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How Do Dairy Feedlot Size and Land Use Practices Affect Groundwater Quality Over Time? A Preliminary Study in New Mexico

Nancy J. McDuffie

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by

Nancy J. McDuffie

Committee
Dr. Jingjing Wang, Chair
John R. Fleck
Dr. Bruce M. Thomson

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Committee Approval

The Master of Water Resources Professional Project Report of Nancy J. McDuffie, entitled How Do Dairy Feedlot Size and Land Use Practices Affect Groundwater Quality Over Time? A Preliminary Study in New Mexico, is approved by the committee:

Dr. Jingjing Wang, Chair Date

John R. Fleck Date

Dr. Bruce M. Thomson Date

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Abstract

Agricultural activities in general and dairy operations in particular, have been identified as a potentially significant source of nitrate contamination in groundwater. The late 1990s was a period of rapid growth for New Mexico's dairy industry. The New Mexico State University Cooperative Extension Service reports that the industry grew from 105 producers and 80,000 cows statewide in 1990 to 175 producers and 310,000 cows in 2003, to 145 producers and 323,000 cows in 2015. New Mexico now ranks ninth in the nation in milk production by volume, fifth in the nation for cheese production, and has the largest number of cows per herd in the nation. Hydrologically, these dairy systems represent a complex conglomeration of multiple potential point and nonpoint sources for nutrient and salt leaching to groundwater. The primary groundwater contaminant at dairies is nitrate resulting from disposal of solid and liquid wastes from the feedlots and dairy barns, which is present in the form of organic nitrogen in dairy wastewater. Wastewater that moves downward through the vadose (unsaturated) zone usually encounters conditions that allow the conversion of organic nitrogen to nitrate, a common contaminant in groundwater. Nitrate is the contaminant of primary concern at dairies because the groundwater standard of 10 mg/l for nitrate is based on human health impacts. This study provides descriptive history of each dairy's wastewater storage and disposal practices, irrigated cropland acreages and irrigation practices over time, and herd size over time. Groundwater samples collected from each dairy at least semiannually were analyzed. The groundwater quality data for nitrate was entered into Excel to perform time-series graphical analyses. The results of the data analyses related to past practices and herd size showed that changes in herd size over time have very little impact on groundwater quality. Land application management practices do seem to have an immediate and long-lasting effect on groundwater quality for nitrate. When over application of dairy wastewater to flood irrigated fields occurs, it negatively impacts groundwater quality. The groundwater quality data downgradient of different dairies in this study shows two ways to reduce the amount of nitrate leaching from land application areas are: 1. Use of more land to control the nutrient loading; or 2. Install infrastructure to irrigate with sprinklers or center pivots to allow more precise use of nutrients. Historical groundwater quality data shows that unlined ponds allow nitrate to move directly into shallow groundwater, but HDPE liners added after the fact often have little to no effect on improving the groundwater quality for many years.

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Introduction

Dairy farming in New Mexico has a long history dating back to Spanish colonization. According to the New Mexico Department of Agriculture, herd populations statewide were as large as 40,000 in 1912, growing to 83,000 by the 1940s (Doremus, 2003). During the middle part of the century herd sizes fluctuated as the dairy industry made the nationwide transition from small independent dairy farms to larger operations, marketing through nationwide cooperatives. The late 1990s was a period of rapid growth for New Mexico's dairy industry. New Mexico State University Cooperative Extension Service reports that the industry grew from 105 producers and 80,000 cows statewide in 1990 to 175 producers and 310,000 cows in 2003 (Doremus, 2003), to 145 producers and 323,000 cows in 2015 (NMDA, 2020). New Mexico now ranks ninth in the nation in milk production by volume, fifth in the nation for cheese production, and has the largest number of cows per herd in the nation (Dairy Producers of NM, 2020).

The large influx of dairies relocating to New Mexico from California, Texas, and Arizona in the early 1990s is attributed to a combination of several factors, including an ideal climate for herd health, availability of ready-made feed supplies, improved methods of transporting milk, and affordable farmland (Doremus, 2003). The largest milk producing counties in New Mexico are Chaves, Doña Ana, Roosevelt, and Curry (NMDA, 2020).

