EVALUATING THE PERFORMANCE OF ON-SITE SEWAGE DISPOSAL SYSTEMS

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Report to

Research Division

Canada Mortgage and Housing Corporation

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Table of Contents

Table of Figures

Table of Tables

1. Introduction

Les systèmes d'assainissement individuels desservent une importante partie de la population canadienne. Pourvu qu'ils fonctionnent bien, ils constituent une solution de rechange efficiente aux installations d'évacuation centrales. Pourtant, ils peuvent mal fonctionner et, le cas échéant, ils entraînent la contamination superficielle là où le sol est incapable d'accepter l'effluent de la fosse septique ou la contamination de la nappe phréatique là où le sol n'assure pas un traitement suffisant.

Les autorités préoccupées par l'utilisation et les effets de ces systèmes doivent savoir si les systèmes existants fonctionnent de façon satisfaisante. Devant la possibilité de problèmes, elles mènent des enquêtes sanitaires qui englobent un examen des lieux, des entretiens, des tests à l'aide de colorants. L'examen des lieux et les tests à l'aide de colorants permettent de cerner des problèmes évidents, mais des résultats négatifs n'indiquent pas l'absence de problème. Des entretiens avec les occupants peuvent fournir des renseignements utiles, mais ils peuvent être biaisés si, par exemple, le répondant estime que la caractérisation d'un problème risque de se traduire par des coûts de réparation dont il saurait bien se passer.

Une enquête menée par le Centre for Water Resources Studies pour le compte de la SCHL conclut qu'il n'existe pas de méthode simple, habituelle ou certaine d'évaluer la capacité d'un système d'assainissement individuel; l'évaluation détaillée, qui est propre à l'emplacement, dépend fortement des connaissances et de l'expérience de la personne qui effectue l'examen (Hennigar, 1993). Le même rapport a relevé un essai sur le terrain, qui, mis au point en Californie (Hantzshe, 1991) a servi à établir la capacité d'absorption du sol et proposé l'évaluation de cette méthode au Canada. L'évaluation de cette méthode fait l'objet du présent rapport.

La méthode vaut lorsque la défaillance du système tient à l'insuffisance de sa capacité d'élimination et du sol à accepter l'effluent de la fosse septique sans occasionner d'engorgement en surface. Elle n'est pas destinée à caractériser la contamination de la nappe phréatique lorsque la capacité hydraulique est suffisante, mais que les effets de traitement sont limités.

La méthode consiste à surcharger une fosse septique d'environ 0,5 m3 d'eau au cours d'une période de 30 à 45 minutes et à observer la tenue en service de la fosse septique et du champ d'épandage (système de distribution) au cours de cette période de surcharge et la période de récupération consécutive. L'augmentation et la diminution du niveau du liquide dans la fosse sont consignées et constituent la base d'évaluation du taux d'acceptation de l'effluent et de la performance générale du champ d'épandage.

La présente recherche poursuivait les objectifs suivants :

- ° décrire à la suite de visites des lieux et d'une analyse documentaire l'expérience tentée en utilisant le test d'évaluation du champ d'épandage
- ° appliquer et évaluer le test dans des conditions rencontrées sur place en Nouvelle-Écosse
- ° évaluer le test à l'aide d'un modèle électronique de l'équilibre hydrologique.

L'utilisation de cette méthode ailleurs n'a pas été signalée. Voici les questions que soulèvent la méthode :

- ° Où a-t-elle été employée et quels en ont été les résultats?
- ° Vu que le test a été mis au point en Californie, est-il valable, et dans quelles conditions, pour le climat et la géologie d'autres régions? À titre d'exemple particulier, les systèmes

d'assainissement individuels fonctionnent bien en Nouvelle-Écosse lorsqu'on estime que l'engorgement périodique se produit à l'intérieur d'un lit d'épandage aménagé en sols glaciaires «étanches». Ce test permet-il de distinguer ces situations de celles où se produit la contamination superficielle?

- Le test est empirique et l'évaluation subjective. Comment les résultats se rapportent-ils à ce que nous savons de l'hydraulique des lits de rétention dans les systèmes de distribution?
- L'application de cette méthode présume de la volonté du propriétaire, pour des raisons personnes ou réglementaires, à autoriser l'examen du réseau, et soulève des questions de responsabilité liée à l'obstruction du système. Un propriétaire de maison peut-il revendiquer que le test a précipité le mauvais fonctionnement du système, par exemple, en acheminant les matières solides de la fosse septique jusqu'au champ d'épandage? En Californie, ce test a été mené dans le cadre d'un programme régional de gestion des eaux usées. Aucun problème n'a été signalé par les auteurs de l'étude californienne, mais il faut garder à l'esprit la possibilité que le propriétaire de la fosse septique prétende que leur système ait bien fonctionné avant le test et malfonctionné par la suite.

S'il est possible de répondre à ces questions de façon satisfaisante, cette méthode pourrait se révéler un outil important pour l'investigation et la gestion de systèmes individuels.

Les résultats de la présente recherche sont censés être utiles aux autorités publiques préoccupées par l'évaluation de l'efficacité des systèmes individuels, en l'occurrence les urbanistes et ingénieurs municipaux, les organismes provinciaux de planification et de réglementation en matière de santé et d'environnement, ainsi que les autorités fédérales participant à la conception, l'approbation et au fonctionnement des systèmes individuels, y compris la Société canadienne d'hypothèques et de logement, ainsi que le ministère des Affaires indiennes et du Nord. On s'attendait également à ce que cette recherche permette de mieux comprendre la performance hydraulique des systèmes individuels dans différentes conditions géologiques et climatiques, et, à longue échéance, de mener vers une meilleure conception et performance des systèmes.

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1. Introduction

On-site sewage disposal systems serve a significant proportion of the population of Canada. These systems provide a cost-effective alternative to central systems when they function properly. But they can and do malfunction, resulting in surface contamination where the soil system is unable to accept the septic tank effluent, or ground water contamination where the local soil system does not provide adequate treatment.

Officials concerned with the use of and effects of these systems need to know if existing systems are functioning satisfactorily. Where the possibility of problems exists, sanitary surveys are conducted. These include site examinations, interviews, and dye tests. Site examinations and dye tests can identify obvious problems, but negative results do not assure that no problems exist. Interviews with householders may reveal useful information, but can be biased if, for example, the respondent feels that identification of a problem may result in unwanted repair costs.

