State of Oregon

Department of Environmental Quality — Memorandum

To:	**Region 2050 Policy Advisory Board**	**Date: April 21, 2005** **DRAFT**
Copy:	**Region 2050 Technical Advisory Committee**	
From:	**Mike Wolf and Bill Mason, RG** **DEQ-Eugene**	
Subject:	**Relative Potential Effects of On-Site Wastewater Treatment Systems on Groundwater Quality under the Rural Growth Scenario**	

As a part of your efforts to develop a Regional Growth Management Strategy, you have been evaluating the potential effects of three alternative growth strategies on the region's natural resources and environmental quality. A recent Region 2050 environmental resource protection analysis report[1] ranks the overall relative effect of each scenario on the environment for the entire region, and comprises the bulk of the environmental analysis to date.

The report concludes that the Rural Growth scenario presents about four times the risk of the other scenarios to groundwater when evaluating the region as a whole. However, the report also recognizes that the risk estimates are highly dependent on land use assumptions, and it did not evaluate the effects of local geology on mitigating or increasing those risks.

In your November 2004 Board meeting, you asked us to evaluate the effects that an increase in rural residential densities in six specific areas of the region potentially might have on local groundwater quality. The purpose of this additional work is to 1) provide examples of tools that communities and their consultants might use to tailor their development plans to minimize potential impacts to groundwater; 2) illustrate various resource constraints in each selected area; and 3) estimate the likely impact onsite septic systems might have on local beneficial groundwater uses given site-specific geologic conditions. Our analysis is focused on the effects of dispersed, single-homeowner-based onsite systems, and does not attempt to evaluate "cluster" or other systems. This memorandum summarizes our findings.

Background

In Oregon, about one quarter of households has an onsite wastewater treatment and disposal system. In conventional onsite systems, household wastewater collects in an underground septic tank, which removes most settleable and floatable material, and acts to partially treat the sewage through anaerobic (low-oxygen) biological decay. The remaining wastewater, which still contains concentrations of pathogens and nutrients, has traditionally been discharged to soil, sand, or other types of absorption fields for further treatment through biological processes, adsorption, filtration, and infiltration into underlying soils. Typically, septic system drainfields "fail" when they allow raw or partially treated sewage to reach the surface where it can pose a threat to human health or the environment.

Given a properly designed, operated, and maintained onsite system in a remote area, we generally expect that the contaminants that are not completely treated (e.g., nitrates) will not reach groundwater in sufficient quantities that they would pose a risk to nearby natural resources (e.g., streams) or beneficial uses (e.g., domestic drinking water well). However, as lot sizes decrease, the chances that the cumulative effects of onsite systems on ground- or surface water increases as the capacity of groundwater to assimilate and dilute contaminants is reached.

The growing trend to make use of onsite systems in urban fringe and higher-density rural residential areas has caused public agencies and researchers to ask the question the Policy Board is asking with respect to potential effects on

[1] Payne, S.; and Heinkel, C. *Environmental Resource Protection in the Southern Willamette Valley: Evaluating Region 2050 Alternative Futures*. October 29, 2004; 73 pp. (http://www.region2050.org/pdf/EnvironEvaluation.pdf)

groundwater quality: "how dense is too dense?" Much of the focus by researchers in the past has been on nitrate, because it "may move relatively unaffected through the soil to accumulate in underlying ground waters" (Hantzsche and Finnemore, 1992), is easily measured, and because it tends to move in the subsurface at the same rate as groundwater. More recently, the focus of the research has included other substances such as pharmaceuticals, detergents (that can mobilize pollutants), and toxic organic chemicals such as dichlorobenzene (often a component of commercial plumbing cleaners), all of which have been found to pose potential threats to groundwater. Less is known about the occurrence of viruses in private household wells, but recent studies (e.g., Borchardt et al, 2003) found that endemic diarrheal illness was associated with septic system densities.

With a regional planning effort like Region 2050, there is an opportunity to avoid placing the highest densities of onsite systems in areas with vulnerable groundwater resources.