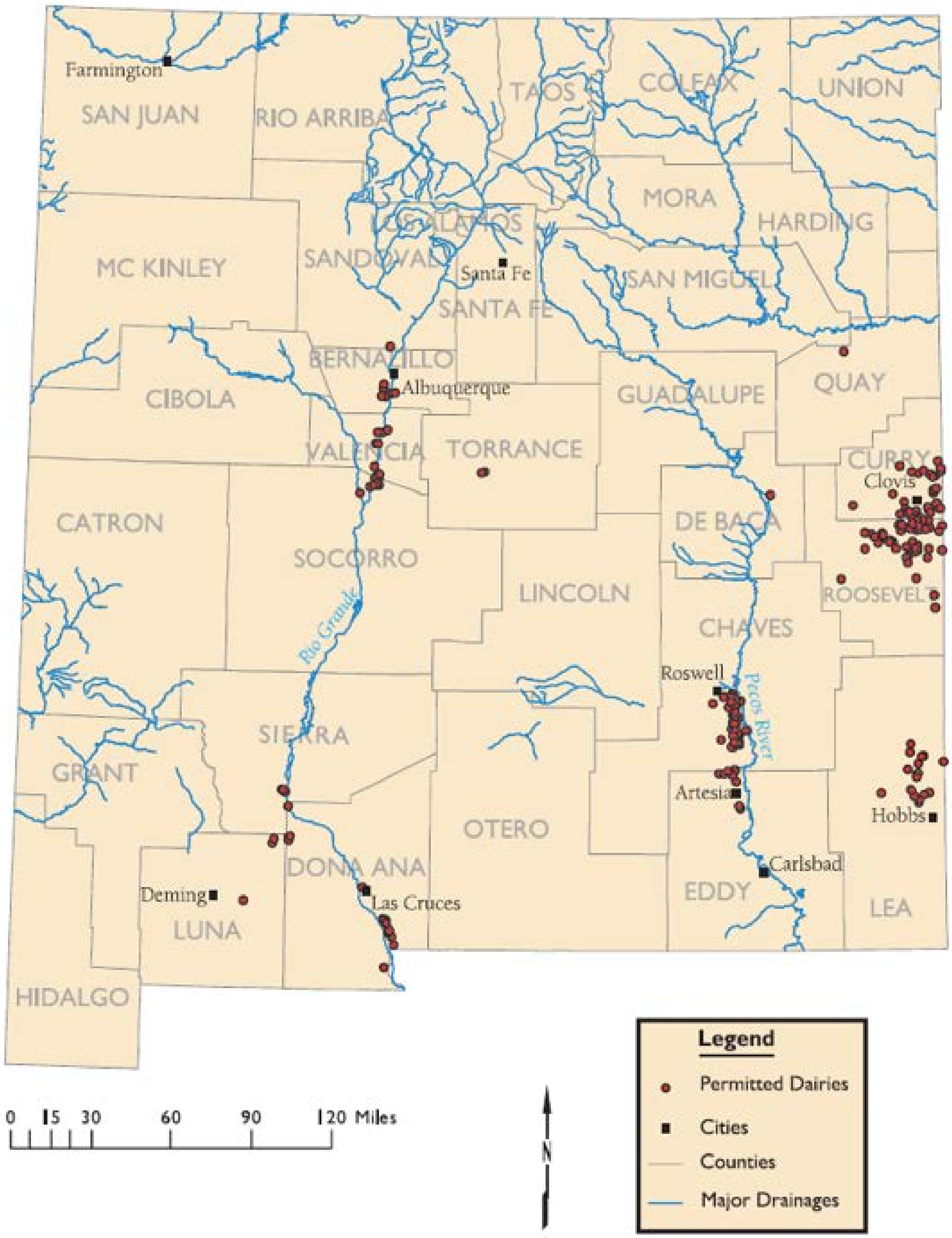


Figure 1 – Permitted Dairies in NM
(NMED 2006)

I. Laws and Regulations Governing Water Quality at Dairy Facilities

Both state and federal agencies play a significant role in water quality protection in New Mexico. New Mexico's groundwater protection program was well established before most federal legislation and regulations addressing groundwater quality were adopted. In 1967 the state's first water quality protection law, the Water Quality Act, was adopted by the New Mexico legislature. This law was amended in 1973 to allow the State of New Mexico to adopt regulations requiring permits for water quality protection (NMSA§74-6-1 through 74-6-17). By 1977 the State of New Mexico had adopted a comprehensive groundwater quality program applicable to most types of discharges through regulations promulgated by the New Mexico Water Quality Control Commission (WQCC). The WQCC regulations are the basic framework for New Mexico's water quality management and protection programs (Doremus, 2003). Key features of the WQCC regulations include numerical groundwater quality standards, groundwater discharge permit and pollution prevention requirements, and abatement requirements.

The foundation of the state's groundwater pollution prevention program is the groundwater discharge permit regulations. These regulations require that a person or entity discharging onto or below the land surface demonstrate that the discharge will not cause violation of any groundwater or stream standard. The New Mexico Environment Department (NMED) Ground Water Quality Bureau (GWQB) is responsible for administration of the WQCC groundwater regulations, 20.6.2 NMAC as they apply to mining, industrial, domestic, and agricultural discharges. Groundwater discharge permits include industry specific and site-specific requirements pursuant to the Supplemental Permitting Requirements for Dairy Facilities, 20.6.6 NMAC (Dairy Rule).

II. Sources of Groundwater Contamination at Dairies

New Mexico's dairies are concentrated in three areas (NMDA, 2020). Two of these areas are located over alluvial aquifers along the lower Rio Grande, and the Pecos River near Roswell. The third area is clustered in the east-central and southeastern side of the state on the Llano Estacado, which overlies the Ogallala aquifer (Doremus, 2003). Shallow groundwater and highly permeable coarse-grained sediments in alluvial environments along the Pecos and Rio Grande Rivers are highly vulnerable to migration of contaminants to groundwater (Doremus, 2003). The permeable sediments overlying the Ogallala aquifer and its equivalent are also vulnerable to contaminant migration, although groundwater occurs at greater depths in this area. These basins are also the almost exclusive source of domestic and municipal drinking water (Doremus, 2003).

Dairy facilities utilize water for all steps of the milk collection, including cleaning, sanitization, heating, cooling and floor washing. Dairy farm effluent, which refers to manure and liquid waste deposited throughout the milking process, is diluted while washing the milking shed floor (Williamson et al., 1998; Hooda et al., 2000). Animal waste in dairy effluent is a major source of pollution through nutrient enrichment of streams and groundwater which may, in turn, have a significant impact on the environment (Wilcock et al., 1999; Ali et al., 2006; Atalay et al., 2008; Kay et al., 2008; Van der Schans et al., 2009). The harmful effects of agricultural activities on groundwater (Gillingham and Thorrold, 2000; Dahiya et al., 2007; Monaghan et al., 2009) are becoming more and more of a concern worldwide (Mohammad and Kaluarachchi, 2004). Storm water runoff is required to be contained in ponds and/or channeled to the milking barn effluent lagoon to be evaporated or land applied. An anaerobic lagoon or storm water pond must be able to contain run off from a 25-year 24-hour storm event. Manure solids, including those scraped off corral areas are dried on-site for use as bedding material (Harter et al, 2002). Most often, manure solids are hauled off-site by truck.

