer. It is seldom applied just pre- or post emergent, and it is frequently applied under conditions adverse to the preservation and utilization of nitrogen. Another significant problem is that many of the most mobile and persistent parameters are not nutrients, are not taken up by crops, and cause significant harm to human and environmental health.

It is no longer adequate to base agricultural controls on nutrient management alone. All parameters of concern to human and environmental health must be given equal weight in devising solutions.

Microbes**:** It was not so long ago when the farm family was able to develop immunity to fecal organisms, contacted directly or ingested by drinking water drawn from shallow dug wells, often poorly sealed and poorly located (Goss et al. 1998).

Not long ago it was also mistakenly thought that groundwater was protected from penetration by microbes, or at the very least, microbes could not survive any measurable distance in the groundwater (Bevan and Germann, 1982, Shutter et al. 1994). Microbes have been proven to leach through the overlying soil, and to travel appreciable distances once in the groundwater zone (Frind et al. 1990, Patni 1984)

Today, microbes present a more serious threat to human health. Examples include pathogenic bacteria such as E. coli 0157:H7, pathogenic protozoa such as cryptosporidium, viruses, and antibiotic-resistant bacteria or super-bugs.

Salt: Environment Canada, under the Canadian Environmental Protection Act, is in the process of assessing the toxicity of salt amongst a list of 25 priority substances. Salt is deleterious to aquatic and terrestrial ecosystems, and is highly mobile and persistent in the natural environment. If salt is declared toxic, Environment Canada will develop and implement control measures that will ultimately affect agriculture. Animal manure and commercial fertilizers alike are very high in salt content. In one study, chloride in liquid swine manure in open manure storage tanks was found to range from 1208 to 1482 mg/l (Ausable Bayfield CA, 1991)

Nitrate: Evidence that nitrate is a significant threat to groundwater has been available for over 50 years (Fitzgerald et al. 1997, Fleming 1992, Frank et al. 1991). Nitrate in excess of 10 mg/l causes blue-baby syndrome (Shuval and Gruener 1972, Comly 1945, Craun et al. 1981). Municipalities such as Strathroy, Waterloo, and Woodstock are all managing individual supply wells with nitrate in excess of the Provincial Drinking Water Objective. There is no evidence, however, that livestock agriculture is any more significant a source of nitrate in groundwater, when compared with cash cropping. Since nitrate in groundwater is a major concern, managing nutrients in a cash-crop system must be given equal priority.

Phosphorus: Phosphorus is a nutrient that is washed off with soil sediments (USGS 1999) and causes surface water to age prematurely through the process of eutrophication (Schindler 1975). This is a cycle of increased growth of aquatic plants and algae, increased turbidity, increased water temperature, and reduced oxygen content– all of which produce an undesirable environment for fish, human recreation, and rural development (Smith et al. 1999, Heckey and Kilham 1988). Phosphorus has long been the subject of land stewardship and best management practices. Great progress has already been made on this topic, but if anything, these efforts should be redoubled.

3. Capacity to Assimilate Contaminants

In engineered waste treatment systems, the capacity to treat waste is a design parameter. In natural systems such as land-application, however, capacity is a function of variables including climate, waste strength, loading rates (gallons/acre), surficial soils (i.e., pedology), subsurface geology, hydrogeology, and agronomic factors (e.g., cropping, tillage). In an ideal world, we could quantify all of these factors and predict the capacity of, for example, a sub-watershed to degrade or assimilate a quantifiable contaminant load.

Although the behavior of these individual variables has been studied and is fairly well understood, it remains a huge challenge to account for their complex interactions. It is also difficult to quantify the incredible variability that is encountered when it comes to actual conditions in nature.

Perhaps the single most important variable is climate; the one we have the least control over. The agronomic benefit, and in turn, the environmental impact, of land-applied animal manure is almost completely dependant on climate conditions (Dean and Foran 1991). The important factors include previous soil moisture, rainfall, water table elevation, temperature, solar radiation, wind, and humidity.

Although it is a huge challenge, the next generation of waste management tools for farmers and municipalities must account for climate by using the most advanced computer models available.

4. Livestock Agriculture vs. Cash Crop

Livestock agriculture is not the only rural land-use that is threatening the hydrologic cycle. Cash cropping systems have the potential to cause equal if not greater threat to groundwater resources (Kolpin et al. 1993, Hubbard et al 1984). Cash cropping can result in nitrate levels arriving at the water table well in excess of the Provincial Drinking Water Objective (Meuller et al. 1995). The next generation of controls must address cash crop systems of agriculture.

1.0 PROPOSAL TO STRENGTHEN THE EXISTING FRAMEWORK

1.1 Introduction

In the following section, a framework is proposed that could be used to approve applications for new or expanded livestock facilities, as well all other rural development proposals. The framework draws upon the disciplines of agriculture, engineering, geology, ecology, and chemistry for its foundation. Elements of the framework bear similarity to accepted policies such as watershed planning, wellhead protection, aquifer vulnerability assessment, risk assessment, environmental assessment (EA), and environmental management systems (EMS).

The proposed framework is conceptual in scope. It does not spell out any actual criteria, but it provides examples of factors that enter into establishing the assessment criteria. Adoption of the framework does not, however, require that the Township start from scratch. OMAFRA's GIS tools (see Figures 1 through 4) were used in the last decade to gather much of the data required in the Township of Ashfield. As well, model jurisdictions can be found across North America and Europe where the required criteria have already been researched, tested, and put into place (Ervin and Lusch 1992, Stemenvoort et al. 1992, Lemme et al. 1990, Evans and Myers 1990). An Official Plan Amendment has recently been passed in the RMOW to adopt this framework in the urban context (RMOW 2000).

1.2 Conceptual Planning Framework

There are two key components to the proposed framework: the establishment of a township-wide surface and groundwater vulnerability assessment, and the performance of a risk assessment on all new developments. The two assessments are combined to arrive at an overall risk rating. The combined rating then determines the nature of limits or constraints on the application.

The Township-wide vulnerability assessment would rank all landscapes as possessing an inherently high (3), medium (2), or low (1) vulnerability to contamination. Factors that influence the inherent vulnerability of surface and groundwater include:

- Surface slope
- Soil type
- Soil chemistry
- Vegetative stream buffers
- Local and regional hydrology
- Underlying stratigraphy
- Depth to groundwater
- Characteristics of the unsaturated zone (e.g., hydraulic conductivity, porosity, thickness)
- Characteristics of the saturated zone or aquifer (e.g., hydraulic conductivity, porosity)
- Recreational value of regional surface water features
- Economic value of local groundwater

The Township would then be required to assess and rank all proposed agricultural developments as possessing a high (3), medium (2), or low (1) risk. Factors that influence the relative risk of a proposed agricultural operation include:

- cropping rotation
- fertilizer and manure application rates
- barn foundation design
- manure storage structure design
- use of polymer liner or external membrane
- leak detection technology
- method of manure handling

1.3 Implementing a Risk-Based Planning Framework

The following scenario provides a practical but hypothetical example of how the two systems of scoring can be combined to provide a useful planning tool. The description is intended to be illustrative. Fleshing out the framework (determining the consequences of each risk ranking) would depend on local conditions.

A high-risk operation proposing to locate in a high vulnerability area (total score = 6) might simply not be permitted. The applicant's options include reducing the risk of the operation by changing construction or operating methods, or re-locating the proposed operation to a region of lower inherent vulnerability.

A proposal with an overall risk rating of medium (total score = 4 or 5) might be permitted after being required to:

- Perform a site-specific surface water and groundwater assessment including a mandatory terrain conductivity survey utilizing non-invasive geophysical instruments (see below for description).
- Perform a prediction of contaminant transport and fate using a validated computer model.
- Establish a full-fledged Environmental Management System (EMS) with 3rd party auditing or review.
- Perform diagnostic surface and groundwater monitoring (also requirement of the EMS)
- Follow the requirements set out for lower risk proposals.