A study undertaken by the Centre for Water Resources Studies for CMHC concluded that "There is no simple, routine, or certain procedure to assess the capacity of an on-site system; a detailed assessment will be site-specific and will rely heavily on the knowledge and experience of the individual who conducts the examination." (Hennigar, 1993). The same report identified a field test, developed in California (Hantzshe, 1991), that has been used to assess the hydraulic capacity of soil absorption systems, and recommended evaluation of this procedure for Canadian conditions. Evaluation of that procedure is the subject of this report.

The procedure is applicable to those situations where system failure is defined in terms of inadequate capacity of the disposal system and host soil to accept the septic tank effluent without surface ponding. It is not intended to identify groundwater contamination where the hydraulic capacity is adequate but the treatment effects are limited.

The procedure involves surcharging a septic tank with approximately 0.5 m^3 of water over a 30 to 45 minute period, and observing the response in the septic tank and the leachfield (distribution system) during the period of surcharge and the recovery period afterwards. The rise and fall of the liquid level in the tank is noted and used as the basis for evaluating the rate of effluent acceptance and general performance of the leachfield.

The objectives of the project reported were to:

- document experience with use of the leachfield evaluation test, by site visits and literature review
- apply and evaluate the test under field conditions in Nova Scotia
- evaluate the test using a spreadsheet water balance model.

Use of this procedure in other jurisdictions has not been reported. Questions that arise about the procedure are:

- Where else has it been used, and with what results?
- Given that the test was developed for conditions in California, can it be applied, and under what conditions, in the climate and geology of other regions? As a particular example, on-site systems function successfully in Nova Scotia in situations where periodic ponding is believed to occur within a disposal bed in "tight" glacial soils. Can this test distinguish these situations from those where surface contamination will occur?

- The test is empirical, and the assessment subjective. How do the results relate to what we know about the hydraulics of clogging mats in distribution systems?
- Application of this procedure assumes the willingness of the owner, for personal or regulatory reasons, to allow the system to be examined, and raises questions about the liability associated with interference with the system. Can a home-owner claim that the test precipitated system malfunction by, for example, washing solids from the septic tank into the disposal field? In California, this test was conducted under the auspices of a waste-water management district program. No problems were reported by the authors of the California study, but the possibility of a septic system owner claiming that their system functioned properly before the test and malfunctioned after should be kept in mind.

If these questions can be answered satisfactorily, this methodology has the potential to be an important tool for the investigation and management of on-site systems.

The results of this research are intended to be of value to public officials concerned with assessment of the effectiveness of on-site system. These will include: municipal planners and engineers, provincial health and environment planners and regulators, and federal officials involved in design, approval and operation of on-site systems, including Canadian Mortgage and Housing Corporation and Department of Indian and Northern Affairs. As well as this research was also expected to contribute to a better understanding of the hydraulic performance of on-site systems under a variety of geological and climate conditions, which can in the long run lead to better system design and performance.

2. Methodology

2.1 Literature Review and Site Visits

A search was made of the extensive on-site reference list held by CWRS, and of other relevant sources, to identify and document additional applications of the leachfield evaluation test.

One site visit was made to California, to obtain first-hand information about the application of the hydraulic leachfield test reported in (Hantzshe, 1991)). Information was obtained from Questa Engineering, the consultant that included the tests in a site inspection program at the Sea Ranch development, and the officials of Sea Ranch. Another visit was made to Wisconsin, as an extension to a trip to attend a meeting in Ontario. Opportunities were taken during each trip to obtain additional information about technologies and management of on-site systems. It is intended that this information will be used in subsequent CWRS publications and projects.

2.2 Application and Evaluation of the Test

Tests were conducted at three private homes serviced by on-site systems. Water meters and piezometers were installed at each location. At each site records were maintained of water consumption and ground water levels for a period of seventeen months, and a leachfield evaluation test was conducted at each location at the beginning and end of the test period.

2.3 Water Balance Model

A spreadsheet water balance model, developed for a previous CMHC project (Mooers, 1992)) was applied as a basis for interpretation of the results of the information obtained at the field sites, using local Atmospheric Environmental Service data recorded during the period of the study.

3. Literature Review and Site Visits

Results of the literature review were disappointing. No description of a hydraulic test or its use appeared in any publication the authors could identify, except the original article that prompted this project. (Hantzshe, 1991).

Site visits to Questa Engineering and the Sea Ranch development in California (Waller,1994), and to Ayers Associates in Madison, Wisconsin (Waller,1995), produced much valuable information about system inspection, monitoring and maintenance. Information related directly to the hydraulic leachfield test is presented below.

Also included here is anecdotal information, from two Nova Scotia consultants and one internet source, related to the use of the hydraulic tests of distribution systems.

3.1 Test Procedure

Hantzsche et al (Hantzshe,1991) described the role and application of the leachfield evaluation test in the context of management of the on-site Wastewater Disposal Zone in the Sea Ranch subdivision in Northern California.

The Disposal Zone was established under provisions of the California Health and Safety Code. That legislation enables public agencies that have powers to manage sewer systems to form, under specified conditions, On-Site Wastewater Disposal Zones. The Sea Ranch was established by the Sonoma County Service Area No. 6, which contracted with the Sea Ranch Homeowners Association to undertake the septic system inspection programs for the subdivision.

The Sea Ranch Zone includes 1560 residential parcels, the majority of which are, or will be, serviced by on-site systems.

The septic system inspection program involves

- Establishment and maintenance of complete septic system files and record keeping system for all properties in the Zone.
- Performance of routine field inspection of all septic systems in the Zone.
- Issuance and periodic renewal of operating permits for all septic systems in the Zone.
- Preparation of annual report of Zone activities, including inspection findings and water quality summaries.
- Preparation and distribution of educational information to property owners in the Zone concerning proper septic system practices and activities of the Zone.