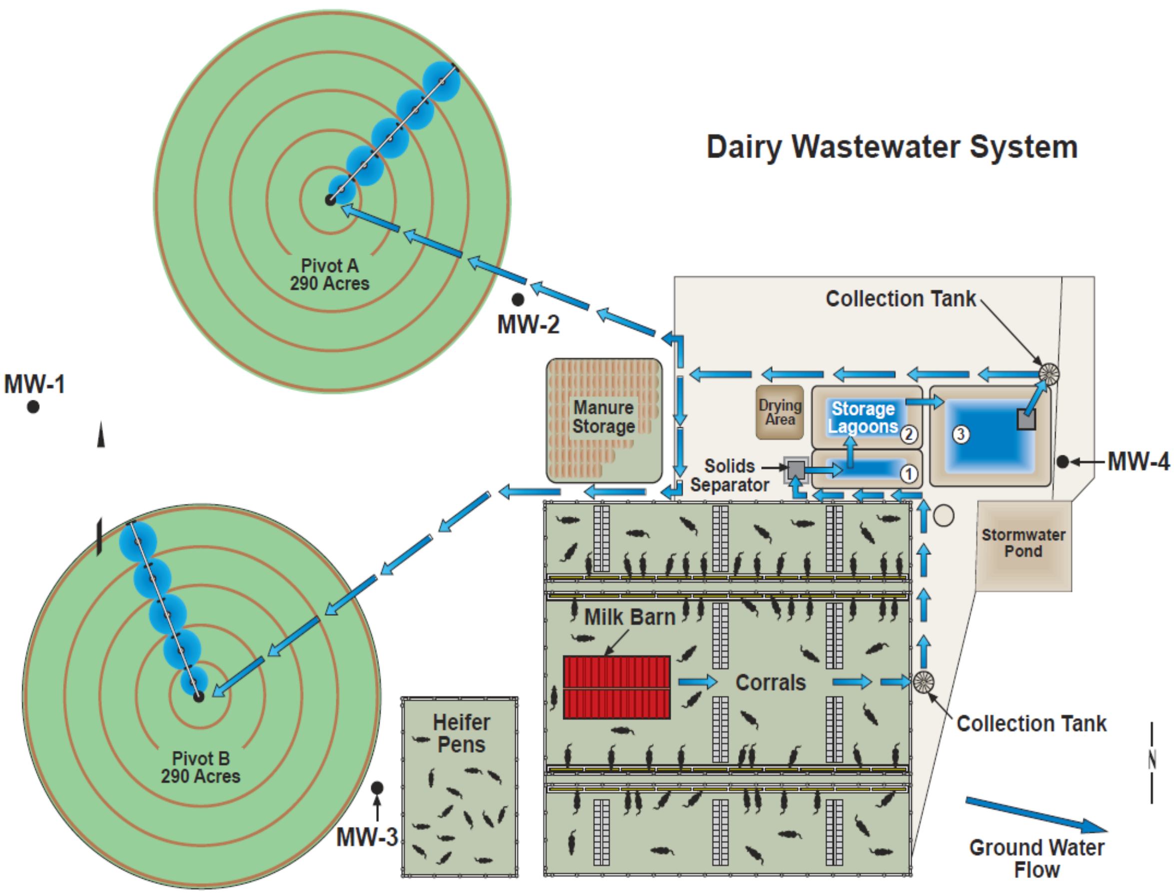


Figure 2 – Dairy Wastewater Diagram
(NMED 2006)

Agricultural activities in general and dairy operations in particular, have been identified as a potentially significant source of nitrate contamination in groundwater of these basins (Lowry, 1987; Mackay and Smith, 1990; Burow et al., 1998; Boyajian and Ross, 1998). The primary potential source of groundwater nitrate and salt within dairy systems is manure. In the arid climate of the Western United States, manure management practices differ in many ways from those in the colder climates of traditional dairy regions in the north-central and north-eastern US or in Central Europe (Harter et al, 2002). In the lower Rio Grande basin, precipitation of 6.28 inches occurs annually (WRCC, 2020). Dairies commonly use shade covered corrals (exercise yards, animal holding areas) (Meyer et al., 1997). Washwater is flushed into a liquid manure storage pond (also called a ‘‘lagoon’’). Lagoon manure water is recycled for flushing of the milking floor (Harter et al, 2002). Manure solids are separated from the liquid portion in settling basins or by mechanical devices. Manure solids, including those scraped off corral areas are dried on-site for use as bedding material (Harter et al, 2002). Most often, manure solids are hauled off-site by truck. Cow wash and milk barn operations continuously add fresh water to the liquid manure recycling system, thereby gradually filling the storage lagoon (Harter et al, 2002). Intermittent runoff from the corrals is also captured by the recycling system and stored in the lagoon system. The diluted liquid manure is eventually applied to adjacent forage crop land via flood, furrow or pivot irrigation systems (Schwankl et al., 1996; Meyer et al., 1997). Irrigations with liquid manure typically occur during spring and summer to create pond storage capacity for the winter (Harter et al, 2002).

Irrigated fields comprise the majority of the land area within a typical dairy (a few hundred to tens of thousands of acres). Depending on climate crops may be grown nearly year-round. Most dairies grow corn (maize) silage during the summer followed by fall planting of cereal grains (oats, Avena sativa, wheat, Triticum sp., or barley, Hordeum sp.), which is harvested as forage in early spring (Harter et al, 2002). In some regions this double cropping system is rotated with alfalfa (lucerne, Medicago sativa) or other crops that receive applications of diluted liquid manure. Historically dairy operators managed the land application of manure as a waste disposal system, not as a nutrient management system (Harter et al, 2002). Application to fields has historically often been dictated not by seasonal crop nutrient demands but primarily by the capacity and layout of the irrigation system, by pond storage capacity, and by the type of crop (some crops are perceived to be too sensitive for manure application) (Harter et al, 2002). Since the adoption of the Dairy Rule, the addition of manure, both liquid and solid, to meet the perceived nutrient requirements of the crop is required to be tracked and reported to NMED.

Hydrologically, these dairy systems represent a complex conglomeration of multiple potential point and nonpoint sources for nutrient and salt leaching to groundwater (Harter et al, 2002). The primary groundwater contaminant at dairies is nitrate, which is present in the form of organic nitrogen in dairy wastewater. Wastewater that moves downward through the vadose (unsaturated) zone usually encounters conditions that allow the conversion of organic nitrogen to nitrate, a common contaminant in groundwater (Harter et al, 2002). Total nitrogen concentrations in dairy wastewater typically range from 200 to 500 mg/l as compared with domestic wastewater, which averages 60 mg/l. Nitrate is the contaminant of primary concern at dairies because the groundwater standard of 10 mg/l for nitrate is based on human health impacts (Doremus, 2003). Chloride and total dissolved solids present in the wastewater may also threaten groundwater quality. NMED has identified groundwater contamination at permitted dairies, contamination that is primarily associated with waste disposal practices (Doremus, 2003).

The vulnerability of certain soils to rapid infiltration is an important consideration in the design of land application programs. As the dairy industry has grown in New Mexico, so has the understanding of management practices best suited for groundwater protection at dairy operations. Initially, permits for dairies focused primarily on wastewater lagoons, the need for liners, and groundwater monitoring (Doremus, 2003). As the understanding of contaminant sources has progressed and data from groundwater monitoring has become available, a more integrated approach to groundwater protection based on site-specific dairy operations has been developed (Doremus, 2003). The Dairy Rule which was amended and became effective in 2015 now requires crop and nutrient management plans and include soil sampling to provide for early detection of potential groundwater contamination. All dairies with lagoon systems now are required to have properly constructed liners with engineering oversight (Doremus, 2003). The Dairy Rule has improved the consistency in the requirements for all dairy facilities. The Agriculture Compliance Section of the GWQB has been working with permitted facilities to bring them into compliance with the Dairy Rule. As a result of these types of improvements, groundwater discharge permits are more protective of groundwater quality today than in the past.

This paper provides a descriptive history of dairy size, land use, and potential impacts to groundwater quality since the late 1980s to 2019. It discusses how source control, such as synthetic lining of lagoons and irrigation practice changes over time impact the groundwater quality data, using a time-series dataset from select dairy farms as a snapshot.

Literature review

Many studies have been done to determine the impact wastewater seepage has on soil and groundwater (Ham and DeSutter 1999; Elliot et. al. 1972; Dye et. al. 1984; Chang and Entz 1996). Soil profiles have been examined to determine how wastewater seepage impacts soil characteristics (Ham et. al. 1999. ch. 2; Volland 1998; Lakshmi and Davalos 2000; Haberstoh and Roberts).

