**CDM**

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August 15, 1994

Mr. Bill Keener, Director
Charlotte County Utilities
20101 Peachland Blvd Suite 301
Port Charlotte, FL 33954

RE: Septic Tank/Pollutant Loading Estimates Reaching Receiving Waters
Technical Memorandum - Doc #94-33
Charlotte County Wastewater System Expansion Program
CDM Project/DCN: 6073-110-RT-OSDS

Dear Mr. Keener:

As follow up to the inquiries at the BOCC Workshops addressing the issue of how much nutrient loading may be reaching the receiving waters/harbor as a result of septic tanks, the attached technical memorandum has been prepared. As discussed in the document, the methodology currently applied to the Port Charlotte Phase I sewer expansion area is similar to that which was utilized by the Sarasota Bay National Estuary Program (NEP). The first order loading reduction rate has been assumed to be similar to that which was established for the Sarasota Bay study as a conservative and reasonable estimate.

The estimated total average annual loadings from septic tanks to receiving waters include the sum of the loadings from the failing and the working septic tanks. Estimated total loadings average annual are presented in Table 1. Under present conditions, the loadings range from 39,400 to 122,100 lb/yr for total nitrogen (TN) and 3,600 to 7,500 lb/yr for total phosphorus (TP). The loadings for the year 2000 are roughly twice as high, ranging from 75,300 to 231,600 lb/yr for TN and 5,600 to 13,200 lb/yr for TP.

This pollutant loading effort associated with septic tanks proved useful in coordination with the ongoing SWIM Program which the Southwest Florida Water Management District (SWFWMD). A total nutrient budget on a "watershed basis" is being prepared by SWFWMD and septic tank loadings is one aspect which is being considered. This information should be consistent with previous documents which CDM has relied upon throughout the consideration of the Phase I expansion program.

Alternative methods of wastewater treatments would result in lower pollutant loadings to receiving waters and Charlotte Harbor. The Phase I project proposes to provide central sewer systems by the year 2000 to areas that are presently served by septic tanks. The collected wastewater will be properly treated to reuse levels and then used for residential lawn irrigation. The report summary on page 10 states:

> **Estimates of current (year 1992) and future (year 2000) annual average septic tank loadings of total nitrogen (TN) and total phosphorus (TP) are developed, using a methodology applied previously for the Sarasota Bay National Estuary Program. Loading estimates are developed for both failing septic tanks and for working septic tanks, assuming a range of septic tank failure rates. Because the discharge concentrations from septic tanks are quite high relative to other methods of wastewater treatment, the mass loadings are significant. Other wastewater treatment and disposal methods such as reuse, after installation of central sewer and wastewater treatment facilities, would reduce the nutrient loadings to receiving waters by about 75 to 90 percent.**

Also, an independent "peer review" was conducted of this draft document with individuals such as Hans Zarbock, Coastal Engineering (SWIM Program Consultant); Dr. David Tomasko, Sarasota Bay NEP; Mr. Jerry Kuehn, Ardaman & Associates and Mr. Stephen Torchia, Giffels-Webster Engineers, Inc. per our request. Each reviewers comments are enclosed for your use in addition to a memorandum responding to the professional inquiries.

If there are any questions, please do not hesitate to contact me or Mr. Robert Matthews regarding this subject.

Very truly yours,

CAMP DRESSER & McKEE INC.

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## TECHNICAL MEMORANDUM

## SEPTIC TANK NUTRIENT LOADINGS REACHING RECEIVING WATERS
## PORT CHARLOTTE PHASE I WASTEWATER EXPANSION AREA

## DOC #94-33

### INTRODUCTION

Total nitrogen (TN) and total phosphorus (TP) loadings from septic tanks in the Port Charlotte Phase I service area are estimated from existing data. The loadings are estimated using the methodology applied previously for the Sarasota Bay National Estuary Program (SBNEP) study (CDM, 1992a; CDM, 1992b). Results are generated assuming current (year 1992) and projected future (year 2000) septic tank proliferation. An overview of the methodology, the data values used to analyze the Port Charlotte study area, and the results are provided below.

### METHODOLOGY

The methodology used to assess the septic tank loadings that reach receiving waters incorporates the following considerations:

- The discharge from septic tanks can be characterized by a flow rate and a constituent concentration. The product of these data is the septic tank loading to the soil.

- Some of the loading will be removed before the septic tank discharge reaches the water table, due to physical, biological or chemical processes.

- A percentage of the septic tanks in the study area are "failing". Generally, failing septic tanks are characterized by discharges that do not receive adequate treatment. Failures may be caused by clogging of the soil infiltration zone, high water table, direct connection with receiving waters (rather than infiltration), and overloading of the septic tank with respect to the design.

- "Working" septic tanks are characterized by discharges that enter the surficial aquifer after migrating through 2 feet or more of unsaturated soil. The effluent then moves laterally toward the receiving water, with significant travel times to the receiving water. Typical velocities in the surficial aquifer of the study area are expected to be on the order of 0.1 ft/day or less. Depending upon the distance of the septic tank from the receiving water, the travel time for working septic tanks may range from months to years.

- As the septic tank discharge travels laterally through the surficial aquifer, the mass of constituent may be reduced through physical, chemical or biological processes. In many studies, a first-order decay rate is assumed to represent the loss of mass over time. The assumption of first-order removal is used in this septic tank loading analysis.

- Because of the substantial travel times through the surficial aquifer and the assumption of first-order constituent decay, the constituent mass that reaches the receiving water from a failing septic tank is expected to be greater than the constituent mass from a septic tank that is functioning properly.

## SEPTIC TANK DISCHARGES

Septic tank discharge rates in the Phase I study area have been estimated previously (CDM, 1994). As of 1992, it is estimated that 2.48 million gallons per day (mgd) of residential wastewater and 0.64 mgd of commercial wastewater are generated from septic tanks in the study area, for a total of 3.12 mgd. The residential estimate is based on a total of 14,400 unsewered and developed residential lots, assuming a per capita flow rate of 75 gallons per day and 2.3 persons per residential connection. Commercial flow estimates are based on a flow rate of 1,500 gallons per day per acre of commercial area. For the year 2000, the estimated wastewater flow rates (assuming that new development will use septic tanks) are 4.21 mgd for residential uses and 1.69 mgd for commercial uses, for a total of 5.90 mgd. The year 2000 flow represents an 89 percent increase over the year 1992 flow.

Values of TN and TP concentrations for septic tank discharges are established based on the Sarasota Bay NEP study as well as several recent monitoring studies (Anderson, 1990; Ayres, 1993). In the NEP study, an extensive literature review was conducted to determine septic tank effluent characteristics and groundwater concentrations near the water table at septic tank sites. The results indicated that while most effluent TN concentrations ranged between 40 and 80 mg/l, and TP concentrations ranged between 4 and 16 mg/l, values as high as 125 mg/l and 90 mg/l respectively were recorded. Values of 78 mg/l for TN and 15 mg/l for TP are selected as typical effluent concentrations at the drainfield. However, the literature also showed that groundwater concentrations near the water table were less than the average effluent concentrations, indicating that some of the TN and TP is removed as the effluent percolates downward to the water table. Based on groundwater monitoring data, it was assumed that the concentrations of TN and TP after percolation to the water table are 39 mg/l and 2 mg/l, respectively. This corresponds to 50 percent removal of TN and about 90 percent removal of TP during percolation to the water table. These values are consistent with the values found in the literature.

The sum of loadings from septic tanks consists of the loadings from properly functioning and "failed" septic tanks. In some cases, septic tanks may function properly for a portion of the year (e.g., dry season), and provide reduced treatment during other parts of the year (e.g., wet season) when the seasonal high groundwater encroaches on, or inundates the drainfield. This is particularly probable for systems installed prior to 1983 because the state requirements at that time did not require the two foot of unsaturated soil required for proper treatment.

On the other hand, there are some tanks which are chronic failures and never provide satisfactory treatment. The loadings from seasonal failures, chronic failures and septic tanks which function properly year round were estimated separately, as described in this memorandum. The total discharge from septic tanks consists of contributions from the following: septic tanks that are working properly, septic tanks that have seasonal failure and septic tanks that are in a chronic state of failure.

Working Septic Tanks

Figure 1 presents a schematic representation of groundwater flow that was used in the septic tank loading analysis. As shown in the figure, the model assumes that the surficial aquifer receives inflows from infiltrating stormwater and septic tank loadings. These inflows are routed laterally through the surficial aquifer, and then discharged into a canal or stream.

The analysis, which is conducted using a LOTUS 1-2-3 spreadsheet, assumes that septic tank TN and TP loadings that reach the surficial aquifer will be reduced as the loading travel laterally through the surficial aquifer. This reduction is represented as a first-order relationship which relates the loading reduction to the travel time within the surficial aquifer. Therefore, the methodology must include some calculation that can estimate lateral velocities in the aquifer.

The velocity at any point in the aquifer will depend upon the flow rate, the thickness of saturated flow, and the porosity of the aquifer. The basic equation is

$$v_x = \frac{q_x}{86,400\,(T_0)\,(p)} \qquad (1)$$

where

| | | |
|---|---|---|
| $v_x$ | = | Groundwater velocity at distance $x$ from stream/canal (ft/d) |
| $q_x$ | = | Groundwater flow rate at distance $x$ (cfs per foot of width) |
| $T_0$ | = | Thickness of groundwater flow (ft) |

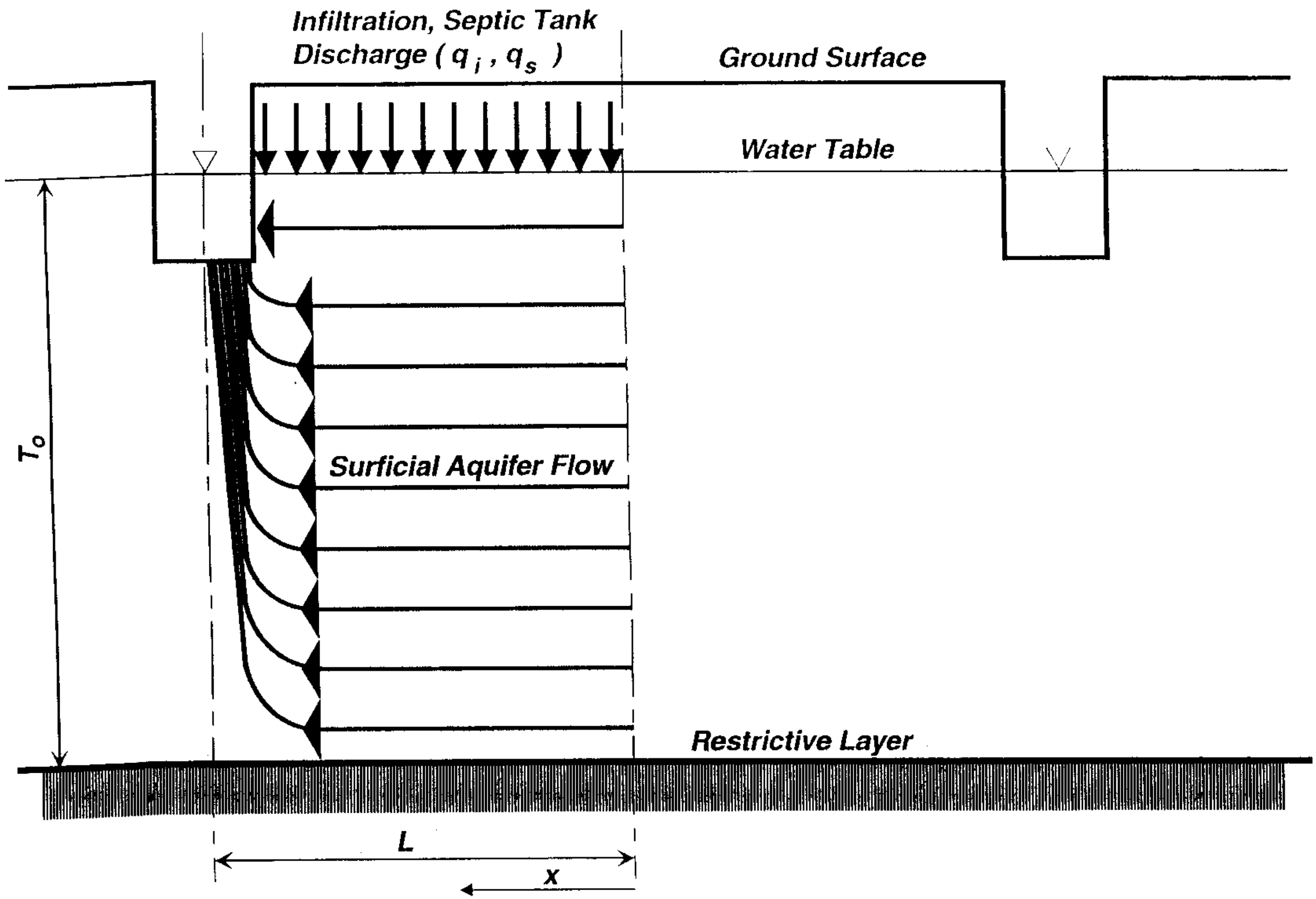



**Figure 1**
**Surficial Aquifer Flow to Receiving Stream**

$p$ = Porosity (dimensionless), ratio of soil voids volume to total volume

86,400 = Number of seconds in one day

Values of $T_0$ = 100 feet and $p$ = 0.30 are established based on a Southwest Florida Water Management District report (SWFWMD, 1988), and local experience. These values are generally assumed to be constant within the study area. However, as the groundwater flow approaches the canal or stream, the thickness of flow will approach a value equal to the stream or canal depth, which may be significantly less than the standard assumption of aquifer thickness. Thus, the value of $T_0$ is adjusted to account for the reduction in flow thickness.