Low risk proposals (total score = 3 or less) would be permitted after meeting less stringent requirements:

- Supply accurate map of subsurface drainage and plan of drainage re-design.
- Identify well records within a specified radius, inspect condition and test groundwater.
- Perform nutrient management plan to determine fertilizer recommendations.
- Obtain and test soil samples by a 3rd party.
- Predict 10, 25 and 50-year loading of nutrients, inorganic salts, and bacteria by completing a simplified computer simulation.
- Complete a peer-reviewed Environmental Farm Plan

A risk-based approach becomes independent of an animal unit threshold. The above example was perhaps the most rigorous example that could be devised. It is possible that in The Township of Ashfield there is no landscape where a new barn could not be located, independent of size, as long as certain operating conditions are met. The example demonstrates that it is possible to foster rural development across a wide spectrum of scale, providing that tolerances for risk are established and respected, and there is a requirement to collect and report baseline and performance data.

1.4 Technical and Administrative Tools

In order to adopt part or all of the system described above, the Township of Ashfield would have to be prepared to play an increased role in local resource stewardship. This would involve establishing and maintaining databases, making data available to applicants and the public, and taking an increased role in evaluating applications, inspecting facilities, and auditing operating practices.

The Township would also need to play a role and perhaps adopt local responsibilities in specific extra-jurisdictional (county, watershed or provincial) priorities such as establishing a network of sentinel farms, ambient surface water quality monitoring, and a provincial groundwater quality monitoring network.

A brief outline of the technical and administrative tools available to assist Ashfield in achieving these increased responsibilities is presented below.

1.4.1 Watershed Vulnerability Assessment

In the absence of on-site or communal waste treatment systems designed to meet engineered specifications and performance criteria (discharge limits), we rely on the landscape and natural processes to degrade and assimilate waste products.

In order to maintain a balance between what we produce and what the ecosystem can handle, at the very minimum, we should permit land-use activities according to a pre-determined inherent vulnerability of the landscape. An understanding of surface and ground water vulnerability to contaminants provides a rational, scientific basis for assessing future land-use applications (Fernandez et al. 1993).

A watershed vulnerability assessment recognizes that all physical settings are not created equally. As described in the preceding section, many biological, physical, and chemical factors interconnect to determine vulnerability (Meij and Abdalla 1990).

For example, it is commonly recognized that thick, heavy clay aquitards provide inherent protection to underlying groundwater from surface contaminants. It is also recognized that when these conditions support a shallow, poorly drained water table, nitrate removal (through bio-degradation) is at its maximum.

On the other hand, vast regions of the province with well drained surface soils and relatively deep water tables have had levels of nitrate in groundwater exceed the Provincial Water Quality Objectives (Fleming 1992, Goss et. al. 1998).

A first attempt at establishing an aquifer vulnerability assessment for all of Huron County was made by OMAFRA (see Figure 1: Susceptibility of Groundwater to Contamination, Huron County). It was based on the map of Physiography of Huron County (Figure 2). This first attempt was overly simplified; however, key data files have already created.

Several methodologies exist in the literature that could be adopted in the context of the Township of Ashfield. The Regional Municipality of Ottawa-Carlton is currently performing a groundwater vulnerability assessment using the DRASTIC methodology.

1.4.2 Township Geographic Information System (GIS)

In order to create and maintain a Township Vulnerability Assessment Map, a GIS is an essential tool (van Stemenvoort et al. 1993). Even just to maintain the status quo in the Township of Ashfield, a GIS would greatly improve on the review of applications for new or expanding livestock facilities. Currently, no site visit is made by OMAFRA, so there is no means of verifying the data that is supplied. A GIS would assist with the rapid verification of such information as slopes, location of wells, soil type etc.

A GIS consists of layers of data, geographically referenced, including but not limited to roads, infrastructure, well records, surface hydrology, soil classification, land-use, and water quality monitoring data.

OMAFRA and the Maitland Valley Conservation Authority have already created many layers of digital data in a GIS for the Township of Ashfield. An individual or company could be contracted with to maintain such a system for the Township.

1.4.3 Modeling the Water Cycle and Contaminant Transport

Tools are currently available to simulate the water balance on the farm, but they are not yet in use in Ontario (Gogolev and Ostrander 2000, Schroeder 1994). These tools can be coupled with models that simulate the transport of parameters like nitrate, bacteria, and chloride, to determine their chemical concentration at the water table (Healy 1990).

These tools are in wide usage in scientific and regulatory contexts throughout North America (Gogolev and Delaney 2000), and it is only a matter of time before the permitting of agricultural facilities in Ontario is guided by the results of computer simulations.

In the near future, landowners will use models that simulate the weather on their farm for 5, 10, 20 or 100 years into the future. After providing input data concerning tile drains, soils, slope, crop type, and depth to groundwater, the model will calculate the predicted loading of key manure or fertilizer derived parameters to surface water and the groundwater.

While there are many models capable of predicting the water and chemical balance on a farm, the following example will focus on a suite of 5 of the most highly verified numerical models developed for the unsaturated zone: HELP, PESTAN, VS2DT, VLEACH, and SESOIL. These 5 codes have been combined with a comprehensive weather generator in a windows-based graphical-user-interface called WHI Unsat Suite, by Waterloo Hydrologic (WHI, 1999).

WHI Unsat Suite employs a sophisticated weather-generator to create statistically reliable daily values of precipitation, air temperature, and solar radiation for up to 100 years into the future. A site-specific simulation is based on historical data for a nearby weather recording station.

The Hydrologic Evaluation of Landfill Processes, or HELP, is a USEPA model developed to study and regulate landfills. It simulates the hydrologic balance using the following inputs:

- Multi-layered soil profiles
- Horizontal drainage
- Change in surface slope
- Vegetation type

HELP in turn simulates the following:

- Surface ponding
- Snowmelt
- Run-off
- Infiltration
- Evapo-transpiration
- Vegetative growth
- Soil moisture storage
- Lateral subsurface drainage
- Unsaturated vertical drainage

Applying the HELP model to farmland allows calculation of expected partitioning of precipitation into 3 components: tile flow, run-off, and recharge to groundwater. It is then possible to estimate annual loading rates of nitrate or bacteria, for example, by one of several methods. The computer codes described below are coupled with the HELP model to calculate loading rates to the groundwater.

The Variably Saturated 2-D Flow and Transport Model, or VS2DT, is a US Geological Survey model describing the transport and transformations of contaminants in the unsaturated zone. It is based on the solution of Richard’s Equation.

VS2DT simulates the following:

- Surface storage
- Infiltration
- Soil evaporation
- Plant transpiration
- Vegetative growth
- Unsaturated vertical flow
- Pollutant transport with hydraulic dispersion
- Pollutant decay

- Pollutant adsorption
- Ion exchange

SESOIL is a USEPA model that simulates water transport and chemical fate. It is widely used as a screening tool to assess unsaturated-zone contaminant fate and transport for regulatory requirements. It is particularly well suited to the manure issue.

SESOIL simulates the following:

Surface run-off
Soil erosion
Variably flow as a function of average moisture content
Advective transport through soil
Sorption
Volatilization
Degradation
Cation exchange
Hydrolysis
Metal complexation

PESTAN is a US EPA model that evaluates the environmental impacts of potential non-point agricultural sources of groundwater contamination. It simulates one-dimensional transport of pesticides through soil to the groundwater. It is not as sophisticated as VS2DT, but provides a useful pre-screening tool.

VLEACH is a USEPA model widely used for the assessment of potential groundwater impacts and volatilization of volatile organic contaminants. It is highly simplified one-dimensional finite difference model, which was developed to assist in permitting pesticide usage.

In order to demonstrate the application of computer models to the problem of manure run-off, WHI has performed a generic simulation with Visual HELP. The following input parameters were utilized:

Land area = 100 acre
Surface slope = 1%

Slope of tile run = 1%
Hydraulic conductivity of subsoil = 1E-7
Weather station = London Ontario
Tile spacing = 50 ft.

The model was able to calculate the lateral drainage water collected from the tiles assuming systematic spacing over the 100 acres, for each of 7 years into the future. The results of the simulation are contained in Appendix 1. Drainage volume via tile drains was estimated at between 4000 and 9000 m3.