Precipitation, evaporation, initial quality of water used in the milking barn (a.k.a. process water), and changes in the chemical composition of the animal waste are important factors that determine the quality of the wastewater (Dye et. al. 1984). Wastewater in the lagoon can contain concentrated organic matter, nutrients (nitrogen and phosphorous) and salts from manure, bacteria, viruses, pharmaceuticals, hormones, and other potential harmful contaminants generated by the cattle and milking process (Bitton 1999). Lagoons are designed to be anaerobic to manage the organic manure components and nitrogen found in wastewater. A portion of organic material settles on the bottom of the lagoon forming a mat that may restrict flow from the lagoon to the subsurface soils and groundwater (Barrington and Broughton 1988; Dye et. al. 1984). Organic matter is also converted to carbon dioxide and methane gas through intense microbial activity, and the process maintains low oxygen levels in the lagoon (Koelliker and Miner 1973). Under anaerobic conditions, a significant portion of nitrogen is lost to the atmosphere as ammonia (NH_3) (Koelliker and Miner 1973).

At some dairies, the water level in the lagoon is maintained by pumping and mixing wastewater and irrigation water, which is then land applied by flood or sprinkler irrigation. Using the wastewater as fertilizer can increase soil fertility, improve soil physical properties, and save fertilizer costs (Waskom and Davis 1999). However, if manure and wastewater are applied in a manner which exceeds the nutrient uptake rate, nutrients can be lost by leaching and run off, impacting the quality of soils and groundwater.

I. Dairy Wastewater Quality

The quality of the dairy wastewater is one factor that determines the nature of subsurface contamination beneath dairy facilities. The wastewater is a combination of process water and milking barn wastes (Dye et. al. 1984). The process water is typically pumped from on-site wells and used to clean the cattle prior to milking sessions and to clean floors and milking equipment between milking sessions. During the cleaning, nutrients (e.g. nitrogen and phosphorous), raw organics (i.e. foodstuff), cleansing agents, and pharmaceuticals can become entrained in the process water (Dye et. al. 1984).

The initial quality of the process water is an important consideration when predicting the chemical composition of wastewater. For example, Dye et. al. reported that all the nitrate (NO_3^-) present in process water is the result of oxidation of total Kjeldahl nitrogen (TKN), largely in the form of ammonia-nitrogen, as the water passed through the milking barn and left as effluent (Dye et. al. 1984). For clarity, ammonia-nitrogen (NH_3-N), represents both ammonium ion (NH_4^+) and ammonia (NH_3). TKN measures both NH_3/ NH_4^+ and organic nitrogen. Further comparison of the quality of process water and dairy wastewater indicates that bicarbonate (HCO_3^-), potassium (K^+), total dissolved solids (TDS), pH, and the reduced forms of nitrogen are elevated in the wastewater (Dye et. al. 1984). Evaporation, precipitation, chemical processes, and biological processes affect the quality of the wastewater once it is in the anaerobic treatment lagoon. The quality of lagoon effluent is dominated by monovalent cations (Na^+ and K^+), monovalent anions (HCO_3^- and Cl^-) and ammonia-nitrogen (Dye et. al. 1984).

II. Nitrate Migration Beneath Land Application Areas and Nutrient Management

When properly applied, manure increases soil fertility, improves the physical properties of the soil, and minimizes fertilizer expenses. However, improper land application of dry and liquid dairy manure can pose adverse risks to the subsurface soil and groundwater environments. The important considerations when planning to land apply manure are: (1) the nutrient content of the manure; (2) the concentrations of residual and available nutrients in the soil; and, (3) the nutrient needs of the crops (Waskom and Davis 1999). These three factors determine the appropriate manure (agronomic) application rate for specific farm operations. Waskom and Davis (1999) define agronomic rate as, "a nutrient application rate based upon a field-specific estimate of crop needs and an accounting of all N [nitrogen] and P [phosphorous] available to that crop prior to manure (and/or fertilizer) application…an application rate that does not lead to unacceptable nutrient losses."

The major nutrient components of dairy manure are nitrogen (N), phosphorous (P), potassium (K). The smaller elemental components are calcium (Ca), magnesium (Mg), manganese (Mn), zinc (Zn), copper (Cu), and sulfur (S) (Waskom and Davis 1999). The nutrients (N and P), salts (containing Ca, Mg, and/or Na for example), heavy metals (Zn for example), organic material, and pathogenic bacteria are the primary constituents responsible for environmental deterioration (Waskom and Davis 1999).

When the amount of nutrient in the applied manure exceeds the amount of nutrient that is utilized in plant growth in the fertilized soil, the residual nutrients can pollute subsurface soil and groundwater (Chang and Entz 1996; McCalla 1974). Factors that determine the amount of nutrient (e.g. NO3-) loss to the environment are: (1) the amount of NO3- in the soil; (2) the amount of soil water percolation; and (3) the amount of N loss through plant uptake, ammonia volatilization, and denitrification (Weed and Kanwar 1996).

Chang and Entz (1996) and Chang et. al. (1990) reported on the long-term (1973 to 1992) effects of annual applications of solid, cattle-feedlot manure on irrigated and non-irrigated clay loam soils planted with barley. Manure application rates varied for non-irrigated and irrigated soils. Prior to each application the manure was sampled for its nutrient content; however, the analysis results weren't reported. Arrington and Pachek reported on the nutrient content of manure in an arid climate (Livestock Waste Management undated).

According to Chang and Entz (1996), there was little or no leaching loss of NO3-N from the root-zone (120cm to 150 cm depth) in the non-irrigated soil. However, excessive nitrate that accumulates above the root zone of land application areas can threaten groundwater quality during heavy precipitation. During a high precipitation year, and the NO3-N level in the non-irrigated soil was as high as 23 Mg/ha within the root zone (120 cm to 150 cm depth). There was significant NO3-N leaching loss from the root zone of the irrigated soils that ranged from <72 kg/ha to 400 kg/ha. In addition, nitrate concentrations increase with increasing manure application rates in irrigated soil (Chang and Entz 1996; Mathers and Stewart 1984 and 1981). There was evidence of organic nitrogen mineralization in the non-irrigated soils based on the amount of organic nitrogen applied in the manure and the amount that accumulated in the soil. Mineralization of organic nitrogen is a slow process that releases historically applied nitrogen, which can contribute to nitrate concentrations found in soils and groundwater overtime.

Sanderson and Jones (1997) determined the forage yields, nutrient uptake, soil chemical changes, and nitrogen volatilization from bermudagrass treated with solid dairy manure from 1992 to 1995. Manure was applied at increasing rates annually throughout the duration of the study. Soil water had low concentrations of nitrate (<3 ppm) at the 18 inch and 36 inch depths, and this was attributed to rapid plant uptake and slow organic N mineralization. Significant nitrogen was lost to the atmosphere as ammonia within 6 hours of application, and nitrogen didn't exceed 7 ppm in the top 6 inches in the soil. Maximizing the nitrogen loss by ammonia volatilization from the manure would limit the amount of nitrate-nitrogen that can accumulate in the soil beneath land application areas (Adriano et. al. LWM undated). On the other hand, significant loss of nitrogen from manure fertilizer may decrease crop yields. Waskom and Davis (1999) state that a surface application of manure should be incorporated as soon as possible to minimize N losses due to volatilization or run off. The rate of volatilization will increase when conditions are warm, dry, and windy. Volatilization losses from liquid manure may be large relative to dry manure losses because the conversion from NH4(liquid species) to NH3 (gaseous species) is quick.