The equation used for the adjustment is

$$T_x=\sqrt{(T_0^2-(T_0+x-L)^2)} \quad (2)$$

where $x$ and $L$ are distances as shown in Figure 1. This equation is based on the lowest flowline following a circular path from the bottom of the surficial aquifer up to the centerline of the stream or canal, and is applied only when the value of $L$-$x$ is less than the value of $T_0$.

The value of $q_x$ is the sum of the infiltration flow $q_i$ and the septic tank discharge flow $q_s$, which is applied over the upgradient area (i.e., over the distance $x$). The infiltration flow $q_i$ represents the groundwater contribution from the canal or stream drainage area. In the Sarasota Bay NEP study, a groundwater recharge rate of 6.6 inches per year was estimated for undeveloped land, based on analysis of long-term rainfall records and long-term flows from the Myakka and Manatee Rivers. Assuming that development results in impervious areas that will reduce the amount of rainfall infiltration and associated groundwater flow, the value of 6.6 inches is adjusted downward to reflect the groundwater flow in the Port Charlotte study area.

Values of infiltration flow are calculated for both the present and future conditions. Assuming that about 50 percent of the study area is currently developed (CDM, 1994), and that the overall value of directly connected impervious area (DCIA) in the developed areas is 40 percent, the recharge rate for present conditions is reduced by 20 percent, yielding a value of 5.28 inches per year for present (year 1992) conditions. For the year 2000 analysis, it is assumed that due to the increased development and the resulting increase in DCIA, the present recharge rate is reduced by 50 percent. Under those assumptions, a value of 3.30 inches is calculated for infiltration flow.

Similarly, the septic tank discharge rate $q_s$ is calculated for both present and future conditions. For the present conditions, the annual flow rate of 3.12 mgd is distributed over the total Phase I study area (22.5 square miles) to yield a rate of 2.91 inches per year. To be conservative, it is assumed that all of the septic tank discharge flow will percolate to the surficial aquifer and travel to the receiving stream or canal. It is possible, however, that some of the discharge would be lost to evapotranspiration, thus reducing the flow rate in the aquifer. For future conditions, the annual flow rate of 5.90 mgd corresponds to a rate of 5.50 inches per year.

The total recharge rate for future conditions will be greater than for existing conditions, and will have a greater percentage attributed to septic tank discharges. For the present condition, the sum of the infiltration and septic tank flows is 8.19 inches per year, with 36 percent attributed to septic tanks. In contrast, the future combined flow rate is 9.20 inches, an increase of 12 percent over present conditions. In addition, 64 percent of the future recharge rate is attributed to septic tanks, as compared to 36 percent for present conditions.

Whereas rainfall infiltration into the aquifer is applied uniformly across the distance $L$, the septic tank discharge is applied uniformly between $x = 0$ and $x = (L-M)$. The distance $M$ represents the assumed minimum setback distance for septic tanks, based on local or state regulations. Since December 1982, the setback requirement for septic tanks in Florida has been 75 feet. However, the minimum setback distance prior to December 1982 was 50 feet, and the lower value was applicable to lots that were platted prior to December 1982, even if the septic tank was built after the new setback distance was established. Consequently, many septic systems in the study area are less than 75 feet from canals and streams. To be conservative, a value of 50 feet is assumed for $M$.

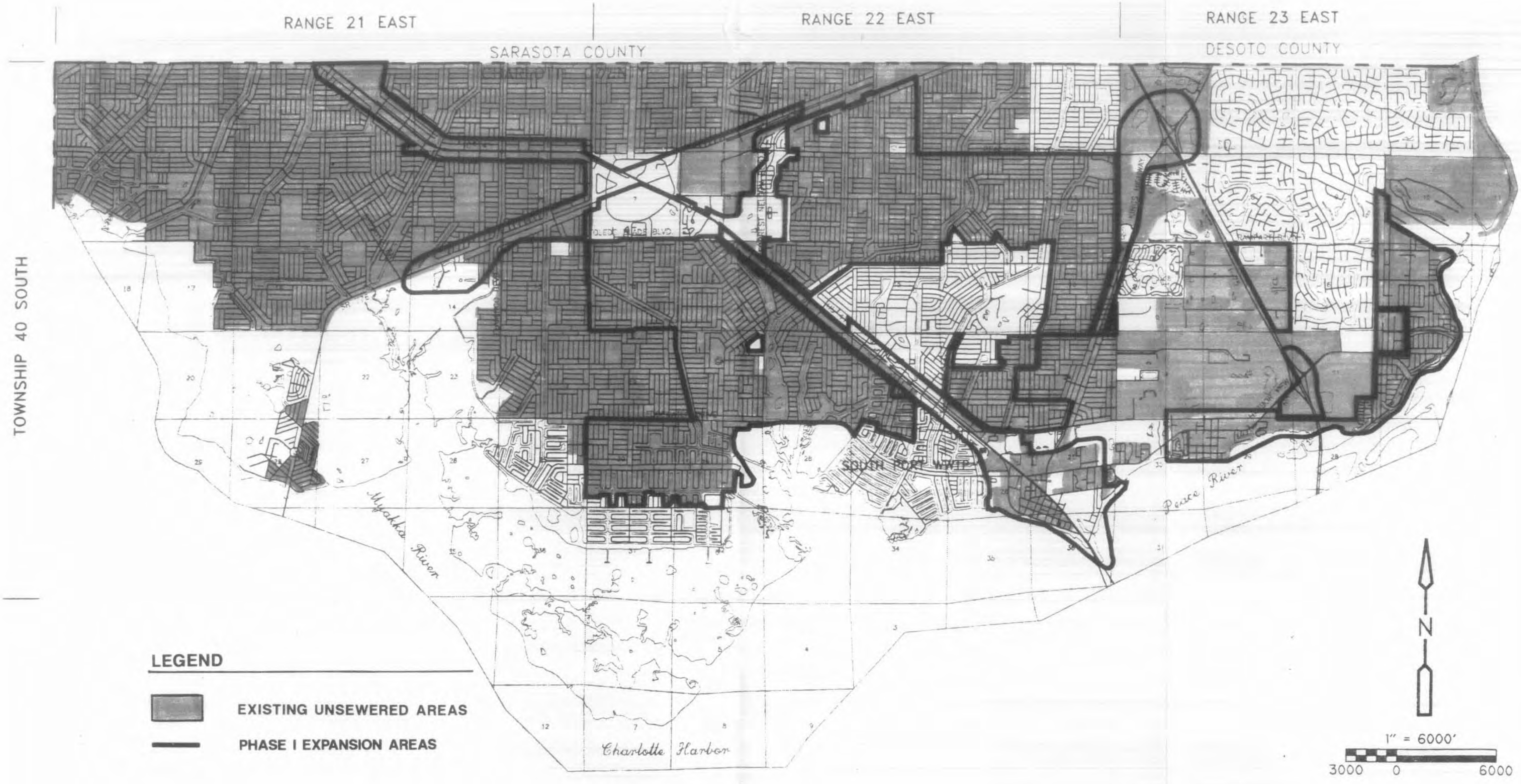
Within the spreadsheet, the flow values are used to calculate values of $v_x$, at increments of 10 feet, from the stream/canal out to a distance $L$, which is the maximum average distance from the land area to the stream/canal. The value of $L$ is estimated using data from Figure 2, which shows both the major stream/canal systems and the land areas within the Phase I study area. The following equation is used:

$$L = \frac{A}{2S}$$

*where*

| | | |
|---|---|---|
| $L$ | = | *average maximum groundwater flow distance (ft)* |
| $A$ | = | *total land area within the Phase I study area (sq ft)* |
| $S$ | = | *total length of receiving water (streams, canals, rivers) in study area (ft)* |

From Figure 2, the established values for $A$ and $S$ are 22.5 square miles (6.27 x $10^8$ square feet) and 34.4 miles (182,000 feet), respectively. By Equation 2, an average maximum flow distance of 1,723 feet is calculated. A rounded value of 1,700 feet is used as the value of $L$ in the analysis.

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**PORT CHARLOTTE UTILITY UNIT**
**EXISTING UNSEWERED AREAS**

**Figure 2**

The maximum travel time from the distance $L$ to the stream or canal is determined by determining the travel time between each 10-foot increment represented in the spreadsheet, and then summing these travel times. The travel time between two consecutive locations is calculated as

$$T_{x,x+10} = \frac{10}{\left(\frac{V_x + V_{x+10}}{2}\right)} \tag{3}$$

where

| | | |
|---|---|---|
| $T_{x,x+10}$ | = | travel time from distance $x$ to distance $x+10$ (days) |
| $v_x$ | = | velocity at distance $x$ (ft/d) |
| $v_{x+10}$ | = | velocity at distance $x+10$ (ft/d) |

By developing travel time values at 10-foot increments, the travel time from any location to the stream or canal can be determined. Furthermore, by applying the first-order load reduction factor, the load reduction can be estimated for any load location, using equation 5:

$$P_a = P_l e^{-kT_{x,L}} \tag{4}$$

where

| | | |
|---|---|---|
| $P_a$ | = | loading after reduction within aquifer (lb/day) |
| $P_l$ | = | loading from septic tank to aquifer (lb/day) |
| $k$ | = | first-order loading reduction rate (1/day) |
| $T_{x,L}$ | = | travel time between distance $x$ and stream or canal (days) |

Septic tank loadings to the aquifer are assumed to be uniform between a distance of $M$ feet and a distance of $L$ feet from the stream or canal. Thus, the overall delivery of septic tank loadings to the canal or stream is calculated in the spreadsheet as an average of the deliveries calculated from all locations between $M$ feet and $L$ feet from the canal or stream.

The value of $k$ was assigned based on the Sarasota Bay study. In that study, the value of $k$ was established based on instream TN monitoring data. For several instream water quality stations, the point source and nonpoint source loadings from the tributary areas were calculated, and the difference between the measured instream loadings and the combined estimate of point and nonpoint source loadings was attributed to septic tanks. The value of $k$ was then adjusted such that there was good agreement between the measured instream loading and the combination of calculated point, nonpoint and septic tank loadings. A calibration value of k = 0.00055/day was established in the Sarasota Bay study, and is used in the initial Port Charlotte loading estimates.

When the selected parameter values were applied in the analysis, the results indicated that between 9 and 10 percent of the septic tank load reaching groundwater from properly functioning septic tanks is expected to ultimately be discharged to receiving waters in the study area. For present conditions, a value of 9.1 percent delivery is calculated using the spreadsheet method described earlier. For future conditions, the value increases to 9.9 percent, because the increased recharge rate results in higher groundwater velocities. The total loadings from septic tanks which function properly year round are then estimated as the product of the percentage of working septic tanks (75, 90 or 100%), the total septic tank effluent flow rate (3.12 mgd for present and 5.90 mgd for future conditions), the septic tank effluent concentrations of TN and TP reaching the water table, and the delivery rate based on travel time through the surficial aquifer (9.1% for present conditions, 9.9% for future conditions).

Seasonal Failure Adjustment

The minimum technical standards for the construction of onsite sewage disposal systems were revised in December 1982. Revised Chapter 10D-6 of the Florida Administrative Code requires a separation of at least 24 inches between the base of the drainfield and the water table even during the wet season. This requirement increased the overall effectiveness of treating domestic wastewater on site. An effort to determine the location and quantity of septic tanks in Charlotte County construction prior to the 1983 requirement changes was undertaken in co-operation with the department of Health and Rehabilitive Services (HRS). The following method was used to identify the percentage of pre-1983 septic systems in the study area. A set of 1983 - Real Estate Date. Inc (REDI) aerial photographs (taken in October of 1983) was used to locate pre-1983 improved properties within the proposed wastewater expansion area. The improved property locations were then transfered to an aerial flown in December of 1993. In addition, information contained on the 1983 REDI aerials was cross checked against a record of septic tank locations provided by the HRS. Based on information compiled from this identification method, it was determined that of the approximately 29,000 septic systems located within the Port Charlotte MSBU boundaries nearly 50% were constructed prior to 1983.