Groundwater Basics[2]

Although it is beyond the scope of this memo to explain the details of hydrogeologic science, we will define a few key terms:

Aquifers are typically saturated regions of the subsurface which produce an economically feasible quantity of water to a well or spring (e.g., sand and gravel or fractured bedrock often make good aquifer materials).

Permeability is a measure of the ability of a material (e.g., silt, sand, gravel, or fractured bedrock) to transmit fluids through it.

There are two end members in the spectrum of types of aquifers: *confined* and *unconfined* (with semi-confined being in between). Typically (but not always) the shallowest aquifer at a given location is unconfined, meaning it does not have a lower permeability confining layer between it and the ground surface. Unconfined aquifers usually receive recharge water directly from the surface from precipitation or from a body of surface water (e.g., a river, stream, or lake) which is in hydraulic connection with it. Confined aquifers have a lower permeability confining layer between it and the ground surface, and often occur at depth.

Estimation Tools

The buildup of nitrates in shallow, unconfined aquifers has been evaluated often over the past several decades. Several studies have produced methods for estimating long-term groundwater increases of nitrate on an area-wide basis that would be convenient and simple enough for planners to apply to routine evaluations of proposed land use developments (e.g., Perkins, 1984; Wehrmann, 1984; Tinker, 1991). One that we have used successfully within the Oregon Department of Environmental Quality (DEQ) was proposed by Hanzsche and Finnemore in 1992.

The remainder of this section will be devoted to describing how this type of tool can be used to evaluate differing parcel densities and wastewater treatment system levels for various chemicals.

Hanzsche and Finnemore (1992) proposed to simplify the prediction of long-term impacts by looking at the inputs and outputs of a chemical and water over the gross developed area. The key terms in the analysis include the rate (e.g., gallons per day) that wastewater enters the soil over the developed area; the estimated concentrations of the chemical of concern (e.g., nitrate) in wastewater; the expected loss of the chemical in the soil due to "treatment" by the soil; and average recharge of rainfall[3]. They also made a number of simplifying assumptions, which we will not go into in this memo, but that are explained clearly in their journal article. To demonstrate the validity of their approach, they compared their estimates using their simplified method to actual groundwater quality data for three California communities, and found a close correspondence between the estimated and actual values.

[2] Much of the language in this section is either pulled directly from, or is a paraphrase of, material in Wikipedia, the free content encyclopedia (http://www.wikipedia.org). Another excellent resource for learning more about groundwater in Lane County is the OSU Extension Service groundwater page at: http://groundwater.orst.edu/

[3] Recharge differs from rainfall because some of the rain runs off into streams, some is taken up by plants and trees, and some evaporates before it infiltrates into the ground.

To illustrate their approach in a community closer to home, we calculated an estimated nitrate groundwater concentration for the Coburg area using data that are readily available on the internet. Our rough estimate of 12 mg/l nitrate concentration in groundwater (details in Table 1) compares favorably to data that we have collected in the past in areas with high septic system densities (e.g., DEQ, 2004). This concentration would correspond to a housing density of 5 units per acre. Table 2 includes an estimate, with all other parameters equal, using 2-acre parcels, with a result of only 2.5 mg/l. (For perspective, the federal drinking-water standard for nitrate is 10 mg/l, although concentrations in the 2 to 3 mg/l range have been possibly linked with bladder cancer in some recent studies.)

This type of analysis can also be used to evaluate the effects of lot size on groundwater nitrate concentrations. Using the same parameters (recharge, effluent concentration, etc.) as in Tables 1 and 2 but varying the lot size, we find that nitrate concentrations increase dramatically for lot sizes smaller than approximately 2 acres (Figure 1).

