



TECHNICAL MEMORANDUM

Client: Malaga Water District
Project: General Engineering Services
Project File: MAL 0220186.00.0004
Project Manager: Ryan Peterson, PE
Composed by: Adam Neff, LHG, and Ryan Peterson, PE
Subject: Wellhead Protection from Nitrate Contamination
Date: January 26, 2026



1/26/2026

1.0 Executive Summary

This technical memorandum evaluates the risks posed to the Malaga Water District's (District) municipal groundwater supply by ongoing and proposed residential development using individual on-site septic systems within the District's Wellhead Protection Areas (WHPAs). Accelerating residential density—enabled by Chelan County (County) zoning decisions and the creation of a large Limited Area of More Intensive Rural Development (LAMIRD)—is increasing nitrate loading to the Malaga aquifer and threatens long-term drinking water quality.

1.1 Regulatory Framework and District Authority

Federal and state laws require water systems to protect groundwater sources. Under the Safe Drinking Water Act and Washington Administrative Code (WAC) 246-290-135, the District must maintain a Wellhead Protection Program and delineate WHPAs. Chapter 57.08 Revised Code of Washington (RCW) assigns water-sewer districts the authority and obligation to minimize or eliminate pollutants entering state waters. The state's antidegradation policy (WAC 173-200-030) prohibits allowing contaminants to degrade groundwater unless strict public-interest and treatment thresholds are met.

1.2 Wellhead Protection Areas and Past Errors

The District's WHPAs were historically calculated using the Washington State Department of Health's (DOH) Calculated Fixed Radius (CFR) method. However, key updates based on increasing pumping volumes were inadvertently omitted in earlier Water System Plans (1994, 2004, 2012, 2019), resulting in WHPAs that were too small. Updated WHPAs developed during the 2025 well approval process show significantly larger capture zones, especially for Well Nos. 1 and 2, which now pump nearly triple the annual volume as when early WHPAs were defined.

1.3 Chelan County Land Use Actions and LAMIRD Concerns

The County's zoning and land-use decisions have enabled dense residential development (12,000 square-foot (sf) lots) within areas designated by state code as "Critical Aquifer Recharge

Areas” (CARAs). The County has previously approved subdivisions in District WHPAs without requiring aquifer vulnerability assessments. The County’s LAMIRD expansion around Malaga increased dense residential zoning areas by 500%, contrary to Growth Management Act requirements that LAMIRDs be tightly limited to pre-1993 development. As a result, hundreds of homes—and their septic systems—now overlie portions of the aquifer that feed District wells.

1.4 Nitrate Trends and Evidence of Septic Influence

District nitrate test results dating back to 1981 show a clear long-term upward trend at Wells 1 and 2, with a notable acceleration since approximately 2015. Comparative data from a nearby private well (Malaga Market) show parallel increases, indicating consistent aquifer-wide changes rather than laboratory variability. The United States Geological Survey found that residential development utilizing on-site septic systems for waste disposal at densities greater than 1 housing unit per acre had a strong correlation to nitrate contamination.

Simple comparisons of nitrate levels with home construction timelines—adjusted 4 years for vertical and horizontal travel time—show compelling correlation between new septic systems and increasing nitrates at both the upper (Wells 5 through 8) and lower (Wells 1 and 2) wellfields. Approximately 100 acres of vacant, upgradient land remains zoned for continued dense development.

1.5 Review of Developer-Prepared CARA Studies

CARA reports prepared for recent subdivisions have underestimated aquifer vulnerability as follows:

- Treating septic contributions as “minimal” despite evidence that nitrates will measurably increase.
- Reducing decades of nitrate data to a single average value, obscuring clear upward trends.
- Omitting readily available groundwater data required by County Code 11.82.050(2)(C).
- Misinterpreting DOH guidance by asserting that increases less than 2 mg/L are “minor”; DOH has clarified that this claim is incorrect and context-dependent.
- Understating aquifer susceptibility despite DOH’s high susceptibility ratings for District wells.
- Failing to address cumulative impacts of multiple subdivisions within the same WHPA.

Additionally, the proposed mitigation—household-level advanced septic treatment units—lacks a plan for maintenance, monitoring, compliance verification, or enforcement.

1.6 Regulatory and Financial Risks

If nitrate levels exceed 7.5 mg/L, DOH may require the District to implement a nitrate management plan. At 10 mg/L (the federal Maximum Contaminant Level), the District would

need to provide treatment, blending, or alternative water, at substantial expense. A nitrate treatment facility is estimated to cost \$3 to \$5 million in capital and \$200k to \$500k annually, which is unsustainable for a small district and inconsistent with County goals for affordable housing.

1.7 Recommended Actions

1. Encourage construction of infrastructure to convey sewage out of the WHPA, enabling both development and groundwater protection.
2. Limit or prevent additional septic-based development within WHPAs unless verifiable advanced treatment or sewer conveyance is provided.
3. Require larger minimum lot sizes (approximately 2.5 acres) for any new septic-served parcels within CARAs.
4. Seek state and federal funding for sewer planning and construction; utilize Utility Local Improvement District/Local Improvement District financing mechanisms for cost recovery.
5. Ensure future CARA studies undergo independent technical review, as allowed by County code.

1.8 Conclusion

The current trajectory of dense, septic-served development in the District's WHPAs is incompatible with long-term protection of the drinking water supply. Existing data show rising nitrate contamination concurrent with increasing residential density. Regulatory frameworks require that groundwater of higher quality be protected from degradation, and the financial consequences of inaction could be severe. To safeguard the District's wells—now and for future decades—development densities and wastewater practices within WHPAs must be substantially revised.

2.0 Introduction

This technical memorandum has been prepared to summarize concerns related to the recent and proposed development of single-family residences utilizing individual on-site septic systems within the designated WHPA for the District's municipal water supply wells. This document describes the risks to groundwater quality from existing and future development, discusses the applicable regulatory framework for development within the WHPA, and suggests approaches to protect the long-term public drinking water supply.

2.1 Authority of Enforcement

The Federal Safe Drinking Water Act requires every state to develop a Wellhead Protection Program. The state DOH administers the program. Other state agencies such as the Departments of Ecology (Ecology) and Agriculture integrate wellhead protection into their programs.

The District has the duty and authority to protect the groundwater resource.

WAC 246-209-100 requires all Group A water systems to include a wellhead protection plan in their Water System Plan (WAC 246-290-135).

RCW Title 57 Water-Sewer Districts, Chapter 57.08 outlines the powers of water and sewer districts. Specifically, RCW 57.08.005 states the following (emphasis added):

A district shall have the following powers:

(10) Where a district contains within its borders, abuts, or is located adjacent to any lake, stream, groundwater as defined by RCW 90.44.035, or other waterway within the state of Washington, to provide for the reduction, minimization, or elimination of pollutants from those waters in accordance with the district's comprehensive plan, and to issue general obligation bonds, revenue bonds, local improvement district bonds, or utility local improvement bonds for the purpose of paying all or any part of the cost of reducing, minimizing, or eliminating the pollutants from these waters;

Additionally, RCW Title 90.54 Water Resources Act of 1971, Chapter 90.54.090 states the following (emphasis added):

State, local governments, municipal corporations to comply with chapter.

All agencies of state and local government, including counties and municipal and public corporations, shall, whenever possible, carry out powers vested in them in manners which are consistent with the provisions of this chapter.

3.0 Background

The District is a municipal water service provider located southeast of Wenatchee along the west bank of the Columbia River in Chelan County, Washington. The District's service area covers approximately 23 sections (14,000 acres) and serves approximately 1,800 people based

on the growth projections from the 2019 *Water System Plan* (WSP) (RH2 Engineering, Inc., 2019).

The District’s groundwater supply wells are summarized in **Table 1**.

Table 1 - Well Construction Details

	Well 1	Well 2	Well 5	Well 6	Well 7	Well 8
Diameter (in)	12	12	8	12	16	16
Wellhead Elev. ¹ (ft)	688 ²	688 ²	757 ²	745.2	754.1	756.7
Depth (ft)	118	125	210	242	230	217
Screen Diameter (in)	12-tel	12-tel	7	10	14	14
Screen Length (ft)	15	17	15	48	35	25
Screen Details	60-slot 103’-118’	60-slot 108’-110’ 80-slot 110’-115’ 100-slot 115’-125’	100-slot 179’-184’ 80-slot 184’-194’	60-slot 191’-215’ 100-slot 215’-239’	100-slot 188’-223’	80-slot 181’-206’
Static Water (ft) ³	77	74	142	128	136	136
Tested gpm	1,000	75	300	1,200	1,600	1,600
Tested Drawdown (ft)	4	0	1	2.75	1	12
Test Duration (hrs)	4	4	7	290	4	4
Operational gpm	370	340	300	--	1,200	1,200

¹ Based on NAVD 88

² Estimated

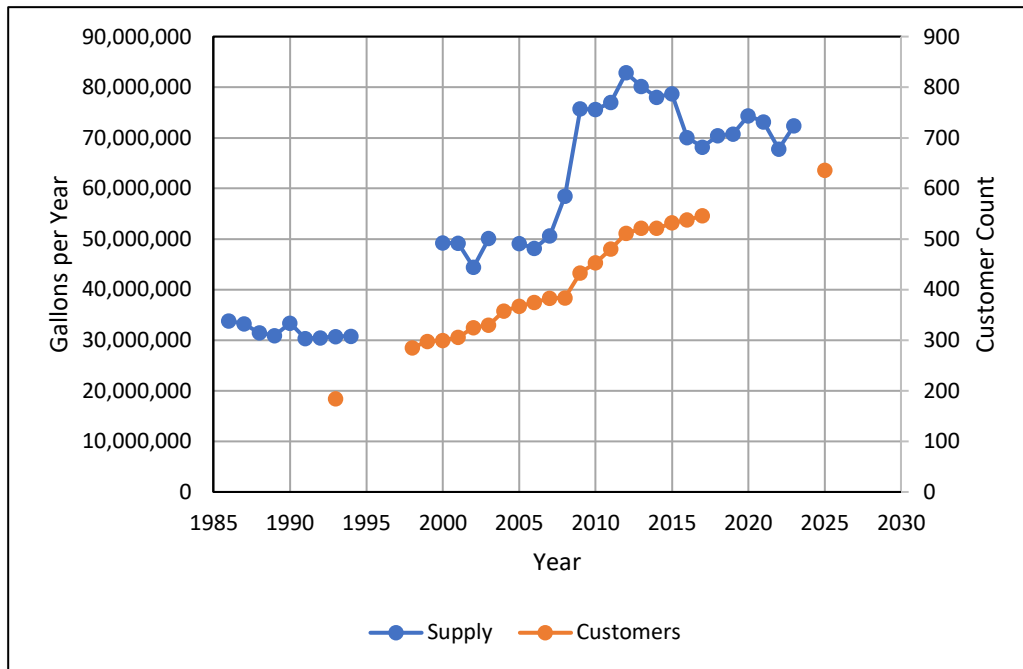
³ Water level below ground surface from original well logs.
gpm = gallons per minute

4.0 Water Use

4.1 Historical and Forecasted Demands

A history of annual water supply and customer connections is shown on **Chart 1**. The information was pulled from past WSPs; no efforts were made to research the data gaps since the trends are clear.

