IDAHO CONSERVATION LEAGUE

THE 2020
GROUNDWATER REPORT

Groundwater Quality in the Magic Valley

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EXECUTIVE SUMMARY

Groundwater quality in the Magic Valley is being degraded as a result of contamination, primarily by the overapplication of fertilizers and animal waste across the Snake River Plain. The groundwater in this region is stored in the Eastern Snake Plain Aquifer (ESPA) – southern Idaho's most important source of drinking water. Although the ESPA supplies drinking water to over 300,000 Idahoans, it is particularly susceptible to contamination because of geologic factors and human activities, including the rapid growth of the industrialized dairy industry in recent decades. The estimated 425,000 dairy cows in the Magic Valley (IDA, 2019) produce as much manure as a city of 12 million people - if that city had no wastewater treatment plants. The nitrogen and phosphorus input from fertilizer, animal waste, and other sources far exceeds what typical crops can uptake, with the remainder susceptible to leaching into the groundwater.

In July 2019, the Idaho Conservation League released our first groundwater quality report for the Magic Valley. In the past year, we acquired a large amount of new groundwater data - primarily from researchers and specialists at various state and federal agencies - to update this report for 2020.

Our key findings since the last groundwater report:

1. For the third straight year, elevated total phosphorus concentrations were measured at a number of springs fed by the Eastern Snake Plain Aquifer, continuing a troubling trend of worsening water quality as identified in the 2019 report.
2. County-level analysis of groundwater data for the Magic Valley indicates that the highest and most harmful nitrate concentrations are typically found in Twin Falls, Cassia, and Minidoka counties.
3. There is growing epidemiological evidence that long-term ingestion of nitrate in drinking water increases the risk for a myriad of adverse health effects, particularly colorectal cancer. This increased risk is tied to nitrate levels below regulatory limits, indicating that the current drinking water standard may not adequately protect the public from nitrate-related health conditions.
4. 18% of public water systems in the Magic Valley have average nitrate concentrations >5 mg/L based on samples collected in the last five years, a concern given potential nitrate health effects.

A combination of stricter regulation of fertilizer and animal manure application by the appropriate state agencies along with industry-wide implementation of best management practices (e.g. cover crops, residue management, no-till planting) is necessary to prevent further groundwater contamination. This problem affects everyone who relies on groundwater in the Magic Valley, and we all share a responsibility to address the issue in accordance with our respective impacts, from the dairy operation with 10,000 cows all the way down to the individual homeowners who fertilize their front yards.

Tim Palmer photo.

INTRODUCTION

Clean water is important to Idahoans who fish and recreate in our lakes and streams. / Hannah Binninger photo.

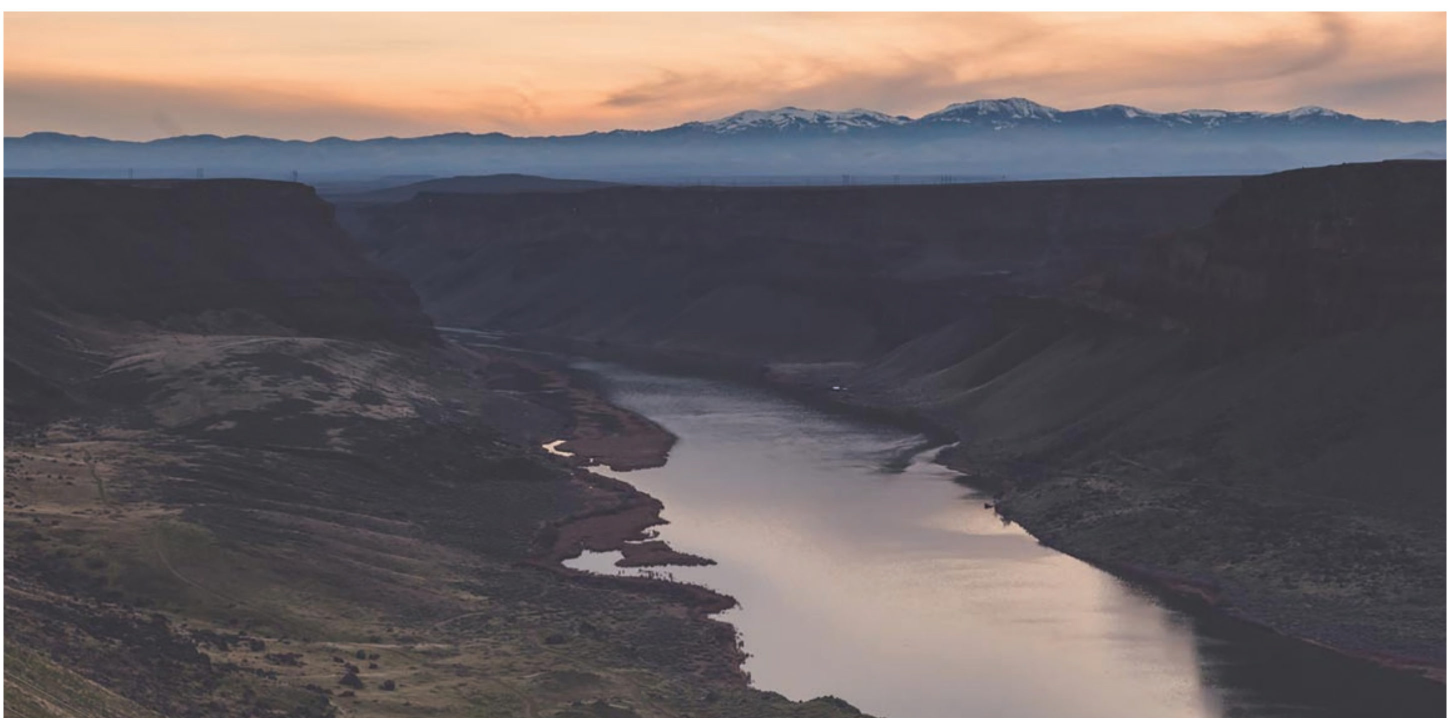
The Idaho Conservation League is Idaho's leading voice for conservation. With offices in Boise, Ketchum and Sandpoint, we work to protect the air you breathe, the water you drink and the wild places you and your family love.

The Idaho Conservation League (ICL) is currently engaged in a multi-year campaign to make the Snake River in southern Idaho swimmable and fishable again. For decades, water in the Snake River, its tributaries, and its aquifer has been polluted and overdrawn, resulting in poor water quality and declining flows. A river system that begins as a blue-ribbon trout stream in eastern Idaho and western Wyoming presently morphs into a polluted waterway that at times is unsafe to touch by the time it empties into Hells Canyon near the Oregon border. The massive scale of the problem will require an equally extensive basin-wide restoration plan involving a significant state-federal partnership.

A key objective of ICL's Snake River campaign is to improve groundwater quality in the Magic Valley region, as the ESPA is an integral piece of the Snake River system. Although the aquifer is often treated as "out of sight, out of mind" by many, it supplies drinking water to over 300,000 Idahoans and helps support a large swath of irrigated agriculture in what would otherwise be high desert. The purpose of this report is to provide an overview of the main threats to groundwater quality in the Magic Valley, examine trends in the available water quality data, and highlight public health concerns stemming from aquifer contamination – in short, to provide a snapshot of the current health of the aquifer.

The motivation for ICL's initial groundwater report in 2019 was the recognition that water quality in the aquifer was declining. The sources of pollutants that impact groundwater quality in the Magic Valley are well established (e.g. Frans et al., 2012; Skinner and Rupert, 2012; Rupert et al., 2014). Proliferation of irrigated agriculture and the rapid growth of the industrialized dairy industry have resulted in significantly increased quantities of contaminants (primarily nitrogen and phosphorus) being introduced to the landscape and subsequently transported to the underlying aquifer. Nitrate concentrations, which are already elevated in much of the Magic Valley's groundwater, continue to be a persistent problem (Mahler and Keith, 2002; Skinner, 2017). Based on available data, phosphorus seems to be a growing problem with increasing concentrations found at many ESPA-fed springs along the Snake River. Degraded groundwater quality can lead to a host of health problems and presents a serious threat to one of the most important drinking water sources in Idaho.

The arrival of the COVID-19 pandemic has highlighted the importance of public health across Idaho and the entire globe, including the fundamental need to access clean water for drinking and sanitation for local communities and industries alike. The pandemic has also had a significant economic impact on the agricultural, dairy, and fish farming industries in the Magic Valley that are discussed in this report. While the ramifications of the pandemic are still evolving, this report calls attention to important issues and we remain committed to working with partners to address the threats to maintaining access to clean water for Idaho's citizens and businesses.



Peter Lovera photo.

THE EASTERN SNAKE PLAIN AQUIFER

Geography & Geology

The Eastern Snake Plain Aquifer (ESPA) covers approximately 10,800 square miles in southern Idaho, spanning from St. Anthony to Hagerman (Figure 1). The underground aquifer generally mimics the surface geology of the Snake River Plain, a broad ground depression formed by repeated volcanic activity in the last 12 million years. The northern boundary of the ESPA generally coincides with the southern terminus of mountain ranges in central and eastern Idaho, while the southern boundary closely mirrors the course of the Snake River. The overall groundwater flow from northeast to southwest parallels a gentle regional elevation gradient in that direction. This flow pattern results in two main areas of discharge from the aquifer to the Snake River: a series of springs near American Falls and the Thousand Springs area near Hagerman (Link and Phoenix, 1996).

