On-Site Rule Revision Issue:
Minimum Land Area - WAC 246-272A-0320

Problem Statement

Minimum land area requirements have been part of the State Board of Health regulations for on-site sewage systems (OSS) since the first comprehensive statewide rule that took effect in 1974. Minimum land area requirements are intended to ensure three things:

1. There is enough space for all OSS components to be installed and ensure all required setbacks are met.
2. There is enough space for the reserve drainfield to be maintained in a ready to use condition in the case that a replacement drainfield has to be installed.
3. There is enough space to accommodate the nutrient loading from the OSS without negatively impacting surface water or groundwater.

The first two of these (1&2) can arguably be accomplished with appropriate setback requirements. This, however, can lead to systemic issues with lots near the minimum size due to site complications/limitations. And once platted, a lot is generally presumed to be buildable.

<u>NITROGEN (and nutrients of concern)</u>

Nitrogen is the primary nutrient of concern in regard to number 3 above. Phosphorus is a secondary nutrient of concern.

Humans generate 13.3 g of nitrogen per person per day and 3.28 g of phosphorus per person per day[1]. Conventional (septic tank and drainfield) OSS are designed to convert ammonia and organic nitrogen to nitrate. This results in less toxic and offensive end products that are more suitable to be returned to the environment.

Unlike pathogens or dangerous chemicals found in sewage, nutrients do not usually immediately affect healthy adults upon contact or ingestion. In general, most people can safely metabolize nutrients in water at levels commonly found in nutrient-contaminated water. Nutrients are important components of natural cycles and are critical for plant growth. Plants readily absorb and use them when available to them under the right conditions. Large quantities of nutrients are applied as fertilizers and are part of waste streams associated with commercial animal operations. They present a problem in groundwater when they are concentrated to high levels. Consequently, excess nutrients from OSS have traditionally been considered a nuisance more than a public health threat.

Over time, many groundwater and surface water bodies across the nation have been contaminated by nitrates. Nitrogen sources and the concentration of development leading to nitrogen contamination have increased significantly in recent decades. Sophisticated monitoring, treatment, and management techniques have been developed to detect and combat this. Because nitrate is very water-soluble it is difficult and costly to remove from water. EPA, Water Environment Foundation, and other experts recommend watershed management and nitrate pollution prevention as the most cost effective alternative for nitrate management [2,3]. The mindset around nutrient management has changed significantly over time and continues to evolve as science progresses and the negative impacts of nutrients are better understood.

Nitrogen's effects are the greatest and are the focus of this discussion.

Infants less than 6 months of age cannot metabolize nitrates. If an infant drinks water, or eat foods made with water, containing concentrated nitrates it can cause a potentially fatal illness known as methemoglobinemia[4]. Accordingly, EPA has set a maximum concentration of nitrate allowed in drinking water at 10 mg/L. People with certain health conditions are also susceptible to illnesses related to drinking water with high levels of nitrate. These include people without enough stomach acids, people with methemoglobin reductase deficiency, pregnant women or women trying to become pregnant (in these cases the baby may be at risk of spontaneous abortion or certain birth defects). Studies indicate that chronic nitrogen ingestion may have other negative health effects for adults but many significant points in the science are currently inconclusive and agreed upon guidance on a regulatory approach is not available[4].

Nitrogen and phosphorus both contribute to harmful algal blooms (HABs) in freshwater and marine waters across the nation[2,5,6,7]. This is the most significant impact from phosphorus pollution from OSS. HABs can lead to eutrophication and lowered dissolved oxygen levels, which degrade aquatic habitats. Some HABs also release toxins into the environment which can impact drinking water supplies and make shellfish and other seafood unsafe to eat[8].

Nitrogen has been identified as a contaminant of concern in drinking water wells, streams, rivers, lakes, and in marine waters in Washington[9,10,11]. OSS represent one of many contributing factors in many, if not most, of these cases. Each OSS contributes relatively little nitrogen to any local hydrogeological nitrogen cycle. The impacts of their contributions become significant when many OSS are built discharging to a single aquifer.