All septic systems in the Zone are targeted for a routine inspection one every three years. The only exceptions to this are special alternative designs, for which inspection frequency is established on a case-by-case basis; these systems may be inspected annually or more frequently if deemed appropriate.
The inspection procedures include:

- A "Fact Sheet" is developed and maintained for each property to facilitate the file review. Appropriate entries are then made on a field inspection form in preparation for the field visit.
- A general site review involves walking the property to confirm the location of the septic tank, leachfield, and other pertinent features of this system. The septic tank and disposal field areas are checked for any obvious signs of existing system problems such as surfacing effluent, odours,

greywater bypasses, selective fertility (i.e., lush vegetation in the leachfield area) or any other condition that may suggest an existing or potential problem.

- If the tank is equipped with access risers (i.e., manholes) over the inlet and outlet ports, these are inspected for structural integrity and water tightness. If the septic system utilizes a pump, this is also inspected to observe the condition of the pump basin, the electrical equipment, float controls and the actual operation of the pump itself.
- Leachfield Evaluation: Following the septic inspection, the leachfield area is examined for signs of wetness or other indicators of drainage problems. Then a hydraulic loading test is performed on the system.
- If the field inspection finds the septic system to be failing and in need of prompt corrective work, an Abatement Notice is issued in lieu of an Operating Permit. The Abatement Notice is an enforcement action, and provides for very specific actions to be taken by the property owner regarding the submittal plans and implementation of corrective work. Operating Permits and Abatement Notices are signed by the Zone Manager and are officially recorded on the property deed at the County Recorder's Office. A copy is also sent to the property owner.

The hydraulic test involves surcharging the septic tank with approximately 150 gallons of water over a 30 to 45 minute period, and observing the response in the septic tank and the leachfield during the period of surcharge and the recovery period afterwards. The rise and fall of the liquid level in the tank is noted and used as a basis of evaluating the rate of effluent acceptance and general performance of the leachfield. The guidelines used for evaluating system performance from the hydraulic load test are given in Table 1. Additional checks are made in the leachfield area, including observation of water level changes in inspection wells, if they exist. Testing of pump systems is done in a similar manner by surcharging the pump basin, observing the pump operation, and inspecting the leachfield area during and following the surcharging.

Appendix A includes a detailed review of the Hydraulic Load Tests, from a manual prepared by Questa Engineering for the Sea Ranch. Procedures are included for both gravity feed and pumped systems.

Rating	Septic Tank Response to Hydraulic Loading
Excellent	No noticeable rise in water level during filling.
Good	Maximum water level rise of about 2.5cm, with rapid decline to initial level within 5 minutes after end of filling.
Satisfactory	Maximum water level rise of about 5cm, with decline to initial level within 15 minutes after end of filling
Marginal	Maximum water level rise of about 7.5 cm, with decline to initial level within about 30 minutes after end of filling.
Poor	Water level rise of more that 7.5cm, with decline not reaching initial level within 30 minutes after end of filling.
Failed	Water level rise of more than 7.5cm, with no noticeable decline within 30 minutes after end of filling.

Table 1. Hydraulic Load Test Rating Guidelines (2)

3.2 Comments on Hydraulic Load Test

Questa Engineering noted that interpretation of results of the hydraulic load test requires experience, and an understanding of the system being examined. For example, if there is a difference in elevation between the tank outlet and the distribution system, a clogged system may not be reflected in increased tank levels if the accumulated water is contained in the system and connecting pipe.

It was noted that the test protocol in Appendix A refers to tank outlet level, and if this could not be observed, the inspection report would include a disclaimer indicating that the outlet was not visible.

If the house served by the system has been unoccupied prior to the test at Sea Ranch they request that fixtures be run before the test to simulate normal usage.

Sea Ranch officials explained that the rate at which water is added to the tank is important i.e. that 150 US gallons added over 15 minutes corresponds to 10 USGPM (379l/min), and if more or less water is added the time should be adjusted accordingly.

If addition of water to the septic tank creates a backup before the complete 15 minutes have elapsed, no more water is added, and the system is examined for blockages.

An internet discussion (Friedman, 1997) indicated that hydraulic loading tests are common in many US states and some provinces, but no details were available.

A representative of Ayers Associates expressed concern that the hydraulic loading test might flush solids from the septic tank into the distribution system. He also noted that the test doesn't account for variations in subsurface water content prior to the test.

Discussions with consultants in Nova Scotia indicated that other practitioners have conducted tests of systems, prior to real estate inspections, by turning on all taps in the house for a long period of time, followed by inspection of the distribution system for evidence of failure. Concern was expressed that a test conducted in this manner, with no apparent systematic protocol for the amount and rate of water use, could create problems that include flooding of the distribution system and/ or excessive drawdown on the household well.

4. Field Sites

4.1 Introduction

Three sites in rural Nova Scotia were selected, representing a range of soil conditions, system operation, and loading rates. Each site was instrumented with a observation well in the groundwater, down gradient of the disposal field, an observation well or port in the disposal field, and a septic tank riser (if needed) to allow easy access to the septic tank. In two cases water meters were installed on the main intake line to allow monitoring of daily water use. In the other case water use records were obtained from the utility.

The procedure used at each site can be summarized as follows:

- Examine the area of the leachfield for signs of breakout or wetness
- Measure the location of the static water level in the septic tank at the outlet used as an initial reference point
- Gently begin adding water to the septic tank at the rate of 550L per 30 to 40 minutes
- Observe and record the liquid level in the tank during surcharging. Typically the liquid level will rise from 1 to 3 cm, at which point the level should stabilize for the remainder of filling; and then return to the initial level in a matter of minutes after filling has stopped.
- After the filling cycle is finished, the liquid level decline in the septic tank is observed and recorded until the initial level is reached. If the initial level is not attained within 30 minutes the test is terminated and final water level recorded.
- Examine the area of the disposal field for signs of surfacing effluent, wetness, or odour during and after surcharging.
- Based upon the liquid level readings during the test, a hydraulic performance rating is assigned in accordance with Table 1.

4.2 Results

Site One

Site one is a two bedroom house occupied by 2 adults. The water source is a dug well. The disposal system consists of a 2700 litre, single chamber concrete septic tank which gravity drains into a 24 metre long contour disposal field. The disposal system was installed in November of 1990 to replace an outdated septic tank and area bed prior to a property transaction. According to the owners the system had not been pumped since installation.