This volume can then be used to calculate the average loading of a contaminant of interest. If chloride, phosphorus, or nitrate, for example, had an average concentration in tile drainage water of 100 mg/l, then the annual discharge of that parameter via tile drains from the 100-acre parcel would be between 400 and 900 kg.

1.4.4 Sentinel Farms

Without introducing discharge-controlled waste treatment, or Certificates of Approval, we are dependent on natural processes to transform waste products. Natural systems have been much more difficult to study in the lab and in the field, as compared with engineered systems, such as sewage digesters. With natural systems, it is difficult to predict the transformation products and pathways, and therefore, to predict the environmental impact.

There is a need, therefore, to perform on-going field-scale research. Such research would serve two goals:

- To improve our predictive ability (e.g., at a given manure application rate, what will the concentration of nitrate in groundwater be in 20 years time?).
- To provide an early warning system if the management system fails to adequately protect the environment and human health (e.g., are bacteria migrating in the groundwater?).

A network of Sentinel Farms could fulfill the two goals above. It would consist of a small number of farms (20 to 50 across the province) representing a wide range of landscapes, where monitoring would be carried out on a much more detailed scale than would normally be practical. The high quality of the data would support more accurate computer simulations, which in turn would be calibrated or verified by the on-going monitoring.

Regulatory monitoring will never adequately satisfy scientific demands (e.g., accuracy, reproducibility, and statistical significance). Sentinel Farms, if monitored properly, could justify less rigorous standards for routine monitoring of individual farms (so long as auditing is in place).

Implementing Sentinel Farms as a verification tool in a risk-based planning and approvals environment provides one component of quality assurance. In the current environment of voluntary Nutrient Management Plans, it would provide the only form of verification to the public.

It would not be necessary for each rural municipality across Ontario to duplicate this activity. A network should be designed provincially, and individual locations should be managed locally.

1.4.5 Terrain Conductivity Survey

In Section 1.3 above, conducting a terrain conductivity survey is cited as a useful tool for both municipal government and landowners in managing the environmental impact of manure storage and spreading. The procedure and its application to agricultural operations are described below.

Non-invasive surface geophysical tools (Geonics EM-31, EM-34, EM-38) have been used to investigate groundwater plumes from leaks, spills and the routine spreading of manure in Ontario and elsewhere in Canada with a high degree of success (McNiell 1994). A hand held device emits waves of electromagnetic energy, which in turn are received by the device after the waves reflect off material in the subsurface. The quantity that is measured in the subsurface is the bulk conductivity.

When manure enters the groundwater, it changes the conductivity of the pore water. These variations in pore water conductivity, as compared to the conductivity of the soil matrix, can often be interpreted from measurements of the bulk conductivity of the subsurface. The method has proven to be a relatively quick and inexpensive screening tool to identify point (manure leaks around barns and storage tanks) and non-point (spreading) sources of manure-derived parameters in the groundwater.

Interpreting these tests is complicated by the three following sources of interference:

- Highly conductive background water due to years of fertilizer or manure spreading.
- The presence of farm buildings, machinery, and services, all emitting a conductivity of their own.
- Naturally occurring subsurface soils with variable conductivity (e.g., clay vs. sand).

It would be ideal, therefore, to perform a Terrain Conductivity Survey on land prior to erecting a new barn or manure storage. No matter what conductivity anomalies are discovered (previous nutrient applications, natural soil stratigraphy), this picture of the subsurface represents the “before” conditions. Should there be a leak or spill, then an ‘after’ picture will be able to verify this. The “before” picture is used to subtract any prior readings of conductivity.

For the landowner, the ‘before’ survey establishes due diligence and protection from previous contamination of the subsurface. The ‘after’ survey provides a useful detection tool if volume discrepancies occur. The ‘after’ survey also provides a useful investigative tool for municipal government in the event of off-site contamination.

1.4.6 The Role of Nutrient Management Planning in Regulation

Nutrient management planning is essential for a farmer to manage croplands in the most economic fashion. It supports achieving maximum yields by matching nutrient requirements with actual soil conditions. Increasingly farmers are sampling soil on a finer grid, thereby refining the application of nutrients to meet site-specific needs (Fleming et. al. 1999). In a livestock system, the nutrient management plan further economizes resource use by replacing commercial fertilizer with the nutrients derived from livestock manure.

Nutrient management planning is a simple process of balancing inputs and outputs. OMAFRA has developed NMAN2000, a computerized advisory system to simplify and speed-up the process of calculating nutrient needs. The program is a highly useful graphical-user-interface that allows the user to simulate a multitude of scenarios.

The nutrient management process should be implemented and adopted widely across the rural development sector. Its use should be expanded within the livestock sector, as well as extended to cash crop systems and other non-farm land-uses like golf courses.

It should not, however, form the backbone of the regulatory control initiated to protect public health. The NMP falls within the context of a larger Environmental Management System, which is an in-house, self directed strategy designed to help producers balance economic and environmental targets.

NMAN2000 has no predictive capability. In a multi-year simulation, even the calculation of soil phosphorous and potassium levels uses the initial soil test value, as opposed to the previous year's simulated value. Soil depletion or excesses are not carried forward, so in effect, each year in a simulation goes back to the baseline soil test value.

NMAN2000 does not consider any variables such as climate, and does not solve any mathematical relationships describing nutrient partitioning between plant, soil, air, and water. NMAN2000 does not account for microorganisms in any way. Finally, it does not provide an accurate balance for nitrogen because it is missing the following key components: soil storage (initial conditions), atmospheric deposition, denitrification, leaching, and run-off.

NMAN2000 does address environmental protection by the use of three arbitrary, upper limits on application rates of nitrogen and phosphorus. In terms of the hydrologic cycle, an index approach is not adequate.

1.4.7 Review and Re-design of Subsurface Drainage

There is no such thing as a "closed loop" system when it comes to land drainage. Water only flows from high to low, through the path of least resistance. Once collected, water will continue to flow, or it will artificially mound, even when tiles are cut-off and capped. Water can not be recycled through field tiles without the use of a pump. When establishing methodologies for dealing with barn foundations that intercept field tiles, the use of the term "closed loop" system must be eradicated because it implies a technique that is physically impossible.

Tiles draining toward a barn can not simply be cut off and capped. Water continues to drain in the direction of the barn, and under the right conditions, subsurface drainage water will simply come to the surface, or make its way to the foundation of the barn and create a mound. The appropriate solution is to cut-off the existing tiles and join them to a new header tile. The upstream part of the drained field is then re-routed around the barn and back into the downstream side of the drainage network. The tile that is cut-off should be removed from the ground for a defined distance beyond the downstream edge of the barn.

The process for approving new or expanded livestock barns needs to be modified to address subsurface drainage.

1.4.8 Inspection, Monitoring, and Surveillance

Lack of proper inspection of agricultural facilities around the province has in the past resulted in inappropriate construction methods, structural failure, and violation of operating guidelines, policies, and agreements.

Inspection should focus on initial construction, monitoring systems, and perhaps routine activities like manure spreading.

1.4.9 Auditing

The proposal put forth by this report does not necessarily require that auditing take place, due to the rigorous pre-screening of applications and the monitoring and reporting requirements. If, on the other hand, the Township promulgates another voluntary by-law, then auditing will be essential. As with all voluntary forms of regulation (e.g., the Income Tax Act), compliance can only be encouraged through an auditing program.

Auditing differs from inspection in that it is random, unannounced, and should have the authority to obtain economic information such as fertilizer purchased, as well as procure physical samples for analysis.

1.4.10 Surface Water Quality Monitoring

The network of adequately monitored surface water stations across Ontario has fallen below an acceptable level. This as resulted from downloading from the Federal and Provincial governments, reduced funding to Conservation Authorities, and the uncoordinated management of health and environmental objectives. Although emphasis has recently been placed on the inadequacies of groundwater monitoring, we can not lose sight of the importance of monitoring surface water quality. This is particularly meaningful for residents of a shoreline municipality.

The Township of Ashfield needs to play a role in coordinating the allocation of Federal, Provincial, and local resources to surface water quality monitoring within its boundaries. Without a renewed and updated effort in this area, it will never be possible to know what the impact of agriculture really is on Lake Huron. The current pass/fail system of monitoring bacteria, for example, was never designed for statistical interpretation. After all these years of monitoring beaches, it remains impossible to conclude if there are any trends, up or down.