Chart 1 - Water Use and Customer Count History



Well meter data from 2021 through 2023 was collected in mid-2024. The results are shown in **Table 2**.

Table 2 - Recent Water Use

	2021	2022	2023
Annual (gallons)	73,150,000	67,811,000	73,400,000
Annual (cf)	9,780,000	9,066,000	9,813,000
Average Day (gpd)	200,400	185,800	198,400
Maximum Day (gpd)	430,000	400,000	380,000

cf = cubic feet
gpd = gallons per day

The WSP also forecasted growth within the District through 2040 (**Table 3**). Values shown are average day demand (ADD), maximum day demand (MDD), and peak hour demand (PHD). ADD can be multiplied by 365 to get the total forecasted annual demand.

Table 3 - Water Demand Forecast

	2020			2025			2040		
	ADD (gpd)	MDD (gpd)	PHD (gpm)	ADD (gpd)	MDD (gpd)	PHD (gpm)	ADD (gpd)	MDD (gpd)	PHD (gpm)
Zone 1	155,935	365,462	545	170,110	398,683	594	207,575	486,490	725
Zone 2	4,742	12,193	51	5,173	13,302	55	6,312	16,232	67
Zone 3	12,437	34,273	93	13,567	37,388	102	16,555	45,622	124
Zone 4	22,962	61,666	184	25,049	67,272	201	30,566	82,088	245
Zone 5	12,077	20,544	64	13,175	22,411	69	16,077	27,347	85
Zone 6	2,074	2,884	28	2,262	3,147	30	2,760	3,840	37
Zone 7	1,537	5,705	38	1,677	6,224	42	2,046	7,594	51
Total	211,764	502,727	1,002	231,014	548,426	1,093	281,892	669,212	1,334

As shown, the estimated annual use was forecasted to increase from 77 million gallons (MG) (211,764 gpd multiplied by 365 days) in 2020, to 103 MG in 2040. The WSP forecasted these demands could be met by Wells 1, 2, and 5.

About a year after completion of the WSP, Microsoft (MSFT) proposed a facility requiring water service from the District. As a condition of said service, the District required that MSFT construct improvements to both equal MSFT’s anticipated needs and provide capacity for future District customers. New customers supported by this extra capacity would provide revenue to offset the District’s costs to operate and maintain the new infrastructure.

MSFT’s estimated ultimate water demands are 18,700,000 gallons per year and 540,000 gpd MDD as presented in the Project Report, Wells 7 and 8, Ford Property Reservoirs, and Transmission Mains (RH2 Engineering, Inc., 2025).

The estimated annual MSFT demand equates to approximately 200 single family homes, 25% of recent District demand, and 18% of the estimated 2040 demand. Upon completion of the MSFT development and assuming modest growth within the District (2% annually), the District’s total annual water use may increase beyond what was forecasted in the WSP, to 122 MG by 2040.

5.0 Wellhead Protection Areas

The federal Safe Drinking Water Act (1974) requires that all states develop a wellhead protection program (WHPP). Washington State’s WHPP is administered by DOH. This wellhead requirement is intended to PREVENT the contamination of groundwater used for drinking water, as described in DOH’s *Wellhead Protection Program Guidance Document* (2017). The DOH requires that all Group A water systems create a WHPP, that establishes a WHPA around each source.

DOH suggested that most systems can use the Calculated Fixed Radius (CFR) method for estimating the WHPA.

The calculated fixed radius method draws a circular protection area for a specified time-of-travel threshold. A simple volumetric flow equation is used to calculate the radius. The

calculated fixed radius method is part of the basic Washington State susceptibility assessment (DOH, 2017).

The CFR is a simple tool used by most water systems to establish their WHPAs. It utilizes some very basic information on well construction and water use, then makes some very generalized assumptions on groundwater flow. Effectively, the radius for any specific duration is based on a steady state assumption that all of the water within the aquifer (the pore space between soil clasts) flows radially toward the well for the entire height/thickness of the well screen. **Figure 1** is a snapshot of reported by the DOH Source Water Assessment Program (SWAP) online mapper.

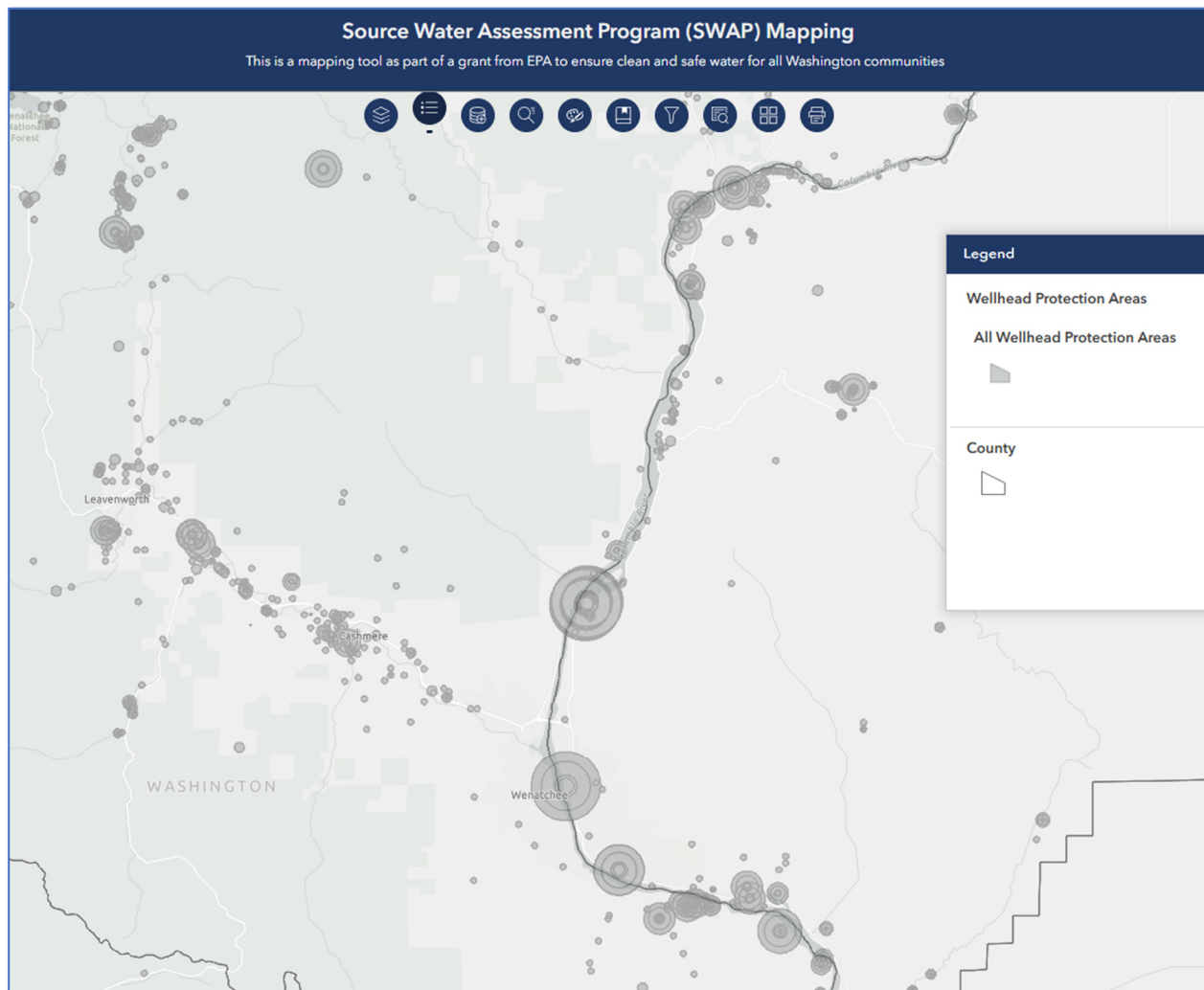


Figure 1 – Wellhead Project Areas – Greater Wenatchee Region

As shown in **Figure 1**, the water systems within the greater Wenatchee valley area show the typical circular concentric ring pattern resulting from the CFR method.

The 1994 WSP by Forsgren Associates depicted a 2,000 foot radius for Wells 1 and 2 (**Figure 2**).