A 5 cm diameter monitoring well was installed down gradient of the disposal field, to a depth of 4 metres with a 1.5 m well screen. One end of the disposal field was excavated and 0.15m diameter PVC pipe was installed to the depth of the bottom of the gravel layer, as show in Figure 1. A water meter was installed on the water inflow line showed an average usage of 0.5 m^3/day over the period of the test. Water levels in the groundwater and the disposal field were recorded and are shown in Table 2. The soil at this site is a poorly sorted clayey till overlain by a thin more organic rich layer.

At the time of the first test the septic tank at this site showed no scum layer. The sludge layer thickness measured approximately 30 cm. Table 3 shows the test results from site one. A water meter was attached to a garden hose and water was drawn from the exterior tap at the site. As shown in Table 3, 550 litres was introduced to the system over 45 minutes.

The liquid level in the tank rose 2cm while the water was being added to the system and returned to near the starting level within 20 min. of the end of loading. Water levels in the disposal field rose 5cm during the water addition and had not decreased at all even 20 minutes after water additions had stopped. Piezometer 1 showed the groundwater level adjacent to the disposal field was 1.22 m below the surface and was unaffected by the test.

The septic tank showed no scum layer during the second test. The sludge layer was approximately 43 cm thick.

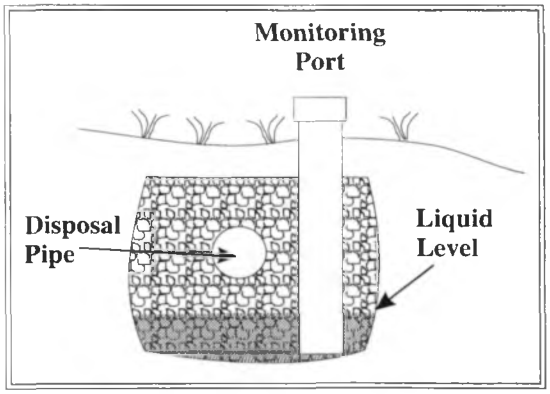

Figure 1. Trench cross-section

The water level in the field monitoring port rose by 8cm during the second test as shown in Table 4. Puddles began to form at the end of the disposal field farthest from the septic tank. For this reason the water addition to the system was stopped at 360 litres.

During the second test the observation well again showed no response. This may be due to the clayey nature of the lower soil levels. Flow across this site most likely takes place in the upper permeable layer of the soil. This shows the sensitivity of observation well placement for system assessment in this type of test.

In both tests the water level in the septic tank remained at the level of the invert of the outflow pipe. This is due to the topographic drop between the level of the invert and the disposal field.

Date	Ob Well (m)	Field (m)
21-Jul-95	1.22	0.53
31-Jul-95	0.74	0.44
19-Jan-96	0.95	0.40
21-Feb-96	0.97	0.50
4-Apr-96	0.71	0.39
24-May-96	0.77	0.45
2-Aug-96	1.02	0.41
11-Sep-96	1.16	0.46
5-Nov-96	1.12	0.36
17-Dec-96	1.21	0.42

Table 2. Site 1 water levels

Water (L)	Time (min)	Tank (m)	Field (m)	Ob Well (m)
0	0	0.75	0.53	1.22
138	15	0.735	0.52	1.22
275	25	0.73	0.5	1.22
412	40	0.73	0.48	1.22
550	45	0.74	0.48	1.22
	55	0.745	0.48	1.22
	60	0.746	0.48	1.22
	65	0.748	0.48	1.22
	70	0.748	0.48	1.22

Table 3. Test One Results from Site 1.

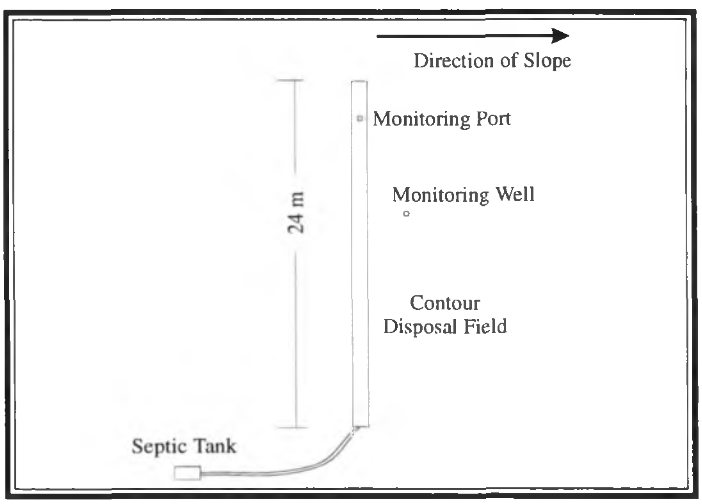

Figure 2. Site 1 layout.

Water (L)	Time (min)	Tank (m)	Field (m)	Ob Well (m)
0	0	0.7	0.45	0.77
75	5	0.68	0.44	0.77
145	10	0.69	0.41	0.77
275	20	0.69	0.35	0.77
360	25	0.69	0.32	0.77
	35	0.7	0.35	0.77
	40	0.7		0.77
	45	0.7	0.37	0.77
	55	0.7	0.37	0.77

Table 4. Test Two Results from Site 1.

Site Two

Site two is a three bedroom house with two adults and three children. The disposal system includes a 3600 litre, single chamber, concrete, septic tank followed by a sampling crock after which effluent flows by gravity into the disposal field. The disposal field is a 30 m type C1 contour trench. The disposal system was installed in 1987. The septic tank was last pumped in September of 1995. At the time of the first test the septic tank showed no scum layer and had no measurable sludge layer.

Eleven shallow piezometers were installed in and below the disposal field(Figure 2). Water is supplied to this household from a central service. Water use records obtained from the utility showed loading rates that average $0.74 m^3$/day.The soil at this site is a light to medium brown poorly sorted till. The matrix consists of silty clay with some fine grained sandstone.

Water	Time	Tank	Field Well (P3)	Ob Well (P4)
(L)	(min)	(m)	(m)	(m)
0	0	1.17	1.15	dry
148	6	1.16	1.15	dry
448	20	1.16	1.15	dry
550	25	1.17	1.15	dry
	45	1.17	1.15	dry

Table 6. Site 2 Test Results.