1.4.11 Groundwater Quality Monitoring

The Ministry of the Environment has recognized the role of ambient groundwater quality monitoring in managing growth and development in Ontario. To this end they have designed a network of provincial groundwater monitors, and allocated funding for Conservation Authorities to collect and manage local data.

The Township of Ashfield will benefit by, but may need to expand on these Province-wide plans, in order to satisfy their own safe-environment goals.

2.0 REVIEW OF ASHFIELD'S NM BY-LAWS

By-law 11, By-law 17 and By-law 18 were reviewed and the following problems have been noted:

1.1 In Section 4.4.2.3, it is not sufficient for the applicant to identify only the nearest well. A radius around the new or expanded facility should be established, and all wells located within the prescribed radius should be identified, inspected, and sampled for bacteria, nitrate, and chloride, as a minimum. The radius should be on the order of at least 2000 ft.

1.2 The By-law makes no provision for abandoned wells. It should stipulate that abandoned wells on properties registered in the NMP must be decommissioned by a licensed contractor, and a Water Well Record must be filed with the MOE.

1.3 Section 4.4.2.5 should be expanded to require provision of the layout of drainage tiles and the location and condition of the outlet drains. Buried or open municipal drains must also be identified and located on a map.

1.4 Section 6.4.2 should specify that the consultant in agriculture is independent from the applicant and any companies at arm's length to the applicant.

1.5 By-law 11 should be expanded to provide security for soil samples. The current By-law provides no clear methodology for obtaining soil samples by an independent party. It stipulates that once obtained, an accredited lab must analyze them. This weakness in the chain of custody, coupled with the By-law's lack of auditing, creates a permissive environment where sample substitution may occur.

1.6 By-law 11 does not require the applicant to provide any background data concerning local water quality, nor monitor water quality at any point in the future. In an environment where following the NMP is wholly voluntary, the absence of water quality monitoring data is a fundamental flaw. In the event of a spill or a leak, the municipality might not be able to prove the origin of the contamination.

1.7 By-law 11 does not require on-site monitoring of foundations. It should be expanded to require that the applicant constructs a perimeter drain around the barn and the storage, and installs an observation well at the outlet.

1.8 By-law 11 does not provide any minimum construction standards to ensure water-tightness of manure storage structures. Concrete floors and walls can only be rendered watertight through the use of polymer liners, membranes, or waterproof coatings. The municipality should investigate these technologies.

1.9 By-law 11 lacks any form of auditing. It must be expanded to specify that random auditing will be conducted. Guidelines for auditing and a protocol must be developed.

1.10 By-law 11 does not provide for site verification of any of the information provided in the NMP. Under the current regime, OMAFRA reviewers do not visit the proposed facility and associated lands, and do not verify in the field any of the information provided. The third party reviewer should conduct site verification.

1.11 By-law 11 provides no clear direction to applicants on managing subsurface drainage in the vicinity of the new or expanded facility. Applicants should be required to supply a detailed plan to re-route field tiles. They must also supply the location of outlet drains and a clear protocol for observation of flow prior to, during, and after manure application.

1.12 By-law 11 provides no prescription regarding the timing of manure application with respect to precipitation, temperature, humidity, and wind speed. Similar to pesticide application, controls must be put in place. If voluntary guidelines can not be complied with in the future, the municipality should consider licensing applicators. In the meantime, the Township of Ashfield needs to develop clear guidelines in this area, before there is any hope that the migration of manure parameters in the hydrologic cycle will be minimized.

1.13 By-law 11 should be expanded to require that applicants submit a methodology for manure application. The plan must include details of road crossings. Minimum standards for construction of piping under roads should be established.

1.14 By-law 11provides no upper limit for manure applications rates. It relies on OMAFRA standards. Unfortunately, these standards are based on hydraulic loading and surface run-off prevention only. They need to consider run-off via tile drains, waste strength, and the assimilation capacity of surface and groundwater. As well, the rates published by OMAFRA have no correlation to the livestock unit limit (1 or 1.5 LU per Acre). The Township of Ashfield should put in place a methodology to prescribe the upper limit on the manure application rate.

1.15 By-law 11 has the intention of protecting the environment, yet the major focus is on growing crops efficiently. This is evidenced by the reliance on NMAN2000 to determine environmental thresholds. NMAN2000 does not have the capability of determining acceptable application rates of nitrogen, microorganisms, or inorganic salts. This report, therefore, recommends that By-law 11 should be scrapped, and a wholly new approach to rural planning and approval should be developed.

3.0 REVIEW OF NMP SUBMITTED BY COUNTRY PORK LTD.

Performing a nutrient management plan in application for a permit to build a new livestock facility allows the applicant to calculate how much commercial fertilizer is required to make up the crop's agronomic need, after the entire manure production volume has been given a nutrient credit. It assures the municipality that manure disposal is not being practiced (e.g., excess application of manure to crops that can't use it like alfalfa), that manure is not being spread on highly erodible soils in close proximity to a watercourse, or that soil phosphorous build-up is not excessive.

The NMP process, however, provides no information about the migration of nitrate, bacteria, protozoa, soluble salts, or phosphorus off the farm via groundwater or surface water pathways. It therefore provides little information about the potential environmental impact of the proposal.

In addition to the three "red flags" mentioned above, environmental protection is addressed by the requirement to provide documentation of pathways (i.e., tiles, wells, and slope) that could allow pollutants to migrate off the farm. Providing this information is fundamental to minimizing pollution from manure spreading, leaks, and spills, in that it acknowledges that these pathways need to be managed.

This important documentation of pathways was not provided in Country Pork's Nutrient Management Plan. The implication of these omissions is discussed below.

3.1 Tile Drainage and Tile Drain Outlets

Tile drains provide a significant pathway for the migration of nutrients, soluble salts, inorganic chemicals, microorganisms, and organic chemicals off farms and into local, provincial and federal watercourses (Dean and Foran 1991, Fleming and Bradshaw 1991). This occurs after accidental leaks and spills, as well as after routine spreading of fertilizer and manure (Cully and Phillips 1982, Fleming and Bradshaw 1992).

There are strategies to avoid or minimize this migration (Wall et al. 1996, Fleming et al 1998, Fleming and MacAlpine 1995, McLellan et al. 1993), and for this reason, the Nutrient Management Plan requires that field tiles be identified if present, and that tile outlets be located.

Neither the presence of the field tiles nor the location the tile outlets were identified in the NMP submitted by Country Pork. Early air photos reveal that the 5 parcels of land (3 owned, 2 with manure spreading agreements) are systematically tile drained, and that they are drained directly into two creeks leading to Lake Huron (see Figure 5: Photo-mosaic of Study Area and Figures 6 and 7).

The OMAFRA checklist noted this omission, and it is highlighted in the Remarks section. The Plan should not have been approved without this information. In order to check the condition of the outlet drains prior to spreading, and monitor them periodically during spreading, their location must be determined and made readily accessible.

Omitting the presence of field tiles has a secondary implication. Fields are drained in the direction of the fall of land. A new barn located in the middle of a systematically drained field will intercept the flow of subsurface drainage on one of its sides. Tiles draining toward the barn can not simply be cut off and capped. Water will continue to drain in the direction of the barn, and under the right conditions, subsurface drainage water will simply come to the surface, or make its way to the foundation of the barn and create a groundwater mound. The appropriate solution is to join the existing tiles to a new header tile and re-route the upstream part of the drained field around the barn and into the downstream side of the drainage network. A plan of this nature should be designed and drawn up before a building permit is issued.

On p. 17 of the NMP it is stated that the barn will be located “not closer than 15 m to field tile”. This statement, while acknowledging the presence of field tiles, does not reflect an understanding of the requirement to manage subsurface drainage in manner that is environmentally sound and consistent with good engineering principles.