Another type of analysis that could be made using the Hantzsche and Finnemore method could be to evaluate the effects of improved treatment on groundwater nitrate concentrations. For instance, we could use the same parameters as in Table 2 but vary the effluent nitrate concentration (in this case, “improved treatment” means with a reduction in effluent nitrate concentrations; we are not referring to other sewage constituents like bacteria) to find the resulting groundwater concentration. Interestingly, we find that improving treatment levels lowers groundwater nitrate concentrations much less than simply increasing lot sizes (Figure 2).

Resource Constraints in Selected Region 2050 Areas

The limitation of tools like these, however, is that they sacrifice applicability or accuracy for ease of use. If we were to apply this method to an area where the drinking water aquifer was deep and protected by a thick, lower-permeability geologic formation, the results would actually be more representative of what would reach surface water than what would reach a deeper groundwater drinking-water source. (In Western Oregon in particular, the infiltrating rainwater has to go somewhere, and if it cannot go deeper because there is a “floor” to the shallower soils, the shallow groundwater will typically flow “downhill” with topography toward the closest stream[4].)

So, the other very important factor to consider when evaluating whether groundwater resources are vulnerable to contaminants originating at or near the ground surface includes the geology of the area. In the next several sections, we will be briefly discussing the geology and the likely vulnerability of the underlying aquifers of the six areas in the 2050 Region that you identified in your November 2004 Policy Advisory Board meeting. These areas include Alvadore, Goshen, Lowell, Pleasant Hill, and Coburg/Junction City.

Before addressing each specific area, however, we would like to describe some of the material we typically use to make similar evaluations of the potential for an onsite system to pose a threat to groundwater resources in our daily work at DEQ. These include “well logs” from the Water Resources Department which describe water well construction details, and include hints concerning the geology of an area[5]; drinking-water supply water quality data from the Department of Human Services (DHS) Drinking Water Program, which include analytical data such as nitrate concentrations in groundwater[6]; an online map of Oregon geology provided by the Northwest GeoData Clearinghouse at Portland State University[7]; the county soil survey maps available from the Natural Resources Conservation Service[8]; ground- and surface water quality data from DEQ[9]; and last but not least, some of the best information available to communities interested in protecting their groundwater supplies is assembled in “Source Water Assessments”, which quantify local hydrogeologic conditions and are provided to communities via a DEQ and DHS Drinking Water Program partnership[10].

---

[4] Technically speaking, groundwater does not flow “downhill”, but in response to differences in hydraulic pressures. This is often referred to as “hydraulic head”.

[5] Enter your Township, Range, and Section in to their web-based application, at http://apps.wrd.state.or.us/apps/gw/well_log/well_log.php and get lists of available well logs.

[6] The internet address for their web-based application is: http://170.104.158.16/ and you will need the name of a water supply provider in the area to access the data.

[7] The map can be accessed from: http://nwdata.geol.pdx.edu/OR-Geology/

[8] http://www.or.nrcs.usda.gov/pnw_soil/or_data.html

[9] http://www.deq.state.or.us/wq/lasar/LasarHome.htm

[10] An example of a groundwater supply source water assessment can be found at http://www.deq.state.or.us/wq/dwp/VenetaSWA.pdf . Unfortunately, most of these assessments are not available online, but can be obtained from the Springfield DHS Drinking Water Program office.

An example of the level of analysis that this program can provide is shown in Figure 3, which is a drinking-water protection area and sensitivity analysis for the Veneta groundwater supply system.

NOTE TO PAB: We are waiting for documents from DHS to ensure that our hydrogeologic summaries below are consistent with theirs. This is simply a documentation step. We have completed our analysis, and adding the text below will not affect the overall conclusions in this memo. Each subsection contains brief summaries of general geology, depths of wells in the area, whether the aquifer is unconfined or confined, contaminant data if available, and general vulnerability of the resource.

Alvadore:

Goshen:

Lowell:

Pleasant Hill:

Coburg/Junction City:

As you can see from our descriptions above, the potential for impacting groundwater resources under denser, rural, unsewered land use scenarios can range from very high potential (e.g., Coburg, where impacts are already apparent) to lower potential in areas where the local aquifers are deep and confined.