Johnson et. al. (1995) reported nitrate concentrations from 11 ppm to 33 ppm in the soil water beneath a land application area that received liquid dairy manure slurry. Adriano et. al. (1971) reported 66 ppm nitrate-nitrogen in soil water in the unsaturated zone beneath irrigated cropland fertilized with liquid and/or solid dairy manure. Vellidis et. al. (1996) reported nitrate-nitrogen soil water concentrations that ranged from 1.45 mg/L to 22.70mg/L in 0 to 2.0 meter depth under cropland fertilized with liquid dairy manure. At the 3.0 meter depth, Vellidis et. al. (1996) reported groundwater nitrate-nitrogen concentrations ranging from 13.08 to 18.11 mg/L. At the 6.0 meter depth, nitrate-nitrogen concentration ranged from 3 mg/L to 7 mg/L (Vellidis et. al. 1996). It was determined that historical fertilizing and subsequent leaching contributed nitrate-nitrogen because no effect by manure applications during the 3 year study was observed in the groundwater. Leaching of the nitrate-nitrogen appeared to be a very slow process through the low permeability soil horizons found at the site of the study. Long term research on a variety of soil types is necessary to conclusively state the environmental impact of liquid dairy manure application on cropland (Vellidis et. al. 1996).

Bobier et. al. (1993) reported the vertical transport rate of nitrate nitrogen was ~76 cm/year (1.0 x 10-7cm/sec) in fine-textured, well-drained vadose zone beneath irrigated cropland fertilized at rates of 0, 300, 400 lb N/acre.

III. Nitrate Migration from Feedlots

Dairy feedlots are an open area where the cattle are and fed (dry lotted) except when they are moved to the milking barn for milking sessions, which typically occur 2 -3 times a day. Manure accumulates in the corral, and the standing cattle compact the manure over time. An anaerobic zone can form beneath feedlot surfaces, which may inhibit the formation and leaching of nitrate (Elliot et. al. 1972); although, this is a debated issue. Nitrogen concentration profiles in soil cores from dairy feedlots show some migration beyond the layer of compact manure (Elliot et. al. 1972). Nitrates at concentrations > 10 mg/L have been detected in groundwater down gradient of dairy feedlots (Chesney 1999). In addition, Vellidis et. al. (1996) and Elliot et. al. (1972) reported elevated concentrations of nitrate and ammonia/ammonium is soil and/or groundwater beneath cattle feedlots. Precipitation and surface run off does dissolve and entrain particulates from the manure/soil feedlot surface (Dye et. al. 1984). Therefore, storm water runoff must be contained in a designated pond or lagoon to prevent groundwater contamination.

Run off from feedlot open areas is an environmental concern due to its high concentrations of nutrients, salts, pathogens, and oxygen demanding (OD) organic material (measured as chemical oxygen demand COD or biological oxygen demand BOD). Wastewater is released from dairy feedlots in two ways: (1) run off due to rain events and snow melt and (3) percolation through the soils. Storm water runoff is required to be contained in ponds and/or channeled to the milking barn effluent lagoon to be evaporated or land applied. An anaerobic lagoon or storm water pond must be able to contain run off from a 25-year 24-hour storm event. It is advisable to limit the quantity of storm water that becomes wastewater by routing run off away from the feedlot (Waskom and Davis 1999).

Sweeten (undated) reported Loehr's 1974 data for total N and total P concentrations for feedlot run off that ranged from 920 to 2100 ppm and 290 to 360 ppm respectively. Dye et. al. (1984) reported TKN at 120 mg/L and 60 mg/L in run off from 2 dairy feedlots in New Mexico, which demonstrates run off does mix with feedlot soils, dissolving and entraining nitrogen components. If the nitrogen contaminated run off is allowed to pool in arroyos or local depressions that typically have rocky, coarse sand bottoms in New Mexico, the wastewater will rapidly infiltrate (Dye et. al. 1984). For the Texas High Plains area, Sweeten (undated) again reported Clark's 1975 and Sweeten's 1981 data for average nitrogen (N) concentrations in fresh run off as 1,083 ppm and in holding ponds as 145 ppm. Average phosphorous (P) in fresh run off was 205 ppm and 43 ppm for holding ponds. The potassium (K) and sodium (Na) concentrations in runoff water are higher than calcium (Ca) and magnesium (Mg). K/Na was 1320 ppm/588 ppm and Ca/Mg was 449 ppm/199 ppm in fresh run off. K/Na was 445 ppm/256 ppm and Ca/Mg was 99 ppm/72 ppm in holding ponds (Sweeten undated).

While containment of run off in a surface impoundment may have limited its threat to surface water bodies, it poses a threat to groundwater because wastewater ponds and anaerobic treatment lagoons, where the storm water runoff may be impounded, have been shown to seep, especially through coarse soils (Korom and Jeppson 1994). Two data analysis studies of groundwater quality information from New Mexico State dairy operations have been conducted (Arnold and Meister 1999; Chesney 1999). Chesney (1999) analyzed nitrate/nitrite and TKN data from 94 dairies, which included 1,031 samples total. The median nitrate/nitrite concentration was 18 mg/L in samples from monitoring wells down-gradient. At 7 of the 12 sites where water is monitored at feedlots, nitrate/nitrite concentrations exceeded 10 mg/L, the maximum contaminant level (MCL). Chesney doesn't report background water quality. Arnold and Meister (1999) did a relatively smaller analysis of 313 groundwater samples collected from 26 monitoring wells near 7 wastewater lagoons at 7 different dairies. They analyzed nitrate, ammonia, TKN, chloride, and total dissolved solids (TDS) data with respect to herd size and type of lagoon lining. Among their findings, the mean concentrations of all the above-mentioned analytes exceeded regulated standards. Nitrate, ammonia, TKN, and TDS varied by the size of the herd so that smaller dairy herds produced lower concentrations of contaminants.

Wastewater may also be released from feedlots by percolation. Nitrogen accumulates in the soil; overtime, the nitrogen can be washed downward by subsequent wetting fronts due to rain and snow melt. Adriano et. al. (1971) analyzed and compared soil profiles within cattle feedlots, irrigated cropland, and irrigated pastures. The nitrate level in the cattle feedlot soils was as high as 119.6 ppm within the first foot, approximately three times as much nitrate compared to cropland and pastures. Nitrate was the dominant form of nitrogen in the soil profiles, due to the aerobic soil conditions. According to the groundwater quality data, Adriano et. al. (1971) suggest the full impact of nitrate in the soils had not yet reached the groundwater table. Waste management practices that optimize nitrogen loss by ammonia volatilization will limit the amount of nitrate in feedlot soils.