For the working septic tank analysis, the concentrations of TN and TP reaching the water table are adjusted to account for the fact that roughly half of the existing septic tanks were installed before a two-foot unsaturated soil depth between the septic tank drainfield and the high water table was required by regulations. It is assumed that the untreated concentrations of TN and TP (i.e., 78 mg/l and 15 mg/l, respectively) are appropriate, during the wet season months of June through September, for the septic tanks installed prior to 1983 since the higher wet season ground water levels would not provide 2 feet for nutrient removal during percolation. Half of the septic tanks produce a TN concentration of 39 mg/l at the water table. The other half produces a 39 mg/l TN concentration for eight months, and a 78 mg/l concentration of total nitrogen for four months of the year. Thus, the tanks experiencing seasonal failures have an annual average concentration of 52 mg/l based on weighting the concentration as a function of season. Combining the calculated concentration for tanks experiencing seasonal failure with the other 50 percent of the "working" septic tanks (at 39 mg/l) results in a weighted annual average concentration of 45.5 mg/l total nitrogen. Therefore, the water table concentrations for "working" septic tanks under present conditions are adjusted upward to 45.5 mg/l and 4.17 mg/l for TN and TP, respectively. For future conditions, the pre-1983 septic tank flows represent 26 percent of the total septic tank flow. Based on this value, the adjusted TN and TP concentrations are 42.4 mg/l and 3.15 mg/l, respectively.

Failing Septic Tanks

There are several types of septic tank "failures". Failures may be seasonal or chronic. Seasonal failures can occur when the water table moves closer to the surface during the summer and less than 24 inches of unsaturated soil exists between the drainfield and the water table. Aside from the seasonal failures, three types of chronic failures may occur.

- Type 1 failure is when the water table is in the drainfield. Thus, there is no nutrient loss in the unsaturated zone. However, nutrients are removed during travel through the surficial aquifer. Based on the 9.1 percent delivery ratio for present conditions, concentrations from a Type 1 failure are 7.1 mg/l and 1.4 mg/l for TN and TP, respectively.

- Type 2 failure is when infiltration through the 2-ft. unsaturated zone occurs (resulting in nutrient removal), but there are no additional losses from groundwater movement. This might occur at houses adjacent to surface water. Concentrations resulting from Type 2 failure are 39 mg/l for TN and 2 mg/l for TP.

- Type 3 failure is when the drainfield is directly connected to a surface water body. There is no reduction of nutrients due to percolation through the unsaturated zone or movement through the aquifer. Concentrations resulting from a Type 3 failure are 78 mg/l and 15 mg/l for TN and TP, respectively.

Since the extent and duration of each type of failure could not be readily quantified, a single type of failure is modeled. Type 1 failure produces the lowest loading while Type 3 results in the highest loading. Type 2 is used for modeling since it represents intermediate conditions and is used to represent the various types of failures that occur. Seasonal failures are addressed in the analysis of working septic tanks described previously.

It is difficult and expensive to determine the exact percentage of septic tanks that are experiencing chronic failure in the study area, so a range of failure rates is investigated. The evaluated failure rates include the following:

- 0 percent. This is the best-case hypothetical scenario, in which all septic tanks are functioning properly except for those experiencing seasonal failure.

- 10 percent. This value is representative of the values that have typically been used in other Florida studies such as the NEP study and the City of Jacksonville Master Stormwater Management Plan study (CDM, 1992). In the Sarasota Bay study, a failure rate of 8 percent was assumed. This value compared favorably with the results of a septic tank survey conducted in Jacksonville, Florida by the Department of Health and Rehabilitative Services. In the study, an inspection of more than 800 sites revealed about 90 violations, or a failure rate of 12 percent.

- 25 percent. This value represents a relatively high failure rate which may be appropriate in the Phase I study area for several reasons. One is that the soils in the study area are not considered conducive to septic tank use due to high water table conditions. Another reason is that many of the existing septic tanks in the study area were installed prior to the development of more stringent septic tank regulations which took effect in December 1982. The old regulations did not require two feet of unsaturated soil between the septic tank discharge and the high water table, which is currently considered necessary for effective treatment.

The total loadings from the failing septic tanks are then estimated as the product of the percentage of failing septic tanks (0, 10 or 25%), the total septic tank effluent flow rate (3.12 mgd for present and 5.90 mgd for future conditions), and the septic tank effluent concentrations of TN and TP reaching the water table (TN = 39 mg/1, TP = 2 mg/1).

TOTAL SEPTIC TANK LOADING

The estimated total average annual loadings from septic tanks to receiving waters include the sum of the loadings from the failing and the working septic tanks. Estimated average annual total septic tank loadings to receiving waters are presented in Table 1. Under present conditions, the loadings range from 39,400 to 122,100 lb/yr for TN and 3,600 to 7,500 lb/yr for TP. The loadings for the year 2000 are roughly twice as high, ranging from 75,300 to 231,600 lb/yr for TN and 5,600 to 13,200 lb/yr for TP.

Alternative methods of wastewater treatment would result in lower loadings to receiving waters and Charlotte Harbor. The Phase I project proposes to provide central sewer systems to the areas that are presently served by septic tanks. The collected wastewater will be treated and then used for irrigation. The reclaimed water will have a TN concentration of approximately 10 mg/l. At this concentration and at typical residential irrigation rates (1.0 inch/week), nitrogen loadings on the order of 2.7 pounds per 1,000 square feet per year are expected. This is approxmately 54 percent of the recommended application rate for nitrogen (3-7 pounds/1,000 square feet per year) for sod. As a result, most studies have assumed that 90-95 percent of the nitrogen applied to well maintained lawns through reuse will be lost as uptake by the sod, denitrification or adsorption to the soil. Of course, any nitrogen from reuse which migrates past the effective root zone to the water table would be subject to the same attenuation as septic tank effluent. An initial 50 percent reduction during infiltration to the water table can be expected and then 9.1 percent of that remaining nitrogen would be expected to migrate laterally to receiving waters and Charlotte Harbor.

One could argue that less than 0.5 percent of the nitrogen loading in properly applied reclaimed water actually reaches surface water based on 90 percent crop uptake, 50 percent infiltration losses, and 9.1 percent lateral groundwater delivery. However, as a very conservative comparison, it is assumed that the only losses in a reuse system are lateral groundwater losses. Thus, the amount of material delivered to a receiving water from a reuse system is assumed to be 9.1 percent based on the delivery calculations for 1992 conditions. The equivalent nitrogen

TABLE 1

NUTRIENT LOADINGS TO RECEIVING WATERS
*FROM SEPTIC TANKS IN THE PORT CHARLOTTE STUDY AREA*

| LAND USE SCENARIO | SEPTIC TANK FAILURE RATE (PERCENT) | SEPTIC TANK LOADING TO RECEIVING WATERS (LB/YR) | |
|---|---|---|---|
| | | TOTAL N | TOTAL P |
| Present (1992) | 0 | 39,400 | 3,600 |
| | 10 | 72,500 | 5,100 |
| | 25 | 122,100 | 7,500 |
| Year 2000 | 0 | 75,300 | 5,600 |
| | 10 | 137,800 | 8,600 |
| | 25 | 231,600 | 13,200 |

Assumptions:

1. *Failing septic tank concentrations* = *39 mg/l* (total N), 2 mg/l (total P).
2. First-order decay of total N and total P as septic tank effluent travels through surficial aquifer to receiving waters.
3. Decay constant = 0.00055/day based on Sarasota Bay NEP analysis.
4. Aquifer thickness = 100 ft, porosity = 0.3.
5. Average annual recharge to surficial aquifer due to stormwater infiltration = 5.28 inches per year (present), 3.30 inches per year (year 2000)
6. Average annual septic tank flow to surficial aquifer = 2.91 inches per year (present), 5.50 inches per year (year 2000)

loading from a reuse system with an annual flow of 3.12 mgd is then 8,650 lb/yr. Compared to the calculated present septic tank loadings of 39,400 to 122,100 lb/yr, the reuse option represents a TN loading reduction of 30,750 to 113,450 lb/yr, which corresponds to a 78 to 93 percent reduction in TN loading from septic tanks to receiving waters. The benefits would be similar under future conditions. Assuming that the reuse water will have a TN concentration of 10 mg/l, and that the delivery ratio for TN will be 9.9% for future (year 2000) conditions, the equivalent loading delivered to the receiving waters would be 17,800 lb/yr. Compared to the calculated future septic tank loadings of 75,300 to 231,600 lb/yr, the reuse option would represent a TN loading reduction of 57,500 to 213,800 lb/yr. Implementation of a reclaimed water system corresponds to a 76 to 92 percent reduction in TN wastewater loading to receiving waters.

## SUMMARY

Estimates of current (year 1992) and future (year 2000) annual average septic tank loadings of total nitrogen (TN) and total phosphorus (TP) are developed, using a methodology applied previously for the Sarasota Bay National Estuary Program. Loading estimates are developed for both failing septic tanks and for working septic tanks, assuming a range of septic tank failure rates. Because the discharge concentrations from septic tanks are quite high relative to other methods of wastewater treatment, the mass loadings are significant. Other wastewater treatment and disposal methods such as reuse, after installation of central sewer and wastewater treatment facilities, would reduce the nutrient loadings to receiving waters by about 75 to 90 percent.

## REFERENCES


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Southwest Florida Water Management District. 1988. Groundwater Resource Availability Inventory: Charlotte County, Florida.

# Memorandum

*To:* *Dr. David Tomasko (SBNEP)*
*Mr. Hans Zarbock, P.E. (Coastal Envir.)*
*Mr. Jerry Kuehn, P.E. (Ardaman & Assoc.)*
*Mr. Steven Torchia (Giffels-Webster Engineers, Inc.)*

*From:* *S. John Calise*

*Date:* *August 10, 1994*

*Subject:* ***PEER REVIEW COMMENTS OF "DRAFT TECHNICAL MEMORANDUM,***
*#94-33 Septic Tank Nutrient Loadings, Port Charlotte Phase I Area"*
*CDM Project/DCN: 6073-110-RT-OSDS*

First, I would like to thank all of the reviewers for their constructive comments. It is encouraging to see that both the Charlotte Harbor SWIM estimates of unit loadings from septic tanks and those in the present report are in substantial agreement.

I would also like to take this opportunity to concur with, and expand upon one reviewer's comments about the impactive nature of septic tanks on the fragile near-shore environment. We agree that it would be a very myopic perspective to discount the impact of septic tanks on the health of Charlotte Harbor based on a simple comparison of loading values and associated percentage of total loadings. Septic tank loads are not distributed across the entire harbor as might be implied by simple percentages. In fact, these loads are introduced primarily in near-shore waters and often in poorly-flushed canals. The resultant eutrophication can affect critical habitats such as sea grasses that cannot survive in deeper waters. Therefore, the degree of environmental damage is obscured using comparisons as simple percentages.

RESPONSES TO SPECIFIC REVIEWER COMMENTS ARE PROVIDED BELOW:

Jerry Kuehn, P.E. - Ardaman & Associates.

The definition of a "failed" system could take several forms, and perhaps the failure rate is much higher as indicated by the reviewer. As Mr. Kuehn suggests, a broad definition is desirable. Moreover, as Mr. Kuehn implies in his discussion of seasonal mounding, even OSDS which fully comply with the current regulations may not provide a full 24 inches of infiltration zone when mounding is significant. Thus, "failures" may be seasonal as well as chronic. Seasonal failures can occur when the water table moves closer to the surface during the summer and less than 24 inches of unsaturated soil exists between the drainfield and the water table.

Several definitions of "failures" were evaluated for purposes of the this report. Since the extent and duration of each type of failure could not be readily quantified, a range of reasonable failure rates were modeled. Aside from the seasonal failures, three major types of failures were considered. In the first type, the drainfield was assumed to be inundated with groundwater year round, and thus no treatment occurs as the septic tank effluent infiltrates. Nitrogen losses in this case are restricted to those which occur with lateral movement of groundwater. A second type of failure considered the case when infiltration and resulting nutrient removal occurs but there are no losses associated with lateral movement of groundwater. This may occur at homes located adjacent to surface water (e.g. canal systems). In a third type of failure considered, the drainfield is directly connected to receiving waterbody. This can occur as a deliberate "straight pipe", or surreptitiously where the effluent pools on the surface and runs as overland flow to a lake, canal, stream or other waterbody.