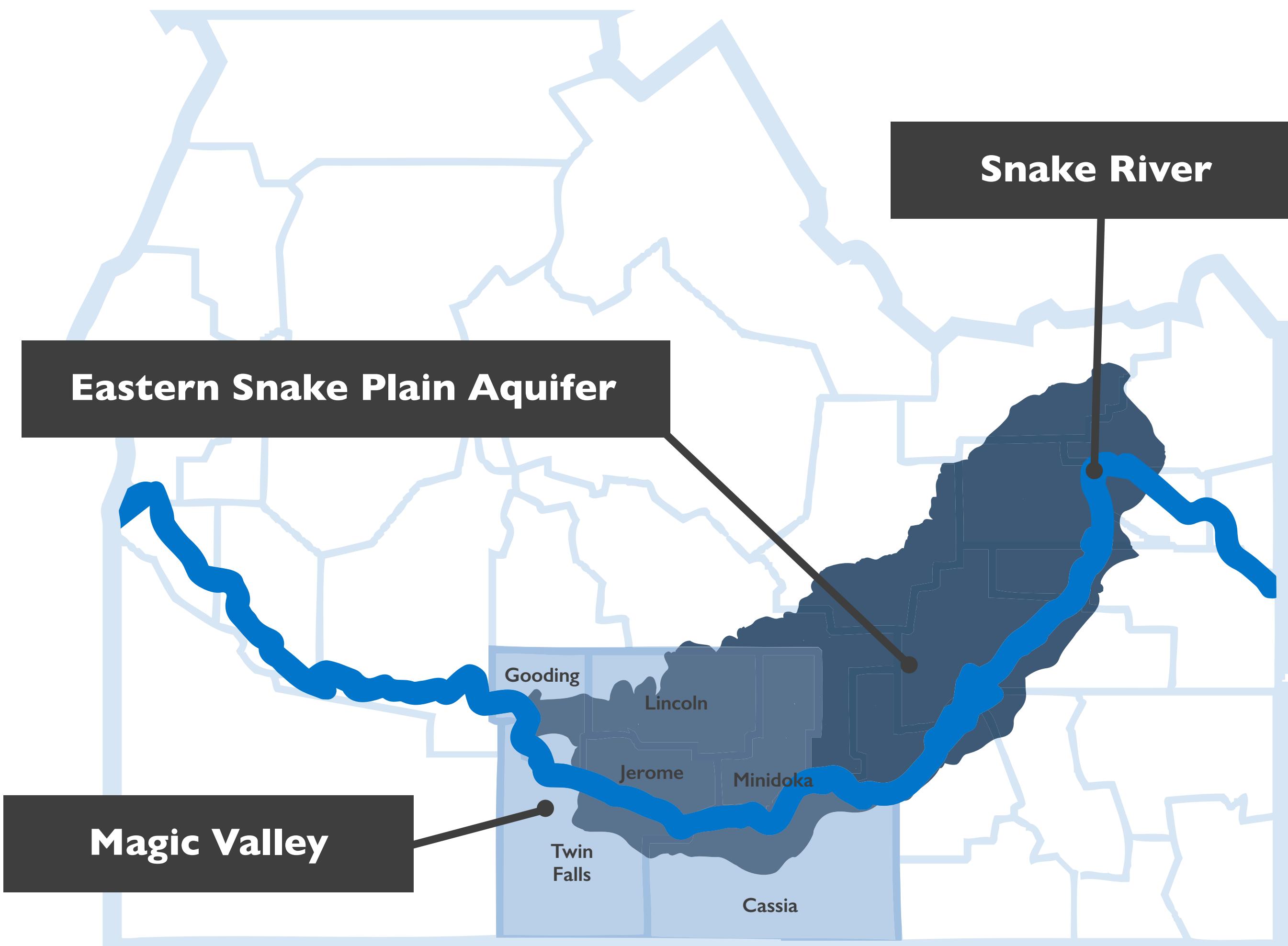


Figure 1. Map of the Eastern Snake Plain Aquifer in southern Idaho.

The ESPA's importance as a high-yielding, productive water supply for Idahoans is a direct result of its geology. Beneath the Snake River Plain, there is a very thick (~5,000 feet) stack of layered basalts formed during volcanism associated with the passage of the North American plate over the stationary Yellowstone hotspot. The basalt is highly fractured and surface water easily enters the aquifer through interconnected pore spaces in rubbly lava flows. Most of the groundwater is stored within the upper 300-500 feet of the aquifer, with a total storage capacity roughly equivalent to that of Lake Erie (200 to 300 million acre-feet) (IDEQ). The aquifer is naturally recharged by snowpack runoff from Idaho's central and eastern mountains, and is currently supplemented by excess irrigation water and managed aquifer recharge.

Importance

The ESPA is the largest aquifer in Idaho and one of the most productive in the world – a truly priceless resource. It is an Environmental Protection Agency-designated sole source aquifer that supplies drinking water to nearly 300,000 people in south-central and eastern Idaho, including the fast-growing I-86/84 corridor from Twin Falls to Rexburg.

This aquifer enables land that would otherwise be high desert sagebrush to produce the bulk of Idaho's agricultural products and support extensive dairies and feedlots. In total, there are 2.1 million irrigated acres on the ESPA, about 60% of Idaho's total irrigated acres (IDWR, 2009). The generally high-quality, aquifer-fed springs along the Snake River support a robust aquaculture industry that earned the region the moniker "Trout Capital of the World." In total, it is estimated the ESPA region produces approximately 33% of all goods and services in Idaho, valued at $14.9 billion annually (IDWR, 2015).

Tim Palmer photo.

GROUNDWATER CONTAMINATION

Given the significance of the ESPA for both drinking water and other uses, it is imperative that Idahoans have access to clean groundwater. This section provides an overview of current contamination issues in the Magic Valley and how they affect groundwater quality.

Susceptibility to Contamination

The ESPA is especially susceptible to contamination compared to other aquifers due to both geologic and human factors (Rupert et al., 2014):

1. ***Geologic Characteristics.*** The same characteristics that make the ESPA such a productive aquifer - well-drained, shallow soils and permeable volcanic rock - also make it susceptible to contamination. The high permeability of the aquifer, which stems from the fractured and porous nature of the basaltic rock, gives contaminants fast pathways into the groundwater system.
2. ***Oxic Conditions.*** Groundwater in the ESPA typically displays oxic conditions, meaning it contains at least 0.5 mg/L dissolved oxygen (Rupert et al., 2014). In oxic conditions, nitrate is unlikely to break down into inert nitrogen gas and can therefore persist for decades as a contaminant in the groundwater system (Dubrovsky et al., 2012).
3. ***Irrigation Techniques***. Excess irrigation water applied to fields seeps into the groundwater, carrying pollutants and other chemicals with it. That shallow groundwater is often withdrawn again and reapplied to the fields, which further concentrates nitrates and other dissolved constituents. Irrigation techniques in the Magic Valley have improved over time as farmers have moved from flood irrigation to sprinkler irrigation and other more efficient methods, reducing the amount of water seeping into the aquifer.

Contaminants of Concern

The primary contaminants of concern affecting groundwater in the Magic Valley are nitrogen and phosphorus. These elements play an important role in plant growth, but in excess quantities can become harmful to human health and the environment. Groundwater contamination in the Magic Valley is unequivocally linked to human activities on the Snake River Plain; naturally occurring levels of nitrogen in precipitation and snow melt are very small and background conditions are typically <0.05 mg/L nitrate. The dominant activities that contribute to groundwater contamination in this region are waste generated by large concentrated animal feeding operations, overapplication of fertilizers on agricultural fields, and to a much lesser extent, household lawn fertilizer application. Nutrient loading models indicated that leaking septic tanks contribute an insignificant amount of nutrients compared to other sources (e.g. Skinner and Rupert, 2012). Current groundwater data in Idaho is not sufficient to provide a specific attribution of nitrogen and phosphorus inputs from different sources. Researchers in Wisconsin have found that 90% of the nitrogen inputs to groundwater were from artificial fertilizers and manure; septic systems and lawn care contributed only 9% and 1% of the nitrogen inputs, respectively (Shaw, 1994).

Fertilizer use for agricultural purposes on the Snake River Plain increased dramatically after 1950 and currently is responsible for roughly 160,000 tons of nitrogen input annually (Frans et al., 2012). Since 1980, the number of dairy cows in Idaho has increased substantially, from 148,000 head in 1980 to 640,000 head in 2019 (USDA, 2020). Roughly 425,000 of these dairy cows are located in the Magic Valley region (ISDA, 2019). In one year, a dairy cow generates manure that contains an average of 58 pounds of phosphorus and 336 pounds of total nitrogen (ASAE, 2005). For comparison, in one year, the average human produces excrement containing 1.3 pounds of phosphorus and 10 pounds of total nitrogen (Del Porto and Steinfeld, 1999). Thus, the estimated 425,000 dairy cows in the Magic Valley produce manure resulting in a total annual nitrogen input equivalent to that produced by the waste of 14 million people, or nearly twice the population of New York City.[1]

Although dairies and other agricultural operations are subject to various state and federal regulations pertaining to fertilizer and waste management, these efforts have not prevented growing contamination of the ESPA. Thus, despite the fact that Idaho dairies had over 2,300 environmental inspections in 2018 (IDA, 2019) a glaring loophole still exists where dairies can "export" their waste to third-party fields that are not subject to the same waste management requirements. Irrespective of the existing industry regulations, the sheer volume of manure produced every day in the Magic Valley remains a massive logistical problem for the dairies that ultimately hinders many efforts to disperse and dispose of that waste properly. In many areas of the Magic Valley, the combined nitrogen and phosphorus input from fertilizer and animal waste far exceeds what typical crops can uptake, with the remaining nitrogen and phosphorus available to leach into surface and groundwater (e.g. Hirsh and Weil, 2019).

The State of Idaho has an ongoing aquifer recharge program in the ESPA, whereby surface water is diverted to designated recharge sites with high groundwater connectivity. The Idaho Water Resource Board (IWRB) has a stated goal of adding at least 250,000 acre-feet of water per year to the ESPA; in the winter of 2019-20, the IWRB's recharge program added nearly 450,000 acre-feet of water to the aquifer. At a basic level, any source of water entering the aquifer in large quantities has the potential to contaminate the groundwater. However, groundwater quality data obtained from IWRB monitoring wells at recharge sites since 2014 indicate quite low levels of nitrate pre (0.885 mg/L) and post (0.758 mg/L) recharge efforts, which are lower than the background nitrate concentrations in the aquifer. Additionally, given that most recharge sites are located in the upper reaches of the aquifer, recharge water will generally mix with the very clean, deeper groundwater

Aerial view of a large dairy in the Magic Valley. EcoFlight Photo.

[1] This statistic is not to be confused with the statistic presented in the Executive Summary that the Magic Valley's cow manure is equal to the waste produced by 12 million people. Because cow manure has slightly more nitrogen per pound than human manure, waste from 425,000 dairy cows produces as much nitrogen as waste from 14 million people but as much total waste as 12 million people.

in that part of the aquifer. Thus, it is unlikely that aquifer recharge is a major source of the nitrogen and phosphorus contamination currently identified in the ESPA. Nonetheless, the IWRB should continue to ensure that clean water is being used to recharge the aquifer to prevent that water use from exacerbating pollution in the ESPA.