Many parts of Washington have experienced an increase in nitrogen sources discharging to aquifers. Even nitrates entering waterways far from nitrate-impacted areas can cause problems in those areas because of its highly solubility and ability to travel vast distances in water. This was seen in Oregon in May of 2018 when toxic algae blooms in Detroit Lake contaminated the drinking water supplies of the cities of Salam and Stayton, withdrawn from the North Santiam River some 35 miles away[12, 14]. For this reason EPA recommends uniform statewide nutrient limits on watersheds rather than local standards based on impairment of local waterbodies[2].

In order to preserve the water resources of Washington, DOH has set a goal that LOSS (directly regulated by DOH) not increase the nitrate level in the groundwater any more than 2 mg/L above background levels at the property boundary (with no more than a 5 mg/L total increase). This is a requirement in areas identified as environmentally sensitive or where nitrogen can have a public health impact. LOSS are required to submit nitrogen balance calculations with their designs, many are required to monitor groundwater nitrogen concentrations for changes, and, where needed, they are required to install and operate nitrogen treatment to ensure that they do not contribute to increasing nitrogen levels. LOSS operated in areas of locally high nitrate groundwater may be required to have increased monitoring or treatment. Nitrate discharging facilities regulated under different rules have similar requirements.

DOH has reviewed the current minimum land area requirements in WAC 246-272A-0320 and has identified several operational issues that result in permitted developments that may negatively impact groundwater and surface water by increasing nitrate levels. The current lot sizes are not large enough to adequately treat and dilute nitrogen when development is permitted at the extent allowed in the rule. Minimum lot sizes need to be increased in all categories to address this.

A primary issue is the portion of land that is left undeveloped and pervious. Pervious surfaces are critical for providing infiltration of precipitation that dilutes nitrates from OSS. Counting acreage that cannot suitably accept, treat, and dilute nitrates in the minimum land area calculation adds considerable risk that the OSS will contribute more nitrate than can be treated and diluted before moving offsite, resulting in the OSS contributing to nitrate pollution and increasing nitrate levels. Establishing Minimum usable land area requirements can address this.

NON-PUBLIC WATER SUPPLIES

Another issue exists with subdivisions into lots with non-public (mostly single family) water supplies (mostly non-public wells) and soil types 1-3. The current minimum lot size for these lots is 1 acre which is 43,560 square feet (sf). Non-public wells require a 100-foot radius zone of protection that cannot include an OSS. This equals 31,416 sf. This leaves 12,144 sf for all components of the OSS. On a square lot this can be nearly impossible to fit, especially with other setbacks. This has historically resulted in many wells with protection zones that extend far onto neighboring properties. This creates many potential issues that may lead to an unprotected well.

CURRENT METHOD II

The current Method II results in particularly problematic land area calculations because of the notion that an individual building lot could be as small as 12,500 sf. An extreme, but not necessarily uncommon example is a three bedroom single family residence (SFR) utilizing an approved public water supply with an OSS installed in type 6 soil. This SFR requires at least 4600 sf of lot area to accommodate the primary drainfield (accounting for space between drainfield trenches). A reserve drainfield of equal size is also required to be maintained undeveloped. This equals 9200 sf of lot area to meet the minimum OSS sizing requirement. The minimum land area size that Method II allows in this scenario is 12,500 sf. Therefore, the current Method II should be considered for wholesale revision or removal.

This should not take the approach of a point-of-compliance at the property line, but instead take a macro-scale approach to account for total nitrogen loading to a given land area. This approach would often then allow for enough land area to deal with all other design considerations, *i.e*., setbacks, slopes, etc. As always, the approach still must include all other considerations for OSS size and siting.

In 2008 the Washington Supreme Court ruled on a case (Thurston v. Griffin) that involved an undersized lot that required waivers for approval of the OSS[13]. The court ruled that LHOs cannot approve developments (as defined in WAC 246-272A) on lots that do not meet the minimum land requirement and also require waivers from other requirements in the WAC. This interpretation agrees with the original intent of WAC 246-272A-0320(5)(e)(iii). The misinterpretation of this section by some LHJs has led to a need to clarify this section.

Recommended Option

The department recommends that section -0320 continues to include a table with minimal increases to the minimum lot sizes (except for subdivisions utilizing non-public water supplies; these will be more substantial increases). These new proposed minimum lot sizes, combined with the addition of a *minimum pervious surface area* provision, in general should give the needed area to accommodate the discussion points above.