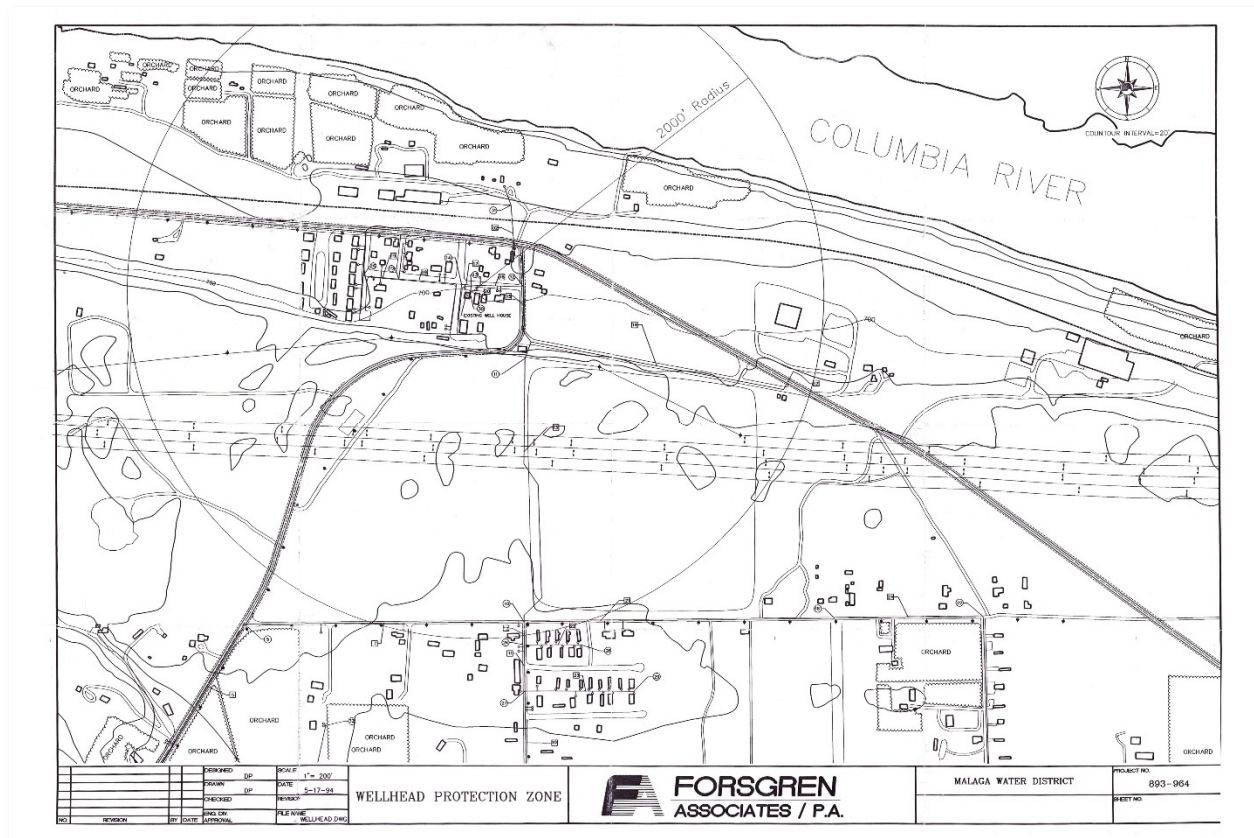


Figure 3 – District Wellhead Protection Area (1994)

The susceptibility assessment for Well 1, included as part of the appendices for the 1994 WSP, states the 10-year travel time radius at 1,240 feet. It is unclear what factored into the discrepancy between the assessment and the figure. The assessment was based on an annual water quantity of 30,750,300 gallons in 1993 (see **Chart 1** earlier).

The next WSP update was completed in 2004 by RH2 and brought forward the results from the 1994 WSP, including the discrepancy.

The 2012 WSP, also prepared by RH2 Engineering, Inc., (RH2) revised the WHPA to 1,240 feet as presented in the 1994 susceptibility assessment. However, the CFR results were not updated for actual water use, which was 50 to 75 MG at that time. This should have resulted in a WHPA radius of 1,497 feet.

Later in 2012, RH2 prepared a project report for Well 5, which included a WHPA using 120 acre-feet (39 MG) for annual flow, resulting in a 10-year radius of 2,107 feet. This area encompasses the Malaga Meadows Subdivision (approved by the County in 2024) and the proposed Malaga Meadows West and Malaga Ridge developments. This was based on the annual water rights attributed to Well 5 at that time, though the well is physically capable of producing about 150 MG annually. Since then, Well 5 has been associated with other District water rights, allowing it to legally produce more than 39 MG per year.

The 2019 WSP (RH2) includes WHPAs around Wells 1 and 2, and Well 5 (**Figure 3**). The Well 1 and 2 radius was again shown as 1,240 feet without revisions for increased use. The Well 5

radius is listed as 2,107 feet, as used in the 2012 Well 5 project report. Reviewing the archived files, the formulas used for Well 5 were inadvertently not populated into the Well 1 and 2 spreadsheet cells.

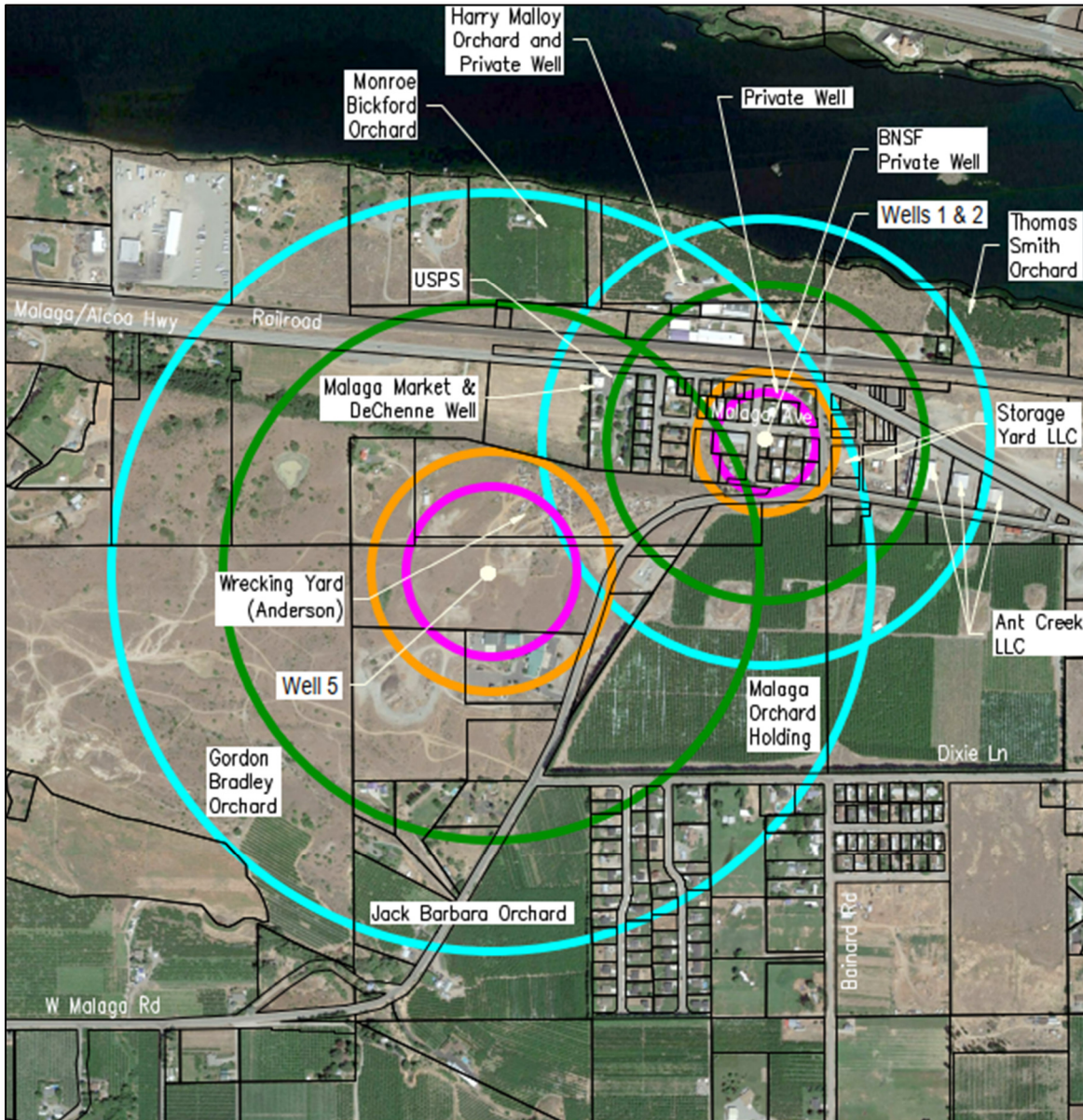


Figure 4 – 2019 WSP District Wellhead Protection Areas

Chapter 5 in the 2019 WSP includes a statement that the groundwater flow is to the southeast generally parallel with the river. This text was from the original preliminary WHPP for Well 5 and is an out of context excerpt of the 2006 *Hydrogeologic Evaluation for Wenatchee Regional Water Supply – Malaga-Alcoa Area* (RH2), which describes in a much larger Wenatchee area regional context that flow near the river may exhibit this behavior. The *Hydrogeologic Opinion CHEL 09-06, Malaga Water District – Ford Technical Memorandum* (RH2, 2009), associated with an Ecology-approved water right change, characterizes flow in Malaga as generally from southwest to northeast, consistent with current assessments.

As part of the 2025 source approval process for Wells 6, 7, and 8, the District updated its WHPP, and the associated WHPAs for all wells. Because there is no defined operational limitations on the District’s sources and to preserve District operation flexibility, each source was assumed to provide the District’s total current estimated annual supply (74 MG). These updates resulted in WHPA’s as identified in **Table 4** and **Figure 4**.

Table 4 - 2025 Wellhead Protection Area Radii

WHPA Radii (ft)	Travel Time (years)			
	0.5	1	5	10
MWD 1 and 2	647	916	2,049	2,897
MWD 5	647	916	2,049	2,897
MWD 6	354	501	1,122	1,587
MWD 7	424	599	1,341	1,897
MWD 8	501	709	1,587	2,244

MWD = Malaga Water District

For Wells 1 and 2, the larger of the two (Well 1) was reported. The largest change in WHPAs is for Wells 1 and 2, reflecting the actual tripling of annual water supply from 1994 to 2023.