Recommendations

As we mentioned in our introduction, the recent Region 2050 environmental resource protection analysis report ranks the overall relative effect of each scenario on the environment for the entire region. It also recognizes that the risk estimates are highly dependent on land use assumptions and it did not account for the effects of local geology on mitigating those risks.

In our memo, we have evaluated the potential effects on local groundwater quality of increasing rural residential densities in six specific areas of the region. During our evaluation, we explored an number of tools that communities and their consultants might use to tailor their development plans to minimize potential impacts to groundwater, and selected one to illustrate how these tools can be used to make decisions about lot size. We also summarize the geologic conditions in each area, and estimate the relative impact that onsite septic systems might have on local beneficial groundwater uses.

The highest risk that onsite systems can pose to human health and the environment is when they are located on small lots in areas with shallow, unconfined, locally used drinking water aquifers. Because the geology and therefore hydrogeology and groundwater resource vulnerability can vary significantly over relatively short distances, we recommend the following:

1. When planning residential lot sizes in areas where onsite systems will be used as the primary wastewater treatment and disposal method, place the highest density lots in areas where the soils are appropriate for septic systems and where the aquifer used locally is least vulnerable to contamination;
2. Whenever possible, use DHS/DEQ Source Water Assessments for the area under consideration as a tool to make decisions about which areas to avoid for intensive residential or industrial development. These Assessments provide a prepackaged, readily available, free, and well-researched summary of local groundwater conditions, aquifer vulnerability, and summary of potential contaminant sources;
3. If information on groundwater resource vulnerability is not readily available, consider hiring a professional groundwater hydrologist to provide advice on which areas to avoid. Often, this does not have to be a sophisticated or complex analysis;
4. If higher-density development must occur in areas with high potential for groundwater resource degradation over the long term, consider community-wide or neighborhood-level wastewater treatment, which is likely to have better controls and monitoring than single-homeowner-based systems;
5. Even in areas with the least vulnerable drinking resources, higher densities of onsite systems can threaten surface water resources. Consider placing highest densities of onsite systems well away from surface water; and

6. Our analysis is focused primarily on the effects of onsite systems on groundwater resources. It does not include other potential impacts covered in the Region 2050 Environmental Resource Protection document such as groundwater impacts due to fertilizers, herbicides, or pesticides in applied to the land surface in higher-density residential development scenarios.

References

Hantzsche, N.N. and Finnemore, J.E., 1992. Predicting ground-water nitrate-nitrogen impacts, *Ground Water*, v. 30, no. 4, pp. 490-499. A copy can be found at: http://deq.state.wy.us/wqd/www/Subdivision.asp

Lee, K.K., and Risley, J.C., 2002. Estimates of ground-water recharge, base flow, and stream reach gains and losses in the Willamette River basin, Oregon", *USGS Water-Resources Investigations Report* WRIR 01-4215. A copy can be found at: http://oregon.usgs.gov/pubs/WRIR01-4215/wri014215.pdf

Perkins, R.J. 1984. Septic tanks, lot size and pollution of water table aquifers. *Journal of Environmental Health*, v. 51, no. 1, pp. 17-18.

Tinker, J.R., Jr. 1991. Analysis of nitrate-nitrogen in ground water beneath unsewered subdivisions. *Ground Water Monitoring Review*, v. 11, no. 1, pp. 141-150. A copy can be found at: http://deq.state.wy.us/wqd/www/Subdivision.asp

Wehrmann, H.A. 1984. Managing Ground Water Nitrate Quality by Mass Balance Modeling in the Rockton-Roscoe Area, Illinois. In *Proceedings of the NWWA Eastern Regional Conference on Ground Water Management*, National Water Well Association, Dublin, Ohio pp. 558-587.