Nitrogen and Phosphorus Leaching

The ability of nitrogen and phosphorus to leach into groundwater is a function of how these elements behave in soils. Due to its chemistry, nitrogen - specifically in nitrate form (NO_3-) - is very mobile in soils and therefore leaches relatively easily into the water (Jury and Nielsen, 1989). Approximately half of all applied nitrogen on agricultural fields drains to contaminate surface and groundwater (Davidson et al., 2012). Phosphorus, on the other hand, is largely retained in soils by a process called adsorption and does not leach easily into water (Sharpley et al., 1993; Sharpley, 1995). This marked difference in mobility helps explain why nitrate has been a more prevalent and severe problem in the ESPA as compared to phosphorus thus far. However, recent research has shown that once a soil's capacity to adsorb phosphorus is reached, the soil can no longer retain phosphorus and the excess will leach into the subsurface (Domagalski and Johnson, 2012). There are indications from recent soil studies in the region that some soils have become saturated with phosphorus and that leaching is occuring in portions of the Snake River Plain (Lentz et al., 2018), but additional study is needed to confirm the extent of this phenomenon.

Groundwater Flow

The pattern of groundwater contamination in the ESPA is primarily driven by the groundwater flow patterns in the aquifer and not the spatial distribution of nitrogen and phosphorus inputs to the land surface. As shown in Figure 2, the aquifer geometry is such that regional groundwater flow is typically from northeast to southwest. The aquifer is recharged with generally high-quality, snowmelt-derived water, which eventually mixes with lower quality groundwater closer to the Snake River. This reduced-quality groundwater (indicated in pink on Figure 2) derives mainly from percolation of human recharged, agriculturally-impacted water with elevated concentrations of nitrogen. North of the Snake River, mixing of the shallow, high-nitrate groundwater with the deeper, low-nitrate groundwater occurs as the aquifer thins with increasing proximity to the river (Rupert et al., 2014). Without this geometry-induced mixing forcing the higher quality groundwater to the surface, nitrate concentrations would be even higher than are currently observed in the ESPA (Skinner and Rupert, 2012).

South of the Snake River, the aquifer is very thin and there is little to no upwelling of high-quality groundwater from deeper in the aquifer, as is often the case in the aquifer north of the Snake (Skinner and Rupert, 2012). Thus, these areas (which include the Twin Falls metro area) are particularly at risk from groundwater contamination because they do not have the benefit of dilution with deeper, cleaner groundwater. Another factor controlling groundwater contamination is the velocity of groundwater. The groundwater north of the Snake River increases velocity as it nears the end of the aquifer and discharges from springs, which does not provide time for vertical mixing between poor-quality surface recharge and upwelling clean regional groundwater. South of the Snake River near Twin Falls, the groundwater does not upwell or accelerate so any poor-quality surface recharge has time to vertically mix and degrade the deeper, cleaner groundwater.

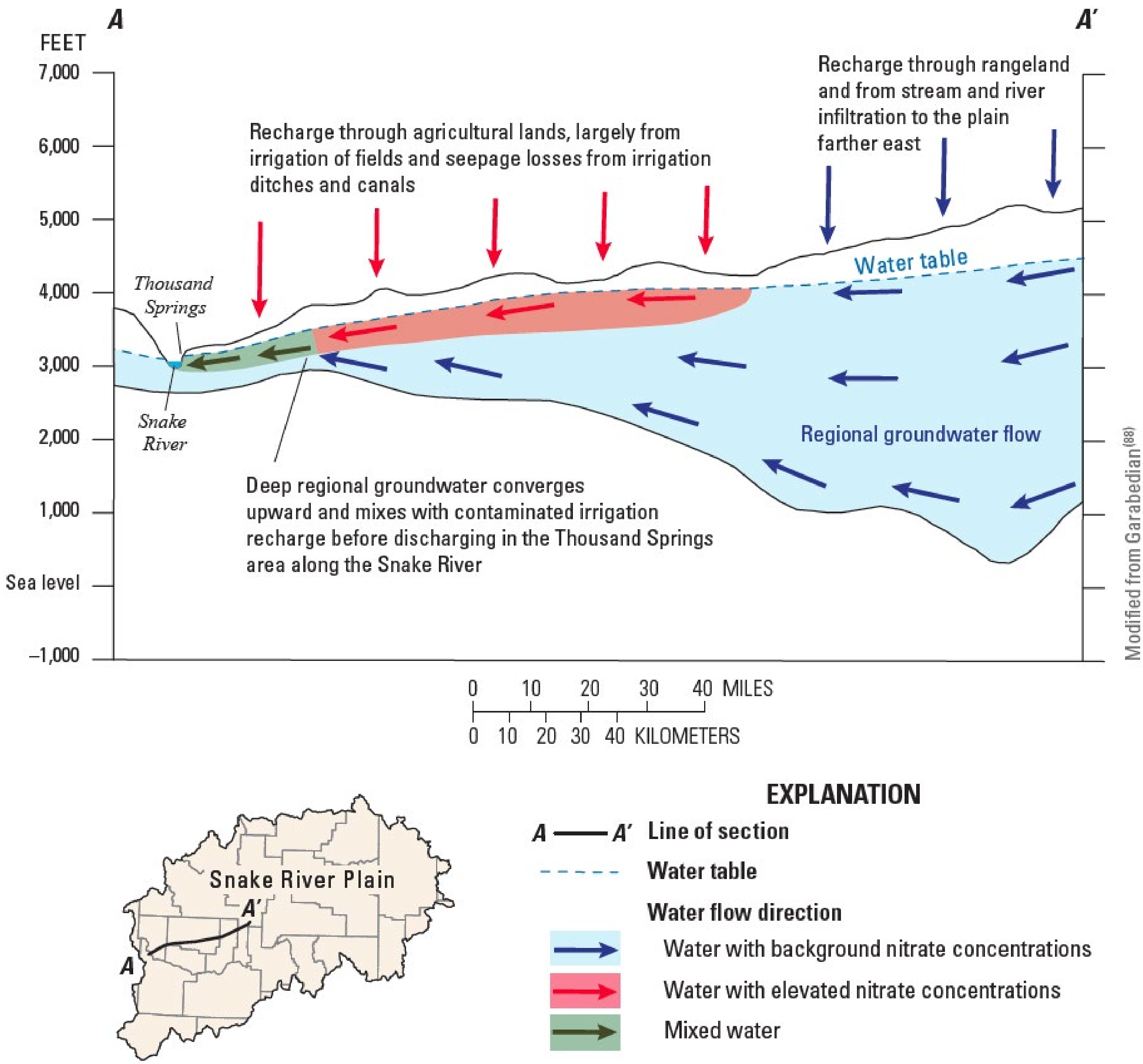


Figure 2. Diagram from Rupert et al., 2014 (Figure 6-9, pg. 49 in that report) showing how groundwater flow patterns in the ESPA influence observed nitrate concentrations.

GROUNDWATER QUALITY

Phosphorus

Phosphorus data for the ESPA remains limited compared to available nitrate data, but since the 2019 Groundwater Report, we have identified several additional data sources. Beginning in 2019, IDWR added phosphorus to the list of constituents sampled at wells that are part of their statewide monitoring program. Data is also collected at the ESPA spring sources for the Idaho Department of Fish and Game (IDFG)-operated hatcheries along the Snake River. In addition, there are numerous aquaculture facilities along the Snake River that measure phosphorus concentrations in their incoming water (typically spring water), and we recently gained access to this data through the facilities' publicly available Discharge Monitoring Reports (DMRs).

Summary of New Data

Beginning in the 2019 sampling season (and continuing for the foreseeable future), IDWR added total phosphorus to the list of constituents that they analyze for when sampling wells as part of the Statewide Ambient Groundwater Quality Monitoring Program. Over time, as more years of data are collected, this sampling by IDWR will significantly enhance our collective understanding of the scope and magnitude of phosphorus contamination in the ESPA. IDWR regularly samples 33 sites in the Magic Valley as part of the statewide program. The mean phosphorus concentration measured in the 2019 sampling cycle was 0.048 mg/L (0.032 mg/L if excluding a significant data outlier), with a median concentration of 0.023 mg/L. Because this was only the first year of phosphorus data collection from this set of wells, those initial sampling results do not yet have much significance. However, assuming that IDWR continues to analyze phosphorus in the statewide program, this dataset will eventually become quite valuable for identifying and tracking trends in phosphorus concentrations over time.

IDFG has phosphorus data for the four fish hatchery facilities they operate along the Snake River that rely on spring water from the ESPA – Hagerman State, Hagerman National, Niagara Springs, and Magic Valley. The springs feeding these hatcheries have complicated plumbing systems; they are fed by groundwater from the ESPA but can be responsive to surface water flows as well. IDFG's data demonstrate a noticeable increase in influent (spring-fed) phosphorus concentrations since 2011 at all four facilities along the Snake (Figure 3). Across all sites, the average influent phosphorus concentrations have at least doubled when comparing the most recent three-year period (2017-2019) to previous three-year periods (2011-2013, 2014-2016). The consistency of increasing phosphorus concentrations at each of the four hatchery spring sources starting in Q4 2017 is notable; this is not just an isolated rise at a single spring source. The maximum single-sample influent phosphorus concentration measured was 0.072 mg/L at the Magic Valley Fish Hatchery in 2018. For reference, the target instream total phosphorus concentration for that section of the Snake River is 0.075 mg/L, as per the current in the Mid-Snake Total Daily Maximum Load (TMDL). Please refer to Appendix I for the full hatchery dataset and additional graphs.