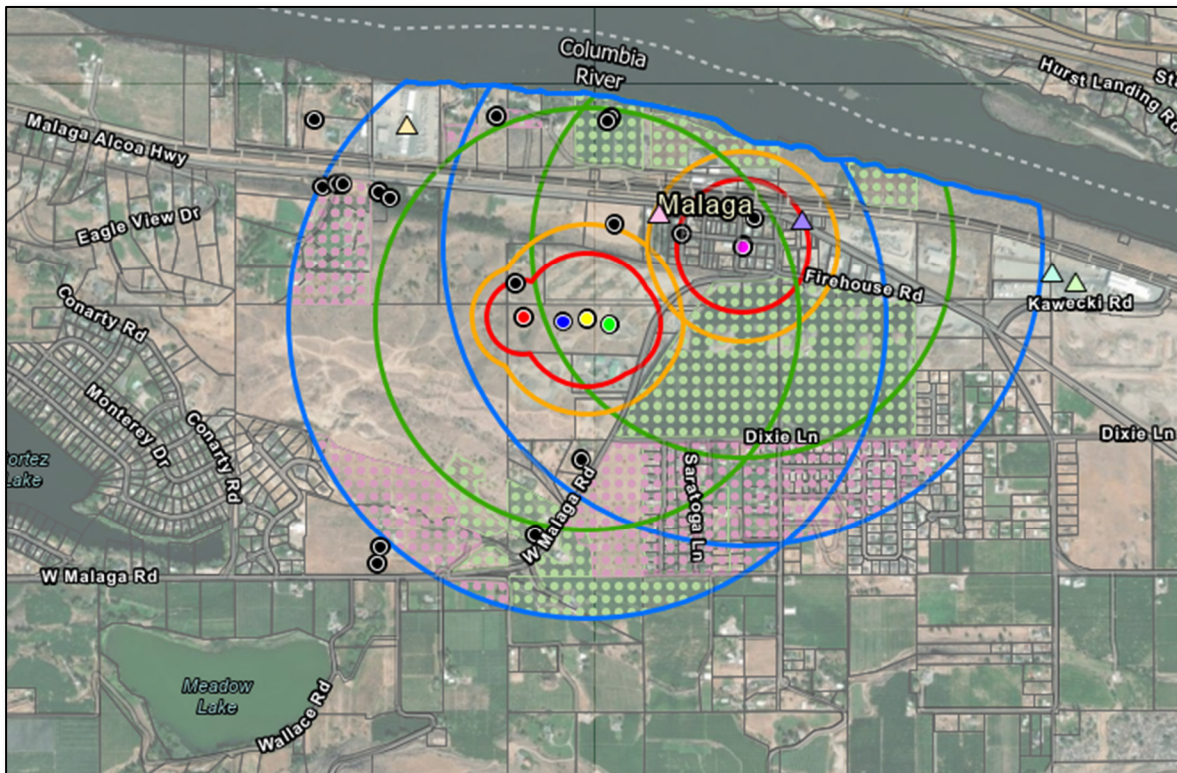


Figure 4 - District Wellhead Protection Areas (2025)

The future WHPAs will increase in size proportional to annual water use increases. The WHPAs will be reviewed during each WSP update at a minimum, typically every 6 to 10 years.

6.0 Critical Aquifer Recharge Area

Per Chapter 11 of the DOH *Wellhead Protection Program Guidance Document*, “*Wellhead protection areas meet the definition of critical aquifer recharge areas.*”

Chapters 11.77 and 11.82 of the Chelan County Code (CCC), updated in 2007, establish the Aquifer Recharge Areas Overlay District. The regulations are intended to protect groundwater quality from contamination due to human actions.

CCC 11.77.010(5) Critical Aquifer Recharge Areas states the following:

The availability of good quality, potable water is essential to the citizens of Chelan County in order to maintain a high quality of life. Identification and protection of aquifer recharge areas that are highly susceptible to potential contamination risks is essential in maintaining the quality of available potable water supplies. This district is intended to identify and protect areas vulnerable to contamination and protect potable groundwater supplies by reducing the possibility of groundwater contamination.

CCC 11.82.040 states the following:

The Administrator shall require an aquifer vulnerability evaluation for any development permit, not otherwise exempted from the chapter, if the site or development meets one of the criteria (1) through (7) below:

(1) Within a wellhead protection area designated under WAC 246-290-135...

WAC 246-290-135 directs water system purveyors to develop a WHPP and establish WHPAs as described by the DOH guidance.

As part of every District WSP approval process the County was provided a copy of the WSP and given the opportunity to comment. For the current WSP, on April 30, 2019, the County Planning Director David Kuhl signed and returned the DOH Local Government Consistency Determination Form, confirming the County had reviewed the plan and that it was consistent with adopted plans and regulations. The 2019 WSP specified a WHPA around the wells shown in **Figure 4**.

Unfortunately, the County appears to have historically ignored this designation. Malaga Meadows, a 41-lot housing development built by Real Homes, was approved on March 6, 2024, within the District’s WHPA without any vulnerability analysis, as was Red Cliff Estates (40 lots, approved in 2008). When RH2 asked how the County administers WHPAs, the County responded that it was for aquifers, not wells, and that the County did not have any aquifers (email communications July 3, 2024).

Subsequently, the County revised that position and required CARA reports for two new developments proposed by Real Homes that are within the 6-month and 1-year travel time zones of the Well 5 property, and 5- to 10-year travel time zones of Wells 1 and 2.

CCC 12.04.020 Suitability for Land Division includes the following statements (emphasis added):

(1) Each proposed land division shall be reviewed to ensure that:

(F) Identified hazards and limitations to development have been considered in the design of roads and lot layouts to assure roads and building sites are not located

in critical areas or on geologically unstable soils, considering the stress and loads to which the soil may be subjected;

(3) Lack of compliance with the suitability for land division or the criteria set forth in this title shall be grounds for denial of a proposed land division, or for the issuance of conditions necessary to more fully satisfy the criteria.

RH2 is unclear on how CCC 12.04.020 applies, and will defer to legal opinion. Nevertheless, it is RH2's opinion that conditions proposed to date by the developer and recommended by the County from the CARA studies are insufficient to satisfy the requirements of this code. Refer to the **Review of CARA Studies** section later in this technical memorandum.

6.1 Susceptibility and Vulnerability

The first two sections of CCC 11.82.010 Aquifer Recharge Areas Overlay District state the following, indicating that "vulnerability" is the primary concern:

(1) Classification is based on an evaluation of the aquifer vulnerability defined as the combination of potential for contaminant loading of a proposed land use, and the susceptibility of aquifer to contamination at the proposed site.

(2) Sites identified by this chapter as having a medium or high aquifer vulnerability rating shall be subject to the performance standards of this chapter

CCC 14.98.1845 states "'Susceptibility' means the condition of being especially sensitive and open to contamination."

CCC 14.98.1940 states "'Vulnerability' means the combined effect of susceptibility to contamination and the presence of potential contaminants."

CCC 11.82.040 and .050 allows a developer to prepare the vulnerability evaluation, upon which the County and Health District will consider while making their decision. This creates a situation of unavoidable and inherent bias as it is in the developer's own interest to define low vulnerability, while it is the County's obligation to protect the aquifer. Of special importance is CCC 11.82.050(2)(c), which requires:

(C) Review of readily available existing groundwater quality information to characterize existing water quality conditions.

The CARA studies prepared by the developer, outlined later in this technical memorandum, did an insufficient evaluation of the existing water quality, failing to accurately represent the current nitrate levels by reducing them to singular average values, and commenting only once in passing that "RH2 notes an increasing trend dating to at least 2015." The author makes no other statements about the increasing trend, and does not appear to have used the information when developing their conclusions. The author dismissed septic systems as a meaningful contaminant, thereby enabling the conclusion that the aquifer has low vulnerability.

CCC 11.77.060(2) states:

The county may retain independent qualified consultants, at the expense of the applicant, to assist in review of critical area reports.

To RH2's knowledge, the County did not retain a consultant for an independent review of the CARA studies and instead moved forward with recommendations for subdivision approval based solely on the CARA studies.

7.0 Malaga Land Use

Malaga is not incorporated and not within an Urban Growth Area (UGA), it lies entirely within unincorporated Chelan County. Because it is outside of a UGA, no sewer services are available. All developments use on-site septic systems.

The District's WHPAs encompass lands zoned by the County as follows: Rural Residential 5 – RR5, Rural Industrial – RI, Rural Commercial – RC, Rural Village – RV, and Rural Residential/Resource – RRR.

7.1 Appendix D of the Chelan County Comprehensive Plan, Malaga Vision Plan

The 2017 *Chelan County Comprehensive Plan* discusses multiple public meetings held and includes an extensive discussion of maintaining “*rural character*,” with said term described over multiple pages in many ways, including low density, with open space, and without “*a proliferation of city-size subdivisions*.” The subsequent vision statement provides little specificity about how this might be implemented.

The County recommended that development in the RRR zone may allow lots smaller than 1 acre and lots smaller than 2.5 acres within the RV zone. No mention is made that lots as small as 0.28 acres (12,000 sf) will be allowed until further into the document. The claim is also made that 12,000 sf lots are “*consistent with the existing rural character and density of the area*” which contradicts earlier descriptions of “*rural character*”.

Appendix D includes no mention of the existing aquifer, groundwater wells, the WHPA, or how unsewered development might impact water quality.

Consequently, Appendix D set the stage for the County to create a Limited Area of More Intensive Rural Development (LAMIRD) to allow urban or near-urban density development without a sewer disposal plan or groundwater protection plan.

7.2 LAMIRD and Lot Sizes

Current zoning descriptions for RRR and RV allow for a minimum lot size of 12,000 sf, if the development can obtain a septic permit from the Chelan Douglas Health District.

This zoning density, more typical of urban settings, appears to be inconsistent with the Growth Management Act (GMA) (1990). The Malaga area was rezoned following the adoption of the 2006 *Comprehensive Plan*. That plan, and the update in 2017, discusses RRR and RV as implementations of a Type I LAMIRD. The codified criteria for the GMA, WAC 365-196-425(6), describes LAMIRDs as identifying areas of pre-existing development that do not comply with the GMA (e.g., Three Lakes, original Malaga townsite), and specifies that the County needs to define a logical outer boundary. That boundary can contain some vacant land so long as it does

not create a significant amount of new development, but that the *“fundamental purpose of the logical outer boundary is to minimize and contain the LAMIRD to the area of existing development as of the date the county became subject to the planning requirements of the act.”* The County, became subject to the requirements in 1993.

The creation of the LAMIRD in 2006 increased the RV zoning from approximately 118 acres to 615 acres, an approximate 500% increase. In 1993, based on a historic aerial photo review, approximately 320 homes were within what would later be the Malaga LAMIRD area. As of 2024, there are about 730 homes. A significant amount of vacant land remains and is zoned for dense development within the LAMIRD.