3.2 Location of Groundwater Wells

The number and location of wells on and off the subject properties were not identified. The 100-ft manure-spreading setback can not be observed when these wells have not been located. On page 7 of the NMP, 2 groundwater wells are identified: “one at neighbors existing house, one at new facility”. It is entirely unclear which two wells are being referred to. What is the “new facility”? If it is the parcel with the proposed barn (F3), there is no record on file with the MOE for a well on that property. If it is a new well, no manure spreading setback or buffer has been shown for F3 on Figure 2 Section 9.

There are at least four “neighbors” with groundwater wells, directly within or adjacent to the fields receiving manure. A search of the MOE Water Well Database reveals that there are at least 6 drilled wells with well records located directly on the parcels proposed to receive manure. These records were available free of charge from the Maitland Valley Conservation Authority (See Appendix 2: Location of Water Wells and Identification of Stratigraphic Units).

Perhaps the most significant omission is the failure to disclose an old, unused; 152-foot drilled well on the parcel identified as F1B. This well sits at the bottom of an open concrete pit, 3 or 4 feet beneath the ground’s surface, in a pool of collected surface water, with no cap or cover over the top of the open casing. This well has not identified, since there is no manure-spreading buffer located around it on Figure 2, Section 9.3. A plan was not proposed for proper decommissioning of the abandoned well.

Unused wells that have not been properly decommissioned pose a serious threat to groundwater. Any spill or leak of agricultural chemicals in a fairly wide radius of this wellhead, combined with normal run-off, could cause damaging pollution of the bedrock aquifer.

Applicants must identify unused wells on parcels of land destined to receive fertilizer, pesticide, or animal waste. Failure to do so represents a failure to understand and comply with the tenets and requirements of the Nutrient Management Plan. It is also a violation of

MOE Regulation 903. A licensed water well contractor must decommission these unused wells, and a water well record filed with the MOE.

3.3 MANURE SPREADING RATE

The applicant has proposed to spread manure over a total of 241 acres per year, at the dual rates of 6800 gal/ac and 5684 gal/acre. These rates should have been rounded off to 7000 gal/ac and 5500 gal/ac respectively, considering the reality of calibrating manure spreaders.

On Page 11 of the NMP it is indicated that "Manure spreading agreements exist for 186 acres at a maximum of 4000 gal per acre per year. Thus an agreement for 744,000 gal per year." In NMAN2000, it is proposed that a total of 5684 gal per acre be applied to half of the available acreage for a total of 528,612 gallons. The rate has been increased because manure is applied every two years, while the total volume is in fact lower. It is not clear why the original rate of 4000 gal/ac has been exceeded, and if this is justifiable. For example, if a field were only going to receive manure once in 5 years, it would not be acceptable to apply 20,000 gallons per year, even though this averages out to 4,000 gallons per year per acre.

The maximum single manure application rate of 6800 gal/ac was determined from OMAFRA's Nutrient Management Workbook. This is an arbitrary value and has not been based on the hydrology or climate of the region. It was based on MOE guidelines governing land application of sewage sludge (bio-solids), and was designed to minimizing surface run-off. It does not consider waste strength as a criterion. 6800 gal/ac represents a manure thickness of approximately 6.5mm over the entire surface.

Without the additional land-base with manure spreading agreements, the manure application rate would have been approximately 10,000 gallons per acre, considering that out of the approximately 300 acres owned, only 150 acres are available to receive manure in any given year. The solution of NMAN2000 required an additional 91 acres for spreading, bringing the total available land-base to 241 acres.

There seems to be a lack of consistency in establishing the maximum permissible manure-spreading rate. The following statement is offered as an alternate interpretation of the maximum spreading rate, based on the original intent of the livestock unit per acre threshold. **The manure from 1.5 livestock units should be spread over at least 1 acre of cropland, in any given year**. This number (1.5) may or may not be valid, however, it is based on waste strength and not run-off potential alone. As such, it is independent of whether the manure is in the solid or liquid form.

In the present case, 450 LU (9000 weaners) generate 1,535,141 gallons of liquid manure, which divided by 300 acres (1.5 LU/ac) gives an annual spreading rate of approximately 5000 gallons/acre. In a biannual rotation of corn and legumes, then access to 600 acres total would be required to provide 300 acres per year available for spreading.

Country Pork proposes to spread manure at a rate of 6800 gal/ac, perhaps twice per year.

The lack of a consistent method for establishing an acceptable manure application rate and the confusion between the maximum single rate versus the annual application rate demands that attention be focussed on standardizing this limit.

3.4 Miscellaneous

Other errors or omissions with the submission were noted:

2.0.1 Single soil samples were taken on fields F1A, F1B, F2, and F3 and they were analyzed for 6 parameters. The four sets of individual results were then averaged, since the field names had not been identified on the sample containers. Not only should more than one sample have been obtained for each field (recommended minimum = 1 sample per 25 acres, OMAFRA), but also the results of a single test from each of 4 fields can not be averaged for the purposes of NMAN2000. The essence of the computer program is to establish field-specific tolerances for two key nutrients. The 4 individual results showed enough variability that they should not have been averaged. At the very least, the highest value should have been used. No samples whatsoever was obtained for two of the parcels (Lease 1 and Lease 2).

Regardless of whether the actual samples turn out to be higher or lower than the default values that were used, NMAN2000 must be re-calculated in order to determine fertilizer application rates. The rates for all 6 fields are incorrect since incorrect soil test values were used.

2.0.2 On page 14 of the NMP it states that “manure will be pumped directly to the fields”. It is only feasible to pump manure directly to F3. The other fields will have to be accessed by piping across the road or trucking. If pumping across the roads is proposed, a plan should be designed and submitted for review. It should utilize permanent lines consisting of long, continuous piping with proper connectors and a shutdown system. Temporary lines through a culvert should be discouraged due to the possible consequences of a leak.

2.0.3 On pg. 22 of the NMP it is indicated that: “Two applications may be required to dispose of the yearly volume, depending on conditions and the fact that manure will only be applied every second year”. If this is a possibility, then this scenario should have been simulated in an alternate calculation of NMAN2000 and supplied with the application for approval.

2.0.4 The applicant intends to minimize soil and phosphorus loss through no-till farming, plus minimize nitrogen losses through manure incorporation. Since these systems are not compatible and can not be conducted simultaneously (Beauchamp 1990), Country Pork should revise their NMP to utilize minimum till practices with manure incorporation.

2.0.5 There are at least two errors on Figure 4: Site layout and results of MDS II calculations. The home located on F2 is not in the center of the radial Minimum Distance of Separation, and the orientation of the map is reversed.