CDM agrees that a range of groundwater velocities are possible. In general, CDM assumed that the groundwater gradient followed the topography of the land and that a slower velocity was representative of the study area at large. Undoubtedly, the gradient (and thus the velocity) will be greater in some locations. **It should be noted that the higher velocities described by Mr. Kuehn would result in much larger loadings because the loss rate is a function of travel time, and thus velocity and distance.**

With regard to equation 3 which describes the methodology of determining groundwater flow lengths, the initial description of the term "S" was taken from stormwater modeling terminology, namely the SWMM runoff module. In stormwater use, "S" is the length of streambank receiving runoff from the contributing uplands. Since both sides contribute, in the draft report the term "S", the actual length used was twice the stream length. In order to clarify this point, the definition of "S" has been changed to reflect that fact that twice the stream length was used in the calculations.

As suggested, the description of percentage reduction in TN resulting from implementation of the sewer/reuse program has been re-written to reflect basis of comparison. In addition, the percentages noted in the Summary section have been corrected to agree with those presented earlier in the text.

Dr. David Tomasko - Sarasota Bay National Estuary Program (SBNEP)

The effluent Total Nitrogen concentrations, both at the drainfield and at the interface with groundwater, were taken from more recent summaries (see Ayres, 1993) that were not available during the SBNEP evaluation. The range of values is fairly large, and values as large as 125 mg/l have been documented. Both the value used in the present study (78 mg/l) and the value used in the SBNEP study (60 mg/l) are typical.

With regard to the page 9 comment, based on typical Charlotte County surficial aquifer characteristics, an estimated 9.1 percent of the nitrogen introduced into the groundwater (after infiltration) will migrate to receiving waters.

With regard to the comments relating to page 10, in order to estimate percentage changes in loads requires that some form of alternate disposal be specified as a reference. For example, if wastewater from a centralized facility is injected into a deep well, then the change in loads delivered to Charlotte Harbor is equal to the entire loading from the existing septic systems. On the other hand, if the wastewater is collected, treated to Advanced Wastewater Treatment standards (AWT) as defined in FS 403.086 and then discharged to surface waters, the reduction in loading is on the order of 60 percent when comparing future flows at AWT (5.90 mgd @ 3.0 mg/l) to future septic tank loads at a 10 percent failure rate. For purposes of the present evaluation, advanced secondary treatment is used for urban reuse. The reviewer's comments (ref: page 11) with regard to putting the quoted reductions in perspective have been addressed with clarifying text in the final report. The percentages reported reference only the changes in nitrogen loading from septic systems within the Port Charlotte Phase I service area. Stormwater, and other inputs will be modelled under on-going SWIM projects by others, but will cover much larger geographic segments.

With regard to movement of nitrate, it may be possible that the movement from spring systems documented by SWFWMD may be the result of differences in geologic formations which are conducive to the formation of spring systems. On the other hand, surficial contamination resulting from agricultural activities has been documented on watershed-wide scales in the mid-west. CDM concurs that both extremes are probably occurring as a result of site-specific factors such as soil types.

The degree that nitrification and denitrification occur greatly impacts the movement. This in turn may be governed by the organic content of the surficial soils as indicated by the references provided by the reviewer. Because of these unknowns, the nitrogen "decay" rates used by CDM in the present evaluation are empirical loss rates based on observed data. Site specific refinements using a site in Charlotte County are planned for the near future. The actual loss mechanisms include denitrification, adsorption and bacterial uptake. CDM agrees that quantification of each mechanism and pathway, including development of decay curves such as provided would be useful, but such investigations are beyond the scope and needs of the present wastewater collection program.

Mr. Hans Zarbock, P.E. - Coastal Environmental Inc.

Item number 3 regarding percentage of failures. The 25 percent failure rate was chosen as a reasonable upper limit to failures, and was characterized in the report as "relatively high". Because the number and duration of failures (e.g. seasonal failures vs. chronic failures) is unknown, a value of 25 percent was chosen to set an upper bound. Nearly 50 percent of the existing septic systems were constructed prior to December, 1982 and are likely to have less than the currently required 24 inches of unsaturated zone under the drainfield. In addition, the OSDS repair permits issued for Casey Key in nearby Sarasota County suggests that 20 percent of the septic systems on this barrier island were exhibiting noticeable failures. Thus, while the actual number is unknown, the choice of 25 percent as an upper bound seems reasonable.

Item number 4 questioned the use of the terminology "the area is nearly developed" based on data provided in the Charlotte County 25 Year Water and Sewer Study by Giffels-Webster, Inc. A copy of the draft technical memorandum was provided to Mr. Stephen Torchia of Giffels-Webster Engineers, Inc. Mr. Torchia commented that the existing dwelling unit count and future growth estimates are consistent with the figures reported in the Charlotte County 25 Year Water and Sewer Study. The increase in growth between 1992 and 2000 justifies increasing the value of directly connected impervious area (DCIA) by ten (10) percent. The text has been revised to remove the reference to the area being nearly developed since year 2000 conditions are not expected to be near the build-out conditions.

Item number 5. CDM agrees that the treatment level achieved is critical to the comparison. The proposed treatment is advanced secondary. Similar facility designs throughout Florida and specifically in Manatee County (North and Southeast Subregional WWTP's) have consistently produced effluent total nitrogen concentrations on the order of 8 -12 mg/l. Thus, for this facility design, 10 mg/l is a reasonable number.

Item number 6. CDM agrees fully with this comment. The difference between the two normalized unit loads (lbs/tank/year) is easily within the uncertainty limits of either estimation, and the results are in substantial agreement. **CDM also concurs with the reviewer's comments about the impacts resulting from near-shore discharges, and how this makes septic tanks impacts potentially more significant than average annual numbers or percentages.**

In closing, Mr. Mike Heyl, Mr. Richard Wagner and I would once again like to acknowledge and thank the reviewers for their time and constructive comments.

CHW4PC11.36

**COASTAL**

July 5, 1994

Mr. S. John Calise, P.E.
Camp, Dresser & McKee, Inc.
20101 Peachland Blvd Suite 207
Port Charlotte, Florida 33954

Re: Review of Technical Memorandum dated June 21, 1994

Dear Mr. Calise:

I have reviewed the referenced document entitled " Pollutant Loading Estimates/Septic Tank", and offer the following comments, as requested in your cover letter dated June 22. I have reviewed this report both for general issues, and with respect to Coastal Environmental, Inc.'s on-going watershed characterization project for SWIM.

1) The background information, including a general description of the issues and processes of concern involved with siting, permitting, construction and operation of septic tank systems is adequately presented. Much of this information was taken from the report "Impact of Septic Tank Operations, Charlotte County, Florida" (CDM, 1994) and was originally developed for work with Sarasota Bay National Estuary Program.

2) The assumptions that were made regarding water use rates, population estimates, water quality characteristics, etc. appear to be appropriate and are generally adequately explained. However, you should be ready to make available the referenced literature review if someone questions the general statement "These values are consistent with the values found in the literature," as found on page 2.

3) Typical ranges of septic tank failure rates do fall within your range of 0-25%, based on my experience. Septic tank inventories that I have worked on (in Pasco and Citrus counties) suggest that failure rates of 5-15% are common in similar coastal communities. Although the upper end of 25% may be high, local conditions may produce that many non-functioning units, especially during the wet season. If the upper value is used for calculation purposes, some type of verification of that failure rate may be called for.

4) I'm not as comfortable with the assumption for future conditions (circa 2000) that "the area is nearly [totally] developed" (page 6 second paragraph). A recent inventory of existing and projected future dwelling units in the Port Charlotte area (Giffles-Webster, 1991) indicates that the total number of year 2000 dwelling units (57,831) will be greater than year 1992 dwelling units (37,097) by only a factor of 1.56.

However, to illustrate the higher potential loadings from septic tank systems under future conditions, you might want to include a "build-out condition" scenario. The Giffles-Webster (1991) inventory indicates that there are 111,170 dwelling units (maximum permitted) that could theoretically be built in the same area under current permitted conditions. This would represent the "almost totally developed" scenario that you now call year 2000 conditions.

5) The reduction in loading resulting from centralized sewer service and reuse of the treated effluent appears reasonable. Because this estimated reduction is based solely on the lower nitrogen concentration in the reuse water (10 mg/L vs. 39 mg/L), and similar delivery rates to surface waters, the level of treatment afforded the domestic wastewater is of primary concern. Because the effluent will be applied to the land, and not discharged directly to surface water, Grizzle-Figg standards will not apply. It must be made clear that these load reductions will apply only if effluent TN concentrations are near 10 mg/L. As you know, typical secondary wastewater treatment often results in TN concentrations of 15-20 mg/L. Also, spray irrigation of reuse water can result in higher evaporation and plant uptake, thus reducing the hydrologic load as well.

6) A comparison of your results and the results from our draft loading report show similar values for "per-unit" septic tank loads. These estimates, shown in Table 1 below, indicate that about 40% of the septic tanks in the coastal areas surrounding Charlotte Harbor are located in the Port Charlotte Utility Area. We used the same numbers for people per household (2.3), daily water use per person (75 gallons), and TN concentration (39 mg/L) as were used in your calculations. However, we used an overall 80% reduction in TN for the septic tank load between the septic tank system and the receiving water. This reduction rate is based on a review of literature values that we developed for estimating nutrient loadings to Tampa Bay from land application of treated domestic wastewater effluent, and is described in our report "Estimates of Total Nitrogen, Total Phosphorus, and Total Suspended Solids Loadings to Tampa Bay, Florida", prepared for the Tampa Bay National Estuary Program.

Your loading estimate used somewhat more detailed methods, incorporating groundwater flow travel time, estimates of failures, and the age of the septic tank systems (pre or post 1983). Although there are differences in our methods, the results are very similar. Based on a failure rate of 10%, your methods give a per septic tank load of 5.04 pounds/year (lb/yr). Our estimates, which simply assume an 80% reduction in TN for all septic tanks with no separate accounting for failures, give a per septic tank load of 4.66 lb/yr. Because these two values are very close, this would suggest that our assumptions and methods are comparable. However, although the 10% failure rate is consistent with my experience in other coastal Florida communities, the rate of non-functioning septic tank systems may be higher in Charlotte County, based on local conditions.

Table 1 - Comparison of CDM and Coastal Environmental, Inc. Estimated 1992 Septic Tank Loads for the Charlotte Harbor Area

| Source/ Scenario | # Septic Tanks | Total Load (lb/yr) | Unit Load (lb/yr/septic tank) |
|---|---|---|---|
| CDM/Pt Charlotte Utility Unit | 14,400 | 72,500 (1) | 5.04 |
| Coastal Env./ Total Harbor Surroundings | 37,765 | 175,920 (2) | 4.66 |

Notes: (1) Based on 10% failure rate.
(2) Based on 80% overall removal rate, with no accounting for failures.

The magnitude of estimated loads to Charlotte Harbor from septic tanks suggests that this source of nutrient inputs is not as high as several other sources, on an annual, harbor-wide basis. Our investigation indicates that nonpoint sources, industrial point sources, and atmospheric deposition all contribute more nitrogen and phosphorus to the harbor than septic tanks. However, there are several factors that may make septic tank impacts potentially more significant than these average annual numbers suggest:

- Septic tank loads most often discharge to such near-shore surface waters as residential canals and small streams and embayments. These water bodies are often confined and relatively isolated from the flushing and circulation of the open water harbor. This can result in localized water quality problems (algal blooms, low dissolved oxygen) in the near shore areas that would otherwise be attenuated through flushing and tidal action.

- Septic tank loads may be more significant during the winter months. During this period, streamflow and rainfall is lower than during the summer wet season, so the relative contribution from septic tanks will be greater. Also, the seasonal population is greatest during the winter months, resulting in higher septic tank discharges.

- Our efforts have focused on nutrient loading and the possible consequences with regard to eutrophication of the estuary. The aspect of public health should also be considered. Pathogens and other hazardous materials may pass through septic tank systems and enter adjoining surface waters.

I appreciate the opportunity to act as an outside reviewer of your report, and hope that these comments have been useful. If you have any questions about my comments or need any additional information, please call me at (813) 577-6161. Our draft report of loadings and freshwater inflows to Charlotte Harbor should be available for review, through SWIM, before the end of the month.

Sincerely,

Hans Zarbock, P.E.
Senior Engineer

cc: Gerold Morrison, Ph.D. - SWIM

SARASOTA Bay National Estuary Program

RECEIVED JUL 7 1994 CAMP DRESSER & McKEE PORT CHARLOTTE

July 6, 1994

Mr. S. John Calise
20101 Peachland Blvd., Unit 201
Port Charlotte, FL 33954

Dear Mr. Calise,

Thank you for the opportunity to review the report from Camp, Dresser & McKee, Inc. entitled "Pollutant Loading Estimates / Septic Tank Review for Charlotte County Wastewater Expansion".