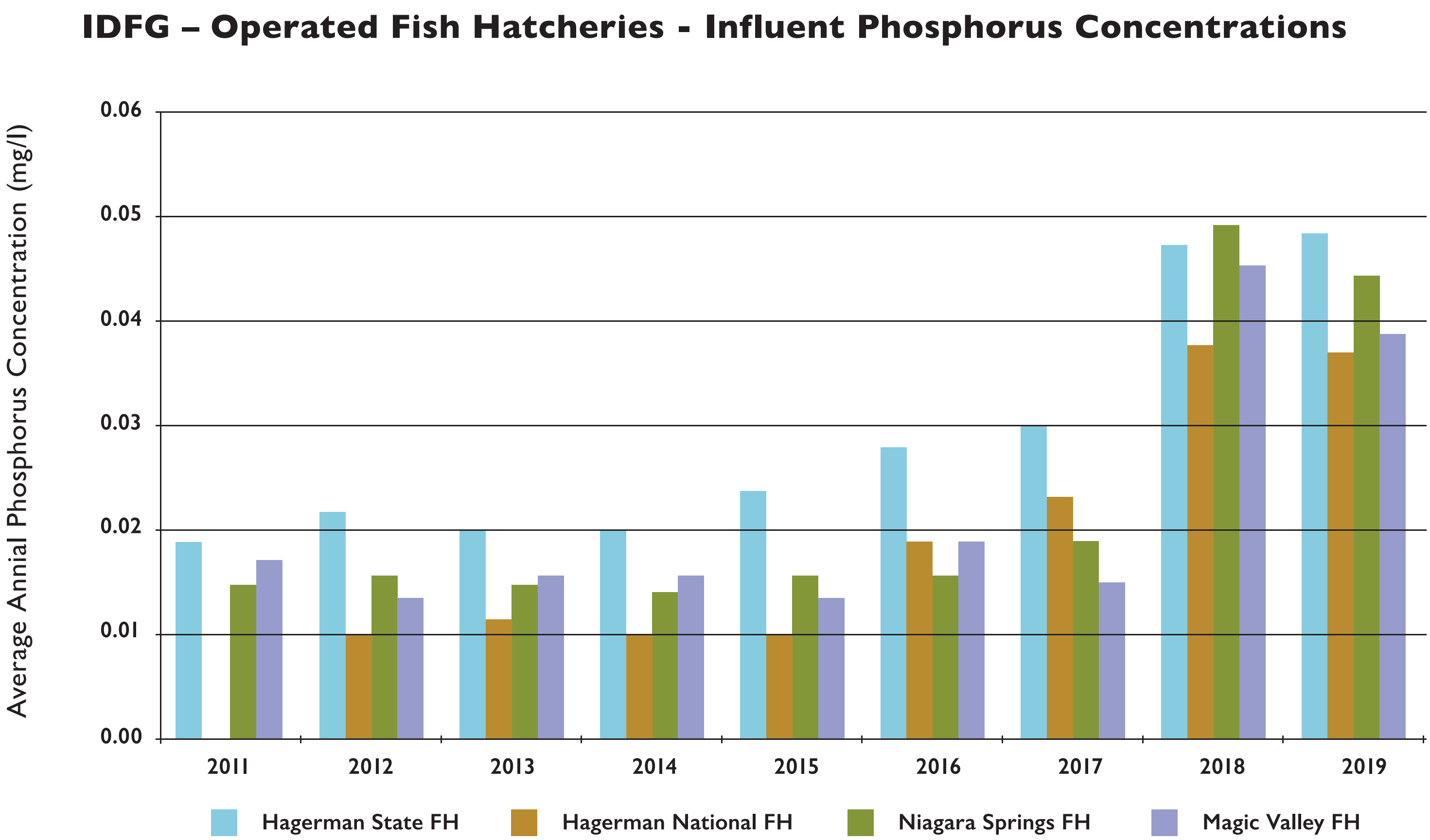


Figure 3. Graph showing increasing phosphorus concentrations in springs fed by the ESPA that flow into Idaho Department of Fish and Game hatcheries along the Snake River. Data obtained from IDFG via public records request.

The numerous aquaculture facilities along the Snake River are required to measure phosphorus concentrations of their incoming water (typically spring water) as part of their discharge permits. This data is publicly available through the facilities' monthly Discharge Monitoring Reports (DMRs). We obtained the DMRs from every aquaculture facility located on the Snake River or its tributaries within the Upper Snake Rock subbasin, where the majority of ESPA-fed springs are located. We then whittled down this large dataset specifically to focus on aquaculture facilities that get their influent water from a single spring source. We did this in order to avoid complicating our dataset with influent water that might have been mixed from multiple spring sources and/or surface water of some kind (creeks, canals, etc.). This approach left us with approximately 25 aquaculture facilities with total phosphorus data for their ESPA-spring sources, with data spanning from October 2008 to December 2019.

For this analysis, we chose to use a total phosphorus (TP) concentration of 0.02 mg/L as a reference point because that is the target groundwater concentration in the Mid-Snake TMDL. Because phosphorus does not tend to easily leach into water due to its chemical properties, groundwater concentrations above background levels are significant. From this data analysis (2008-2019), we found that:

- 56% of the analyzed springs had a majority of samples that were >0.02 mg/L TP, which is the typical maximum natural background concentration of phosphorus in groundwater.
- The average of all 2,728 TP samples from 11 years of data from these 25 springs was 0.0275 mg/L, with 51% of samples >0.02 mg/L TP and 15% of samples >0.04 mg/L TP.
- Roughly 40% of the springs showed elevated TP concentrations in the most recent 3-year time period (2017-2019).

Several data charts from the analyzed springs can be found in Appendix II.

Past Studies

In the U.S. Geological Survey (USGS) study on groundwater quality in Jerome and Gooding counties that was referenced in the "Nitrate" section, the scientists also collected orthophosphate (the dissolved component of total phosphorus) data from a total of 36 wells, which showed elevated concentrations ranging from 0.014 mg/L to 0.081 mg/L (Skinner, 2017).

Projected Trends

Phosphorus concentrations have shown a notable upward trend the last three years in various ESPA-sourced springs. At this time, it is still too early to tell if that is a long-term trend; however, it is reasonable to expect that trend to continue given ongoing land use practices. In addition, there is increasing evidence that continued phosphorus loading from animal waste and other sources could be saturating soils in isolated areas of the Magic Valley. Soil saturation prevents phosphorus adsorption and leads to increased leaching of dissolved phosphorus into the groundwater (Lentz et al., 2018). Previous studies have shown that once phosphorus leaching zones develop, they can have long-term, negative effects on groundwater quality that take several decades to return to levels compliant with water quality standards (Schoumans and Groenendijk, 2000; Sharpley et al., 2013).

Nitrate

Compared to phosphorus, there is a more robust (but still incomplete) dataset for nitrate in the ESPA. The majority of the available data we analysed was obtained from IDWR's Environmental Data Management System (EDMS) database, which compiles groundwater data from the various state agencies that collect groundwater quality data. We also received a subset of more recent nitrate data from IDEQ via public records request. Low levels of nitrate naturally occur in groundwater. Although many wells in the ESPA have background nitrate concentrations less than 0.05 mg/L, concentrations above 2 mg/L indicate that human activities have put nitrate into the groundwater (Mahler and Keith, 2002). The federal drinking water standard for nitrate is 10 mg/L, but recent studies have shown that adverse health effects can occur at nitrate concentrations below regulatory levels (Ward et al., 2018). Many of the epidemiological studies cited in that Ward et al. review paper used 5 mg/L as a marker for "high nitrate drinking water." For that reason, we have chosen 5 mg/L nitrate as a general threshold of concern for health effects related to nitrate rather than the drinking water standard of 10 mg/L (which was developed specifically for infants and blue-baby syndrome). Please refer to the "Public Health Concerns" section of this report for more information.

Summary of New Data

The available groundwater data for the ESPA clearly indicate that nitrate contamination continues to be a significant, widespread issue affecting the drinking water of Idahoans. In our analysis of all publicly available nitrate monitoring well data for the Magic Valley (Gooding, Twin Falls, Lincoln, Minidoka, Jerome, and Cassia counties) going back to 2001, 69% of all well samples had measured nitrate concentrations greater than 2 mg/L (the reference for background nitrate in most statistical analyses)[2]. 36% of these well samples showed nitrate concentrations above 5 mg/L. When looking at just the IDWR data as opposed to the full dataset from across all relevant agencies, or at data from just the last five years, there is not a substantive difference in the percentage of samples that show elevated nitrate levels.

We also analyzed the full nitrate monitoring well dataset on the county level for the Magic Valley. This breakdown, shown in Figure 4, clearly highlights Cassia, Minidoka, and Twin Falls counties as regional hot spots of elevated nitrate levels, each with about 40% of their well samples showing concentrations above 5 mg/L. This data is consistent with what groundwater flow modeling predicts for the ESPA (Rupert et al., 2014), as these three counties are underlain by portions of the aquifer that pinch out towards the Snake River and thus have a higher proportion of shallow, dirty groundwater versus deeper, cleaner groundwater.

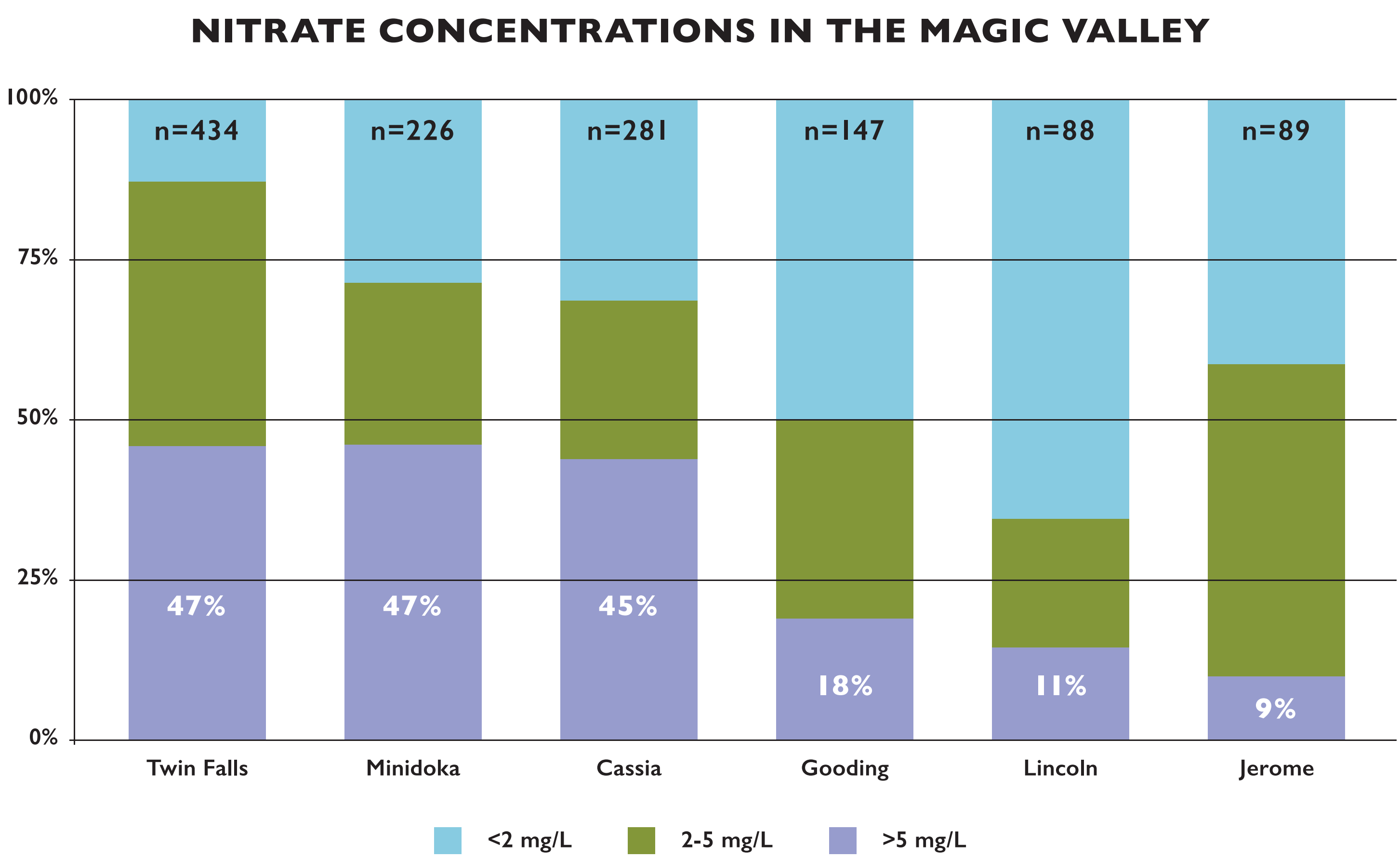


Figure 4. Graph showing the percentage of nitrate samples by concentration for each of the six counties in the Magic Valley. Monitoring well data obtained from IDWR, IDEQ, and ISDA (2001-2019).