The Malaga LAMIRD does not appear to be consistent with the intent of the GMA. This discrepancy is the main driver for development (on septic), without which significantly fewer homes would have been constructed, fewer septic systems would have been built, and less nitrates would have been discharged into the aquifer.

The County’s 2017 *Comprehensive Plan*, in describing the RV zoning, acknowledges the potential impacts of such high-density development in a rural setting: *“Potential impacts to the surrounding area, critical areas, and water quality shall be addressed”* (emphasis added). However, neither the plan nor appendices appear to follow through. There is no analysis of water quality impacts from high-density septic discharge or mitigation to prevent contamination.

8.0 Nitrate Regulations

The United States Environmental Protection Agency (EPA) and DOH enforce water quality limits for drinking water. WAC 246-290-310 sets the Maximum Contaminant Level (MCL) for nitrate at 10 mg/L. The existing nitrate MCL is based on the potential for developing methemoglobinemia, also known as blue baby syndrome. This condition results from nitrate inhibiting the formation of hemoglobin and ultimately restricting oxygen circulation throughout the body, which can occur due to both acute or chronic exposure to elevated nitrates.

Since this standard was set in 1992, a growing body of literature has linked chronic nitrate exposure to several additional health effects (Ward et al., 2018). For example, multiple epidemiologic studies have indicated a relationship between nitrate ingestion and colorectal cancer (Schullehner et al., 2018), thyroid disease (Ward et al., 2010), and neural tube defects (Brender et al., 2004). Many of these additional health impacts arise at nitrate levels below current regulatory limits (Temkin et al., 2019; Ward et al., 2018); levels as low as 2 mg/L of nitrate in drinking water could result in gastrointestinal cancers, thyroid dysfunction, birth defects, and premature births (Hamlin et al., 2020; Minnesota Department of Health, 2025).

The EPA is currently in the early stages of thoroughly reevaluating its guidelines and regulations surrounding nitrate in drinking water (EPA, 2023).

While most documented instances of groundwater nitrate contamination are associated with livestock and agriculture, like the Sumas-Blaine and the lower Yakima Valley, some areas of widespread nitrate contamination are strictly associated with septic discharge, like La Pine, Oregon (Hinkle, et. al., 2006).

When septic systems are used for waste disposal, there becomes an increasing correlation between housing density and nitrate contamination. The United States Geological Survey found that densities greater than 1 unit per acre had a strong correlation to nitrate contamination above 5 mg/L (Persky, 1986). EPA also expresses that groundwater nitrate levels over 1 mg/L indicate human activity (Dubrovsky, 2010).

8.1 Antidegradation Policy

WAC 173-200-030 is the State's Antidegradation Policy. Various opinions have been provided regarding the applicability to this situation, so it is included in its published state with minimal added commentary. Underlines were added for emphasis.

(1) The antidegradation policy of the state of Washington, is generally guided by chapter 90.48 RCW, the Water Pollution Control Act, and chapter 90.54 RCW, the Water Resources Act of 1971. The goal of this policy is to ensure the purity of the state's groundwaters and to protect the natural environment.

(2) The antidegradation policy is as follows:

(a) Existing and future beneficial uses shall be maintained and protected and degradation of groundwater quality that would interfere with or become injurious to beneficial uses shall not be allowed.

(b) Degradation shall not be allowed of high quality groundwaters constituting an outstanding national or state resource, such as waters of national and state parks and wildlife refuges, and waters of exceptional recreational or ecological significance.

(c) Whenever groundwaters are of a higher quality than the criteria assigned for said waters, the existing water quality shall be protected, and contaminants that will reduce the existing quality thereof shall not be allowed to enter such waters, except in those instances where it can be demonstrated to the department's satisfaction that:

(i) An overriding consideration of the public interest will be served; and

(ii) All contaminants proposed for entry into said groundwaters shall be provided with all known, available, and reasonable methods of prevention, control, and treatment prior to entry.

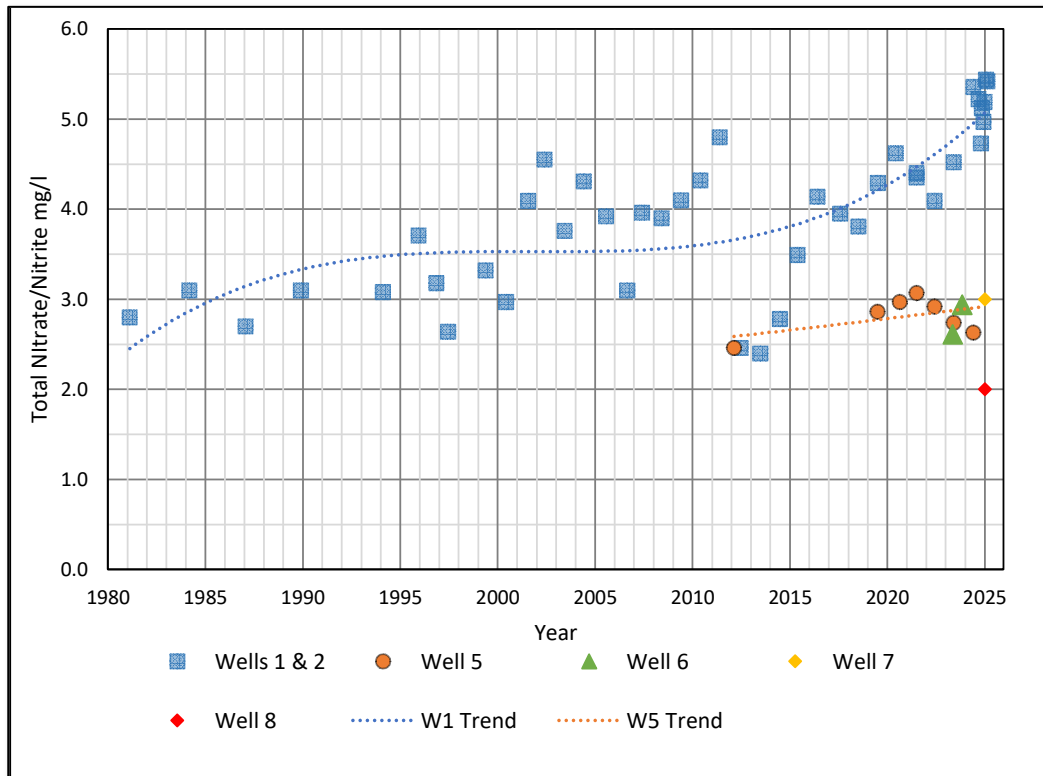
"Criteria assigned" means MCL, which for nitrates is 10 mg/L. Therefore, the Malaga aquifer is of "higher quality" since nitrate levels are below 10 mg/L. WAC 173-200-030(c)(i) and (ii) are inclusive, not exclusive, meaning both conditions must be met.

WAC 173-200-030(2)(a) is also quite clear that no proposed use impacts the groundwater in such a way as to prevent the future use of the groundwater for a beneficial use. Once nitrate levels exceed 10 mg/L, they become injurious to future drinking water uses.

9.0 Comparison of Nitrates to Home Construction

The District has tested its water sources for nitrates for over 40 years. Test results dating back to 1981 were available from the DOH website. **Chart 2** shows test results from all District wells.

Chart 2 – Nitrate Test History



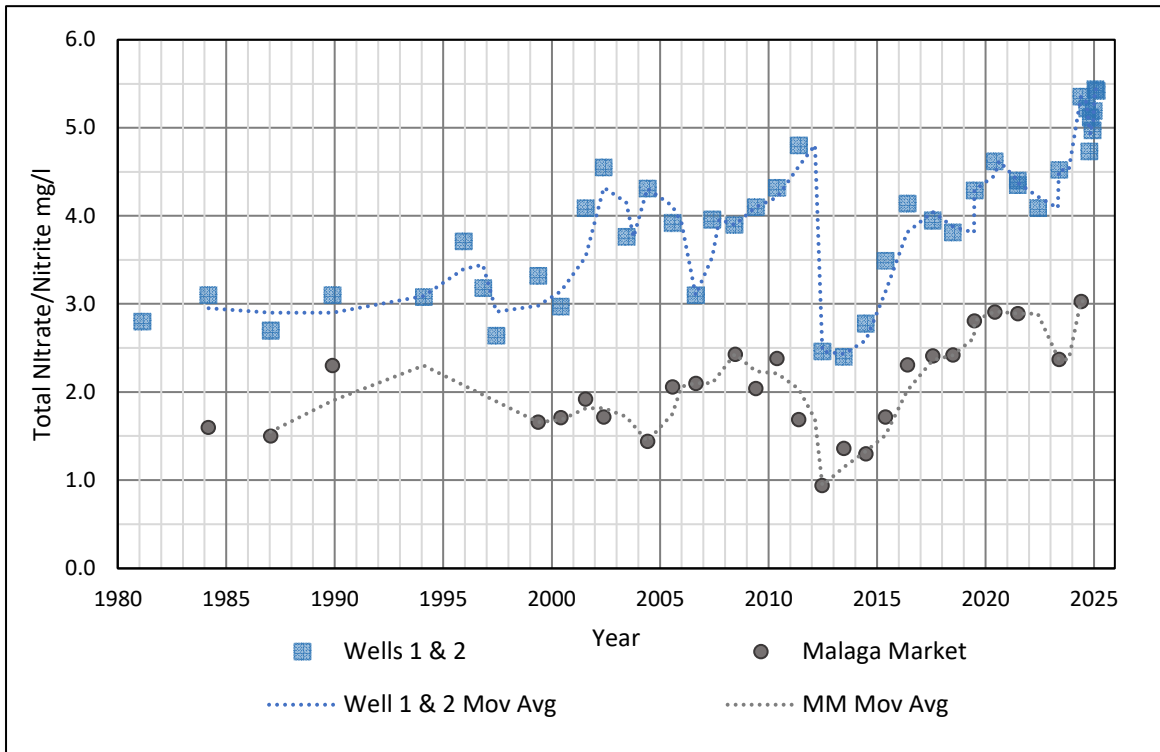
9.2 Wells 1 and 2

There is a long-term increasing trend at Wells 1 and 2, with a concerning rapid increase over the last few years. The developer’s consultant, Bill Sullivan of American Land and Water, opined verbally in a 2025 County meeting that the test result variability imparts a lack of trust in the data. Causes for the variability in the data have been only minimally researched by RH2 due to time constraints. RH2 did review test data for Wells 4 and 5 in East Wenatchee, about 3 miles away on the other side of the Columbia River. The wells were chosen because they are not subject to Malaga aquifer conditions, have high nitrates, and tests were usually performed by the same labs. While variations in those tests were seen, the East Wenatchee variations from the mean were +/- 20% and averaged 9% where District variations were +/-40% and averaged 18%. This implies the nitrate levels are likely affected far more by local aquifer conditions than laboratory methods, otherwise we would expect to see similar variations.