Overall, I found the report to be well-written and consistent with most of the local analyses done in this area (e.g. work by SBNEP and Ayres & Associates). I thought the approach to determining the contributions from failing septic tanks was probably appropriate.

I did have, however, a few points that I think should be addressed. These range from minor to not so minor. Starting with the minor points:

- Why is an effluent TN concentration of 78 mg/l used? For the SBNEP study, a value of 60 mg/l was used. Why the difference?
- On page 5, a value of 9.1 % delivery of TN is justified. Is this 9.1 % of nitrogen leaving the septic tank? Or is it 9.1 % of nitrogen entering the groundwater?
- On page 10, how would calculated load reductions change if Charlotte County does not go forward with household reuse availability?
- On page 11, the 76 to 92 % load reduction potential for receiving waters should be stated with caution. Receiving waters should be defined as canals, not "regions" of Charlotte Harbor. Also, the language makes it sound as if the 76 to 92 % reduction is for all loads. Was stormwater modelled? If so, what is its contribution? If not, what might be the total percent load reduction?

As for major points, I have often wondered why the literature contains such different estimates of the ability of nitrate to travel in groundwater. SWFWMD has documented, with great detail, nitrate movement of over 10 miles for Buckhorn Spring, Alafia Spring, and King's Bay. Meanwhile, Damon Anderson couldn't find elevated nitrate levels when he studied (very thoroughly) some of his households. Could both these extremes be accurate? I believe they are.

One aspect of the nitrogen loading estimate used in this report and elsewhere that has always bothered me is just what exactly nitrogen "decay" means. Is this absorption of ammonium onto soil particles?

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Biological uptake? Denitrification? It seems to me that the decay rate utilizes a "box model" approach that does not ask enough questions about processes. Again, what is meant by "decay"?

During the bus tour, I met with one of the IFAS researchers and we discussed the role of soil organic contents on denitrification rates. He gave me a copy of the enclosed paper. Using the information in Figure 1 and Table II, I modified their work to produce the attached figure, entitled "Denitrification Rates versus Soil Organic Content". With further modification, based on the enclosed paper, I produced the other figure, "Set-back Distance from Surface Water ....".

Certainly, the above-mentioned figures need to be better investigated and refined. Perhaps it is time to start measuring actual processes that are known to minimize the potential for nitrate contamination from OSDS's. Unfortunately, Soil Conservation Service maps do not contain the needed degree of resolution (i.e. low organic contents are in a category of < 1 %, but there is a large difference between denitrification rates at, for example, 1 % versus 0.05 %).

If I can be of any further assistance, do not hesitate to call me.

Sincerely,

David A. Tomasko, Ph.D.

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# Carbon Limitation of Denitrification Rates in an Anaerobic Groundwater System

**P. M. Bradley,**[*,†,‡] **M. Fernandez, Jr.,**[§] **and F. H. Chapelle**[†]

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■ Rates of potential denitrification were determined for anaerobic aquifer sediments collected at a site where groundwater $NO_3$ concentrations ranged from 0.7 $\mu$M to 8.6 mM. A significant relation ($p = 0.046$) was observed between denitrification rates and the in situ concentration of $NO_3$, but $NO_3$ concentration only accounted for approximately 34% ($r^2$) of the variation in activity. The highly significant relation ($p < 0.001$; $r^2 = 0.80$) between potential denitrification and sediment total organic content and the enhanced activity of sediments amended with glucose indicated that denitrification rates in this aquifer system were carbon limited. No significant relation was observed between denitrification and the in situ groundwater pH, but short-term variations in pH influenced both the magnitude and the end products of denitrification.

## *Introduction*

The accumulation of nitrate in groundwater beneath cultivated land commonly reflects the leaching of fertilizer from the surface at rates that exceed the nitrogen requirements of the underlying soil community. In such cases, delivery of $NO_3$ to groundwater via vertically percolating recharge typically exceeds the denitrification potential of aquifer material. In aerobic groundwater systems, the limitation of denitrification is readily attributed to repression of nitrogen oxide reductase activity by molecular oxygen. In anaerobic aquifers, however, the conditions limiting denitrification are less obvious. Numerous studies have demonstrated that nitrogen and carbon availability as well as pH may limit potential denitrification rates in soils (see refs 1 and 2 for review). It is reasonable to hypothesize, therefore, that similar processes may limit denitrification in groundwater systems and that these limitations may contribute to $NO_3$ accumulation in anaerobic aquifers. The purpose of the studies reported here was to evaluate potential denitrification rates in a shallow anaerobic groundwater system underlying a golf course near Tampa, FL, as a function of $NO_3$ concentrations, carbon availability, and pH. The results of this investigation indicate that carbon limitation in anaerobic aquifer sediments can be a primary cause for the accumulation of nitrate in groundwater underlying cultivated lands. Further, this study is intended to illustrate the use of such evaluations to provide practical guidelines for surface applications of nitrogen fertilizers and waste.

## *Study Location*

Sediment samples were collected from a golf course near Tampa, FL. The elevation at the course ranges from 0 to 3 m above sea level. The course is underlain by a fine sand layer which functions as a shallow aquifer. Particle size analysis indicates that the sediment is primarily sand with a maximum silt/clay content of 2% of dry weight (Bradley, unpublished results). The aquifer is confined at a depth of approximately 4.5 m by a sandy-clay layer which ranges in thickness from 4.5 to 7.5 m. The depth to the water table typically ranges from 1 to 3 m across the site.

## *Sample Collection*

Water quality characteristics of the shallow groundwater were determined for the six sites at which sediment was collected. Water samples were collected from steam-sterilized, stainless-steel drive-point samplers after approximately 2 L was purged from each sampler. The groundwater pH and oxygen concentration were measured immediately with calibrated pH and dissolved oxygen meters, respectively. Samples for $NO_3$ nitrogen analysis were collected in 250-mL dark brown plastic bottles containing 13 mg of $HgCl_2$, stored on ice, and shipped immediately to a U.S. Geological Survey laboratory.

Aquifer sediment samples were collected at depths of 1-2 and 3-4 m at six sites using a hollow-stem auger drilling rig equipped with a split-spoon sampler. Cores

[†] U.S. Geological Survey, Columbia, SC.
[‡] University of South Carolina.
[§] U.S. Geological Survey, Tampa, FL.

Table I. Nitrate Concentration and pH Data for Groundwater Collected at the Sites of Sediment Sampling[a]

| site | $[NO_3]$, mM | pH | site | $[NO_3]$, mM | pH |
|---|---|---|---|---|---|
| 1 | 1.2 | 5.4 | 4 | 4.0 | 5.8 |
| 2 | 6.6 | 5.4 | 5 | 0.2 | 6.4 |
| 3 | 8.6 | 5.9 | 6 | ND | 5.5 |

[a] Data are from monitoring wells screened over the 1–4-m depth at which sediment samples were collected. ND indicates that $NO_3$ was not detected (i.e., ≤0.7 μM).

were collected in steam-sterilized, polycarbonate split-spoon liners by drilling to the appropriate depth and driving the sampler into undisturbed sediment. Subsequently, the polycarbonate tube was removed from the sampler, capped and sealed with tape at both ends, and then stored at 4 °C until analyzed for denitrification activity using the acetylene block technique.

*Methods*

The acetylene block technique is based on the inhibition of $N_2O$ reduction to $N_2$ by addition of acetylene such that denitrifying activity is quantified as the rate of accumulation of $N_2O$ (*3*). The general procedure for analysis of denitrifying activity was as follows. Triplicate live treatments and a single biologically inactive control were prepared by aseptically transferring approximately 20 g (dry weight) of sediment to sterile 40-mL serum vials. A 4-mL volume of deoxygenated $KNO_3$ solution was added. The pH of the resultant sediment slurry was adjusted to in situ values by titration with HCl or NaOH as needed. Then the vials were capped with butyl rubber stoppers and flushed with He for 3 min at a flow rate of 300 mL/min. Acetylene, generated from calcium carbide and water, was added to each vial to yield a 10% by volume atmosphere. Control samples, which were identical to all other respects, were created by adding $HgCl_2$ to a final concentration of 5 mM.

$N_2O$ production was followed for approximately 48 h by periodically removing 0.5 mL of headspace for injection onto a gas chromatograph equipped with an electron capture detector. $N_2O$ peak areas were evaluated on a digital integrator and standardized against serial dilutions of commercial gas mixtures. Dissolved $N_2O$ concentrations were estimated using Henry's law coefficients (ref 4, p 109). Potential denitrification rates were estimated from the initial rate of $N_2O$ production per gram of dry sediment by linearly regressing the total amount of $N_2O$ produced per vial against time (*5*). Statistically significant differences between treatment means were determined by one-way ANOVA and Tukey's Studentized range test (*5*).

To determine whether groundwater $NO_3$ concentrations limited denitrification in situ, rates of denitrification were measured for each depth (sites 1–6) at in situ $NO_3$ nitrogen levels (Table I) and at 20.0 mM. In addition, denitrification was determined at intermediate concentrations of either 5 (sites 1, 5, and 6) or 10 (sites 2–4) mM $NO_3$ nitrogen.

The extent to which carbon substrate availability limited denitrification was evaluated by measuring rates for all six shallow samples following glucose amendment. Because sites 2 and 4 demonstrated a significant difference in activity with depth, the effect of carbon amendment on denitrification was also determined for the deep sediments at these sites. The organic content of sediment samples from both depths at all sites was estimated as the percent dry weight loss on ignition at 600 °C for 4 h. Analytical error due to the loss of hydroxyls during combustion is expected to be small since the maximum observed silt/clay

Table II. Physical Characteristics of Shallow (1–2 m) and Deep (3–4 m) Sediments Collected from Six Sites[a]

| | shallow | | deep | |
|---|---|---|---|---|
| site | DW/WW, % | organic, % | DW/WW, % | organic, % |
| 1 | 83.3 ± 0.3 | 0.25 ± 0.05 | 83.0 ± 0.3 | 0.39 ± 0.00 |
| 2 | 83.6 ± 0.1 | 0.81 ± 0.01 | 81.7 ± 1.1 | 2.22 ± 0.18 |
| 3 | 83.5 ± 0.5 | 1.05 ± 0.29 | 86.6 ± 0.5 | 0.34 ± 0.01 |
| 4 | 83.3 ± 0.7 | 0.61 ± 0.14 | 82.7 ± 0.4 | 0.07 ± 0.01 |
| 5 | 85.3 ± 0.1 | 0.18 ± 0.01 | 84.9 ± 0.3 | 0.54 ± 0.16 |
| 6 | 82.7 ± 0.1 | 0.65 ± 0.06 | 84.4 ± 0.1 | 0.52 ± 0.23 |

[a] Data are means (±SD) of duplicates. WW and DW are the masses determined for sediment when moist or dried to constant weight, respectively. Organic content is given as the loss on ignition expressed as a percentage of DW.

Table III. Mean Rates of Denitrification (±SD) for Triplicate Samples of Shallow (1–2 m) and Deep (3–4 m) Sediment from Sites 1–6[a]

| | | rates, nmol $g^{-1}$ $h^{-1}$ | |
|---|---|---|---|
| site | $[NO_3N]$, mM | shallow | deep |
| 1 | 1.2 | 0.02 ± 0.02 | 0.06 ± 0.03 |
| | 5.0 | 0.04 ± 0.04 | 0.15 ± 0.01[b] |
| | 20.0 | 0.07 ± 0.05 | 0.08 ± 0.02 |
| 2 | 6.6 | 0.51 ± 0.15 | 1.55 ± 0.53[b] |
| | 10.0 | 0.41 ± 0.13 | 1.58 ± 0.52[b] |
| | 20.0 | 0.43 ± 0.03 | 1.28 ± 0.70[b] |
| 3 | 8.6 | 0.53 ± 0.12 | 0.37 ± 0.23 |
| | 10.0 | 0.19 ± 0.12 | 0.27 ± 0.00 |
| | 20.0 | 0.32 ± 0.19 | 0.28 ± 0.09 |
| 4 | 4.0 | 0.63 ± 0.09 | 0.04 ± 0.02[b] |
| | 10.0 | 1.05 ± 0.28 | 0.02 ± 0.02[b] |
| | 20.0 | 0.53 ± 0.27 | 0.02 ± 0.01[b] |
| 5 | 0.2 | 0.23 ± 0.02 | 0.22 ± 0.09 |
| | 5.0 | 0.33 ± 0.04 | 0.35 ± 0.03 |
| | 20.0 | 0.22 ± 0.03 | 0.09 ± 0.09 |
| 6 | 0.0 | 0.01 ± 0.00[c] | 0.00 ± 0.00 |
| | 5.0 | 0.43 ± 0.05 | 0.00 ± 0.00[b] |
| | 20.0 | 0.43 ± 0.00 | 0.00 ± 0.00[b] |

[a] Rates were determined for three concentrations of $NO_3N$: in situ, intermediate (i.e., 5 or 10 mM), and high (20 mM). Rates are given as nanomoles of $N_2ON$ produced per gram of dry sediment per hour. The pH equaled in situ values (Table I). [b] Differences between depths are significant for a given $NO_3$ treatment. [c] Differences between $NO_3$ treatments are significant (Tukey's Studentized range test, $p < 0.05$) for a given sediment and depth.

content was 2% of the sediment dry weight.