Chang et. al. (1973) determined the highest nitrate concentrations in the soil beneath a dairy cattle feedlot were found where waste accumulation was relatively low. The majority of the waste accumulated on only 30% of the total feedlot area. Chang et. al. (1973) hypothesize that conditions exist where waste accumulation is heavy that inhibit nitrate formation. The ammonium nitrogen species dominated the top 30cm of the soil profile. Nitrogen in the waste is largely bound in organics, which must undergo mineralization and nitrification (processes that are affected by moisture levels) to release nitrate (Chang et. al. 1973). Nitrate concentrations were highest at the 1.0m -1.2m depths of the soil profiles.

Sweeten (1989) reports from the literature that compact manure/soil in the feedlots acts as a moisture barrier (Mielke et. al. 1974; Mielke and Mazurak 1976), reducing and restricting the flow of salts, nitrate, and ammonium ions into the subsurface soils and groundwater (Schuman and McCalla 1975A). An impervious layer of organic material may promote anaerobic conditions beneath the feedlot surface, inhibit nitrification, and promote denitrification. Denitrification is a biological and anaerobic conversion that favors conditions that fluctuate between aerobic and anaerobic; where sufficient organic material is present and where the soil pH is sufficiently low (Tiedje et. al. 1982).

McCalla and Elliot (1971) sampled and analyzed the soil solution (i.e. soil pore water) within two beef cattle feedlots and determined the presence of a reducing zone from the 1 to 5 foot depth, where carbon dioxide and methane were produced and oxygen levels were low. Beneath a new feedlot, nitrate concentrations were as high as 71.9 ppm at the 1ft depth and 23.1ppm at the 5ft depth. McCalla and Elliot (1971) suggest that the high nitrate concentrations were found because a manure pack had not been established. They don't report how long it takes for an impervious layer of organics to begin inhibiting nitrification and nitrate leaching. The common assumption used to be that this natural liner “self sealed” to limit infiltration to negligible concentrations but has since proven to be false.

Elliot et. al. (1972) find it "reasonable to postulate" that denitrification occurred beneath a dense layer of manure/soils in a feedlot (15 cm below the surface). Soil water samples above and below the 15 cm depth had elevated concentrations of nitrate (101.3μg/mL (ppm) and 3.2μg/mL respectively), ammonium (817.8μg/mL and 51.9μg/mL respectively), and total nitrogen (1,078.0μg/mL and 52.8μg/mL respectively) relative to a cropped field (Elliot et. al. 1972). Schuman and McCalla (1975B) studied the chemical characteristics of the soil profiles in the same feedlot and reported low nitrate concentrations below the impermeable layer. Elliot et. al. (1972) reported that the feedlot did not contaminate groundwater, but the publication does not report groundwater quality data. Contrary to their conclusion, groundwater contamination cannot be ruled out without investigating: (1) preferential flow paths; (2) long-term groundwater quality data; (3) biological characteristics of the manure/soil profile beneath the feedlot; or (4) other possible physical, chemical, and biological processes that influence nitrogen in the soil and groundwater environments.

The literature clearly shows that nitrogen as nitrate and/or ammonia/ammonium from dairy manure and wastewater has contaminated soil and groundwater. The degree to which nitrate-nitrogen and ammonia/ammonium-nitrogen threaten soil and groundwater varies from site to site due to differences in: (1) manure and wastewater management practices (e.g. lagoon construction, land application rates, feedlot surface maintenance); (2) age of the facility; (3)geology; (4) unsaturated zone hydraulics; and (5) climate (i.e. amount of precipitation and temperature).

Field data has led some researchers to believe (properly constructed) earthen-lined, anaerobic treatment lagoons (Sewell 1978; McCook 2000) and feedlots (Sweeten 1989 and undated; Elliot et. al. 1972) are unlikely sources of groundwater contamination. A second group of researchers have reported real groundwater contamination and the potential for contamination over time from the above-mentioned wastewater and manure sources (Lagoons: Dye et. al. 1984; Ham et. al. 2000. ch.1; Volland 2000) (Land Application Areas: Chang and Entz 1996; Vellidis 1996) (Feedlots: Adriano et. al. 1971; Chesney 1999).

IV. Regulatory History

A. Groundwater Regulations

In 2009 the dairy industry approached the Legislature hoping to simplify the groundwater discharge permit regulations. Also, in 2009 it became clear to the GWQB that the existing groundwater regulations (20.6.2 NMAC) and common dairy practices were failing to protect groundwater. Nearly 50% of the more than 170 dairies operating in NM had exceeded a groundwater standard. In that year a law was passed that required the Water Quality Control Commission (WQCC) to adopt a new rule specific to the dairy industry. A rule was proposed in 2010 and approved by the WQCC. 20.6.6 NMAC became effective in January of 2011.

The dairy industry appealed the adoption of the rule to both the WQCC and the NM Court of Appeals. Negotiations continued between stakeholders and NMED and in October of 2012 an amended rule was adopted. The dairy industry appealed again in 2013 and proposed 27 more amendments. These amendments included impoundment liner requirements to change from double synthetic liners with leak detection to 2 feet of compacted clay with a maximum demonstrated permeability of 1x10-7 cm/sec. Requirements for monitoring wells also changed from a prescribed distance from each source (i.e. 75 feet from the upper inside edge of the impoundment), to allowing negotiation of placement depending on the site characteristics.

Other changes to grading and drainage plans, monitoring wells for former sources, allowing settling ponds instead of requiring mechanical separators, and reducing the 60 days of storage in wastewater impoundments to 21 days of storage. A Stipulated Final Agreement was signed by all stakeholders and NMED in April of 2015. The amended Dairy Rule was approved by the WQCC and became effective August 1, 2015.

The Data required by the Dairy Rule is quarterly groundwater monitoring data from all wells at the facility for nitrate, total Kjeldahl nitrogen, chloride, sulfate and total dissolved solids. Monitoring wells are required to be located upgradient of the facility (for background) and down gradient of every potential source of contamination (i.e. lagoons, and crop land where wastewater is used for irrigation). Annual samples from lagoons for the same list of contaminants for nutrient loading information. Lagoons are required to be lined with 2 feet of compacted clay with a maximum demonstrated permeability of 1x10-7 cm/sec with a capacity for 21 days of storage. Dairies with land application areas are required to submit annual nutrient management plans stating each crop to be planted and amount of wastewater or solid manure to be applied to each field. The following year soil and crop analysis to document the nitrogen application amount and removal by the crops is required. Nitrogen is required to be applied in agronomic rates.