Table 1: Region 2050 Rural Growth Scenario Groundwater Evaluation (Coburg; high density development)			
Potential Nitrate Concentrations in Groundwater (annual basis)			Data Source
D_h = housing density =	5	units/acre	Region 2050 Regional Profile, Coburg
W = long-term wastewater flow, per unit =	150	gpd/unit	Hantzsche and Finnemore, 1992
I = D_h*W = average volume of effluent over gross developed area =	10	in/yr	Calculated
n_w = nitrogen concentration in effluent =	45	mg/l	Typical "residential" strength value
d = denitrification fraction in soil =	0.25	unitless	Hantzsche and Finnemore, 1992
R_{avg} = Average recharge of rainfall =	21	in/yr	USGS, 2002
n_b = background nitrate data value in rainfall or groundwater =	1	mg/l	Hantzsche and Finnemore, 1992
n_r = average concentration in recharge water = $(n_w I(1-d)+R_{avg} n_b)/(I+R_{avg})$ =	11.6	mg/l	Volumetric basis using Hantzsche and Finnemore, 1992

Table 2: Region 2050 Rural Growth Scenario Groundwater Evaluation (Coburg; lower density development)			
Potential Nitrate Concentrations in Groundwater (annual basis)			Data Source
D_h = housing density =	0.5	units/acre	Region 2050 Regional Profile, Coburg
W = long-term wastewater flow, per unit =	150	gpd/unit	Hantzsche and Finnemore, 1992
I = D_h*W = average volume of effluent over gross developed area =	1	in/yr	Calculated
n_w = nitrogen concentration in effluent =	45	mg/l	Typical "residential" strength value
d = denitrification fraction in soil =	0.25	unitless	Hantzsche and Finnemore, 1992
R_{avg} = Average recharge of rainfall =	21	in/yr	USGS, 2002
n_b = background nitrate data value in rainfall or groundwater =	1	mg/l	Hantzsche and Finnemore, 1992
n_r = average concentration in recharge water = $(n_w I(1-d)+R_{avg} n_b)/(I+R_{avg})$ =	2.5	mg/l	Volumetric basis using Hantzsche and Finnemore, 1992