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[2] These well samples are predominantly from the ESPA, but a small percentage come from a perched aquifer in the southern Minidoka County/northern Cassia County area that is only influenced by human-related recharge.

Through a public records request to IDEQ, we obtained a dataset containing 1,560 water samples from all of the public water systems (PWS) in the Magic Valley from the last five years. 40% of those individual well samples had measured nitrate concentrations above 5 mg/L. Thirty one of the PWS (18% of the total in the Magic Valley) averaged >5 mg/L over the last five years of sampling. The City of Twin Falls PWS, which serves a population of approximately 50,000, had an average nitrate concentration of 4.8 mg/L over the last five years. Similar to the county-level analysis we did for the monitoring well dataset, the PWS dataset also highlights Cassia, Minidoka, and Twin Falls counties as regional hot spots of elevated nitrate levels, each with about 40% of their PWS samples showing concentrations above 5 mg/L.

Past Studies

A 2012 USGS study analyzed existing nitrate data from the ESPA and found that most wells with numerous samples collected over time showed increasing trends in nitrate concentration (Frans et al., 2012). In 2017, the USGS published a report on groundwater quality in Jerome and Gooding counties. In this report, groundwater samples were taken from 36 wells and analyzed for a number of constituents, including nitrate. The data showed generally increasing concentrations with increasing proximity to the Snake River (Figure 4 in Skinner, 2017), consistent with expected concentration patterns based on groundwater flow dynamics. Nitrate concentrations above 2 mg/L were widespread in southern Jerome County and southeastern Gooding County, with an isolated maximum of 9.93 mg/L (Skinner, 2017).

IDEQ identified 34 "nitrate priority areas" (NPAs) throughout the state during its last assessment in 2014 (the next assessment will be released later this year). These are areas where at least 25% of wells sampled have nitrate concentrations of 5 mg/L or greater. Nine of the 34 NPAs in Idaho are located within the ESPA, including the top priority area (Marsh Creek NPA in the Burley area). In the 2014 assessment, wells sampled within the Marsh Creek NPA were found to have an average nitrate concentration of 7.16 mg/L and a maximum concentration of 40 mg/L, with an increasing trend from previous assessments (IDEQ, 2014). 89% of samples from Marsh Creek were found to have nitrate concentrations above background levels (>2 mg/L), with 23% of samples in excess of the drinking water standard of 10 mg/L (IDEQ, 2014).

Projected Trends

Based on numerical modeling simulations, a 2012 USGS report concluded that current hotspots of high nitrate concentrations (8-12 mg/L) will continue to increase in severity, such as southwest Minidoka County and northern Twin Falls and Cassia counties (Skinner and Rupert, 2012). Paradoxically, areas of high nitrogen input, such as western Jerome County and southern Gooding County, will continue to have relatively low nitrate concentrations (<2 mg/L) because of consistent upwelling of low-nitrate groundwater in those areas (Skinner and Rupert, 2012). USGS numerical model simulations of nitrate in the ESPA indicate that it will take 40-50 years for concentrations to fully respond to the effects of drastically increased nitrogen inputs in recent decades (Skinner and Rupert, 2012). Thus, even if nitrogen inputs were held constant for the next several decades, concentrations would continue to increase for a significant amount of time before eventually leveling off (Skinner and Rupert, 2012). This same study also showed that if all agricultural nitrogen input was stopped immediately, nitrate concentrations would begin to decline in 5-10 years. This phenomenon highlights the notable lag time between land use activities and changes in groundwater quality (Rupert et al., 2014).

IMPLICATIONS

Aimee Moran photo.

Public Health Concerns

Given that the ESPA provides drinking water to over 300,000 Idahoans, the quality of that water is paramount to those that drink it regularly, either from private wells or public water systems (where the water is treated).

Nitrate

Nitrate is a well-established cause of human health problems when it is found above certain concentrations in drinking water (Mahler et al., 2007; Ward et al., 2018). It is colorless, odorless, and tasteless in water and can only be detected by laboratory testing. The U.S. drinking water standard for nitrate is 10 mg/L, a standard developed in 1962 in order to protect against methemoglobinemia (also known as blue-baby syndrome). This condition affects infants younger than six months old. Bacteria in the digestive tracts of infants change nitrate into nitrite, which then enters the infant's bloodstream and reacts with hemoglobin (the molecule that carries oxygen in the bloodstream). This reaction produces a new compound called methemoglobin, which interferes with the blood's ability to carry oxygen. In the worst-case scenario, this process can result in decreasing oxygen levels leading to rare infant deaths (Mahler et al., 2007).

For decades, blue-baby syndrome was considered to be the primary health concern associated with nitrate in drinking water, and is still commonly reflected in regulatory health guidance (Temkin et al., 2019). This is in part due to the fact that the long-term effects of drinking water with moderate to high levels of nitrate have historically been poorly understood (Mahler et al., 2007). Prior to 2010, a scant few studies dealt with this topic. Those that did established possible links between long-term exposure to nitrate concentrations greater than 2 mg/L and increased risk of bladder and ovarian cancer (Weyer et al., 2001) as well as non-Hodgkin's lymphoma (Ward et al., 1996).

More recent studies looking at the long-term health effects of nitrate have begun to come to conclusions with increased confidence. A comprehensive 2018 review of drinking water nitrate and human health found that a large body of epidemiological research supports a connection between the presence of nitrate in drinking water and an elevated risk of cancer, adverse birth outcomes, and other health impacts (Ward et al., 2018). That review concluded that the strongest evidence for a relationship between drinking water nitrate ingestion and adverse health effects is for colorectal cancer, thyroid disease, and neurological birth defects. Crucially, many of those studies observed increased risk of those health conditions with nitrate levels that were below the regulatory level of 10 mg/L (Ward et al., 2018). This conclusion is not entirely surprising because that drinking water standard was specifically designed to protect against blue-baby syndrome, and does not take into account any other type of health risk associated with nitrate ingestion. The growing body of epidemiological evidence linking nitrate in drinking water with a myriad of human health problems other than

Justin Hayes photo.

blue-baby syndrome raises troubling questions about whether the current drinking water standard actually protects the general population (Temkin et al., 2019). Many cancer risks do not have an absolute threshold value, but the risk rises as the carcinogen level (in this case, nitrate concentrations) rises.

Given that the nitrate drinking water standard of 10 mg/L was developed in 1962 specifically for blue-baby syndrome, our conclusion is that this standard should not be viewed as any sort of "magic number" by the general public or by the regulatory agencies. Quite often, we find that elevated nitrate levels in the Magic Valley are downplayed because they do not exceed the 10 mg/L standard. However, that standard is truly only relevant from a health perspective to infants; for state or federal health officials to assure the rest of the population that their drinking water is safe as long as nitrate levels are below 10 mg/L is misguided and not based on current, relevant science. The truth is that we currently do not know what levels of nitrate in drinking water are safe for long-term consumption. In the absence of that specific information, but also recognizing that nitrate levels below regulatory limits likely do increase the risk for adverse health effects amongst adults, the goal should be to reduce nitrate levels as much as possible, not just below the outdated and incomplete regulatory standard.

This past year, the first study of its kind attempted to quantify the health and economic impacts due to nitrate in drinking water in the United States (Temkin et al., 2019). Using a meta-analysis of several existing epidemiological studies of drinking water nitrate and cancer risk, this study found that there are an average of 6,500 nitrate-attributable cancer cases annually with an economic cost of hundreds of millions of dollars for medical expenses alone (Temkin et al., 2019). The study also observed a statistically significant positive association for nitrate exposure and colorectal cancer risk (Temkin et al., 2019). Ultimately, the study concluded that lowering nitrate levels in drinking water would not only lower the risk of related adverse health effects, but would also bring economic benefits by reducing the medical expenses associated with the treatment of those health conditions.

Phosphorus

The presence of phosphorus in drinking water is not known to have direct human health effects. However, phosphorus in the ESPA contributes to the overall rise of phosphorus concentrations in the Snake River. The overabundance of phosphorus in the Snake has contributed to the formation of harmful algal outbreaks, particularly in the numerous slow-moving reservoirs along the length of the river. Recent research demonstrates that phosphorus is the key driver of algal outbreaks in stagnant water environments like reservoirs and lakes (Higgins et al., 2017). In some circumstances, harmful algal outbreaks can produce toxins that cause a variety of illnesses in humans (Fleming et al., 2002). Outbreaks of harmful algae on the Snake River and its reservoirs regularly result in closures of swimming areas and present dangers to humans, animals, livestock and pets.

Failure to Meet Water Quality Standards

If current trends continue, it is increasingly likely that the nitrate drinking water standard of 10 mg/L will be violated in the vicinity of communities such as Twin Falls, Buhl and Paul. Based on USGS numerical modeling, areas that are at higher risk of having water that violates federal/state standards include northern Twin Falls County, northwest Cassia County, and southwest Minidoka County (Skinner and Rupert, 2012). Idaho does not have a groundwater quality standard for phosphorus because it is not directly linked to human health effects in drinking water. However, the aquifer feeds numerous springs that discharge into the Snake River, which is listed as impaired for phosphorus for its entire length along the ESPA. Excessive levels of phosphorus contribute to elevated levels of aquatic plant growth that reduce oxygen levels; this leads to fish kills and reduced habitat quality. It also contributes to outbreaks of toxic algae, which poses a serious human health risk. If the springs that recharge the Snake River carry increasingly significant phosphorus loads, it will exacerbate contaminant-related problems and lead to continued violation of surface water quality standards in the Snake River.

Snake River

NEXT STEPS

South Fork Snake River / BLM Photo.