Section 10.1.2 of the 2020 DOH *Water System Design Manual*, states: “Nitrate in groundwater may fluctuate seasonally due to rainfall, irrigation practices, and other land use practices.”

For a second comparison, tests for the Malaga Market Well were obtained from DOH (**Chart 3**).

Chart 3 – Wells 1 and 2, Malaga Market Well

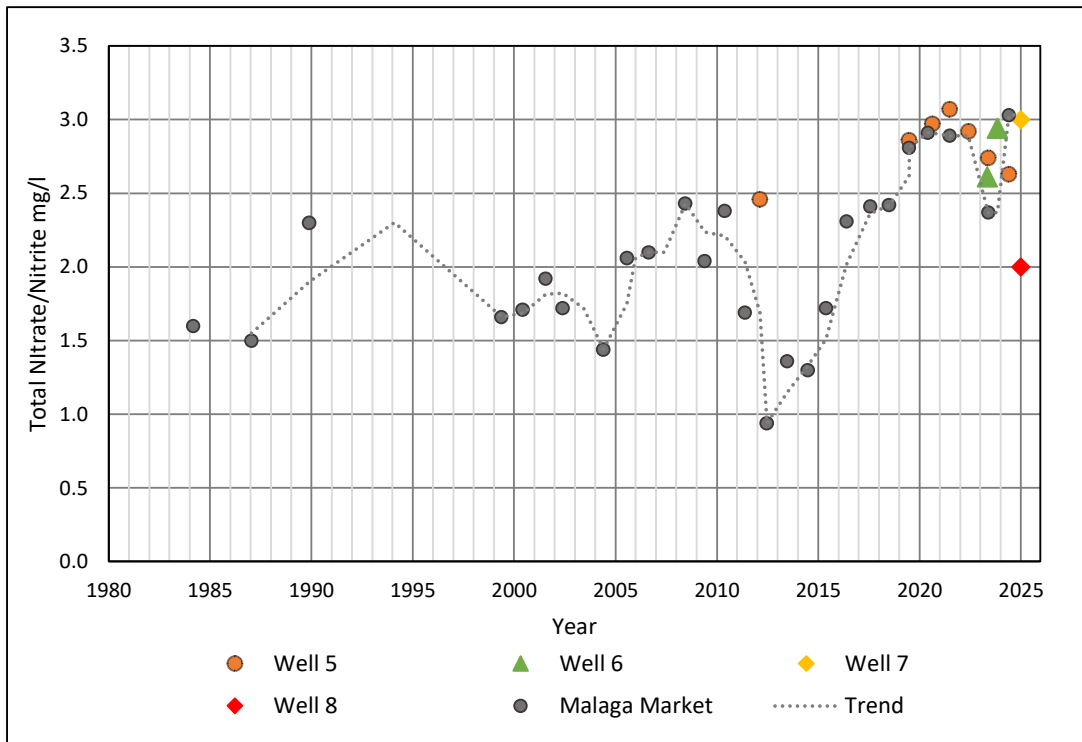


The Malaga Market well is about 1,000 feet west of Wells 1 and 2 and draws from the same aquifer. Being further west from most residential development than Wells 1 and 2, the nitrate levels are expected to be lower than Wells 1 and 2. However, the rise and fall pattern mimics nearly exactly that of Wells 1 and 2, implying that there are no data quality issues, but that local or regional conditions are affecting short term nitrate fluctuations.

9.3 Well 5, 6, 7, and 8

Only recent test data is available for wells 5, 6, 7, and 8, so trends are unlikely to be discernable. The Malaga Market tests are included in **Chart 4** since that well is in line with the assumed aquifer flow path under the Well 5 property, so similar nitrate levels are expected.

Chart 4 - Wells 5-8, Malaga Market Well



As expected, the Well 5 test results match very closely with Malaga Market.

9.4 Home Construction

Home construction records were obtained from the County’s website for properties within the WHPAs. The dates of construction were plotted against the nitrate test records for Wells 1 and 2, and Well 5 (Charts 5 and 6).

Chart 5 – Wells 1 and 2

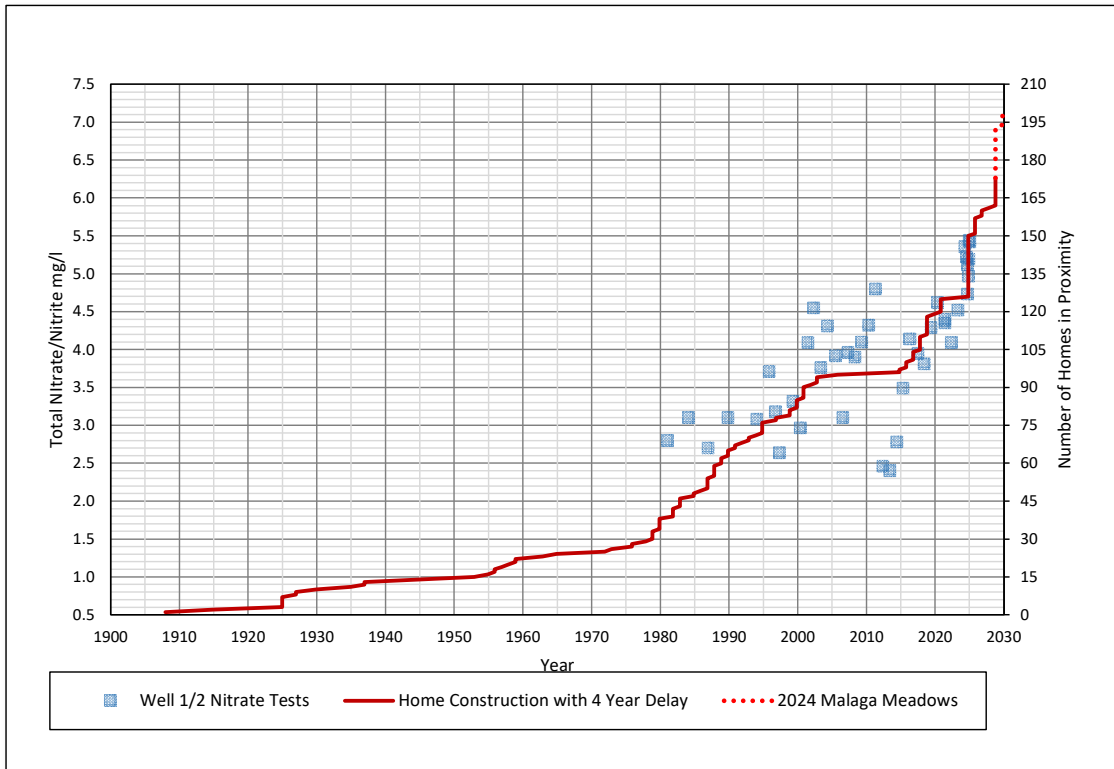
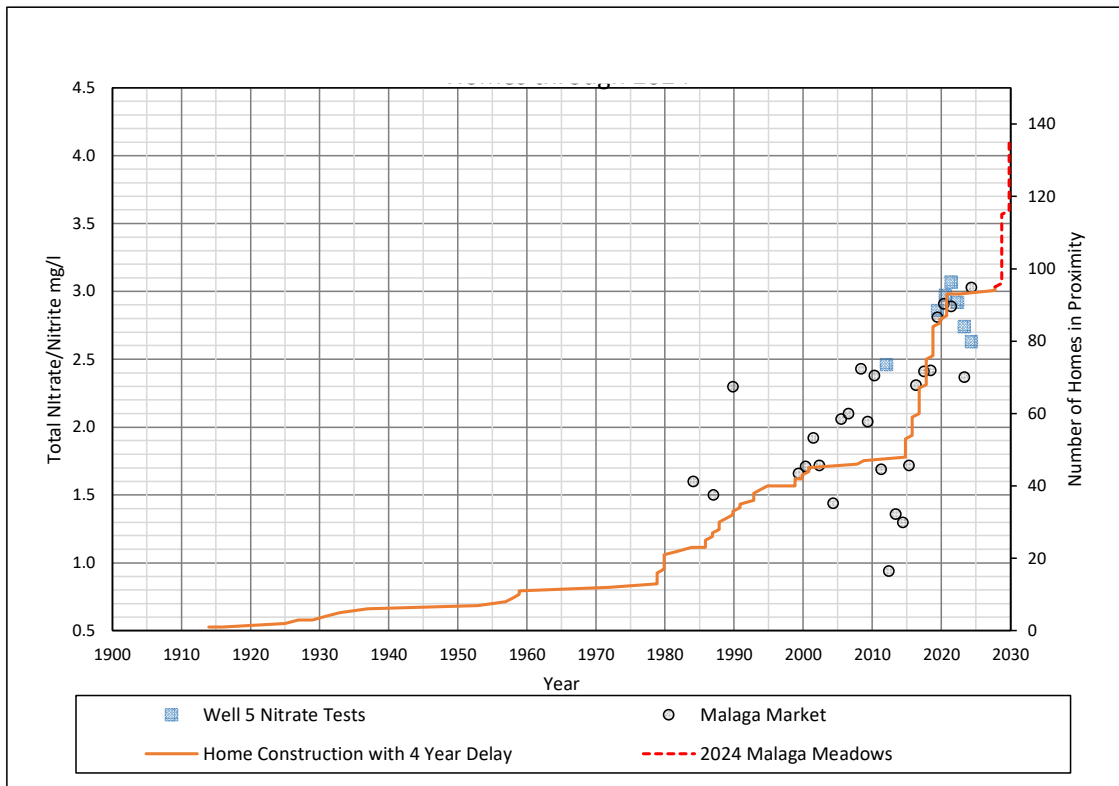


Chart 6 – Well 5



On both charts, the recently built 40 lot Malaga Meadows subdivision is shown as a different dashed line-type since it is not built-out and septic effluent from those lots likely has not have reached the wells yet.