Also add an additional section to allow the possibility to decrease the minimum lot sizes as shown in the table by utilizing a formula that will address the issue of dealing with excessive nitrogen loading in a given land area.

~~RED~~ = deleted existing language BLUE = added new language Green = new language not reviewed by subcommittee

Recommendation & Optional Rule Language to Consider

WAC 246-272A-0010 Definition

"Usable land area" means the minimum land area required per development which is suitable for OSS. This area includes satisfactory soil conditions, vertical separation and horizontal separation(s). This area also includes an area free of all physical restrictions. (See Soil and site evaluation -0220.)

WAC 246-272A-0320 Developments, subdivisions, and minimum land area requirements.

(1) A person proposing a subdivision where the use of OSS is planned shall obtain a

recommendation for approval from the local health officer as required by RCW 58.17.150.

(2) The local health officer shall require the following prior to approving any development:

(a) Site evaluations as required under WAC 246-272A-0220, excluding subsections (3)(a)(i) and (4)(d);

(b) Information consisting of field data, plans, and reports supporting a conclusion the land area provided is sufficient to:

(i) Install conforming OSS;

(ii) Preserve reserve areas for proposed and existing OSS;

(iii) Properly treat and dispose of the sewage; and

(iv) Minimize public health effects from the accumulation of contaminants in surface and ground water.

~~(c) Configuration of each lot to provide a minimum of 10,000 square feet usable land area suitable for OSS;~~

(~~b~~d) Where a subdivision with ~~individual~~ non-public wells is proposed:

(i) Configuration of each lot ~~to~~ shall allow a one hundred-foot radius water supply protection zone to fit within the lot lines; or

(ii) Establishment of a one hundred-foot radius water supply protection zone around each existing and

proposed well site;

(~~c~~e) Where preliminary approval of a subdivision is requested, provision of at least one soil log per proposed lot, unless the local health officer determines existing soils information allows fewer soil logs;

(~~d~~f) Determination of the minimum lot size or minimum land area required for the development using ~~Method I and/or Method II~~ Table X, or the alternative methodology in subsection (3) of this section:

~~METHOD I.~~ Table X, Single-Family Residence Minimum Lot Size or Minimum Land

Area Required Per Unit Volume of Sewage, shows the minimum lot size required per single-family residence. For developments other than single-family residences, the minimum land areas shown are required for each unit volume of sewage. However, the local health officer may require larger lot sizes where the local health officer has identified either nitrogen or phosphorus as a contaminant of concern either through planning activities described in WAC 246-272A-0015 or another process.

TABLE X

Minimum Land Area Requirement Per
Single-Family Residence or Unit Volume of Sewage

Commented [SJJ(1]: Consider Renaming

Type of Water Supply	Soil Type (defined by WAC 246-272A-0220)

	1	2	3	4	5	6
Public	~~0.5 acre~~ 22,000 sq. ft. 2.5 acre[1]	~~12,500~~ 13,000 sq. ft.	~~15,000~~ 16,000 sq. ft.	~~18,000~~ 19,000 sq. ft.	~~20,000~~ 21,000 sq. ft.	~~22,000~~ 23,000 sq. ft.
~~**Individual**~~ **Non-public on each lot**	1.0 acre 2.5 acres[1]	1.0 acre	1.0 acre	1.0 acre	2.0 acres	2.0 acres
Minimum Usable Land Area	2,000 sq ft	2,000 sq ft	2,500 sq ft	3,333 sq ft	5,000 sq ft	10,000 sq ft

[1] ~~See~~ OSS consisting solely of a septic tank and gravity SSAS must have a minimum land area of 2.5 acres per WAC 246-272A-0234(6).