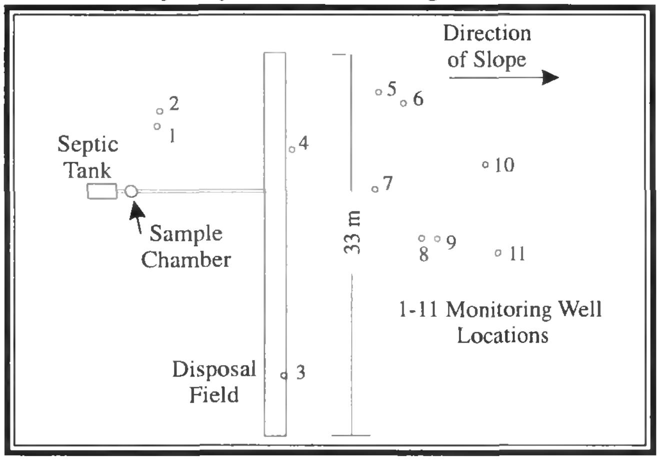

Figure 3. Site 2 layout

Water	Time	Tank	Field Well (P3)	Ob Well (P4)
(L)	(min)	(m)	(m)	(m)
0	0	1.17	0.47	0.97
148	5	1.14		
448	10	1.12		
550	15	1.08	0.41	
	20	1.04	0.39	
	25	1.03	0.36	
	30	1.04	0.31	
	35	1.05	0.3	
	40	1.05	0.27	
	45	1.05	0.25	
	50	1.06	0.24	0.95

Table 7. Site 2 Test Results.

Date	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
8-Sep-95	dry	2.28	1.15	dry	dry	2.52	2.20	dry	2.74	2.39	dry
19-Jan-96	0.84	0.52	0.45	0.90	0.54		0.61				
21-Feb-96	1.03	0.61	1.04	0.56	0.64	0.79	0.60	0.89	1.02	0.68	0.47
4-Apr-96	0.86	0.49	0.44	0.90	0.53	0.66	0.57	0.77	1.05	0.66	0.40
24-May-96	0.93	0.54	0.47	0.97	0.58	0.75	0.58	0.86	1.00	0.73	0.47
2-Aug-96	1.16	0.78	0.43	1.08	0.62	1.05	0.74	0.94	1.19	0.95	0.63
11-Sep-96	1.5	1.16	0.71	dry	1.10	1.49	0.97	1.33	1.46	1.22	0.86
6-Nov-96	1.12	0.73	0.55	1.07	0.67	0.88	0.66	0.94	1.06	0.71	0.45
17-Dec-96	1.11	0.69	0.60	1.11	0.63	0.81	0.52	0.94	1.04	0.62	0.5

Table 5. Site 2 water levels.

At site two a water meter was attached to the household garden hose and used to measure the 550 litres of water which were added to the system over 25 minutes.

As shown in Table 6, water levels in both the septic tank and sample chamber rose only 1cm during the test and recovered immediately upon stopping the water. Groundwater levels adjacent to the disposal field were approximately 1 metre below the surface. No rise in water levels was detectable in either the piezometer installed in the disposal field or any of the surrounding groundwater piezometers.

During the second test the scum layer measured 12 cm thick and the sludge layer was 25 cm deep. The level in the test tank rose 11cm during the test, while the level in the field piezometer rose 23cm and the level in the groundwater observation well rose 2cm. At the end of the test the area around the disposal field trench was moist when walked on.

Site Three

Site three is a household with three adults and two children. The wastewater disposal system consists of a 4500 litre, single chamber, concrete tank followed by a filter chamber. The filter chamber is a well crock equipped with an outflow effluent filter which gravity feeds to a 30 m long contour dis-

Date	Ob 1	Ob 2	Field
22-Aug-95	3.36	0.86	0.54
14-Sep-95	3.76	dry	0.60
19-Jan-96	2.75	0.71	0.63
21-Feb-96	2.79	0.92	0.65
4-Apr-96	2.53	0.82	0.47
24-May-96	2.50	0.73	0.46
2-Aug-96	3.02	0.87	0.47
11-Sep-96	3.57	1.17	0.70
6-Nov-96	3.11	0.94	0.50
17-Dec-96	3.01	0.94	0.66

Table 8. Site 3 groundwater levels.

Water	Time	Tank	Field	Ob Well 1	Ob Well 2
(L)	(min)	(m)	(m)	(m)	(m)
0	0	0.48	0.6	3.76	dry
200	16	0.41	0.5	3.76	dry
400	28	0.39	0.48	3.76	dry
	35	0.40	0.46	3.76	dry
	60	0.45	0.45	3.76	dry

Table 9. Test Results for Site 3.

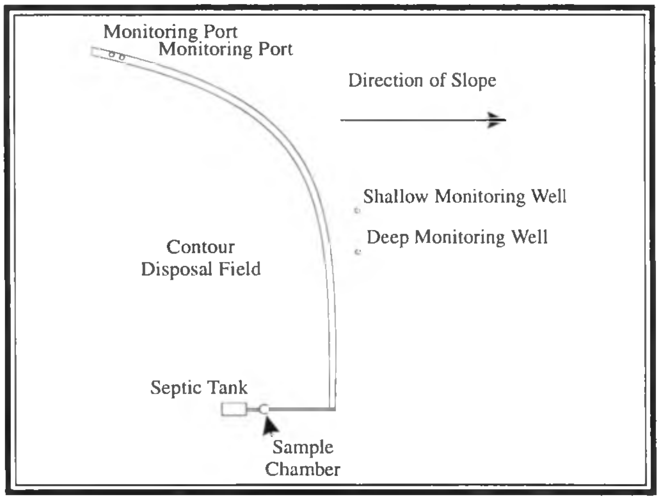

Figure 4. Site Three Layout

Water	Time	Tank	Field	Ob Well 1	Ob Well 2
(L)	(min)	(m)	(m)	(m)	(m)
0	0	0.48	0.45	2.5	0.73
65	2	0.46	0.45	2.5	0.73
130	18	0.46	0.45	2.5	0.73
195	25	0.44	0.45	2.5	0.73
260	35	0.43	0.45	2.5	0.73
325	45	0.42	0.45	2.5	0.73
390	48		0.45	2.5	0.73
	49	0.42	0.45	2.5	0.73
	60	0.42	0.45	2.5	0.73
	71	0.42	0.45	2.5	0.73

Table 10. Test Two Results for Site 3.

posal field (Figure 3). The system was installed in 1990 and the septic tank was last pumped in July 1994. The water supply at site three is from a drilled well. A water meter installed at this site showed an average water use of $0.66m^3$/day.