The influence of pH on denitrifying activity was investigated for the shallow sediments from sites 4 and 5. Treatments (at in situ $NO_3$ concentrations) were created at final pH values of 4, 5.5, in situ, 7, and 8 by titration with HCl and NaOH. The pH measured at the conclusion of the study remained within ±0.2 unit of the initial conditions. As controls for acetylene effects, two live treatments were not amended with acetylene.

*Results*

The concentration of $NO_3$ nitrogen present in the sediments varied from undetectable (less than 0.7 μM) at site 6 to 8.6 mM at site 3 (Table I). $NO_3$ concentrations greater than 0.2 mM were associated with sites of surface application of waste effluent and fertilizer. The pH of the groundwater ranged from 5.4 to 6.4. The organic content of the samples varied from 0.07 to 2.22% of the sediment dry weight (Table II). The ratio of the dry weight to wet weight did not differ significantly with depth. Groundwater oxygen concentrations were less than 12 μM.

Increasing $NO_3$ concentrations did not significantly affect the rate of denitrification except for the shallow sam-

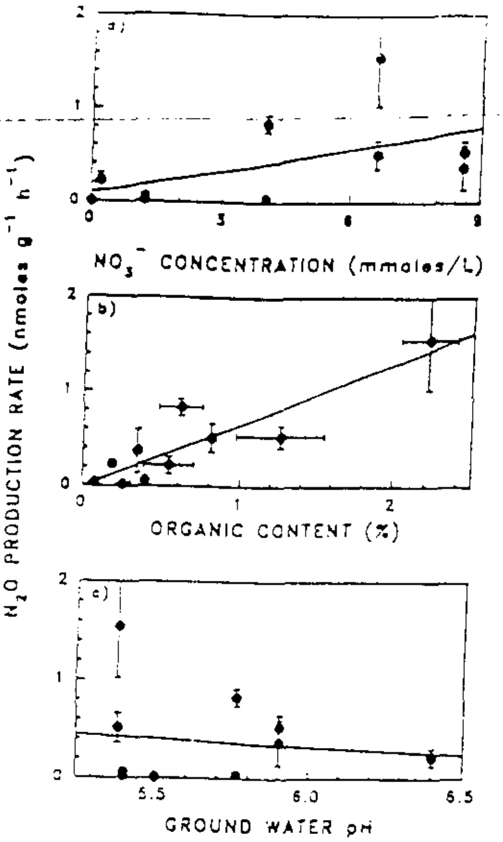


**Figure 1.** Relationship between the potential rate of denitrification (nmol $g^{-1}$ $h^{-1}$) determined for slurries of sediment from sites 1–6 and in situ: (a) groundwater $NO_3$ concentrations ($p = 0.046$, $r = 0.583$), (b) total sediment organic content ($p < 0.001$, $r = 0.894$), and (c) groundwater pH ($p = 0.692$, $r = 0.126$); (b) does not include data from site 6, which lacked sufficient $NO_3$ to support denitrification. Data points represent means (±SD) of triplicate samples.

ples from site 6 (Table III). For this and all other experiments, no significant production of $N_2O$ was observed in the control samples. These results indicate that $NO_3$ availability limited denitrification activity only at site 6 (1–2 m), where the in situ concentration was less than 0.7 μM. At site 1, a slight trend toward greater denitrifying activity with increasing $NO_3$ concentration was observed. Thus, the possibility exists that denitrification rates are $NO_3$ limited at this site, although these differences were not statistically significant (Tukey's Studentized range test, $p \leq 0.05$). A significant relation ($p = 0.046$) was observed between denitrifying activity and the in situ concentration of $NO_3$ (Figure 1a), but $NO_3$ concentration accounted for only 34% ($r^2$) of the variation in activity.

With the exception of sites 2 and 4, the rate of denitrification at in situ concentrations of $NO_3$ did not vary significantly with depth (Table III). However, the deep (3–4 m) sediments at site 2 exhibited a rate of denitrification 3 times that of the shallow (1–2 m) sediments. At site 4, denitrification rates in the shallow sediments were 20 times greater than that of the deep sediments.

Excluding the sediments from site 6, which lacked sufficient $NO_3$ to support denitrification, a significant relation ($p < 0.001$) was observed between denitrifying activity and sediment organic carbon content (Figure 1b). The organic content accounted for approximately 80% ($r^2$) of the variation in denitrification in these sediments. Those samples from sites 2 (3–4 m) and 4 (1–2 m) which exhibited the highest activities in the absence of added carbon did not respond significantly to carbon amendment (Table IV). In contrast, the rates of denitrification for the deep sample at site 4 and the shallow sediments from

Table IV. Mean Rates of Denitrification (±SD) for Triplicate Samples of Sediment from Sites 1–6[a]

| site | depth, m | rates, nmol $g^{-1}$ $h^{-1}$ unamended | rates, nmol $g^{-1}$ $h^{-1}$ amended |
|---|---|---|---|
| 1 | 1–2 | 0.02 ± 0.02 | 1.86 ± 0.86[b] |
| 2 | 1–2 | 0.51 ± 0.15 | 59.66 ± 12.97[b] |
| | 3–4 | 1.55 ± 0.53 | 1.14 ± 0.20 |
| 3 | 1–2 | 0.53 ± 0.12 | 20.09 ± 8.91[b] |
| 4 | 1–2 | 0.83 ± 0.09 | 0.11 ± 0.23 |
| | 3–4 | 0.04 ± 0.02 | 5.40 ± 0.63[b] |
| 5 | 1–2 | 0.23 ± 0.02 | 4.31 ± 0.45[b] |
| 6 | 1–2 | 0.01 ± 0.00 | 0.00 ± 0.00 |

[a] Rates are given for sediments amended with 1 mM glucose as well as unamended controls. $NO_3N$ concentration and pH were equal to in situ levels (see Table I). [b] Differences between carbon treatments are significant (Tukey's Studentized range test, $p < 0.05$) for a given sediment.

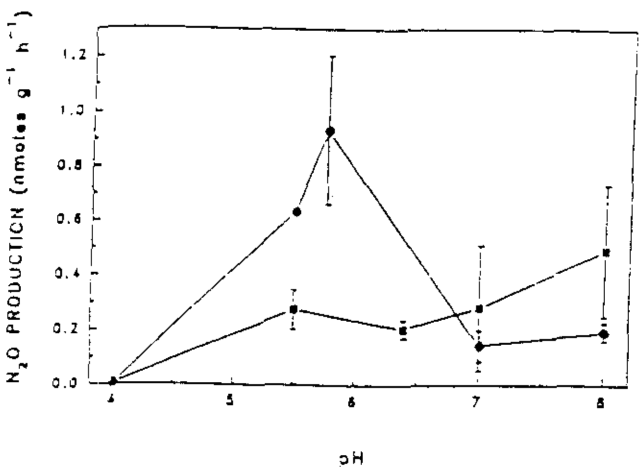


**Figure 2.** Relationship between the potential rate of denitrification (nmol $g^{-1}$ $h^{-1}$) and the pH of slurries of sediment from sites 4 (●) and 5 (■). Data points represent means (±SD) of duplicate samples.

site 2 were at least 100 times greater in the carbon-amended treatments. Similarly, carbon amendment increased the rate of denitrification in the shallow sediments from sites 1, 3, and 5 by a factor of 18. Presumably due to the lack of sufficient $NO_3$ to support denitrification, denitrification rates in the sediments from site 6 did not respond to carbon amendment.

There was no significant correlation ($p = 0.692$) between the rate of denitrification and the pH of the groundwater in this study (Figure 1c). The response of denitrification rates in the sediments from site 4 (1–2 m) to a range in pH from 4.0 to 8.0 indicates that the denitrifiers in these sediments are adapted to in situ pH conditions (Figure 2). The rate of denitrification was maximal at the in situ pH of 5.8 and decreased as pH increased. In contrast, the rate of denitrification in the sediments from site 5 was 2 times greater at pH 8.0 than at the in situ pH of 6.4. For both sediments, denitrification was insignificant at pH 4.0.

The production rate of $N_2O$ in samples that were not treated with acetylene was significant in both sediments over the range of pH conditions examined (data not shown). The rate of $N_2O$ production in untreated samples from site 4 was equal to that found in treated sediments over the pH range 4.0–7.0 but decreased to 77% of the treated rate at pH 8.0. For the sediments from site 5, $N_2O$ production was equal in both treatments at pH 4.0, but the mean $N_2O$ production rate in untreated samples was only 45% of that observed with acetylene for pH of ≥5.5. The difference in $N_2O$ production rates between acetylene-treated and untreated samples is an indicator of the importance of $N_2$ as an end product of denitrification in these sediments. The current results demonstrate that $N_2$ gas was an insignificant end product of denitrification in these sediments at pH 4 but increased in importance with pH. Due to the short duration of this study, it is not possible to determine if the lack of $N_2$ production at low pH is a transient phenomenon or the result of permanent inhibition of $N_2O$ reduction.

### Discussion

The potential rates of denitrification observed in this study were comparable to previous observations from $NO_3$-contaminated aquifers. Sediment from a site at Parris Island, SC, receiving $NO_3$ waste water exhibited rates of denitrification ranging from 1.7 nmol of $N_2O$ $g^{-1}$ $day^{-1}$ for 5–180-m sediments up to 173 nmol $g^{-1}$ $day^{-1}$ for surface sediments (*6*). The rates of denitrification in a shallow aquifer near Long Island, NY, were 0.2–17.0 nmol of $N_2O$ $g^{-1}$ $day^{-1}$ (*7*). Potential denitrification rates for a shallow aquifer which was continuously contaminated with secondarily treated sewage effluent for 55 years were estimated at 0.1–7.8 nmol of $N_2O$ $g^{-1}$ $day^{-1}$ (*8*). In the current study, the potential rates of denitrification for those sediments where $NO_3$ concentrations were significant (sites 1–5) ranged from 0.6 to 37.2 nmol of $N_2O$ $g^{-1}$ $day^{-1}$. The presence of millimolar concentrations of $NO_3$ in the groundwater indicates that the site receives $NO_3$ in excess of ambient denitrification.

In this study, the denitrification potential of sediments from sites 1–5 was not limited by in situ $NO_3$ concentrations. Rates of denitrification in these sediments did not respond to $NO_3$ amendment and thus appeared to be controlled by factors other than in situ $NO_3$ concentrations. This observation is consistent with the results of cell-free systems which exhibit $K_m$'s for denitrification in the range of 5–290 $\mu$M (*2*). Similarly, the current rates were determined for sediment slurries in which the diffusion of $NO_3$ nitrogen to sites of active denitrification is not expected to be a limiting factor. However, within the saturated zone $NO_3$ diffusion may become important, and the possibility remains that in situ denitrification rates may be limited even at the millimolar $NO_3$ concentrations measured in the groundwater.

The current findings are consistent with previous demonstrations of the importance of carbon substrate availability to denitrification. Several researchers have reported that carbon substrate additions stimulate sediment denitrifying activity in the laboratory (*8–13*) and in the field (*14–17*). Comparisons of the activity of sediments differing in organic carbon content have confirmed the relation between denitrification rates and carbon (*13, 18, 19*). In the current study, the enhanced activity under glucose-amended conditions and the relation between organic carbon and the variation in denitrification with depth (sites 2 and 4) provide convincing evidence that denitrification is carbon limited. The highly significant relation ($p < 0.001$; $r^2 = 0.80$) between potential denitrification and total sediment organic content indicates that carbon limitation can be a significant factor contributing to $NO_3$ accumulation in anaerobic aquifers (ref 8; this study).

Although pH is generally considered an important influence on denitrification in natural systems (for review, see refs 1 and 2), no significant relationship between potential denitrification and groudwater pH was observed in the current study. This lack of correlation was probably due to the relatively narrow range in pH observed in situ. Even though the potential rates of denitrification did not correlate well with pH in the field, denitrification was sensitive to short-term changes in pH in this study. Previous investigations involving relatively short term changes in pH generally observed an increase in denitrification with increasing pH (*20–23*). The rate of denitrification in the relatively neutral sediment from site 5 responded to pH in the same manner. However, the more acid sediment from site 4 demonstrated the highest activity at its in situ pH. Parkin et al. (*24*) reported a similar pattern of apparent pH adaptation in an agricultural soil with a 20-year history of low pH (ca. 4).