~~**METHOD II.** A minimum land area proposal using Method II is acceptable only when the applicant:~~

~~(i) Justifies the proposal through a written analysis of the:~~

~~(A)Soil type and depth;~~

~~(B) Area drainage, and/or lot drainage;~~

~~(C) Public health impact on ground and surface water quality;~~

~~(D)Setbacks from property lines, water supplies, etc.;~~

~~(E) Source of domestic water;~~

~~(F) Topography, geology, and ground cover;~~

~~(G)Climatic conditions;~~

~~(H)Availability of public sewers;~~

~~(I) Activity or land use, present, and anticipated;~~

~~(J) Growth patterns;~~

~~(K) Reserve areas for additional subsurface treatment and dispersal;~~

~~(L) Anticipated sewage volume;~~

~~(M) Compliance with current planning and zoning requirements;~~

~~(N)Types of proposed systems or designs, including the use of systems designed for removal of nitrogen;~~

~~(O)Existing encumbrances, such as those listed in WAC 246-272A-0200 (1)(c)(v) and 246-272A-0220 (2)(a)(vii); and~~

~~(P) Estimated nitrogen loading from OSS effluent to existing ground and surface water;~~

~~(Q)Any other information required by the local health officer.~~

~~(ii) Shows development with public water supplies having:~~

~~(A)At least twelve thirteen thousand five hundred square feet lot sizes per single-family residence;~~

~~(B) No more than 3.35 unit volumes of sewage per day per acre for developments other than single-family residences; and~~

~~(iii) Shows development with individual water supplies having at least one two acres per unit volume of sewage; and~~

~~(iv) Shows land area under surface water is not included in the minimum land area~~

~~calculation; and~~

~~(e) Regardless of which method is used for determining required minimum lot sizes or minimum land area, submittal to the health officer of information consisting of field data, plans, and reports supporting a conclusion the land area provided is sufficient to:~~

~~(i) Install conforming OSS;~~

~~(ii) Assure preservation of reserve areas for proposed and existing OSS;~~

~~(iii) Properly treat and dispose of the sewage; and~~

~~(iv) Minimize public health effects from the accumulation of contaminants in surface and ground water.~~

(3) The local health officer shall require all proposals that do not meet the minimum land area requirements in Table X to demonstrate that the proposed development:

(a) Will ~~not negatively~~ minimize impacts to public health or surface water or groundwater quality;

(b) Has given appropriate consideration to:

(i) Topography, geology, and ground cover;

(ii) Climatic conditions;

(iii) Availability of public sewers; and

(iv) Present and anticipated land use and growth patterns;

(c) Will be in compliance with current planning and zoning requirements; and

(d) Will not exceed the nitrogen limit per land area as identified in Table XI.

Table XI

Maximum Allowable Total Nitrogen

Per Land area Per Day (square feet and acre)

		Total Nitrogen (TN) Allowed Per Land area					
Type of Water Supply	**Soil Type**	1	2	3	4	5	6
Public	**mg TN/square foot**	3.7	6.3	5.1	4.3	3.9	3.6
	lb TN/acre	0.36	0.60	0.49	0.41	0.37	0.34
Non-public on each lot	mg TN/square foot	1.9	1.9	1.9	1.9	0.9	0.9
	lb TN/acre	0.18	0.18	0.18	0.18	0.09	0.09

Based on 60 mg/L TN OSS effluent and 360 gal/day

(~~3~~4) The department shall develop guidelines for the application of the alternative method in subsection 3 of this section ~~Method II~~ by July 1, 2021~~2008~~.

(~~4~~5) The local health officer shall require lot areas of ~~twelve~~ thirteen thousand ~~five hundred~~ square feet or larger except when a person proposes:

(a) OSS within the boundaries of a recognized sewer utility having a finalized assessment roll; or

(b) A planned unit development with:

(i) A signed, notarized, and recorded deed covenant restricting any development of lots or parcels above the approved density with the overall density meeting the minimum land area requirements of subsection (2)(df) of this section;

(ii) A public entity responsible for operation and maintenance of the OSS, or a single individual owning the OSS;

(iii) Management requirements under chapter 246-272B WAC when installing a LOSS; and

(iiiv) Extinguishment of the deed covenant and higher density development allowed only when the development connects to public sewers, and either:

(A) A single individual owning the OSS; or
(B) An approved public entity owning or managing the OSS in perpetuity; or
(C) A management arrangement acceptable to the local health officer, recorded in covenant, lasting until the OSS is no longer needed, to include, but not limited to:

(I) A recorded easement allowing access for construction, operation, monitoring maintenance, and repair of the OSS; and

(II) Identification of an adequate financing mechanism to assure the funding of operation, maintenance, and repair of the OSS.