Two monitoring wells were installed adjacent to the disposal bed, one deep well, installed to a depth of 5.77 metres with a 1.5 metre well screen, and a shallow well installed to a depth of 1 metre, consisting almost entirely of a screened section. Soil conditions at this site consist of one metre of silty till underlain by a thick brownish clay.

At the time of the first test the septic tank had a scum layer 15cm thick and sludge layer thickness of 5 to 10 cm. A poorly functioning drilled well at this site necessitated bringing two 200 litre barrels of water to the septic tank. The barrels were separately siphoned into the septic tank, which took approximately 15 minutes each. Water levels in the tank rose 9 cm during water addition and had recovered only 6 cm 30 minutes after water addition, as shown in Table 4.

Neither the deep or shallow piezometers showed any fluctuations during the test. Groundwater levels were 3.7 metres below the surface. Liquid levels in the disposal field observation port increased 12cm during water addition and rose another 3cm over the next 30 minutes. Instead of capping the end of the perforated disposal pipe an elbow and a riser pipe were added to allow access from the surface. Water levels measured in the pipe showed an increase of 29cm during water addition and a recovery of 6cm over the next 30 minutes.

At the start of the second test there was no scum layer in the septic tank. The sludge layer was 15cm thick. The tank had been pumped a month previous to the test. The water level rose 6.5 cm over the course of test and remained high even during the recovery phase of the test. Neither the shallow or deep observation wells showed any water level change during the test.

Water level in the field observation port showed no change during the test. The disposal field showed signs of breakout at the end farthest from the septic tank prior to the test. As two new puddles were present at this end of the field at the end of the test the most likely explanation for the lack of field response is that it was already at the maximum water capacity prior to the test.

4.3 Discussion

This procedure is applicable to those situations where system failure is defined in terms of inadequate capacity of the disposal system and host soil to accept the septic tank effluent without surface ponding. This commonly results from carry over of solids into the disposal field from the septic tank either from a lack of maintenance or excessive hydraulic loading or the formation of an impermeable biomat. It is not intended to identify groundwater contamination where the hydraulic capacity is adequate but treatment effects are limited.

The addition of approximately 550 L of water over 30 to 45 minutes caused no problems with any of the test sites. This addition of water is equivalent to 3 to 4 loads of laundry. At the one site where breakout became apparent the addition of liquid was halted. Water was added gently to the liquid surface during all the tests and resulted in no visible disturbance of tank contents.

Figure 5 shows a schematic of a typical gravity feed system to help explain the response of these systems to the addition of water. As water is added it flows out of the tank through the disposal pipe to the field. If the field is operating properly, the liquid will quickly drain from the disposal field as more water is added to the tank. In a poorly operating system there may already be standing water in the field. If we assume the worst case scenario, in which there is very slow drainage from the disposal field, the gravel will fill to capacity with liquid, after which, if no other flow path can be found, the liquid will fill the disposal pipe back to the septic tank and begin to raise the tank liquid level. In some cases the liquid will find another flow path out of the disposal bed and spill across the property. Indicating a system in which either the biomat has developed to the point that it is resistant to flow, the groundwater level is near the bottom of the disposal field, or the host soil is impermeable.

The potential response of these three systems to the hydraulic load can be calculated assuming the standard width of the disposal field trenches examined is 1 m and the porosity of the gravel in the disposal bed is in the range of 35% and the effluent is distributed evenly across the entire disposal bed. Assuming that no percolation occurs during the loading test (worst case scenario), the rise in the water level in a 30 m long trench (Site Two and Three) from the addition of 550 litres would be approximately 3cm. In a 22 meter long trench (Site One) the rise would be 4 cm.

4.3.1 Site One

During the first test water levels in the septic tank rose 2cm and then quickly returned to almost pre-test levels. The disposal field rose 5cm and remained high till the end of the observation segment of the test indicated a very slowly draining field. Calculated water rise from the addition of 550 litres was 4cm, with the assumption of no percolation during the test. The septic tank showed a similar response during the second test. The disposal field liquid level rose 8cm and again remained high through the test. However, during the second test effluent broke out at the end of the disposal field. The homeowner indicated that the area had been wet for a number of days prior to the test.

This indicates the necessity of checking carefully around the area of the disposal bed during this test. In a normal application it is unlikely that there will be a monitoring port in the disposal field. The tester will only have access to the septic tank and must infer the response of the disposal field. In this case the level in the tank responded as if this was a properly operating system, however, the reason that the effluent level in the tank did not rise was that it was exiting on the ground instead of backing up the pipe to the level of the tank. In systems with a large elevation difference between the septic tank and the disposal field the pressure as the effluent level raises may force effluent out at the surface around the disposal field. Systems with relatively little vertical difference between the tank and the field may be more likely to show an increased tank level as the test proceeds.

This disposal system was installed to replace an out of date and failing system that was installed before the implementation of the current on-site regulations. When the original system failed the options for a replacement system were limited because of the low conductivity soils and lot size limitations and thus the current system is undersized. The interpretation of the first loading test at this site, had the field monitoring port not been in place would have indicated a satisfactory system. The interpretation of the second test was straightforward as effluent was observed on the surface.

4.3.2 Site Two

During the first test liquid levels rose only 1 cm in the septic tank and dropped very quickly after the end of surcharging. As well the disposal field piezometer rose only 1 cm. The second test showed an 11 cm rise in the septic tank level and a 23 cm rise in the disposal field observation well. This site also showed a wet area around the disposal field at the end of the test. The rapid rise in the septic tank liquid level indicates that the disposal field must have been nearly full prior to the start of loading.