Figure 1: Effect of Parcel Size on Nitrate Concentrations

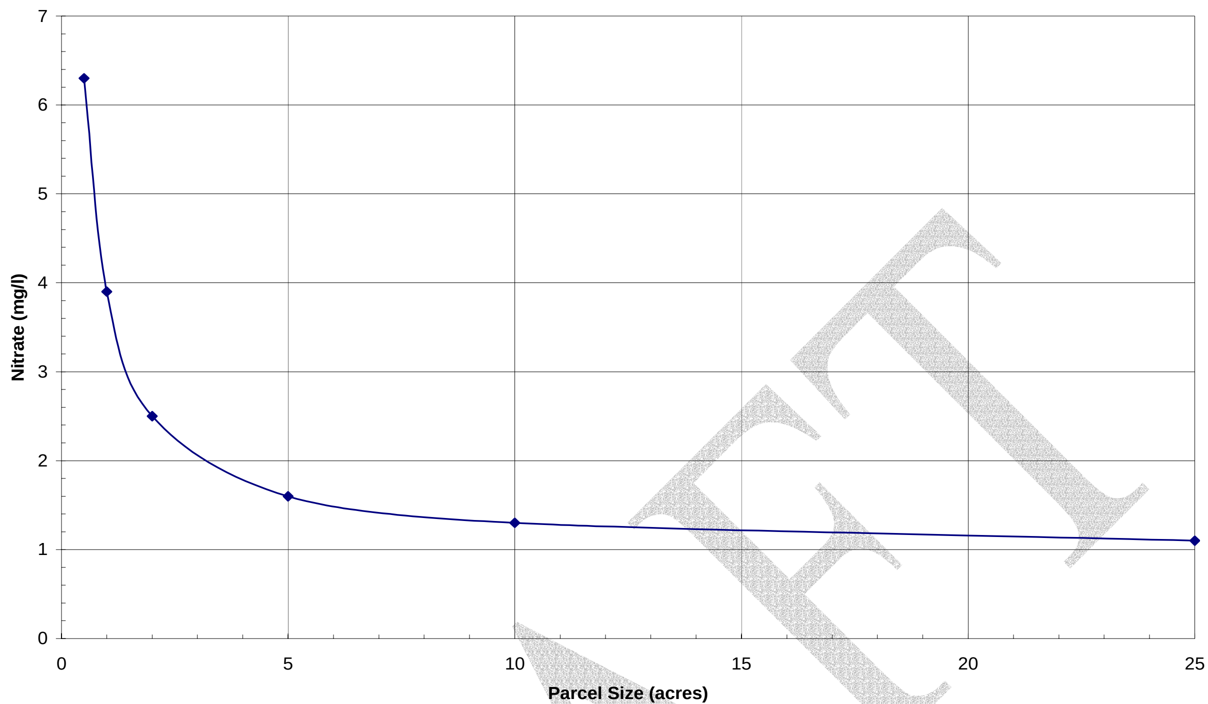

Figure 2: Effects of Treatment Level on Nitrate Concentration

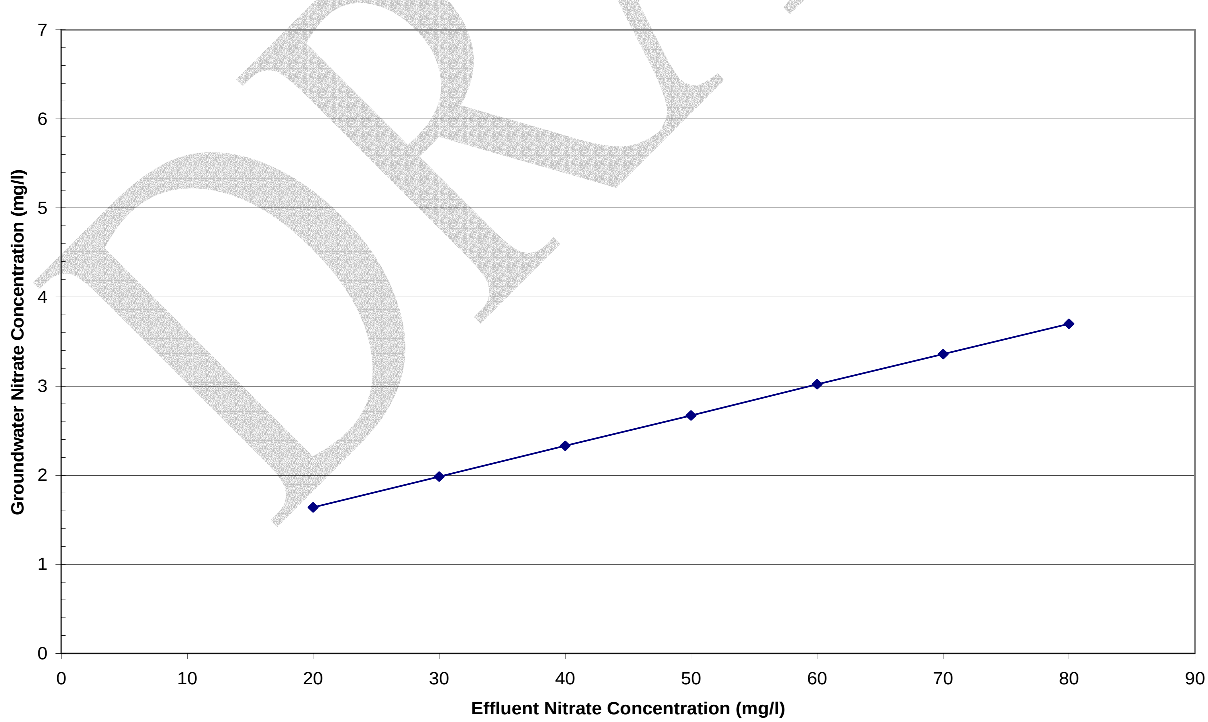

Figure 3

City of Veneta Drinking Water Protection Area
Potential Contaminant Sources and Sensitivity Analysis