Numerous investigators have observed a shift in the predominant gaseous end product of denitrification as a result of increasing acidity (*1, 2, 25*). As pH decreases the end product typically shifts from $N_2$ (pH $\geq$7) toward $N_2O$ (5 < pH < 7) and NO (pH $\leq$5). In the current study, the $N_2O$ production rates of samples with and without acetylene were compared to estimate the relative importance of $N_2$ as an end product of denitrification. Because nitrification may contribute to $N_2O$ production in the absence of acetylene, this comparison may underestimate the extent to which denitrification proceeded to completion (i.e., $N_2$) in the treated vials. However, it seems clear that for both sediments the importance of $N_2$ as an end product of denitrification increased with pH. The fact that $N_2$ production at near-neutral pH was less pronounced for site 4 than site 5 may be due to an inhibition of $N_2O$ reductase by the high $NO_3$ concentrations at this site (*2, 25*).

Since the current results indicate that active communities of denitrifiers are present within the shallow aquifer at the site, the potential exists that $NO_3$ contamination of the groundwater can be minimized. Based on the potential rates of denitrification measured in the current study (without carbon amendment), an initial estimate of the maximum rate at which $NO_3$ can be applied at the site without exceeding the capacity of the denitrifying community is feasible. Sites 1–5 have the potential to remove $NO_3$ nitrogen from the groundwater at rates ranging from 1.2 to 74.4 nmol $g^{-1}$ $day^{-1}$ (without carbon amendment). Although, there is increasing evidence that denitrification may be significant even at high oxygen concentrations (*26–28*), it is generally accepted that nitrogen oxide reductase activity is repressed by the presence of oxygen (for reviews, see refs 1 and 2). Thus, it is assumed that denitrification occurs primarily in the anaerobic saturated zone (*29*). Seasonal variations in the depth of the water table would be expected to influence the denitrification capacity of a unit area of sediment, and for a more accurate estimate, these should be taken into account. However, for the sake of illustration, a mean thickness of 2 m is assumed for the anaerobic zone. Given that the bulk density of these sediments is approximately 1570 kg/$m^3$, we estimate that the in situ denitrifying communities at sites 1–5 have the capacity to remove $NO_3$ at a rate ranging from 3.8 to 233.6 mmol $m^{-2}$ $day^{-1}$.

Additional considerations are necessary to accurately estimate environmentally sound, nitrogen application rates. Most notably, the extent to which surface applications of nitrogen will reach the aquifer will depend primarily on the rate of nitrogen uptake by the plant community and the permeability of the root zone. However, evaluation of those factors which control $NO_3$ sinks within the aquifer should allow for calculation of upper bounds for nitrogen application rates and thereby reduce the potential for $NO_3$ contamination of groundwater.

**Registry No.** $N_2O$, 10024-97-2; glucose, 50-99-7.

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# Sensing the Fugacity of Hydrophobic Organic Chemicals in Aqueous Systems

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Department of Chemical Engineering and Applied Chemistry, University of Toronto, Toronto, Ontario, Canada M5S 1A4

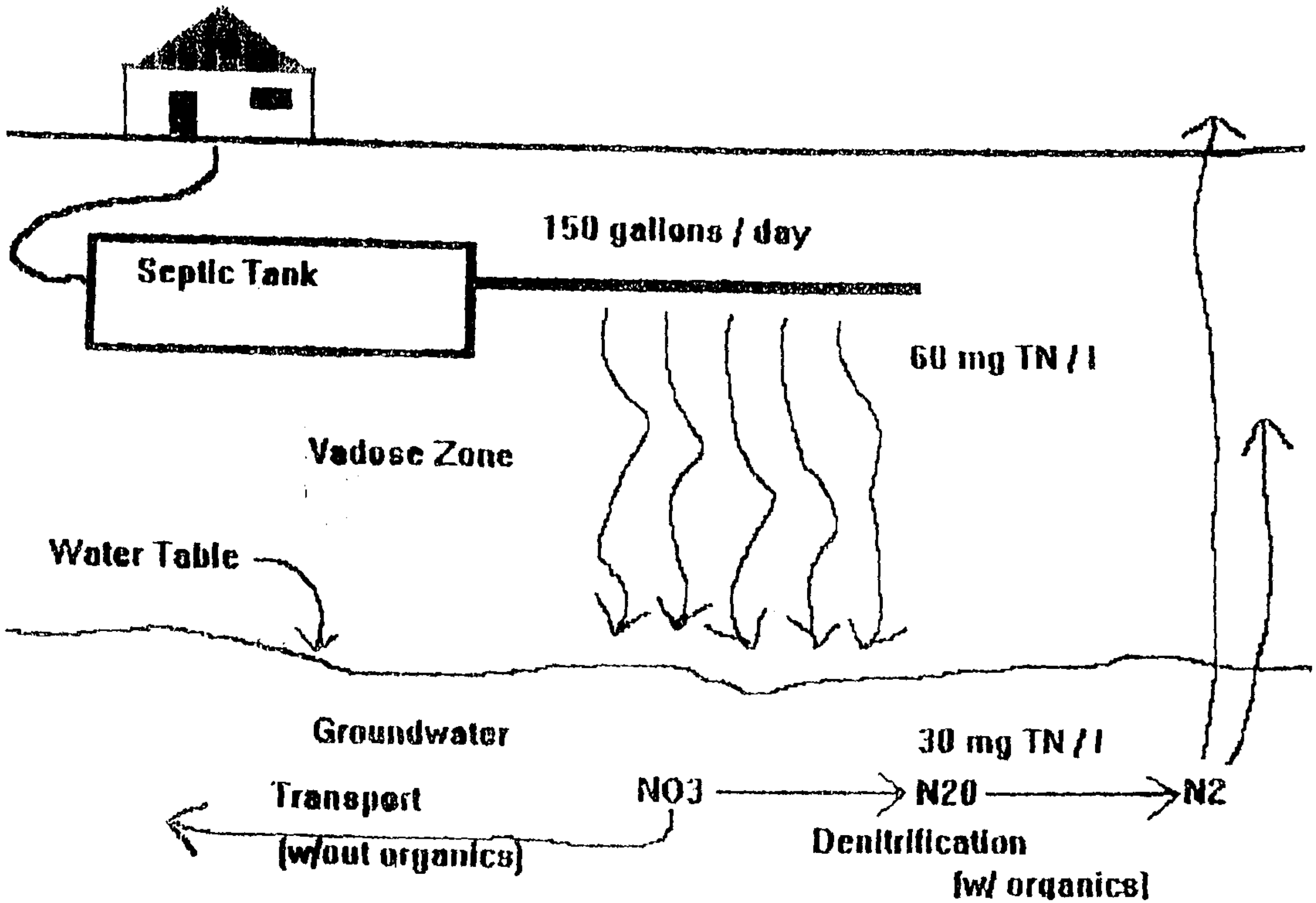
■ It is suggested that sensing the fugacity of hydrophobic chemicals in aqueous systems by measuring their concentrations in an equilibrated air headspace can provide valuable information about the nature and extent of interactions between the chemicals and dissolved and particulate phases present in the water. An experimental air–water closed system is described into which sorbing materials can be titrated and the fugacity response determined by continuous air circulation with periodic gas sampling and GC analysis. The system has been used to measure the cosolvency of octanol and the sorption of five chlorobenzenes and a PCB to humic materials and sediment. The results are in accord with theory based on established partitioning principles, with organic carbon partition coefficients varying from 10 to 100% of the octanol–water partition coefficient. No "solids' concentration effect" was detected.

## Introduction

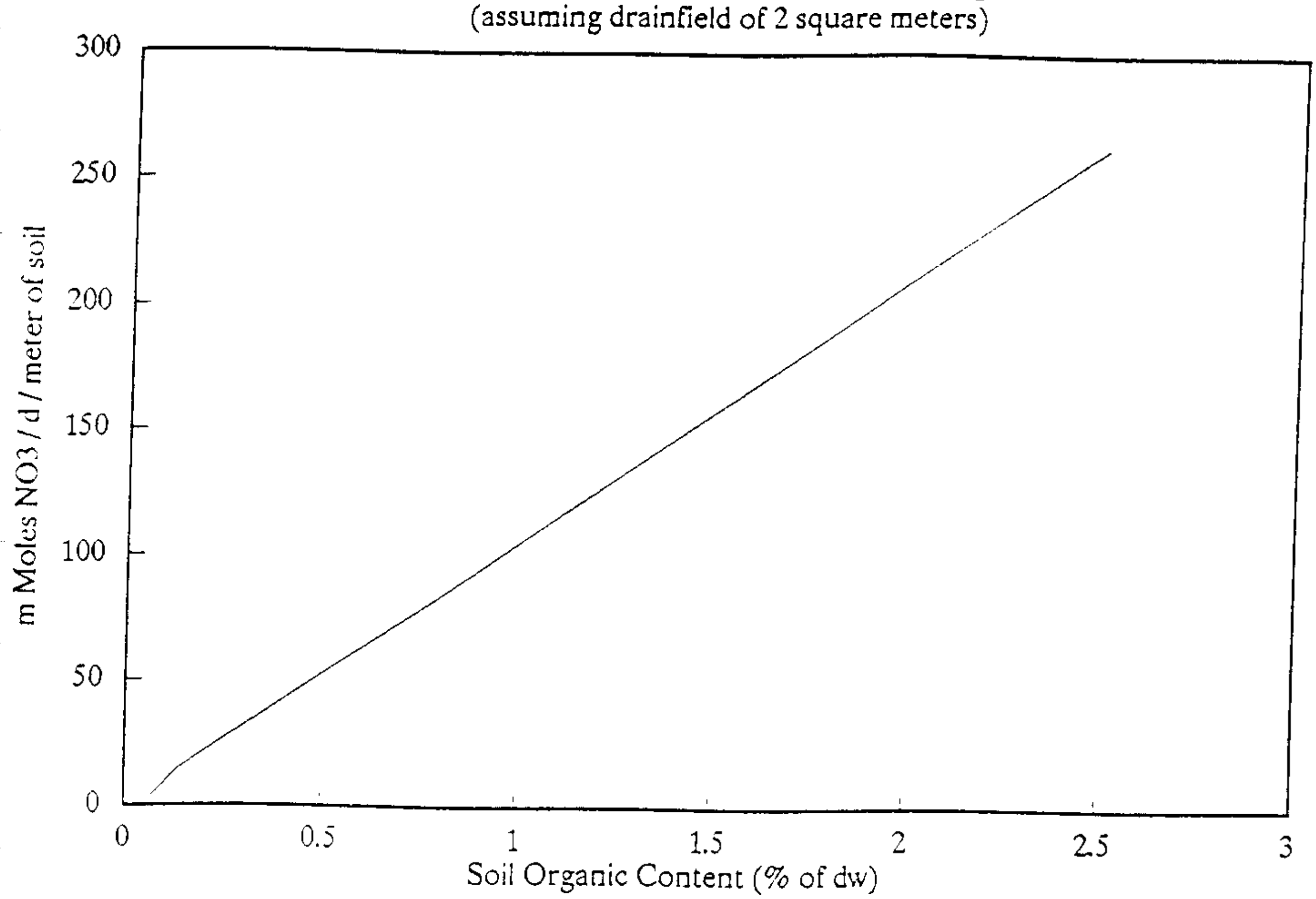
Hydrophobic chemicals, notably the organochlorines, when present in aquatic systems may bioaccumulate to high concentrations and cause toxic effects and are subject to evaporation, sedimentation, and degrading reactions. These processes are profoundly affected by whether the chemical is dissolved or sorbed to particulate matter and the extent to which its activity is modified by interactions with other dissolved materials, such as the naturally occurring fulvic and humic acids, and electrolytes. Although measurements of total concentration of the chemical are relatively straightforward, it is difficult to discriminate between dissolved and sorbed chemical by techniques such as filtering or centrifuging because of uncertainties about the particle size "cutoff". Indeed, it is possible that no distinct discrimination is possible between dissolved and sorbed states because there may be a continuum of particulate matter ranging from truly dissolved low molecular weight fulvic acids to filterable particles of humin. Conventional measurements of the "dissolved" concentration may affect particle aggregation, disturb the sorption process, or displace the equilibrium during separation of the phases. Accordingly, it is desirable to supplement conventional approaches with a nondisturbing or noninvasive analytical technique to sense the condition of the chemical. Such a technique is headspace analysis, which is routinely used for analysis of volatile organic chemicals and has been employed to probe or sense the condition of organic chemicals in aqueous solutions by Yin and Hassett (*1*), Sproule et al. (*2*), and Perlinger (*3*).