B. Doña Ana Dairies Compliance History

A Clean Water Act (CWA) violation occurred in late 2006, and on September 25, 2007 EPA ordered the Doña Ana Dairies to come into compliance with the CWA (EPA, 2007).

In an April 7, 2006, correspondence, NMED required a Stage 1 Abatement Plan for 13 dairies in Doña Ana County, based on analytical results from DP monitoring of on-site compliance monitoring wells that showed concentrations of chloride and total dissolved solids (TDS) exceeding groundwater quality standards promulgated in New Mexico Water Quality Control Commission (WQCC) Regulations Title 20, Chapter 6, Part 2, Section 3103 (20 NMAC 6.2 §3103) of the New Mexico Administrative Code (NMAC).

On October 30, 2006, the Dairies notified NMED that they had reached agreement to work as a group and submit a joint response to NMED's request (Doña Ana Dairies, 2006). On December 11, 2006, on behalf of the Dairies, Golder Associates Inc. (Golder) submitted a Stage 1 and Interim 2 Abatement Plan Proposal to address impacts to groundwater in the area of the Dairies (Golder, 2006).

On March 17, 2010, the NMED issued a notice of deficiency (NOD) to Doña Ana Dairies for the Site Investigation Report dated July 2009 (NMED, 2010). Doña Ana Dairies appealed the NOD to the New Mexico Water Quality Control Commission (WQCC) on April 15, 2010. The WQCC provided a ruling and Doña Ana Dairies negotiated a settlement to satisfy the ruling. The Settlement Agreement was signed by NMED on August 2, 2011 (NMED, 2011). The Final Site Investigation Report that fulfilled the requirements of the Settlement Agreement was submitted in February 2012 with an addendum for the installation of DAD-15 submitted in September 2012.

On November 7, 2013 EA Engineering, Science, & Technology, Inc., on behalf of the Dairies, submitted the Final Stage 2 Abatement Plan.

Study Site

I. Background and Site Characteristics

This study analyzes groundwater quality data from the following 12 dairies (aka Doña Ana Dairies, DAD) that began discharge in the 1980s, along Interstate 10 in Doña Ana County. The Ground Water Quality Bureau of the New Mexico Environment Department issued the following Discharge Permits (DPs):

1. Organ Dairy (Formerly Daybreak Dairy) DP-126
2. Mountain View Dairy DP-70
3. Buena Vista I Dairy DP-86
4. Bright Star Dairy DP-340
5. Dominguez 2 (Formerly D&J Dairy) DP-42
6. Dominguez Dairy DP-624
7. Gonzalez Dairy DP-177
8. Buena Vista II Dairy DP-74
9. River Valley Dairy DP-167
10. Big Sky Dairy DP-833 (with DP-260)
11. Sunset Dairy DP-257
12. Del Oro Dairy DP-692

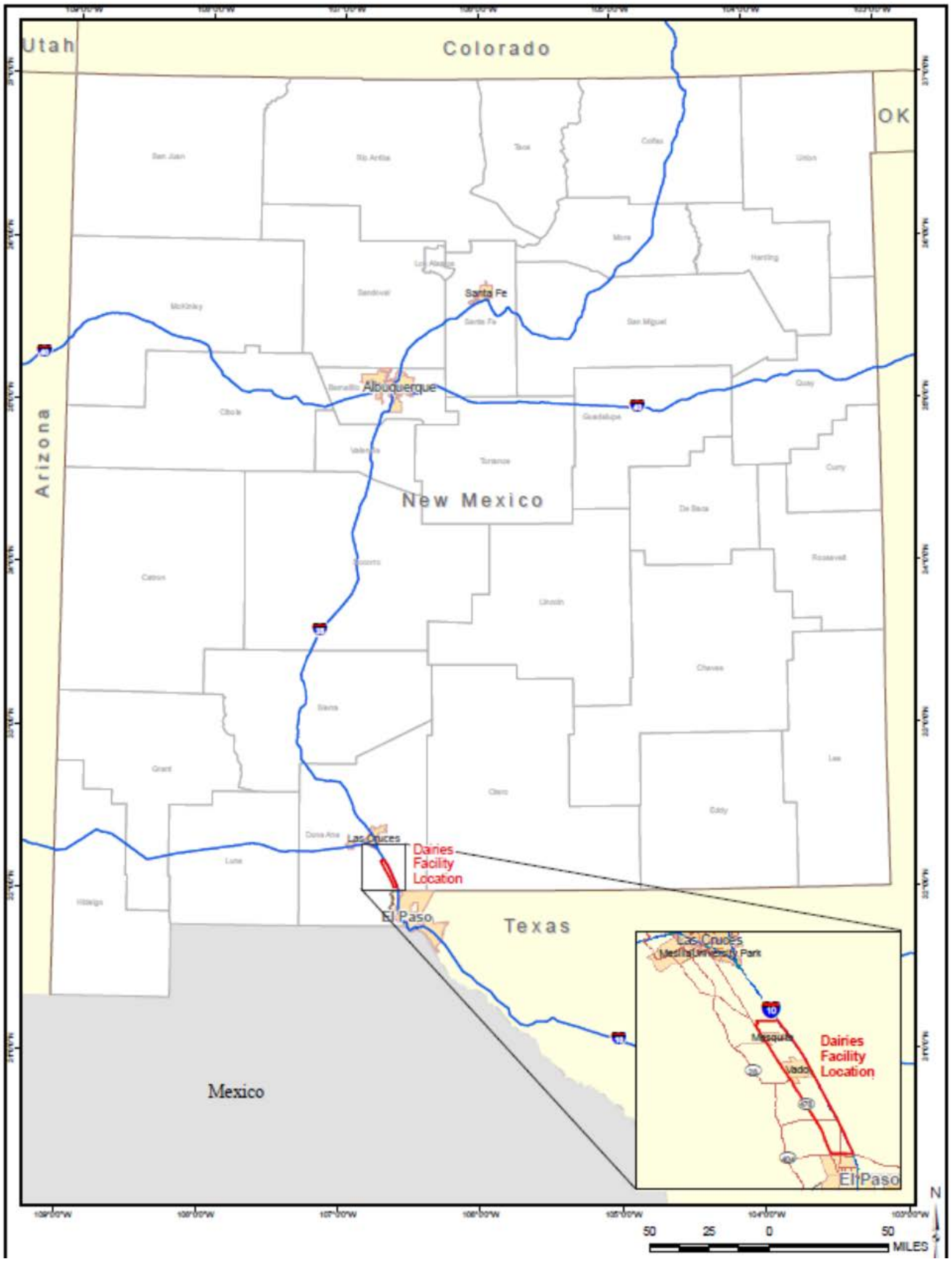


Figure 3 – Site Location Map
(EA Engineering, 2009)

The Doña Ana Dairies are located within a 12 mile stretch along Interstate Highway 10 (I-10) from Mesquite, New Mexico to Anthony, New Mexico. The boundary of the Dairies is roughly defined by I-10 to the east, route New Mexico (NM) State Highway 404 in Anthony to the south, route NM State Highway 478 to the west, and Missionary Ridge Road to the north. Some of the dairies are contiguous, while some are separated by non-dairy properties (Golder, 2008). The dairy facilities are shown in Figure 4.