According to the 5cm calculated potential rise of the level of the liquid in the disposal field it is difficult to explain the 23cm rise that occurred in the second test. One possible explanation is that the flow

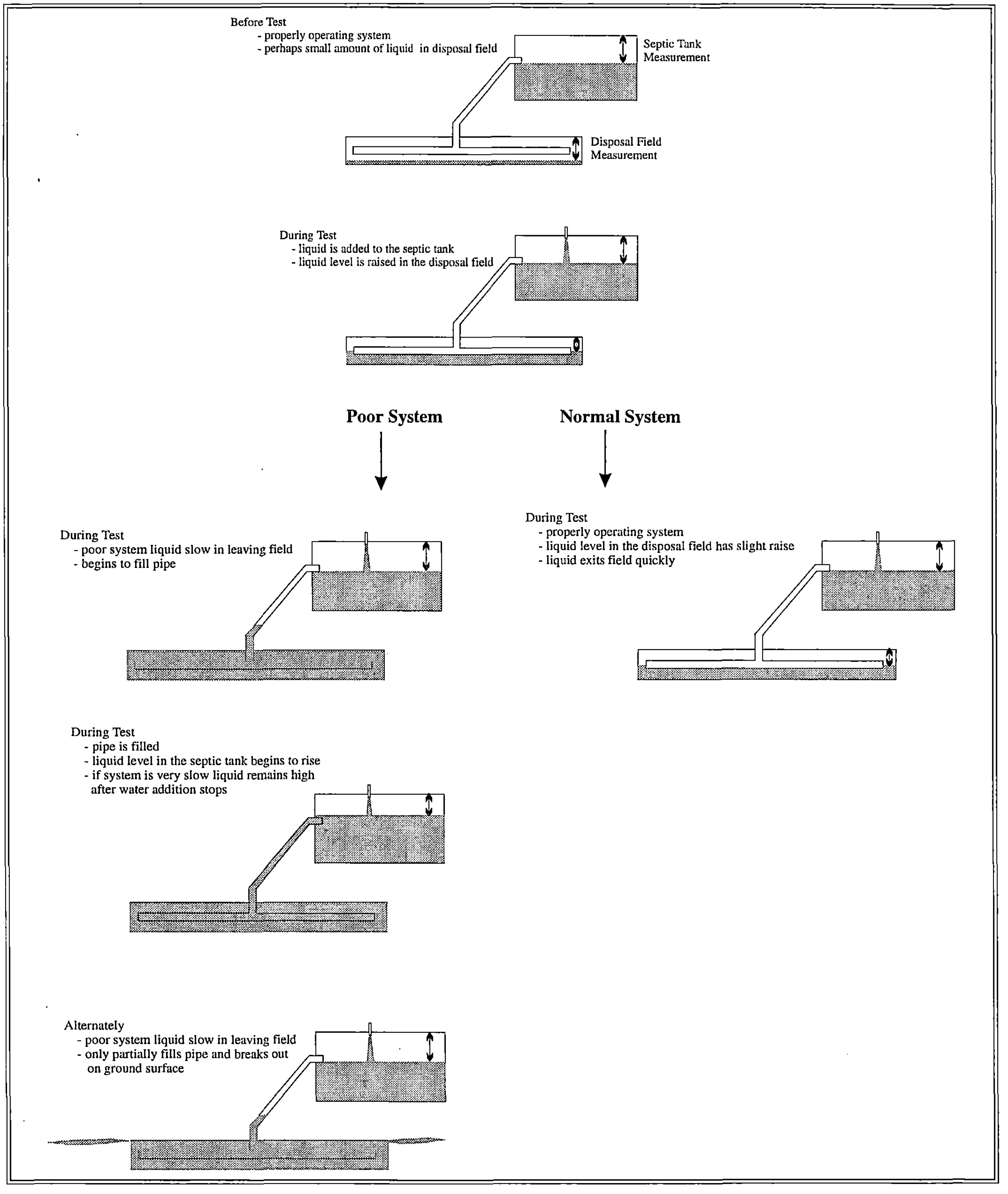

Figure 5. Loading test schematic

from the disposal bed moves only through a concentrated area due to flow restricted areas or that the disposal bed is no longer level and may be ponding in one area of the field.

The availability of the field observation well data gave an understanding of the effect of the groundwater levels on the septic tank response to the test. The evaluation of this system varies dramatically depending on the season. As shown in Table 5 the groundwater levels in September, typically the driest time of the year in Nova Scotia, were approximately 2 metres below the surface. The results from test one, indicated that this system was in very good operating condition (see Table 11). In May, roughly the wettest time of the year, during the second test, the groundwater levels were between 0.5 to 1 metres below the surface. At this time of year the groundwater level is almost at the level of the bottom of the disposal bed. The test results from this time of year indicated that this is a very poor system (Table 11).

This system was installed under the current regulations and has shown a consistent level of operation despite the seasonal high water table. The failing grade provided by the second test is indicative of a seasonal low level of performance and not an overall representation of this site.

4.3.3 Site Three

At site three the liquid rose 9cm in the septic tank during the first test and recovered 6cm during the loading test. The disposal field liquid level rose 15cm during the test and showed no signs of recovery. Although the observation wells were located within a few feet of the disposal field neither showed any response to the load test. This system falls into the failed category as shown in Table 11. During the second test the septic tank rose only 6 cm but showed no recovery. The disposal field showed no increase of liquid level, however, the starting level for this test was the same as the post loading level from the first test, indicating a saturated field prior to the test. This was confirmed by observing effluent breakout at the end of the test.

Based on the septic tank observation alone the first test indicates that this is a poor system. The liquid level rise exceeds 7.5 cm and has not fully recovered within 30 minutes of the end of water addition. Although a full size system there is a very thick layer of clay that underlies the disposal bed and seems to contribute to its poor performance. The owner confirmed that there is a history of breakouts along the far end of the field. The second test results confirm the condition of the field as somewhere between poor to failed.

Rating	Septic Tank Response to Hydraulic Loading
Excellent	No noticeable rise in water level during filling.
Good	Maximum water level rise of about 2.5cm, with rapid decline to initial level within 5 minutes after end of filling.
Satisfactory	Maximum water level rise of about 5cm, with decline to initial level within 15 minutes after end of filling
Marginal	Maximum water level rise of about 7.5 cm, with decline to initial level within about 30 minutes after end of filling.
Poor	Water level rise of more that 7.5cm, with decline not reaching initial level within 30 minutes after end of filling.
Failed	Water level rise of more than 7.5cm, with no noticeable decline within 30 minutes after end of filling.