(56) The local health officer may:

(a) Allow inclusion of the area to the centerline of a road or street right of way in a Method II determination under subsection (2)(d) of this section to be included in the minimum land area calculation if:

(i) The dedicated road or street right of ways are along the perimeter of the

development;

(ii) The road or street right of ways are dedicated as part of the proposed development; and

(iii) Lots are at least twelve thousand five hundred square feet in size.

(ab) Require detailed plot plans and OSS designs prior to final approval of subdivision proposals;

(bc) Require larger land areas or lot sizes to achieve public health protection;

(cd) Prohibit development on individual lots within the boundaries of an approved subdivision if the proposed OSS design does not protect public health by meeting requirements of these regulations; and

(de) Permit the installation of an OSS, where the minimum land area requirements or lot sizes cannot be met, only when all of the following criteria are met:

(i) The lot is registered as a legal lot of record created prior to the effective date of this chapter;

(ii) The lot is outside an area identified by the local plan developed under WAC 246-272A-0015 where minimum land area has been listed as a design parameter necessary for public health protection; and

(iii) The proposed system OSS meets all requirements of these regulations, other than minimum land area, without the use of waivers from this chapter..

(67) The use of a reduced-sized SSAS dispersal component does not provide for a reduction in the minimum land area requirements established in this section. Site development incorporating reduced-sized SSAS dispersal component must meet the minimum land area requirements established in state and local codes.

Supporting Information

History

Minimum land area requirements have been part of the State Board of Health regulations for on-site sewage systems (OSS) since the first comprehensive statewide rule that took effect in 1974. Originally, more often than not, the minimum lot size section primarily dealt with new subdivisions. Over time it has become a significant factor for any new proposed development, including any new single-family residential construction.

The primary purpose of the minimum land area requirement was to help assure that sufficient area would exist for a primary and reserve on-site sewage system, as well as for the building (usually a house) and all the other associated development features (utilities, driveways, parking, outbuildings, storm drainage, etc.). From the public health perspective, it was always the intent to assure sufficient area for a repair/replacement system area was available if a failure occurs. Over time it became apparent that other factors such as nutrient loading are equally important. Eventually the rule also considered maximum gallons of sewage per acre. This was an attempt to deal with nutrient loading concerns.

The square footage of homes has increased substantially over time. In 1986 the national average home size was 1825 square feet. In 2010 it was 2,392. By 2015, the average had increased to 2,687 square feet. The current lot sizes equate to less pervious surface area on a lot of the same size as in 1986. With larger home footprints, there is less land to allow precipitation to infiltrate through the soil and recharge groundwater. With less water infiltrating, there is less dilution of nitrate going to groundwater. Modern onsite stormwater infiltration techniques have been working to mitigate this effect.

During the 2005 State Board of Health rule revision process, the initial recommendation to the State Board of Health was to change the minimum land area requirements for all soil types with a public water source to one half acre. This recommendation suggested every parcel should be initially assumed to be sensitive to nitrogen. The Board decided against this recommendation. A Method II process was then available to provide smaller land areas, with technical justification that an area was not sensitive to nitrogen.

Climate Change

Another factor to be considered is long term planning due to climate change. Climate change is a significant change in the measures of climate lasting for an extended period of time.

"Warming within earth's atmosphere and oceans at the global scale is altering climate patterns in the northwest. Increasing temperatures, shifting patterns in precipitation, rising sea levels and ocean acidification are driving changes that have implications for Washington's natural and built environment. For example, researchers expect that large increases in extreme river flows in some watersheds and more severe heavy rainfall events will increase flood risk. In turn, increased river flooding, as well as sea level rise are expected to impact infrastructure near current floodplains and coastal shorelines. More frequent landslides and coastal erosion are also expected, partly from increasing temperatures, more heavy rain events and sea level rise, although other non-climatic factors such as land use and land cover play key roles as well. Projected declines in summertime precipitation and summer stream flows, as well as the potential for drought will pose a different set of risks for water-sensitive natural resources and infrastructure." (Marnie Boardman, DOH Climate and Health Coordinator)