Rising nitrate and phosphorus concentrations in the Magic Valley's groundwater continue to be a problem that has serious implications for public health and the state's ability to meet its water quality standards. The available groundwater quality data, while still somewhat limited, clearly indicate that nitrate and phosphorus concentrations are well above natural background levels in significant portions of the ESPA. These concentrations are projected to continue to rise for the foreseeable future with likely worsening human health risks, especially in light of recent medical research examining potential links between long-term nitrate ingestion and cancer risk.

Groundwater contamination in the Magic Valley is unequivocally linked to human activities on the Snake River Plain – waste generated by large concentrated animal feeding operations, overapplication of fertilizer on agricultural fields, and to a lesser extent, household lawn fertilizers and leaking septic systems. To meaningfully address this growing problem and substantially curtail groundwater pollution, we suggest the following next steps:

1. Better characterize and publicize the problem. The existing groundwater quality data for the ESPA is only sufficient to highlight a growing problem, not to fully characterize the issue. The state should continue to develop a widespread monitoring well network across the Magic Valley, with the data compiled in a user-friendly, publicly accessible database. In the future we hope to use this data to pair up with demographic information to see if certain communities are particularly at risk from groundwater contamination. First and foremost, Idahoans deserve to know what's in their drinking water and if they are at risk.

2. Implement best management practices industry-wide. Widespread adoption of practices such as cover crops, residue management, and conservation tillage can help reduce leaching and runoff from agricultural fields and lessen nitrogen and phosphorus inputs to the aquifer below. One promising approach comes from an Ohio-based coalition group called H2Ohio, who have identified the 10 most effective and cost-efficient practices proven to reduce agricultural phosphorus runoff and then provide economic incentives to farmers who develop management plans that incorporate those best management practices.

3. Implement more effective and transparent management of animal waste. Existing management regulations are not sufficient to prevent the overapplication of animal waste. A publicly-available inventory of animal waste, nitrogen, and phosphorus generated at concentrated animal feeding operations should be created to increase transparency and accountability amongst some of the biggest contributors of nitrogen and phosphorus. Additionally, the third-party manure application loophole must be closed; currently, dairies can send large quantities of manure to external fields to be land applied without being subject to the same management requirements. This would take action by the Idaho State Legislature. Innovative approaches that extract pollutants from manure should also be explored.

4. Centralize oversight responsibility. The current regulatory structure as defined by the *Idaho Ground Water Protection Interagency Cooperative Agreement* splits the responsibility of groundwater quality protection and sampling amongst five different state agencies, a disjointed and ineffectual approach. Centralizing this responsibility under a single regulatory agency would improve the effectiveness and accountability of the state in dealing with matters of groundwater protection.

Simply maintaining the status quo is unacceptable if we want to protect the quality of our drinking water in the Magic Valley. This is a problem that affects everyone who relies on groundwater in the Magic Valley, and it is the entire community's responsibility to address the issue. ICL will continue to work with the relevant stakeholders and state agencies to address this issue head-on.

Please contact Josh Johnson, Central Idaho Conservation Associate,
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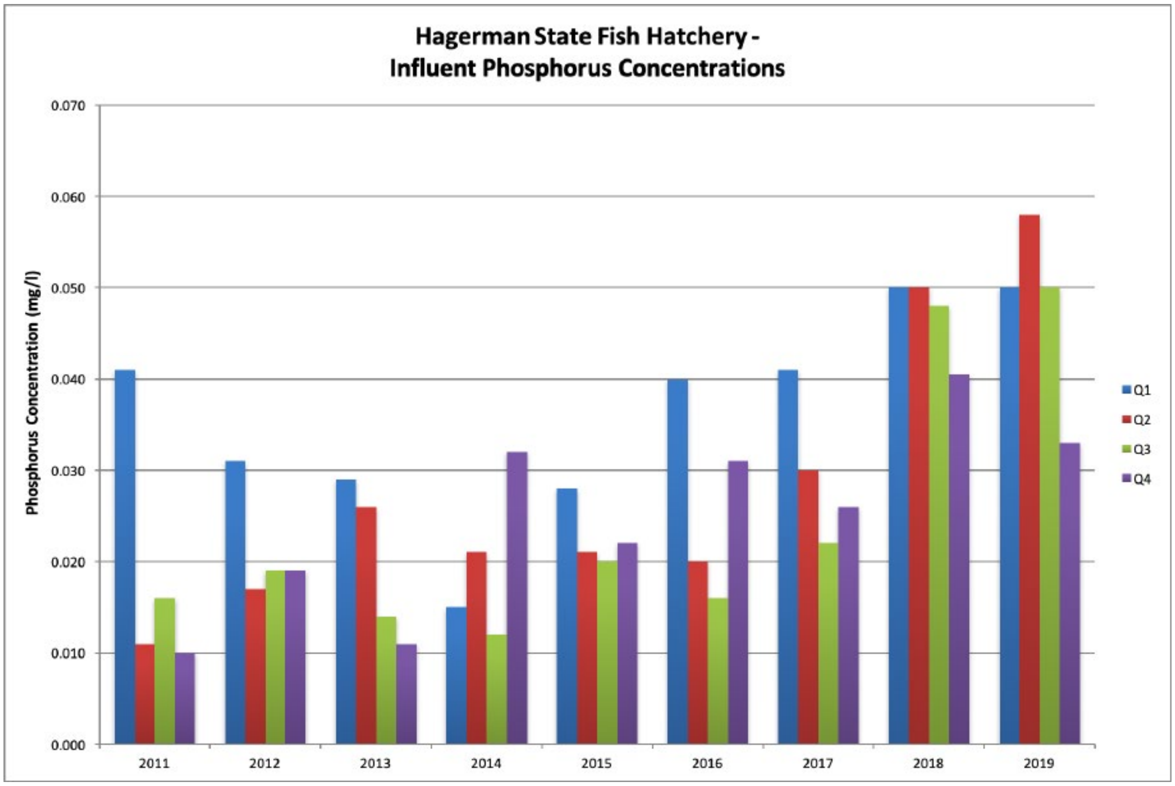
APPENDIX I - FISH HATCHERY INFLUENT PHOSPHORUS DATA[2]