In this study, we describe a headspace system that is essentially a modification of one devised by Hussam and Carr (*4*) and similar to one used for environmental studies by Perlinger (*3*). Measurements are made of changes in the air-phase concentration (and hence the partial pressure or fugacity) of a chemical in equilibrium with an aqueous solution into which potentially interacting materials such as cosolvents or humic materials are titrated. From the response of the fugacity to this titration, the nature and extent of the interactions that occur in solution can be deduced. The approach is explored and illustrated by examining the response of the selected chlorobenzenes to the addition of octanol as cosolvent and humic acids and sediment as sorbents.

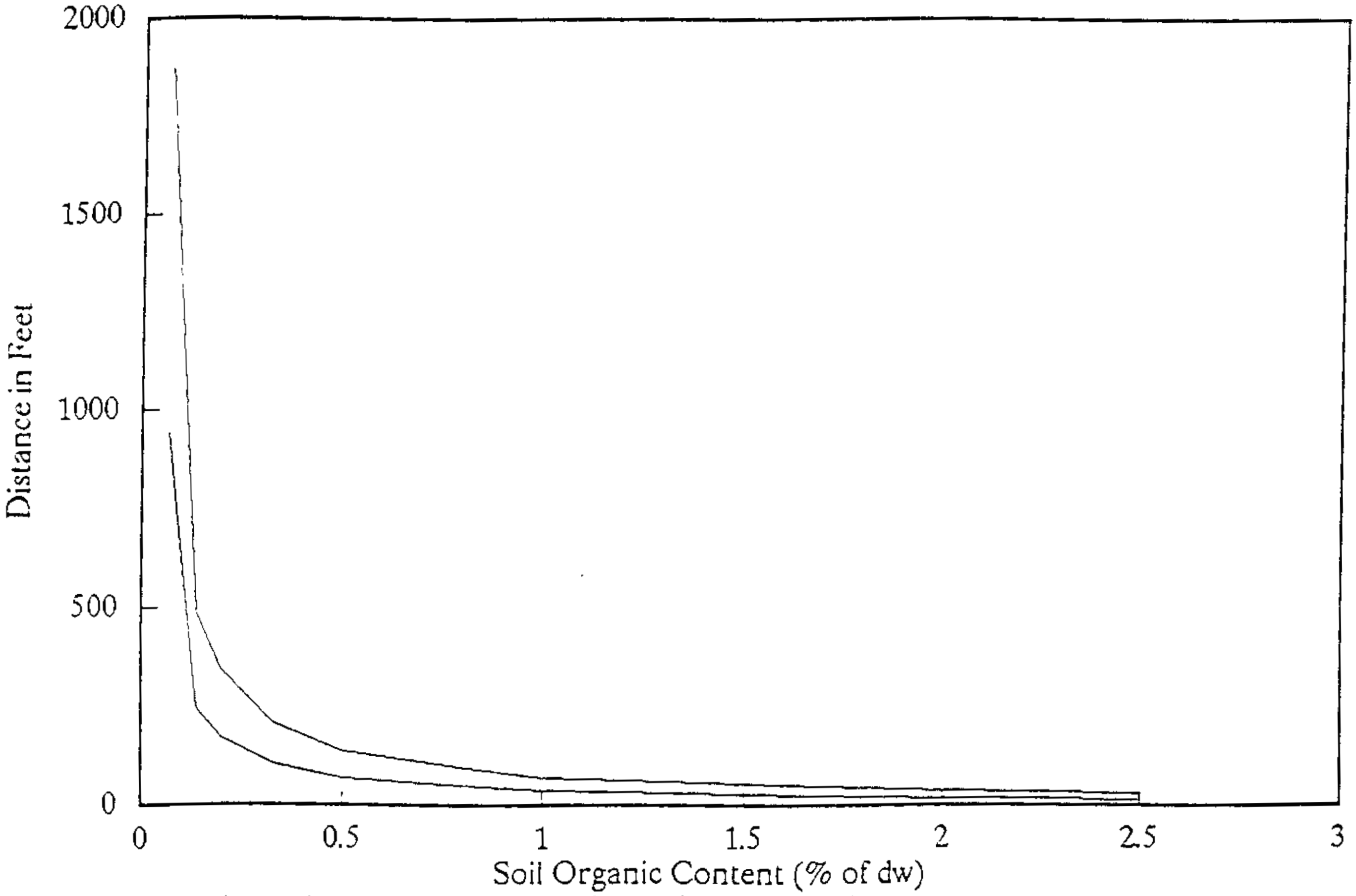
Of particular interest is the ability of the system to probe the "solids' concentration effect" first noted by O'Connor and Connolly (*5*) and discussed by DiToro (*6*) and others.


150 gallons / day
Septic Tank
60 mg TN / l
Vadose Zone
Water Table
Groundwater
30 mg TN / l
Transport
(w/out organics)
NO3
N2O
N2
Denitrification
(w/ organics)

# Denitrification Rates versus Soil Organic Content



Set–back Distance from Surface Water for Septic Tanks versus Soil Organic Content
(distance required for 90 % removal of NO3)




Upper line = 4 people per house, Lower line = 2 people per house

| Soil Organic (% C) | Rate of Denitrifi (mMOL/D/M) |
|---|---|
| 0.07 | 3.8 |
| 0.14 | 14.74 |
| 0.2 | 21.1 |
| 0.33 | 34.8 |
| 0.5 | 52.7 |
| 1 | 105.3 |
| 1.5 | 158 |
| 2 | 210.6 |
| 2.22 | 233.8 |
| 2.5 | 263.3 |

| Soil Organic (% C) | [illegible] Setback (ft) | [illegible] Setback (ft) |
|---|---|---|
| 0.07 | 944 | 1889 |
| 0.14 | 243.3 | 486.7 |
| 0.2 | 170.3 | 340.[illegible] |
| 0.33 | 103.2 | 206.5 |
| 0.5 | 68.1 | 13[illegible] |
| 1 | 34.1 | 68.1 |
| 1.5 | 25.2 | 50.5 |
| 2 | 17 | 34.1 |
| 2.22 | 15.4 | 30.[illegible] |
| 2.5 | [illegible] | 2[illegible] |

JJC

Ardaman & Associates, Inc.

Geotechnical, Environmental and Materials Consultants

RECEIVED -5 1994 CAMP DRESSER & McKEE

June 30, 1994
File No. 94-8583

TO: Camp, Dresser & McKee, Inc.
20101 Peachland Boulevard, Unit 207
Port Charlotte, FL 33954

Attention: Mr. S. John Calise, P.E.

SUBJECT: Peer Review of "Draft Technical Memorandum, Septic Tank Nutrient Loadings, Port Charlotte Phase I Area"

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Dear Mr. Calise:

As requested in your memorandum of June 22, 1994, we have reviewed the draft of the subject technical memorandum and offer the following comments. The headings below correspond with those in the technical memorandum.

**Methodology**

The third item states that, generally, failing septic tanks are characterized by discharges that do not have a substantial travel time through the surficial aquifer to the receiving water. While this definition is probably adequate for the intended use, it is probably not inclusive of all systems which would commonly be considered "failing." A failing system could be defined as any system which is not capable of infiltrating, into the soil, all flows to the system, and any system which is not constructed and/or operated in accordance with the appropriate standards. This definition of failing would probably include many systems which do not meet the definition in the technical memorandum.

In the fourth item, it states that velocities in the surficial aquifer of the study area are expected to be on the order of 0.1 foot/day or less. Although I have not recently inspected conditions in the Phase I area, I can envision that conditions may exist, at least at some locations, that would result in seepage velocities on the order of 1.0 foot/day. For example, assuming the surficial aquifer to have a hydraulic conductivity of 10 feet/day and a porosity of 30%, a hydraulic gradient of only 0.03 (water table slope of 1 foot vertical per 33 feet horizontal) would result in a horizontal seepage flow rate of 1.0 foot/day. I believe that these assumed values are realistic for

DCS 1,119

at least portions of the area. Travel times could, therefore, be on the order of weeks at some sites, instead of months to years.

**Failing Septic Tanks**

There are some other points which may support the use of the 25% failing rate. Even after implementation of the more stringent septic tank regulations in 1982, many systems may have been installed without actually having the 2-foot separation between the drainfield bottom and the high water table. Firstly, the seasonal high water table level at a site is not precisely known and must be estimated based upon the best available information. Even a reputable, experienced soil scientist, geotechnical engineer or hydrogeologist, with expertise in making this estimate, probably cannot estimate the seasonal high water table level to within an accuracy of ±0.5 foot. Secondly, the practice of setting the drainfield 2.0 feet above the seasonal high water table does not account for the possibility of groundwater mounding beneath the drainfield. Groundwater mounding may occur as the septic tank discharge infiltrates the drainfield bottom and reaches the water table, causing a local rise of the water table beneath the drainfield. Such groundwater mounding may be significant (0.5 to 1.0 foot, or more, above surrounding water table levels) at some sites, depending upon site conditions. Considering the above, even properly designed, installed and operated "working" septic tanks may not always have this 2.0 foot separation between the drainfield bottom and the water table.

**Working Septic Tanks**

I did not initially understand equation 3 on page 8. I discussed the equation with Mike Heyl, who stated that he believed that the definition of "S" is poorly worded and that "S" is equal to the total length of the receiving waters in the study area. Mike said he also believed the equation was based upon the assumption of a rectangular watershed, with a receiving water (stream, canal, etc.) running down its center. In this case, would not the correct equation be $L = A/2S$ as the maximum groundwater flow distance (L) would be one-half the width (perpendicular to length "S") of the rectangle. I suggest that "S" be more clearly defined and that the equation be reviewed and verified.

**Total Septic Tank Loading**

In the second paragraph it states that "compared to the calculated present septic tank loadings of ..., the reuse option represents ..., which corresponds to a 78% to 93% reduction in TN loading to receiving waters." As stated, the 78% to 93%

reduction is relative to the present septic tank loadings. In order to avoid confusion that the reduction is relative to TN loadings from all sources, we suggest that the latter part of the sentence be corrected to "... which corresponds to a 78% to 93% reduction in the present TN loading from septic tanks to receiving waters" or similar wording. The same applies to the last sentence of the paragraph, for future conditions.

Summary

In the last sentence, it is not clear where the 50% to 80% was derived, as 78% to 93% and 76% to 92% reductions were estimated in the preceding section.

Please feel free to contact our office if you should have any questions or comments concerning our review. As always, we appreciate the opportunity to be of your service.

Very truly yours,

ARDAMAN & ASSOCIATES, INC.

Jerry H. Kuehn, P.E.
Project Engineer
Eng. Reg. No. 35557

Gary H. Schmidt, P.E.
Vice President
Eng. Reg. No. 12305

JHK/GHS:jam

cc: Mr. Mike Heyl (Camp, Dresser & McKee, Inc., Sarasota, FL)

# GWE GIFFELS - WEBSTER ENGINEERS, INC.

July 14, 1994 REF: 4510.16

Mr. S. J. Calise, P.E.
Camp, Dresser & McKee, Inc.
20101 Peachland Blvd., Unit 207
Port Charlotte, FL 33954

SENT VIA FAX TO 813-743-8073

Subject: REVIEW OF TECHNICAL MEMORANDUM

Dear Mr. Calise:

I have received a draft copy of a Technical Memorandum entitled "Septic Tank Nutrient Loadings, Port Charlotte Phase I Area". In review of this document, the following comments should be noted:

- The existing dwelling unit count and future growth estimates used throughout the document are consistent with those figures reported in the Charlotte County 25 Year Water and Sewer Study.
- Per capita wastewater flow rates of 75 GPD per capita and the use of 2.3 persons per household is consistent with the Charlotte County 1988 COMP PLAN and the Charlotte County 25 Year Water and Sewer Study.
- Although the study was targeted within the Phase 1 Area, it should be noted that within the Port Charlotte Utility Unit there are approximately 110,000 residential single family (RSF) lots. The majority of these are 80'x125' lots (RSF - 3.5 units per acre).
- Of the 110,000 potential single family lots in the Port Charlotte Utility Unit, approximately 30,000 are located in areas where central sewer currently exists. These areas are currently serviced by municipal or privately owned utility companies.

Realizing that the study addresses approximately 14,400 existing septic systems, I feel that it is extremely important to note that the potential at build-out, assuming all growth outside existing service will use septic systems, may reach approximately 70,000 improved properties and will significantly affect pollutant loading estimates.

Sincerely,

GIFFELS-WEBSTER ENGINEERS, INC.

Stephen F. Torchia, Project Manager

SFT:pec

cc: GIFFELS-WEBSTER ENGINEERS, INC.
Atten: Charles Biegun, P.E., Principal-In-Charge
Atten: David Pawlaczyk, Vice President
Atten: Jonathan H. Cole, P.E., Technical Review Committee

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