Survey of Minimum Lot Sizes in Other States and Provinces

Minimum Lot Sizes for New Divisions				
State	Private Water Supply	Public Water Supply	Community or Cluster	Notes
South Dakota	1 acre, unless prior division	20,000 sq. ft.	Local code determines size OSS must meet all setbacks	
West VA	20,000 sq. ft. 10,000 sq. ft. for OSS/reserve 2 acre	10,000 sq. ft. 10,000 sq. ft. for OSS/reserve 2 acre		prior to 1983 may not be usable Conventional systems only if alternative system this size
Manitoba	2 acres with 198 ft width	2 acres with 198 ft width		may get a variance for lots subdivided prior to 9/2009

VA	must meet setbacks	must meet setbacks		
NJ	must meet setbacks 3.2 acres in N sensitive areas.	must meet setbacks 3.2 acres in N sensitive areas.		Lot size reduced to 1 acre w/an approved N attenuation
Arkansas	no minimum	must meet setbacks	No difference	
Utah	1.75 acres determined by by soil type	12,000-20,000 sq. ft. determined by soil type	Not addressed	
Oregon	no minimum in rule	no minimum in rule	no minimum in rule	1 acre loading rate limit with rapidly draining soils. Can be reduced to ½ acre with pressure distribution or treatment.
Alaska	must meet setbacks to DW	must meet setbacks to DW		some local jurisdictions have minimum sizing in zoning
Delaware	0.5 acres	may be minimum of 0.25 acre per county zoning	county zoning dictates	County zoning may change size
NM	0.75 acres	0.75 acres	no minimum	all lots are restricted to 500 gpd/acre
OK	0.75 to 1 acre dep on soil 0.75 acre 1 acre 0.75 acre 0.75 acre 2.5 acre	0.5 to 1 acres dep on soil 0.5 acre 1 acre 0.5 acre 0.5 acre 2.5 acre		conventional or shallow extended field Pressure distribution Evapotranspiration/Absorption Field Drip Irrigation Field Spray Irrigation Field Lagoon Minimum lot size excludes road easement
Massachusetts	440 gpd/40,000 sq. ft.	440 gpd/40,000 sq. ft.		This equates to a 4 bedroom dwelling. Loading may be increased to 660 gpd depending on technology and if land credit is aquuired.
Georgia	43,560 sq. ft. (1 acre) 150 ft	21,780 sq. ft. 100 ft	Permitted by the State lot sized by local plan/zoning	Minimum lot size Minimum Lot Width

	600 g/acre/day	1200 g/acre/day		Maximum Sewage Flow
New York	must meet setbacks	must meet setbacks		
Colorado	local regs/setbacks met	local regs/setbacks met		some counties have 5 acre min if fractured bedrock
Maryland	20,000 to 40,000 sq. ft. depends on soil Minimum lot width from 100, 125, 150, and 150 feet	15,000 to 30,000 sq. ft. depends on soil Minimum lot width 100,100, 100, and 150 feet	if community drainfield minimum 10,000 sq. ft. 10,000 sq. ft. may include slopes that exceed 25 percent	factors to consider topography soil type and condition history of nearby failures extent of water/OSS in adjacent areas. May require a minimum of 43,560 with 175 min lot width 10,00 sq ft minimum usable area
Alabama	43,560 sq. ft (1 acre)	15,000 sq. ft.	no minimum lot size	except hydric, mine spoils, shrink swell soils Lots may be reduced with Engineered design