Figure 1. SUSCEPTIBILITY OF GROUNDWATER TO CONTAMINATION
Huron County

Figure 2. PHYSIOGRAPHY Huron County

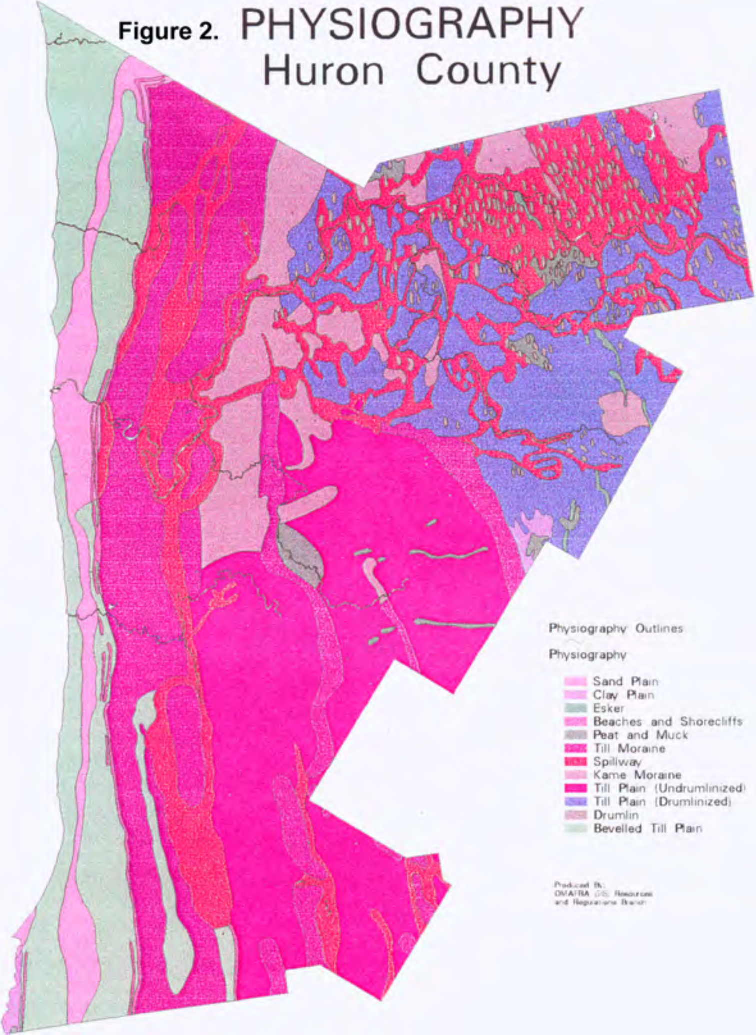


Figure 3. SOILS of Huron County

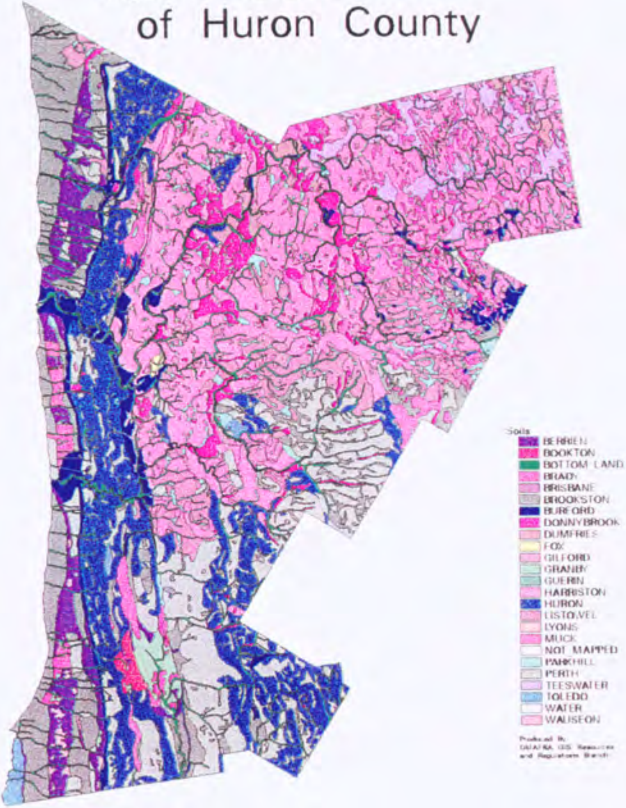


Figure 4. AGRICULTURAL LANDUSE SYSTEMS
Huron County

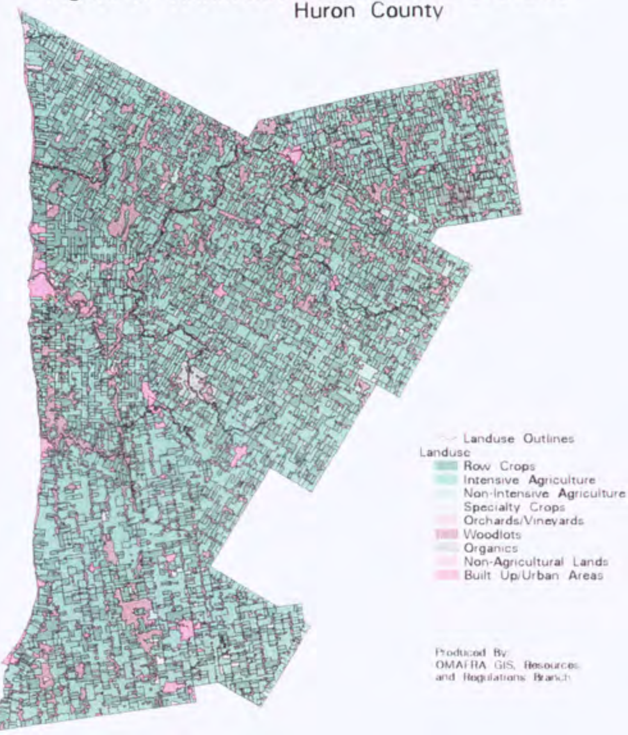


Figure 5: Photo-mosaic of Study Area: May 1992 (scale 1:15,000)

Figure 6: Blow–up of Air Photo of F3: May 1992 (scale approx. 1:5)

Figure 7: Blow-up of Air photo of F1A, F1B, Lease1 and Lease 2: May 1992 (scale approx. 1:5)

Appendix 1:

Visual HELP Simulation of Tile run-off for 100-acre farm, Huron County

1. Profile. EPA profile1

Model Settings

[HELP] Case Settings

Parameter	Value	Units
Runoff Method Initial Moisture Settings	Model calculated Model calculated	(-) (-)

[HELP] Surface Water Settings

Parameter	Value	Units
Runoff Area Vegetation Class	100 Good stand of grass	(%%) (-)

Profile Structure

Layer	Top (in)	Bottom (in)	Thickness (in)
Siltv Loam	0.0000	-36.0000	36.0000
Fine Sand	-36.0000	-44.0000	8.0000
Sandy Clay Loam1	-44.0000	-68.0000	24.0000
Loamy Fine Sand	-67.9995	-77.4000	9.4005
Clay	-77.3990	-128.1785	50.7795

1.1. Layer. Silty Loam

Top Slope Length: 25000.0000
Bottom Slope Length: 600.0000
Top Slope: 1.0000
Bottom Slope : 0.0000

[HELP] Vertical Perc. Layer Parameters

Parameter	Value	Units
total porosity	0.501	(vol/vol)
field capacity	0.284	(vol/vol)
wilting point	0 135	(vol/vol)
sat. hydr. conductivity	1.9E-4	(cm/sec)
subsurface inflow	0	(mm/year)

1.2. Layer. Fine Sand

Top Slope Length: 600.0000
Bottom Slope Length: 600.0000
Top Slope: 0.0000
Bottom Slope : 1.0000

[HELP] Lateral Drainage Layer Parameters

Parameter	Value	Units
total porosity	0.457	(vol/vol)
field capacity	0.0830.033	(vol/vol)
wilting point	0.0031	(vol/vol)
sat. hydr. conductivity	0.0000	(cm/sec)
subsurface inflow		(cm/day)

1.3 Layer. Sandy Clay Loam 1

Top Slope Length: 600.0000
Bottom Slope Length: 0.0000
Top Slope: 1.0000
Bottom Slope : 0.0000

[HELP] Barrier Soil Liner Parameters

Parameter	Value	Units
total porosity	0.45	(vol/vol)
field capacity	0.28	(vol/vol)
wilting point	0.14	(vol/vol)
sat. hydr. conductivity	1 E-7	(cm/sec)
subsurface inflow	0	(mm/year)

1.4 Layer. Loamy Fine Sand

Top Slope Length: 0.0000
Bottom Slope Length: 0.0000
Top Slope: 0.0000
Bottom Slope : 0.0000

[*HELP] Vertical Per. Layer Parameters*

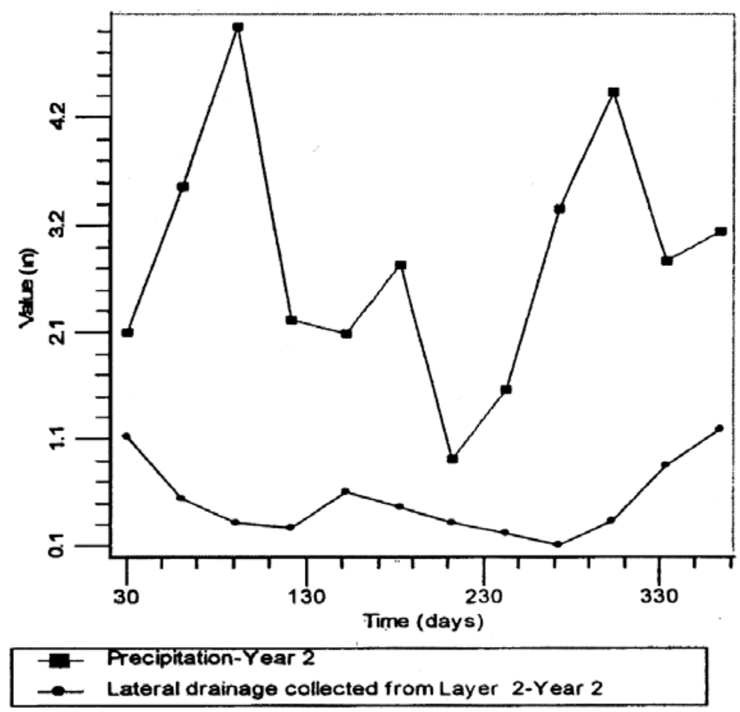
Parameter	Value	Units
total porosity	0.501	(vol/vol)
field capacity	0.284	(vol/vol)
wilting point	0.135	(vol/vol)
sat. hydr. conductivity	0.00019	(cm/sec)
subsurface inflow	0	(mm/year)