These are simple comparisons with no individual adjustments for distance or bearing. The only adjustment was to offset all home construction by 4 years as an estimated average time for septic effluent to pass vertically through the varying geologic layers to reach the aquifer and then horizontally to the wells.

While this does not prove nitrate increases from septic systems, the comparison seems difficult to dismiss as a coincidence.

9.5 Proximity Effect

The closer a septic system is to the well, the less the effluent will be dispersed, diffused, or diluted to lower concentrations before being withdrawn. The angular offset (bearing) from the general aquifer flow direction has a similar effect. RH2 performed estimations of the effect of distance and bearing of each home from the wells, but the results were similar enough to the simple comparison presented in **Charts 5** and **6** that they provided no additional insight.

Nitrate levels at Wells 5 through 8 are lower than Wells 1 and 2 likely because the existing dense residential development is closer to Wells 1 and 2. Real Homes has proposed two subdivisions near the Well 5 site and in-line with the assumed aquifer flow direction, more so than existing developments, with the exception of the original town site around Wells 1 and 2. Therefore, contamination from septic effluent may be higher per lot from these proposed subdivisions than from most existing lots. There are about 100 acres of vacant land zoned for development on septic system directly upgradient from Wells 5 through 8 in the WHPA.

10.0 Review of CARA Studies

Real Homes hired American Land and Water to prepare CARA reports for the proposed Malaga Ridge and Malaga Meadows West subdivisions. The two reports are essentially identical, except for the specifics related to lot count. RH2 reviewed those reports on behalf of the District and discussed the review with the author. The author made some revisions per the discussions but made no change to the conclusions. RH2 agrees with much of the content, but disagrees on several important points.

As discussed in the **Critical Aquifer Recharge Area** section, the County code centers on an evaluation of aquifer vulnerability.

10.1 Aquifer Vulnerability.

The CARA author provided estimates of potential nitrate increases measured at the property line (point of compliance) that could result from the development. However, these estimates are highly sensitive to assumptions used for the aquifer hydraulic gradient, orientation and location of septic fields, treatment system effectiveness, and aquifer transmissivity at any given location. What is important is the acknowledgement that septic systems may cause a

measurable increase in nitrate levels, contradicting the author's own conclusions that septic systems are an insignificant risk and of "de minimus" and "minimal impact".

Historical nitrate test data only after 1995 is mentioned. The data is then condensed to singular average values. The author notes the increasing trend in passing with no follow-up.

Wells 5 and 6 (upgradient): Nitrate concentrations from six samples collected between 2012 and 2023 ranged from 2.5 to 3.1 milligrams per liter (mg/L) and averaged 2.9 mg/L.

Wells 1 and 2 (downgradient): Nitrate concentrations from 30 samples collected between 1995 and 2024 ranged from 2.5 mg/L to 5.3 mg/L and averaged 3.9 mg/L. RH2 Engineering (2024) notes an increasing trend in these wells dating to at least 2015.

The CARA is not in compliance with CCC 11.82.050(2)(C), which states the CARA must include the following:

(C) Review of readily available existing groundwater quality information to characterize existing water quality conditions;

Nitrate test data is readily available to anyone through the DOH Sentry website.

By not including all nitrate test data, not displaying the data graphically, and condensing the results to a single average value, the CARA could be interpreted as the author does not believe there is an upward trend, and such trend is only RH2's opinion. The increasing trend is not an opinion; it is a fact (**Charts 2 and 3**).

The Author inaccurately describes the aquifer vulnerability as follows:

The vulnerability of the flood deposit aquifer to impacts from the proposed Project is assessed to be low considering low to moderate aquifer susceptibility and relatively minor impacts typically associated with properly designed and permitted residential developments and OSS.

Considering the low to moderate susceptibility of the aquifer to contamination and low aquifer vulnerability to the proposed residential development, we assess the risk of potential impacts to the environment and public health from the Project to be low.

Considering the low to moderate susceptibility of the aquifer to contamination and low risk of contamination from the proposed residential development, we assess the vulnerability of the aquifer to potential impacts from the Project to be low.

Stating a low risk of contamination is inaccurate. There is a high, or even 100% chance of contamination from septic effluent. The magnitude of contamination is the only issue subject to interpretation.

The author seems to dismiss the State's well susceptibility ratings and disconnects the wells from the aquifer, consequently qualifying the aquifer as having low to moderate susceptibility.

DOH's source susceptibility assessments are rated as high for District Wells 1, 2, and 5 and moderate for Malaga Market's well. This rating is based on the presence of coarse-grained soils and depth to groundwater less than 150 feet (DOH, 2005). DOH's source susceptibility rating

addresses individual supply wells while an aquifer susceptibility and vulnerability rating under Chapter 11.82 CCC addresses potential impacts to the underlying aquifer from proposed development.

In multiple locations the author states that DOH considers any increase of less than 2.0 mg/l nitrate levels to groundwater to be minor. This 2.0 mg/l value is then used by the author as the basis to establish vulnerability.

(Malaga Ridge CARA) Applying DOH's Level 1 nitrate loading screening tool to the Project indicates aquifer loading from the Project estimated at 1.2 mg/l will be within the criterion of 2 mg/l considered by DOH to be a minor increase.

The 2 mg/L value comes from a single sentence within instructions on how to use a Large On-Site Sewage System (LOSS) spreadsheet. The specific text from those instructions states: *"In general, a moderate impact is an increase greater than 2 mg/l above background."*

Each CARA is written independently for each subdivision, without acknowledging the cumulative effect of the two subdivisions which could be more than 2 mg/L.

Stating that any increase less than 2 mg/L is acceptable without a reference baseline is inappropriate. For example, if adding less than 2 mg/L results in exceeding regulatory levels or triggers, that is not a minor increase by any definition.

RH2 emailed Ashley Beebe, the DOH Nitrate and LCR Program Manager, to ask if DOH would opine on this position. Based on the following excerpt from Ashley's email, it is clear that 2.0 mg/L is not considered by DOH to be a minor impact. Underlines are added for emphasis.

Ashley Beebe: This may be a question better suited for our LOSS team, which is where the referenced publication comes from. I've never seen any such statement in our drinking water publications on nitrate. I will let Sheri chime in if she has seen it in any DOH engineering guidance. And I agree with your point that if a 2.0 mg/l increase causes a trigger exceedance (5.0 mg/l) or an MCL exceedance (>10.0 mg/l) it would consider a more than moderate impact. The document references a Level 1 analysis, so I would use this a reference to the LOSS team on how they make these determinations.

A subsequent response from Andrew Jones, DOH LOSS Program and Reclaimed Water Supervisor, included the following:

Andrew Jones: In compliance with the Washington State Water Antidegradation Act, the DOH LOSS Program aims to limit nitrogen impacts at the point of compliance. We want the impacts to be less than 2 mg/l above background, or no more than 5 mg/l total. In areas with pristine groundwater, this effectively means limiting impacts to 2 mg/l total nitrogen at the point of compliance.

The 2 mg/l total nitrogen value is not an effluent limit, but a calculated value to identify Large On-Site Septic Systems (LOSS) that may have a nutrient impact to unconfined or semi-confined aquifers. The value is calculated using a simple nitrate balance that predicts effluent nitrogen concentration at a chosen point of compliance. DOH uses the value to identify LOSS that require additional study and/or treatment. Existing groundwater nitrogen values are also considered when evaluating the potential impact

from LOSS. Areas with high groundwater nitrogen levels require additional studies to determine the potential nutrient impact. Nitrogen treatment for a LOSS is required on a case-by-case basis and there is no set value for treatment limits. Setting effluent limitations for nitrogen effluent values is based on an environmental review that at a minimum considers the dispersal area soil type, flow analyses, depth to groundwater, topography, and the presence of environmentally sensitive areas that may be impacted. Septic systems most likely to require nitrogen treatment are those with high nitrogen in the waste stream, large flows, vulnerable aquifers, and areas with high background nitrogen.

Regarding multiple systems, the DOH considers each LOSS on an individual basis to evaluate the environment and public health impact of an area. The nitrate balance is used as a first-pass conservative assessment. It's only one tool we use to determine treatment limits. Sometimes, if a LOSS is proposed in sensitive areas, we also require full Hydrogeological Report to fully assess downstream impacts. The impact at point of compliance informs the permitted treatment requirements. We may determine that a LOSS must meet a treatment limit of 20 mg/l total nitrogen, in order to limit total nitrogen impacts at the point of compliance to 2 mg/l.

The CARA author has verbally opined that the State Antidegradation policy does not apply to this situation. Andrew Jones of DOH opines otherwise (see previous).

Following a discussion of geology overlaying the aquifer, the CARA states the following:

In consideration of these factors, the flood deposit aquifer is considered to have a low to moderate susceptibility to contamination.

When approached in the context of isolated contamination events, such as a fuel spill that can be responded to, this opinion is not unreasonable as the geology provides a time buffer. However, susceptibility to a perpetual source of contamination (septic systems) is high because the geology is not a true barrier. This is evident from the existing nitrate contamination.

Regarding aquifer vulnerability the CARA concludes the following:

Considering the low to moderate susceptibility of the aquifer to contamination and low risk of contamination from the proposed residential development, we assess the vulnerability of the aquifer to potential impacts from the Project to be low.

The underlined text appears to be a direct conclusion from the assertion in their preceding paragraphs that a nitrate increase from any one subdivision expected to be less than 2.0 mg/L is not consequential.

The CARAs include proposals to provide individual septic treatment systems at each household to reduce nitrates by an estimated 60% to 70%. The following are several issues with this proposal and questions that are not addressed.

- The proposed systems are not specifically for nitrate treatment: it is a side effect. The percentages are averages claimed by the manufacturer and individual results vary significantly.

- How will the systems be maintained?
- How will nitrate levels be verified?
- What is the mitigation if test results fail? Who is responsible?
- Who is responsible for tracking and enforcement?