References

1. Crites, Tchobanoglous, Small and Decentralized Wastewater Management Systems, 1998.
2. US EPA, Preventing Eutrophication: Scientific Support for Dual Nutrient Control, Feb 2015
3. Water Environment Federation, The Nutrient Roadmap Primer: A preview for smarter nutrient management
4. US EPA, Final Report: Dose-Response of Nitrate and Other Methemoglobin Inducers on Methemoglobin Levels of Infants.
5. US EPA, Onsite Wastewater Treatment Systems Manual, Feb 2002
6. CDC, Harmful Algal Bloom (HAB)- Associated Illness webpage
7. Lapointe, B. et al, Evidence of sewage-driven eutrophication and harmful algal blooms in Florida's Indian River Lagoon
8. Hickey, H., University of Washington, Ocean conditions contributed to unprecedented 2015 toxic algal bloom, Sep 2016
9. WA Department of Ecology, Nitrate in groundwater data and assessment webpage
10. Morgan, L., Washington Nitrate Prioritization Project, May 2016
11. WA Department of Ecology, River and Stream Water Quality Monitoring Report: Water Year 2013, Nov 2014
12. Urness, Z., Salem's water contaminated by toxic algae: What we know, Statesman journal, May 29, 2018
13. *Griffin v. Thurston County*, 165 Wn.2d 50, 196 P.3d 141 (2008)., viewed: https://casetext.com/case/griffin-v-bd-of-health
14. City of Salem: Salem's Water Source, https://www.cityofsalem.net/Pages/salem-water-source.aspx
15. Gold, A.J. and Sims, J.T., Research Needs in Decentralized Wastewater Treatment and Management: a Risk-Based Approach to Nutrient Contamination, national Research needs Conference Proceedings: Risk-Based Decision Making for onsite Wastewater Treatment, EPRI, US EPA, national Decentralized Water Resources Capacity Development Project 2001.1001446, Palo Alto, CA, 2000.
16. Hantzsche, N.N. and Finnemore, J.e., 1992. Predicting ground-water nitrate-nitrogen impacts, *Ground Water*, v. 30, no. 4, pp. 490-499.
17. USDA Urban Hydrology for Small Watersheds, TR-55, June 1986.
18. Adler, R., Aschenbach, E. Baumgartner, J., Conta, J, Degen, M., Goo, R., Hudson, J., Moeller, J., Montali, D., Piluk, R., Prager, J. Recommendation of the On-Site Wastewater Treatment Systems Nitrogen Reduction Technology Expert Review Panel, Final Report.
19. Bureau of Sewage and Water, Commonwealth of Virginia DOH, Nov 1, 1988 Calculating the Nitrate Concentration in Ground Water Below Mass Drainfields.
20. WERF, Influent Constituent Characteristics of the Modern Waste Stream from Single Sources, 2009.
21. AEIdeas, Carpe Diem, June 5, 2016, Mark J. Perry
22. Storm water infiltration by Gabe Weaver.
23. World Health Organization, 2018, Water Sanitation Hygiene

24. Snover, A.K, G.S. Mauger, L.C. Whitely Binder, M. Krosby, and I. Tohver. 2013. Executive Summary. In *Climate Change Impacts and Adaptation in Washington State: Technical Summaries for Decision Makers*. State of Knowledge Report prepared for the Washington State Department of Ecology. Climate Impacts Group, University of Washington, Seattle, pp. ES-2 – ES-5.
25. Snover, A.K, G.S. Mauger, L.C. Whitely Binder, M. Krosby, and I. Tohver. 2013. Section 6: How Will Climate Change Affect Water in Washington? In *Climate Change Impacts and Adaptation in Washington State: Technical Summaries for Decision Makers*. State of Knowledge Report prepared for the Washington State Department of Ecology. Climate Impacts Group, University of Washington, Seattle, pp. 6-4 and 6-11.
26. Snover, A.K, G.S. Mauger, L.C. Whitely Binder, M. Krosby, and I. Tohver. 2013. Section 10: How Will Climate Change Affect Infrastructure in Washington? In *Climate Change Impacts and Adaptation in Washington State: Technical Summaries for Decision Makers*. State of Knowledge Report prepared for the Washington State Department of Ecology. Climate Impacts Group, University of Washington, Seattle, pp. 10-1, 10-3 – 10-6.
27. Mauger, G.S., J.H. Casola, H.A. Morgan, R.L. Strauch, B. Jones, B. Curry, T.M. Busch Isaksen, L. Whitely Binder, M.B. Krosby, and A.K. Snover. 2015. Chapter 5: How Will Climate Change Affect Landslides, Erosion and Sediment Transport? In *State of Knowledge: Climate Change in Puget Sound.* Report prepared for the Puget Sound Partnership and the National Oceanic and Atmospheric Administration. Climate Impacts Group, University of Washington, Seattle, pp. 5-6 – 5-9.
28. Anderson, D.L., R.J. Otis, J.I. McNeillie, and R.A. Apfel. 1994. In-situ Lysimeter Investigation of Pollutant Attenuation in the Vadose Zone of a Fine Sand. On-Site Wastewater Treatment: Proceedings of the Seventh International Symposium on Individual and Small Community Sewage Systems, American Society of Agricultural Engineers, St. Joseph, MI