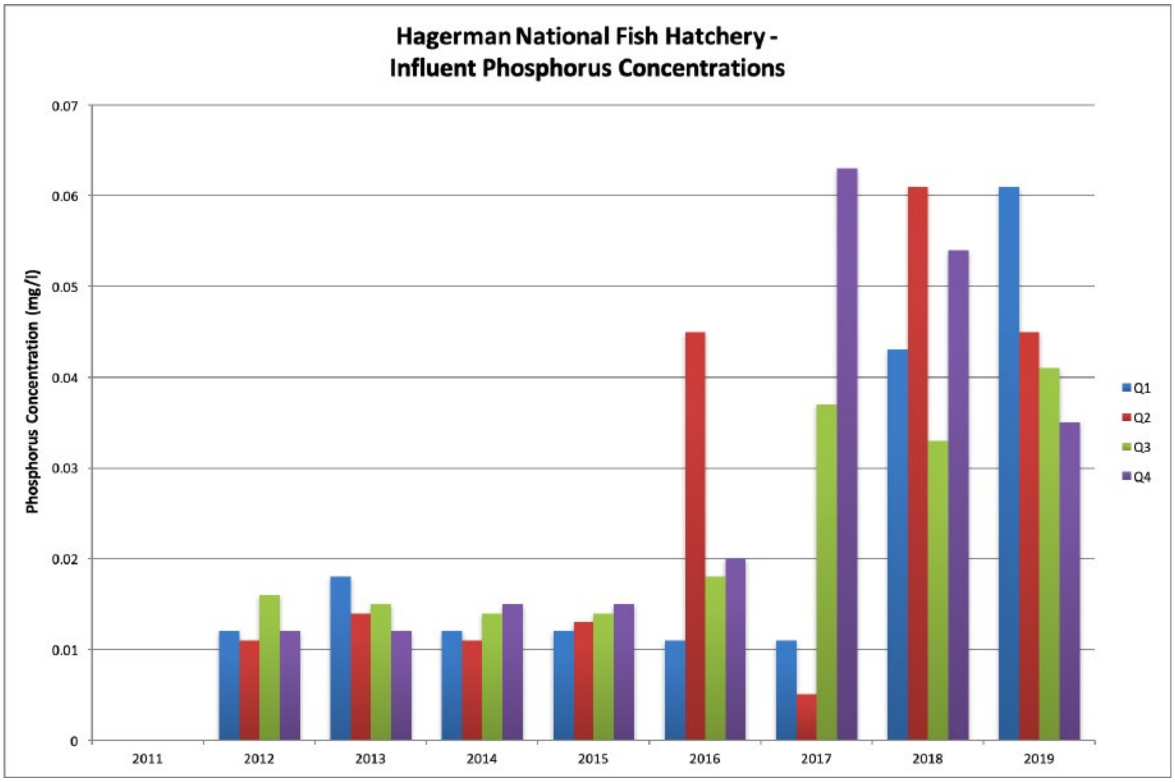


Hagerman State Fish Hatchery

Phosphorus

Switched labs in Feb 2017

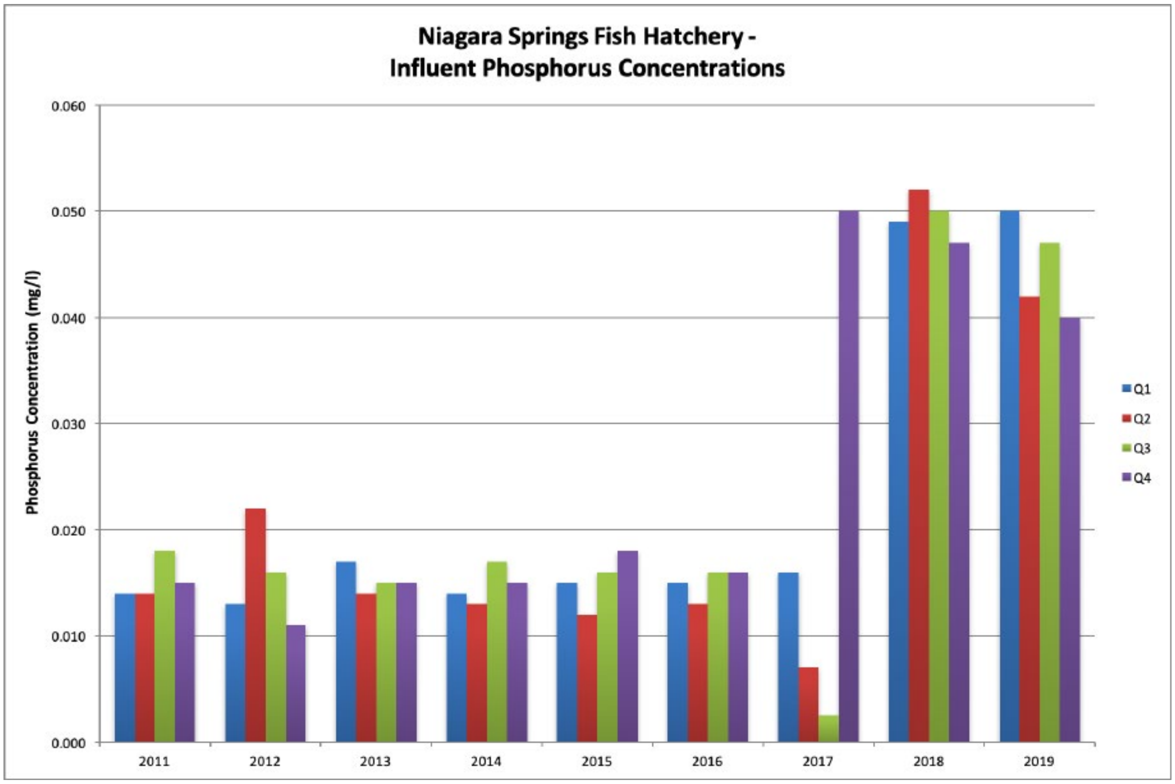
	Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	Average 2011-2016	Average 2017-2019
Quarter 1	**Influent**	0.041	0.031	0.029	0.015	0.028	0.040	0.041	0.050	0.050	0.031	0.047
	Gross	0.051	0.038	0.076	0.051	0.053	0.066	0.031	0.060	0.098		
	Net	0.010	0.007	0.047	0.036	0.025	0.026	-0.010	0.010	0.048		
Quarter 2	**Influent**	0.011	0.017	0.026	0.021	0.021	0.020	0.030	0.050	0.058	0.019	0.046
	Gross	0.020	0.028	0.041	0.056	0.048	0.058	0.050	0.059	0.074		
	Net	0.009	0.011	0.015	0.035	0.027	0.038	0.020	0.009	0.016		
Quarter 3	**Influent**	0.016	0.019	0.014	0.012	0.020	0.016	0.022	0.048	0.050	0.016	0.040
	Gross	0.022	0.026	0.036	0.039	0.046	0.030	0.042	0.056	0.072		
	Net	0.006	0.007	0.022	0.027	0.026	0.014	0.020	0.008	0.022		
Quarter 4	**Influent**	0.010	0.019	0.011	0.032	0.022	0.031	0.026	0.041	0.033	0.021	0.033
	Gross	0.044	0.052	0.035	0.033	0.038	0.037	0.030	0.072	0.053		
	Net	0.034	0.033	0.024	0.001	0.016	0.006	0.004	0.031	0.020		
	average	*0.020*	*0.022*	*0.020*	*0.020*	*0.023*	*0.027*	*0.030*	*0.047*	*0.048*		



Hagerman National Fish Hatchery

Phosphorus

	Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	Average 2011-2016	Average 2017-2019
Quarter 1	Influent		0.012	0.018	0.012	0.012	0.011	0.011	0.043	0.061	0.013	0.038
	Gross		0.039	0.058	0.053	0.027	0.041	0.031	0.063	0.063		
	Net		0.027	0.040	0.041	0.015	0.030	0.002	0.020	0.002		
	off line		0.265	0.227	0.369	0.299	0.285	0.222	0.287	0.209		
Quarter 2	Influent		0.011	0.014	0.011	0.013	0.045	0.005	0.061	0.045	0.019	0.037
	Gross		0.032	0.035	0.022	0.184	0.032	0.011	0.066	0.048		
	Net		0.021	0.021	0.011	0.171	-0.013	0.006	0.005	0.003		
	off line		0.341	0.234	0.288	0.332	0.359	0.134	0.114	0.058		
Quarter 3	Influent		0.016	0.015	0.014	0.014	0.018	0.037	0.033	0.041	0.015	0.037
	Gross		0.030	0.021	0.024	0.025	0.023	0.032	0.044	0.042		
	Net		0.014	0.006	0.010	0.011	0.005	-0.005	0.011	0.001		
	off line		0.060	0.067	0.087	0.072	0.068	0.039	0.076	0.059		
Quarter 4	Influent		0.012	0.012	0.015	0.015	0.02	0.063	0.054	0.035	0.015	0.051
	Gross		0.028	0.022	0.025	0.030	0.035	0.071	0.054	0.053		
	Net		0.016	0.010	0.010	0.015	0.015	0.008	0.000	0.018		
	off line		0.289	0.314	0.219	0.304	0.229	0.0158	0.190	0.238		
	average		0.0102	0.0118	0.0104	0.0108	0.0188	0.0232	0.0382	0.0364		

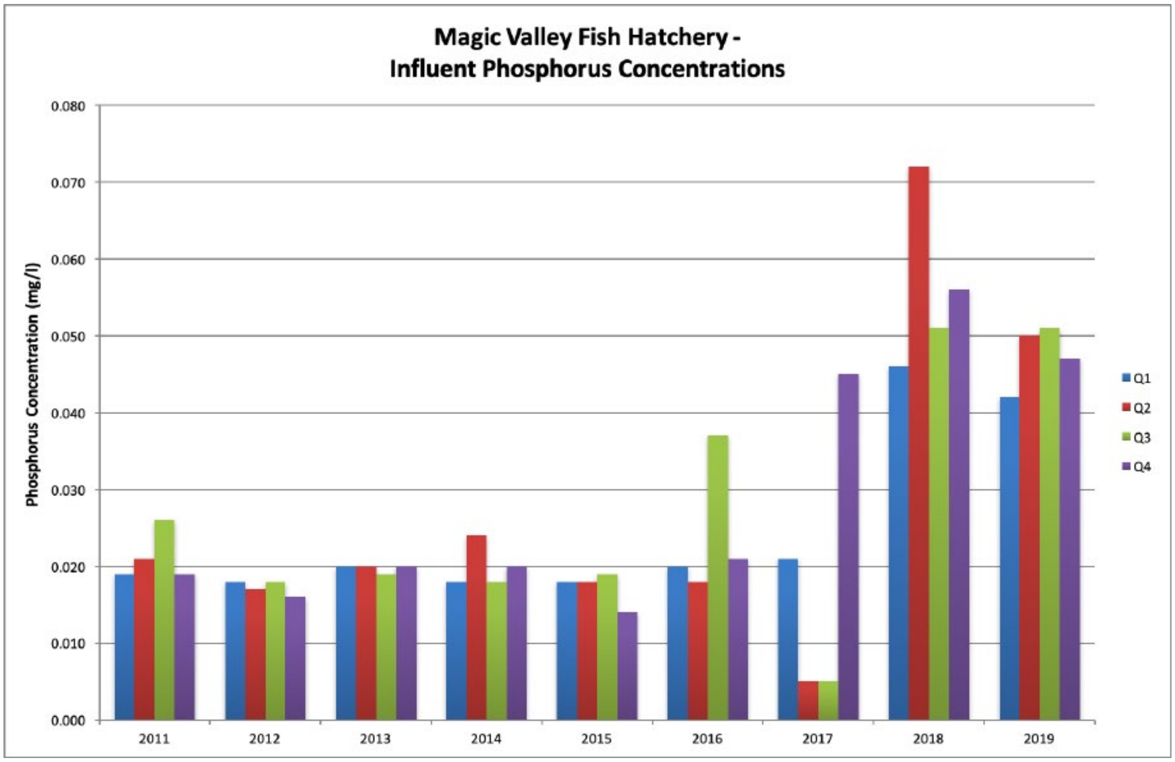


Niagara Springs Fish Hatchery

Phosphorus

Switched labs in Feb 2017

	Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	Average 2011-2016	Average 2017-2019
Quarter 1	**Influent**	0.014	0.013	0.017	0.014	0.015	0.015	0.016	0.049	0.050	0.015	0.038
	Gross	0.040	0.046	0.037	0.074	0.031	0.041	0.025	0.054	0.057		
	Net	0.026	0.034	0.020	0.060	0.016	0.026	0.009	0.005	0.007		
Quarter 2	**Influent**	0.014	0.022	0.014	0.013	0.012	0.013	0.007	0.052	0.042	0.015	0.034
	Gross	0.039	0.026	0.017	0.024	0.015	0.018	0.005	0.054	0.048		
	Net	0.025	0.004	0.003	0.011	0.003	0.005	-0.002	0.002	0.006		
Quarter 3	**Influent**	0.018	0.016	0.015	0.017	0.016	0.016	0.003	0.050	0.047	0.016	0.033
	Gross	0.027	0.022	0.025	0.024	0.021	0.023	0.008	0.056	0.039		
	Net	0.009	0.006	0.010	0.007	0.005	0.007	0.006	0.006	-0.008		
Quarter 4	**Influent**	0.015	0.011	0.015	0.015	0.018	0.016	0.050	0.047	0.040	0.015	0.046
	Gross	0.034	0.030	0.042	0.029	0.038	0.023	0.070	0.051	0.046		
	Net	0.019	0.019	0.027	0.014	0.020	0.007	0.020	0.004	0.006		
	average	*0.015*	*0.016*	*0.015*	*0.015*	*0.015*	*0.015*	*0.019*	*0.050*	*0.045*		