11.0 Financial Impacts

The financial impact of allowing this contamination issue to go unresolved or not taking it seriously enough is significant. Should nitrate levels continue to increase, the District must develop a plan for how to manage the water quality once levels reach 7.5 mg/L (DOH 2020 *Water System Design Manual*, section 5.1.2). At 10 mg/L, typical approaches are blending with other sources (potentially unavailable to the District), providing bottled water (an interim mitigation), or constructing a treatment facility plus perpetual operation. Other drinking water wells (Malaga Market, exempt private wells, etc.) drawing from the aquifer may have similar impacts.

A nitrate water treatment plant is roughly estimated at \$3 to \$5 million in capital costs and another \$200k to \$500k annually to operate. Such high costs must be borne by a relatively small number of customers, contradicting one of the County's stated goals of providing affordable housing. The District already receives concerns from citizens over the cost of their water bill, and has received requests to create "Senior" rates for those who are on a fixed income who cannot afford their existing bill.

This would also be categorized as an "injurious to [this] beneficial use" as stipulated in the Antidegradation Policy per WAC 173-200-030(2)(a).

11.1 Conditional Water Availability

Table XI of WAC 246-272A-0340 (1)(d) is typically used to establish minimum lot sizes. Though it also includes a provision that:

... The local health officer may require larger lot sizes than the minimum standards established in Table XI or Table XII of this section.

Minimum Land Area Requirement For Each Single-Family Residence or Unit Volume of Sewage and Minimum Usable Land Area							
		Soil Type (defined by WAC 246-272A-0220)					
		1	2	3	4	5	6
Minimum Land Area	Public Water Supply	21,780 sq. ft. (0.5 acre)	13,000 sq. ft.	16,000 sq. ft.	19,000 sq. ft.	21,000 sq. ft.	23,000 sq. ft.
		2.5 acres ¹					
	Nonpublic Water Supply	1.0 acre	1.0 acre	1.0 acre	1.0 acre	2.0 acres	2.0 acres
		2.5 acres ¹					
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 OSS consisting of only sewage tanks and gravity SSAS must have a minimum land area of 2.5 acres per WAC 246-272A-0234(7).

The requirements are more stringent for non-public water supply because this assumes each lot has its own well, so larger lots are prudent to protect small drinking water wells from the septic systems on each lot (WAC 246-272A-0340(1)(d)). In the case of the District, the large public wells are not remote, and the septic systems are proposed within the WHPA of the public wells. So, the Nonpublic Water Supply category is more applicable by intent. The District wells produce about 600 times the annual amount of water as a typical single family private well, thus drawing water in from further distances. Even this prescriptive 2.5 acre lot density may be insufficient to protect water quality. If more information about nitrate levels and health risks is obtained, the District might modify its position.

On August 21, 2025, the District provided a letter to Chelan Douglas Health District stating the District can provision water availability to single-family lots within the WHPAs, assuming they are allowed at all, no smaller than 2.5 acres and with advanced septic systems capable of reducing effluent nitrate rates to 15 mg/L or less. Smaller lots would be acceptable if the sewage effluent was collected and conveyed outside of the WHPA. While the District is concerned about any new nitrate loading to the aquifer, WAC 246-272A-0320 establishes 2.5 acres as the largest minimum size, though it does give discretion to the local Health Officer to adjust this value.

On November 13, 2025, CDHD sent memos to the two Chelan County Community Development planners overseeing the proposed developments and advised them that the CDCH's approval of the developments was conditional on 2.5 acre minimum lot sizes. That requirement was accepted by both planners in the revised staff reports to the hearings examiner.

Depending on the type of treatment systems, assuming full buildout at 2.5 acres per lot (about 130 lots), the home construction to nitrate level comparison (**Charts 3 and 4**) is a correlation and not a coincidence, and there are no other existing remote nitrate sources yet incoming. The District might expect to see an increase of approximately 1 mg/L to 3 mg/L over the current levels at full build out.

12.0 Conclusions

The LAMIRD established by the County does not follow the intent and may outright conflict with WAC 365-196. The LAMIRD as established currently allows an urban, or near urban, level of housing density without providing a plan for sewage disposal or protection of the drinking water aquifer.

Though the comparison of nearby home construction to nitrate levels appears compelling, there is an unquantifiable chance that nitrates from more remote areas could also be seen in the future, leading to further increases of nitrate loading into the aquifer. Septic effluent from recent construction (Malaga Meadows) has likely not yet reached the wells. Because of this, construction of additional septic systems within the aquifer recharge area should be prevented, or at least severely limited and mitigated with advanced treatment systems.

Construction of systems to transport sewage out of the aquifer recharge area would allow for development at the maximum density allowed by code and protect the groundwater. This also provides easy points of connection should a future conventional sewer system be constructed.

State grants exist to study this type of situation and there may be other funding sources to build sewer systems. Mechanisms such as reimbursement agreements (Chapter 57.22 RCW) and LID or ULID (Chapters 35.43 and 57.16 RCW) allow for reimbursement of up-front costs when benefiting properties connect to the systems. Multiple public agencies and private cooperation would be the best approach to expedite the efforts.

13.0 References

Brender, J. D., Olive, J. M., Felkner, M., Suarez, L., Marckwardt, W., and Hendricks, K. A. (2004). Dietary nitrites and nitrates, nitrosatable drugs, and neural tube defects. *Epidemiology*, 15(3), 330–336. <https://doi.org/10.1097/01.ede.0000121381.79831.0b>

Burow, K. R., Nolan, B. T., Rupert, M. G., & Dubrovsky, N. M. (2010). *Nitrate in groundwater of the United States, 1991–2003*. *Environmental Science & Technology*, 44(13), 4988–4997.

Chelan County Board of Commissioners. (2006). *Comprehensive Plan land use and zoning map amendment hearing minutes*. Chelan County Government. <https://chelancountywa.gov/files/board-of-commissioners/archives/2006/200611-nov-13.pdf>

Chelan County Board of Commissioners. (2017). *Chelan County Comprehensive Plan: 2017–2037*. Chelan County Government. <http://chelancountywa.gov/community-development/pages/comprehensive-plan-2017-2037>

Forsgren Associates. (1994). *Malaga Water District 1994 Comprehensive Plan*. Final approval September 23, 1994.

Hamlin, Q. F., Martin, S. L., Kendall, A. D., & Hyndman, D. W. (2022). *Examining Relationships Between Groundwater Nitrate Concentrations in Drinking Water and Landscape Characteristics to Understand Health Risks*. GeoHealth.

- Hinkle, S. R., Böhlke, J. K., Duff, J. H., Morgan, D. S., and Weick, R. J. (2007). Aquifer-scale controls on the distribution of nitrate and ammonium in ground water near La Pine, Oregon, USA. *Journal of Hydrology*, 333(2–4), 364–382. <https://doi.org/10.1016/j.jhydrol.2006.09.020>
- Minnesota Department of Health. (2025, September 15). *Nitrate in Drinking Water*. <https://www.health.state.mn.us/communities/environment/water/contaminants/nitrate.html>
- Persky, J. H. (1986). *The relation of ground-water quality to housing density, Cape Cod, Massachusetts* (U.S. Geological Survey Water-Resources Investigations Report 86-4093). U.S. Geological Survey. <https://doi.org/10.3133/wri864093>
- RH2 Engineering, Inc. (2019). *Malaga Water District 2019 Water System Plan*. Final approval August 14, 2019.
- RH2 Engineering, Inc. (2012). *Malaga Water Comprehensive Water System Plan*. Final approval January 2012.
- RH2 Engineering, Inc. (2009). *Hydrogeologic Opinion CHEL 09-06, Malaga Water District – Ford Technical Memo*. Approved February 18, 2010.
- RH2 Engineering, Inc. (2004). *Malaga Water District Water System Plan*. Final approval April 2004.
- Schullehner, J., Hansen, B., Thygesen, M., Pedersen, C. B., and Sigsgaard, T. (2018). Nitrate in drinking water and colorectal cancer risk: A nationwide population-based cohort study. *International Journal of Cancer*, 143(1), 73–79. <https://doi.org/10.1002/ijc.31306>
- Temkin, A., Evans, S., Manidis, T., Campbell, C., and Naidenko, O. V. (2019). Exposure-based assessment and economic valuation of adverse birth outcomes and cancer risk due to nitrate in United States drinking water. *Environmental Research*, 176, 108442. <https://doi.org/10.1016/j.envres.2019.04.009>
- United States Congress. (1974). *Safe Drinking Water Act*, Pub. L. No. 93-523, 88 Stat. 1660. Retrieved from <https://www.govinfo.gov/content/pkg/STATUTE-88/pdf/STATUTE-88-Pg1660.pdf>
- US EPA. (2023). *Protocol for the Nitrate and Nitrite IRIS Assessment (Oral) (Preliminary Assessment Materials)*. U. S. E. P. Agency. <https://iris.epa.gov/Document/anddeid=338654#>
- Ward, M. H., Jones, R. R., Brender, J. D., de Kok, T. M., Weyer, P. J., Nolan, B. T., Villanueva, C. M., and van Breda, S. G. (2018). Drinking water nitrate and human health: An updated review. *International Journal of Environmental Research and Public Health*, 15(7), 1557. <https://doi.org/10.3390/ijerph15071557>
- Ward, M. H., Kilfoy, B. A., Weyer, P. J., Anderson, K. E., Folsom, A. R., and Cerhan, J. R. (2010). Nitrate intake and the risk of thyroid cancer and thyroid disease. *Epidemiology*, 21(3), 389–395. <https://doi.org/10.1097/EDE.0b013e3181d6201d>
- Washington State Department of Health. (2020). *Water System Design Manual* (331-123). Office of Drinking Water. <https://doh.wa.gov/sites/default/files/2022-02/331-123.pdf>

Washington State Department of Health. (2017). *Washington State Wellhead Protection Program: Guidance Document*. Office of Drinking Water. <https://doh.wa.gov>

Washington State Department of Health. (n.d.). *Source Water Assessment Program (SWAP) Mapping Tool*. Office of Drinking Water. Retrieved from <https://doh.wa.gov/community-and-environment/drinking-water/source-water/gis-mapping-tool>

Washington State Legislature. (1990). *Growth Management Act*, Revised Code of Washington, Chapter 36.70A. Retrieved from <https://app.leg.wa.gov/rcw/default.aspx?cite=36.70Aandfull=true>