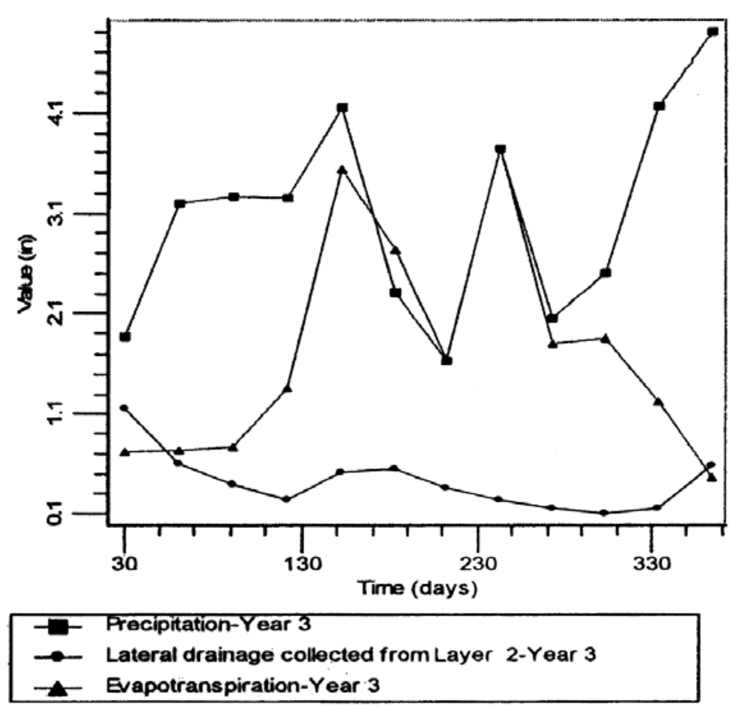
1.5 Layer. Clay

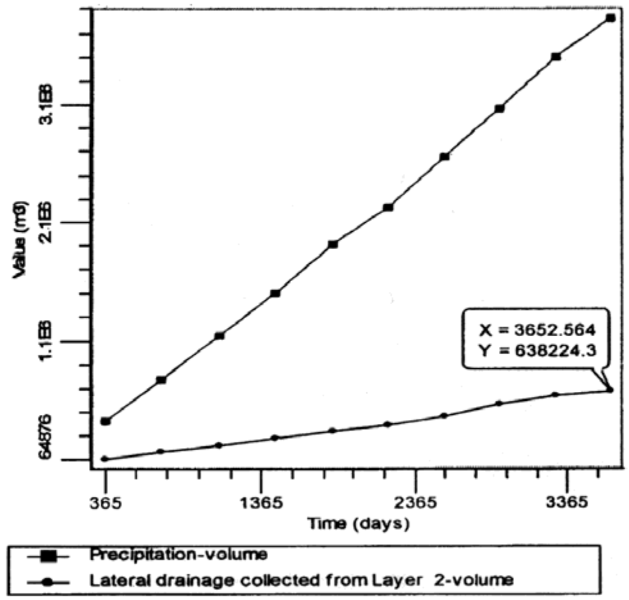
Top Slope Length: 0.0000
Bottom Slope Length: 0.0000
Top Slope: 0.0000
Bottom Slope : 0.0000

[*HELP] Barrier Soil Liner Parameters*

Parameter	value	Units
total porosity	0.475	(vol/vol)
field capacity	0.378	(vol/vol)
wilting point	265	(vol/vol)
sat. hydr. conductivity	0.0000000057870370	(cm/sec)
subsurface inflow	0	(mm/year)


Value (in)
0.1
1.1
2.1
3.2
4.2
30
130
230
330
Time (days)
Precipitation-Year 2
Lateral drainage collected from Layer 2-Year 2


Value (in)
0.1
1.1
2.1
3.1
4.1
30
130
230
330
Time (days)
Precipitation-Year 3
Lateral drainage collected from Layer 2-Year 3
Evapotranspiration-Year 3



Annual Totals volume (m3)

	Year-1 (m3)	Year-2 (m3)	Year-3 (m3)	Year-4 (m3)
Precipitation (m3)	3.8708E+05	3.4957E+05	3.7579E+05	3.5977E+05
Runoff (m3)	8.8133E+04	9.4362E+04	9.9076E+04	1.0100E+05
Evapotranspiration (m3)	2.1937E+05	1.6870E+05	2.0644E+05	2.0453E+05
Change in water storage (m3)	1.3856E+04	1.4249E+04	2.2681 E+04	-5.6355E+03
Water budget balance (m3)	-5.8134E-03	-5.2500E-03	-5.6438E-03	-5.4031E-03
Soil water (m3)	5.7060E+05	5.6925E+05	5.7703E+05	5.9250E+05
Snow water (m3)	0.0000E+00	1.5603E+04	3.0499E+04	9.3989E+03
Lateral drainage collected from Layer 2 (m3)	6.4876E+04	7.1381E+04	4.6716E+04	5.9000E+04

(continued)

	Year-5 (m3)	Year-6 (m3)	Year-7 (m3)	Year-8 (m3)
Precipitation (m3)	3 9857E+05	3.1837E+05	4.2820E+05	4.1460E+05
Runoff (m3)	1.2046E+05	7.7838E+04	1.4686E+05	1.0214E+05
Evapotranspiration (m3)	1.8396E+05	1.7446E+05	1.8370E+05	2.1506E+05
Change in water storage (m3)	3.2514E+04	8.7848E+03	2.4678E+04	5.1874E+03
Water budget balance (m3)	-5.9860E-03	-4.7814E-03	-6.4309E-03	-6.2267E-03
Soil water (m3)	6.0907E+05	62212E+05	6.5598E+05	6.4499E+05
Snow water (m3)	2 5344E+04	2.1077E+04	1.1897E+04	2.8075E+04
Lateral drainage collected from Layer 2 (m3)	6.0772E+04	5.6411 E+04	7.2091 E+04	9.1331 E+04

(continued)

	Year-9 (m3)	Year-10 (m3)	Total (m3)
Precipitation (m3)	4.2674E+05	3.2889E+05	3.7876E+06
Runoff (m3)	8.2056E+04	9.7178E+04	1.0091 E+06
Evapotranspiration (m3)	2.4454E+05	1.9658E+05	1.9973E+06
Change in water storage (m3)	2.4623E+04	-6.7480E+03	1.3419E+05
Water budget balance (m3)	-6.4090E-03	-4.9394E-03	-5.6884E-02
Soil water (m3)	6.6226E+05	6.5525E+05	6.1590E+06
Snow water (m3)	3.5428E+04	3.5688E+04	2.1301 E+05
Lateral drainage collected from Layer 2 (m3)	7.4643E+04	4.1002E+04	6.3822E+05

Appendix 2:

Location of Water Wells and Identification of Stratigraphic Units.