Magic Valley Fish Hatchery

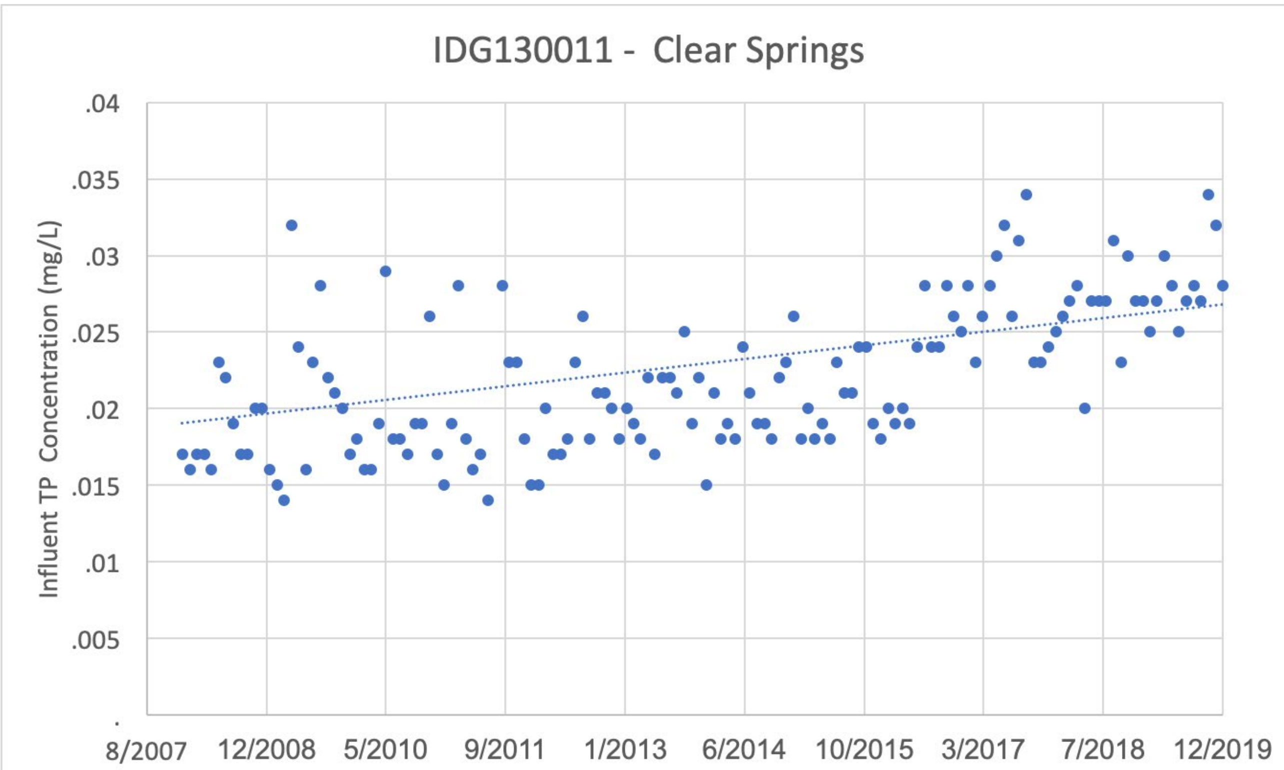
Phosphorus

Switched labs in Feb 2017

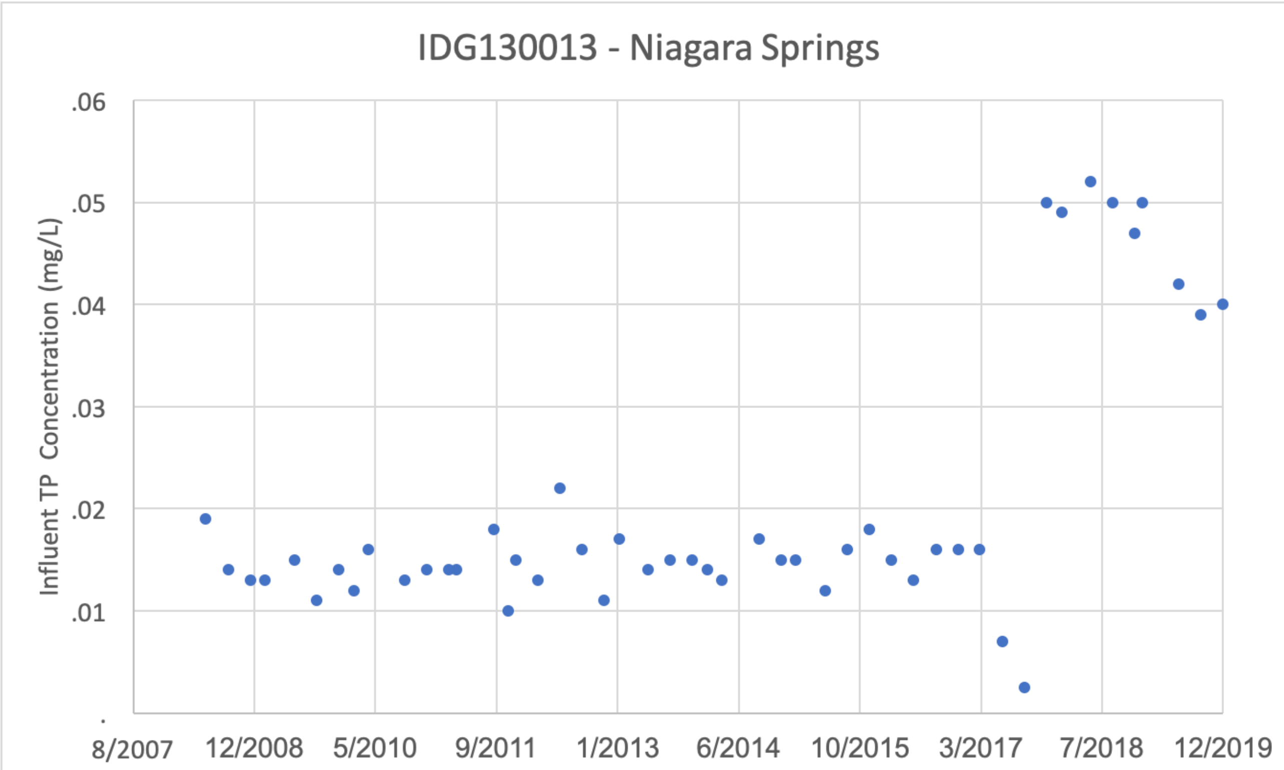
	Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	Average 2011-2016	Average 2017-2019
Quarter 1	**Influent**	0.019	0.018	0.020	0.018	0.018	0.020	0.021	0.046	0.042	0.019	0.036
	Gross	0.030	0.034	0.026	0.038	0.031	0.041	0.031	0.053	0.049		
	Net	0.011	0.016	0.006	0.020	0.013	0.021	0.010	0.007	0.007		
Quarter 2	**Influent**	0.021	0.017	0.020	0.024	0.018	0.018	0.005	0.072	0.050	0.020	0.042
	Gross	0.077	0.048	0.047	0.054	0.037	0.056	0.005	0.087	0.068		
	Net	0.056	0.031	0.027	0.020	0.019	0.038	0.000	0.015	0.002		
Quarter 3	**Influent**	0.026	0.018	0.019	0.018	0.019	0.037	0.005	0.051	0.051	0.023	0.036
	Gross	0.025	0.023	0.025	0.022	0.030	0.050	0.038	0.061	0.052		
	Net	0.000	0.005	0.006	0.004	0.011	0.013	0.036	0.010	0.001		
Quarter 4	**Influent**	0.019	0.016	0.020	0.020	0.014	0.021	0.045	0.056	0.047	0.018	0.049
	Gross	0.033	0.036	0.034	0.036	0.039	0.031	0.065	0.060	0.051		
	Net	0.014	0.020	0.014	0.016	0.025	0.010	0.020	0.004	0.004		
	average	*0.017*	*0.014*	*0.016*	*0.016*	*0.014*	*0.019*	*0.015*	*0.045*	*0.038*		

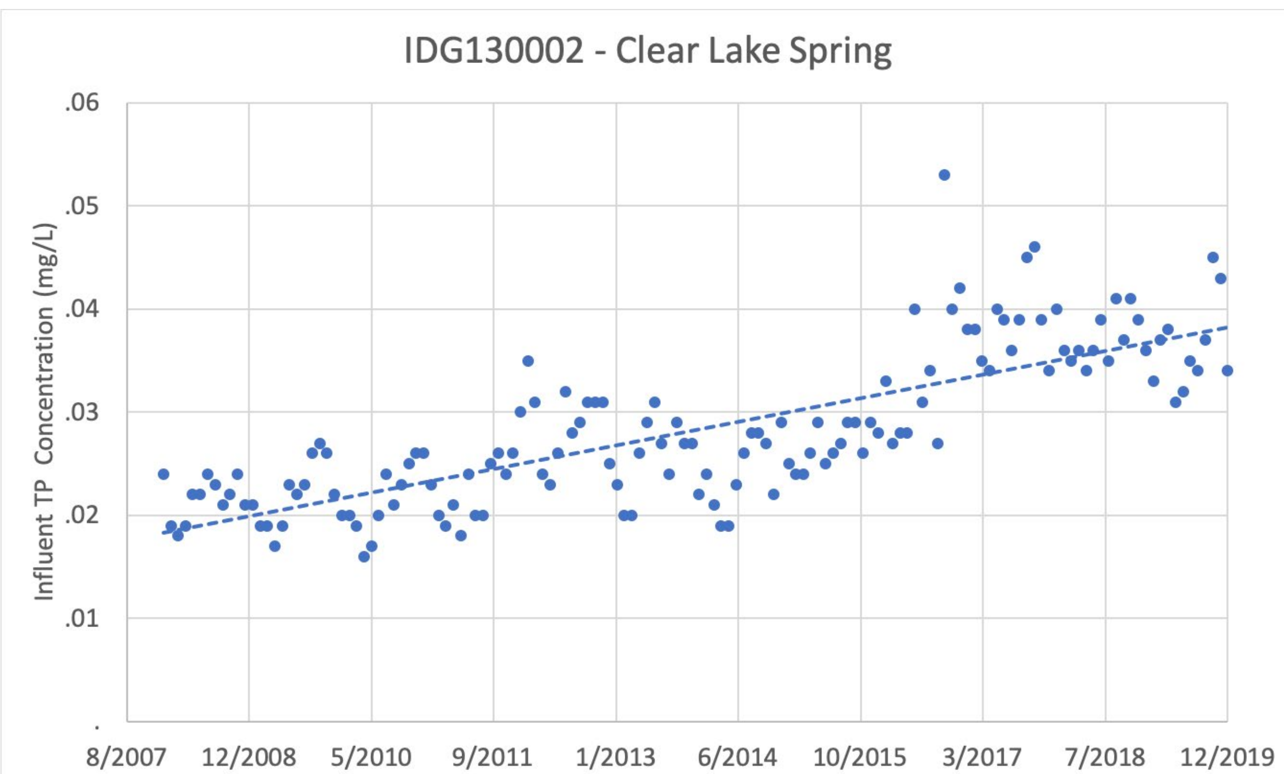
APPENDIX II - AQUACULTURE FACILITY INFLUENT PHOSPHORUS DATA[3]

*We chose to show data from three different spring sources that show an increasing trend in phosphorus concentrations. Not every spring source shows a clear trend due to spatial variability amongst different springs, no springs showed decreasing trends over the same time period.



[3] Data is from publicly-available Discharge Monitoring Reports, obtained through IDEQ and EPA


IDG130013 - Niagara Springs
Influent TP Concentration (mg/L)
.06
.05
.04
.03
.02
.01
.
8/2007
12/2008
5/2010
9/2011
1/2013
6/2014
10/2015
3/2017
7/2018
12/2019


IDG130002 - Clear Lake Spring
Influent TP Concentration (mg/L)
.06
.05
.04
.03
.02
.01
.
8/2007
12/2008
5/2010
9/2011
1/2013
6/2014
10/2015
3/2017
7/2018
12/2019