Table 11. Hydraulic Load Test Rating Guidelines

4.3.4 Assessment and Application of Test

The loading test applied here is for standard gravity-fed leachfields and does not apply if the system utilizes a pump. An important point to bear in mind during this test is that a careful observation of the disposal field is necessary as the lack of liquid level rise in the septic tank is not necessarily an indication of proper system performance.

Sites with poor water supplies require arranging for water to be transported. At site three this required transporting two 200 litre plastic barrels of water. This may not always prove logistically possible. At the sites with adequate water supplies, determining the quantity of water added to the tanks was greatly simplified by putting a standard household water meter on the hose used to fill the tank. The sluggish results of the spring (high water table) tests may indicate that a lower loading rate is appropriate for use in Nova Scotia if this test is to be conducted during the wet portion of the year.

For the purposes of a site assessment there is a rough hierarchy of inspection procedures as follows:

1. statement of declaration regarding system performance
2. inspection of household and grounds
3. inspection of household, grounds, and uncovering/pumping of the septic tank
4. all of the above including a loading test
5. all of the above including a test excavation of the disposal field

This shows the relative importance of the loading test. For most situations steps one to three in the above list will give a good level of understanding of the system operation and maintenance. If the investigation to this point indicates a poorly maintained system or points to specific problems the next procedural step should be a loading test.

The hydraulic loading test requires about 1 hour when the system and site are prepared in advance. It takes significantly longer on a site where the septic tank is not immediately accessible, where an inspection port must be installed in the distribution system, or where a water supply is not readily available.

The test can serve an important role when used as part of a routine inspection and maintenance program, for example as part of a Watershed Management District or a service contract system. It can also provide useful information as part of real-estate inspection or sanitary survey, but given the time and cost involved for a site that is not prepared for the test, its use might be limited to sites or situations where preliminary inspection or prior knowledge suggests that more information is necessary.

If the hydraulic loading test reveals problems the next step would be an excavation of a portion of the disposal field to examine potential ponding or clogging of the gravel or soil.

5. Water Balance

Development and application of the water balance model to interpret monitoring results at the three field sites was undertaken after the field monitoring was complete.

Appendix B provides a summary description of the model, developed for a previous project, it was approved using data from the three field sites.

6. Conclusions

6.1 Literature Review and Site Visits

The literature review and site visits indicated that:

- Apart from the information related to the Sea Ranch system, there appears to be little information or documentation of the use of a hydraulic load test for an on-site system.
- The Sea Ranch provides an important example of the application of the test as a component of systematic program for management of on-site systems.
- The hydraulic load test can provide significant information about the condition of an on-site system.
- Examination of the performance of an on-site system might occur in the context of (1) routine inspection, as part of a management plan, for system performance evaluation, maintenance and repairs (2) inspection/evaluation conducted as part of a real estate transaction
- This project assembled considerable information about these procedures, which should be the basis of further documentation of existing practices , prepared for transfer to regulators, designers and practitioners.

6.2 Field Sites

Results of applications of the test to 3 existing systems indicated that:

- The test provided a useful indication of the state of these systems, two of which were on the verge of failure and the other performing properly.
- Test results reflected seasonal effects: when tests were conducted in wet periods all systems yielded poor test results.
- Routine use of the test may be limited to inspection and maintenance programs where systems have been prepared for use of the test. Because of time involved in site and system preparation its use for other applications - such as real estate inspections or sanitary surveys- may be limited to sites or situations where prior knowledge or preliminary examinations indicate potential problems.
- Absence of increased septic tank water level during the test does not necessarily imply adequate system performance: examination of the distribution system area is required to determine if breakout has occurred.
- The test is time consuming and is not recommended for routine use: it is better used where it is suspected that performance of an existing system is questionable.

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8. Acknowledgments

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Special thanks is offered to the homeowners who allowed us to monitor their systems, Steve Sauver for invaluable support in site location, instrumentation and monitoring, and to Hilchie Environmental for on-site advice.

Appendix A: Hydraulic Load Test [1]

General

The inspector should then proceed with the hydraulic load test of the septic tank and disposal field. The test, as described here, is conducted only for standard gravity-fed leachfields, and does not apply if the system utilizes a pump. The test is conducted by surcharging the septic tank with about 550 litres of water over a 20-30-minute period; and then observing the rise of water in the tank and the subsequent draining process. A garden hose discharging into the outlet side of the tank can be used to surcharge the tank. The hose shall remain well above the water level in the tank to prevent cross contamination. Before starting the test, the flow rate from the hose should be determined (i.e., with 20-litre bucket and stop watch) to properly gauge the amount of surcharge water added to the tank. Alternatively, a portable water meter can be installed between the house faucet and the hose to directly measure the water volume added.

Test Procedures

The step-by-step procedures for the hydraulic load test are then as follows:

- Measure the location of the static water line in the septic tank (at the outlet side) as an initial reference point.
- Begin surcharging the tank with water to start the hydraulic load test.
- Observe any rise in the liquid level at the outlet pipe and measure the water level at the end of filling. Typically, the liquid level will rise from 1 to 3 cm, at which point the liquid level should stabilize for the remainder of filling; and then return to the initial level in a matter of minutes after filling is stopped.
- After the filling cycle is finished, the water level decline in the septic tank is observed until the initial level is reached; and the time to achieve this is recorded. If the initial level is not attained within 30 minutes, the test is terminated and the final water level noted.
- Based on the water level readings during the test, a hydraulic performance rating shall be assigned to the system in accordance with the guidelines provided in Table 11. It should be emphasized that these are guidelines only, and special circumstances may be cause for modifying the evaluation and rating of particular systems.

Leachfield Inspection

At the completion of the hydraulic load test, the drainfield area and downslope areas should be rechecked again for indications of surfacing effluent, wetness, or odors. If any of these conditions exist, further investigation will be necessary to determine if the drainfield is failing and the cause of the failure. Additional investigative work may include water quality samples or dye testing. The cause of seepage could be related to gopher holes, site drainage or erosion problems, excessive water use or simply the age of the disposal system. Any indication of a leachfield failure should be noted on the inspection form and an abatement notice should be issued in accordance with Zone Ordinances.

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1. Adapted From: Questa Engineering Corporation, 1989, Water quality monitoring and septic system inspection program, Sea Ranch Disposal Zone, No.2.

Appendix B: Water Balance Model

In final review stage.