TYPE	CODE	WIDTH	DES	REM
FM		00		FM
FM	00	00	UNKNOWN TYPE	FM00
FM	01	00	FILL	FMO1
FM	02	00	TOPSOIL	FM02
FM	03	00	MUCK	FMO3
FM	04	00	PEAT	FM04
FM	05	00	CLAY	FM05
FM	06	00	SILT	FM06
FM	07	00	QUICKSAND	FMO7
FM	08	00	FINE SAND	FMO8
FM	09	00	MEDIUM SAND	FM09
FM	10	00	COARSE SAND	FM10
FM	11	00	GRAVEL	FM11
FM	12	00	STONES	FM12
FM	13	00	BOULDERS	FM13
FM	14	00	HARDPAN	FM14
FM	15	00	LIMESTONE	FM15
FM	16	00	DOLOMITE	FM16
FM	17	00	SHALE	FM17
FM	18	00	SANDSTONE	FM18
FM	19	00	SLATE	FM19
FM	20	00	QUARTZITE	FM2O
FM	21	00	GRANITE	FM21
FM	22	00	GREENSTONE	FM22
FM	23	00	PREVIOUSLY DUG	FM23
FM	24	00 _	PREV. DRILLED	FM24
FM	25	00	OVERBURDEN	FM25
FM	26	00	ROCK	FM26
FM	27	00	**	FM27
FM	28	00	SAND	FM28
FM	29	00	FINE GRAVEL	FM29
FM	30	00	MEDIUM GRAVEL	FM30
FM	31	00	COARSE GRAVEL	FM31
FM	32	00	PEA GRAVEL	IFM32
FM	33	00	MARL	FM33
FM	34	00	TILL	FM34
FM	35	00	WOOD FRAGMENTS	FM35
FM	36	00	BASALT	FM36
FM	37	00	CHERT	FM37
FM	38	00	CONGLOMERATE	FM38
FM	39	00	FELDSPAR	FM39
FM	40	00	FLINT	FM40

TYPE	CODE	WIDTH	DES	REM
FM	41	00	GNEISS	FM41
FM	42	00	GREYWACKE	FM42
FM	43	00	GYPSUM	FM43
FM	46	00	QUARTZ	FM46
FM	60	00	CEMENTED	FM60
FM	61	00	CLAYEY	FM61
FM	62	00	CLEAN	FM62
FM	63	00	COARSE-GRAINED	FM63
FM	64	00	CRYSTALLINE	!FM64
FM	65	00	DARK-COLOURED	FM65
FM	66	00	DENSE	FM66
FM	67	00	DIRTY	FM67
FM	68	00	DRY	FM68
FM	69	00	FINE-GRAINED	FM69
FM	70	00	FOSILIFEROUS	FM70
FM	71	00	FRACTURED	FM71
FM	72	00	GRAVELLY	FM72
FM	73	00	HARD	FM73
FM	74	00	LAYERED	FM74
FM	75	00	LIGHT-COLOURED	FM75
FM	76	00	LIMY	TFM76
FM	77	00	LOOSE	FM77
FM	78	00	MEDIUM-GRAINED	FM78
FM	79	00	PACKED	FM79
FM	80	00	POROUS	FM80
FM	81	00	SANDY	FM81
FM	82	00	SHALY	FM82
FM	83	00	SHARP	FM83
FM	84	00	SILTY	FM84
FM	85	00	SOFT	FM85
FM	86	00	STICKY	FM86
FM	87	00	STONEY	FM87
FM	88	00	THICK	FM88
FM	89	00	THIN	FM89
FM	90	00	VERY	FM90
FM	91	00	WATER-BEARING	FM91
FM	92	00	WEATHERED	FM92

ID	Layer	Depth	Color	mat1	mat2	mat3	Thickness
300007	1	100		05			100
300007	2	136		15			36
3001967	1	8	6	05			8
3001967	2	69	3	05			61
3001967	3	98	3	05	06		29
3001967	4	112	6	17	15		14
3001967	5	141	6	15			29
3003582	1	1	8	02			1
3003582	2	15	6	05	81	85	14
3003582	3	64	3	05	85		49
003582	4	71		28	11	85	7
3003582	5	97	2	14	12	73	26
3003582	6	123	6	15	73		26
3003582	7	136	6	15	73	65	13
3003582	8	140	6	15	85	75	4
3004166	1	1		02			1
3004166	2	22	6	05			21
3004166	3	71	3	05			49
3004166	4	83	6	05	12	73	12
3004166	5	139	6	15	78	73	56
3004362	1	1		02			1
3004362	2	17	6	05	85		16
3004362	3	112	6	05	73		95
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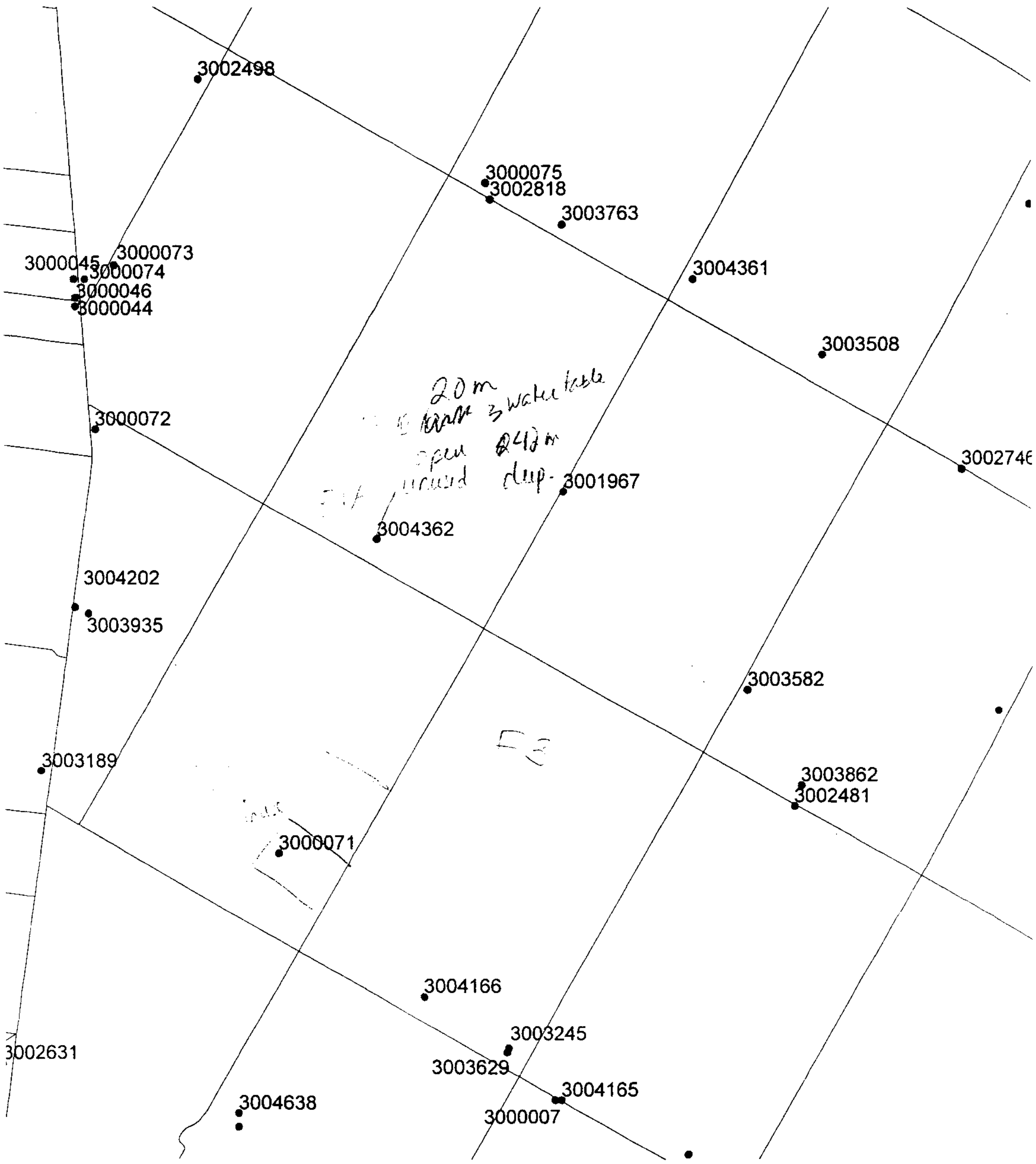
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