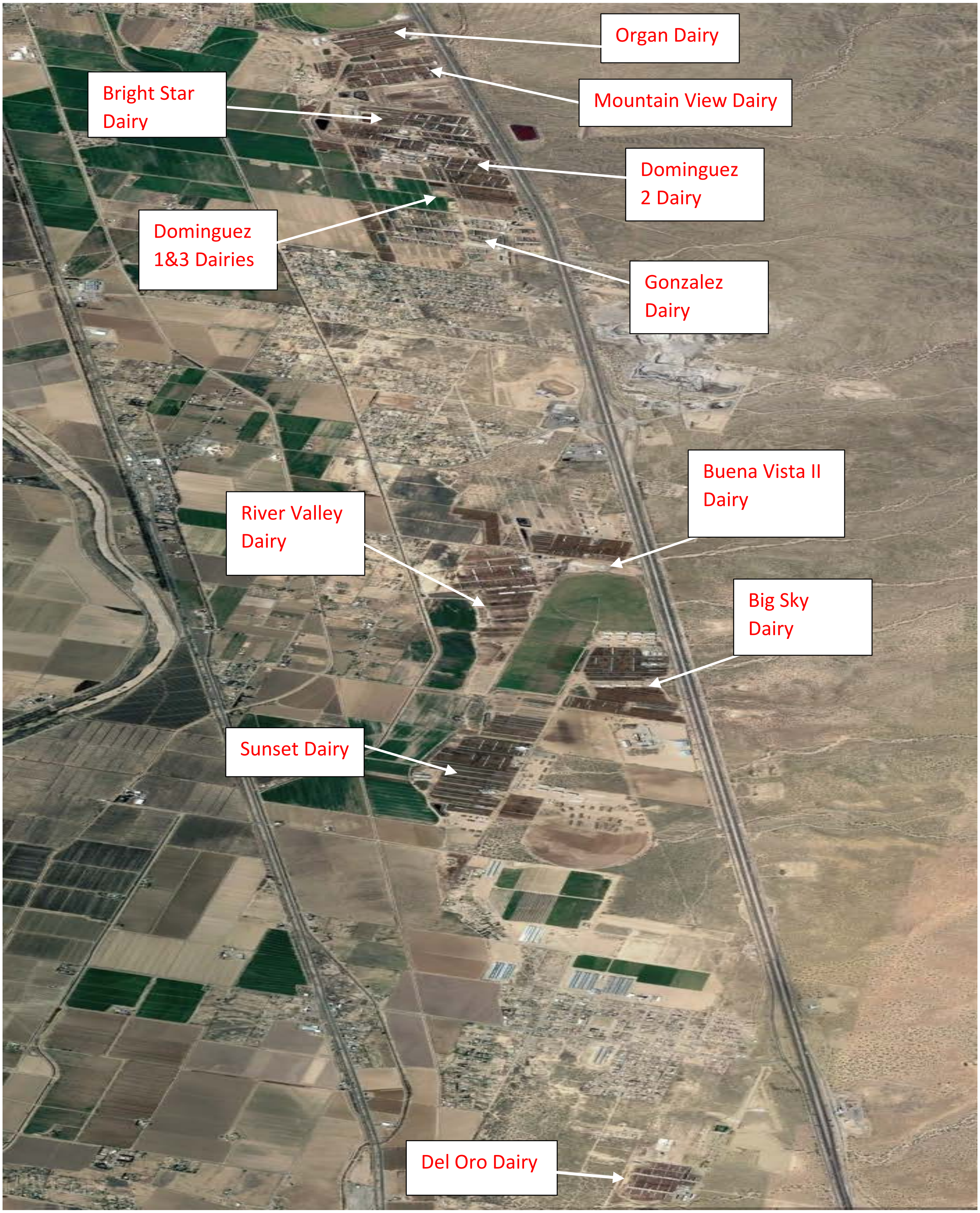


Figure 4– Dairy Facilities Map (Google 2020)

For ease of discussion and due to groundwater contamination and abatement requirements, the Doña Ana Dairies have been divided into three sections as follows:

- Northern Portion – Consisting of former Day Break Dairy (Organ Dairy), Mountain View Dairy, Buena Vista Dairy I, Bright Star Dairy, former D&J Dairy (Dominguez 2), Dominguez Dairy, and Gonzalez Dairy
- Central Portion – Buena Vista Dairy II, River Valley Dairy, Big Sky Dairy, and Sunset Dairy
- Southern Portion – Del Oro Dairy

II. Topography

The Doña Ana Dairies are located within the Rio Grande Subsection of the Mexican Highland Section of the Basin and Range Physiographic Province (Hawley, 1986). Hawley defined a physiographic province as a region with a pattern of landforms that are distinct from those of adjacent provinces and is formed by distinct combinations of underlying geological frameworks and topographic and hydrographic conditions that have interacted through geologic time.

This area of the Rio Grande Valley lies within the Mesilla Bolson, which is an intermontane basin located between uplifted areas to the east and west of the Valley. Significant uplifts and basins in the vicinity of Las Cruces were identified by numerous investigators, including (King et al, 1971). The geomorphology of the area of the Mesilla Bolson is representative of the Basin and Range Province, with sub-linear, roughly north south-trending mountainous uplifted areas consisting of older bedrock and Tertiary (ranges) separated by intervening down-thrown areas (basins) filled primarily with unconsolidated to semi consolidated clastic materials derived from alluvial fans, fluvial deposition and lacustrine deposition(Golder, 2008).

The Mesilla Valley is bounded by the Organ Mountains and Franklin Mountains on the east, the Jornada del Muerto Basin to the north, the Sierra de Los Uvas and the Potrillo Mountains to the west, and Sierra Juarez to the south in Mexico (Golder, 2008).

The existing flood plain of the Rio Grande River ranges in width from about 0.25 miles in narrow canyon where erosion-resistant bedrock units are present to as much as 5 miles in the Mesilla Valley (King et al, 1971).

The river gradient is approximately 4.5 feet per mile in the reach between Caballo Reservoir and El Paso (Conover, 1954). Elevations in the area range from more than 7,000 feet above mean sea level (MSL) in the Franklin Mountains and the Organ Mountains to 5,000-6,000 feet in the Sierra de Los Uvas and West Potrillo Mountains to about 3800 feet above MSL in the Rio Grande River near Anthony, New Mexico (Wilson et al, 1981). A topographic map is Figure 5.

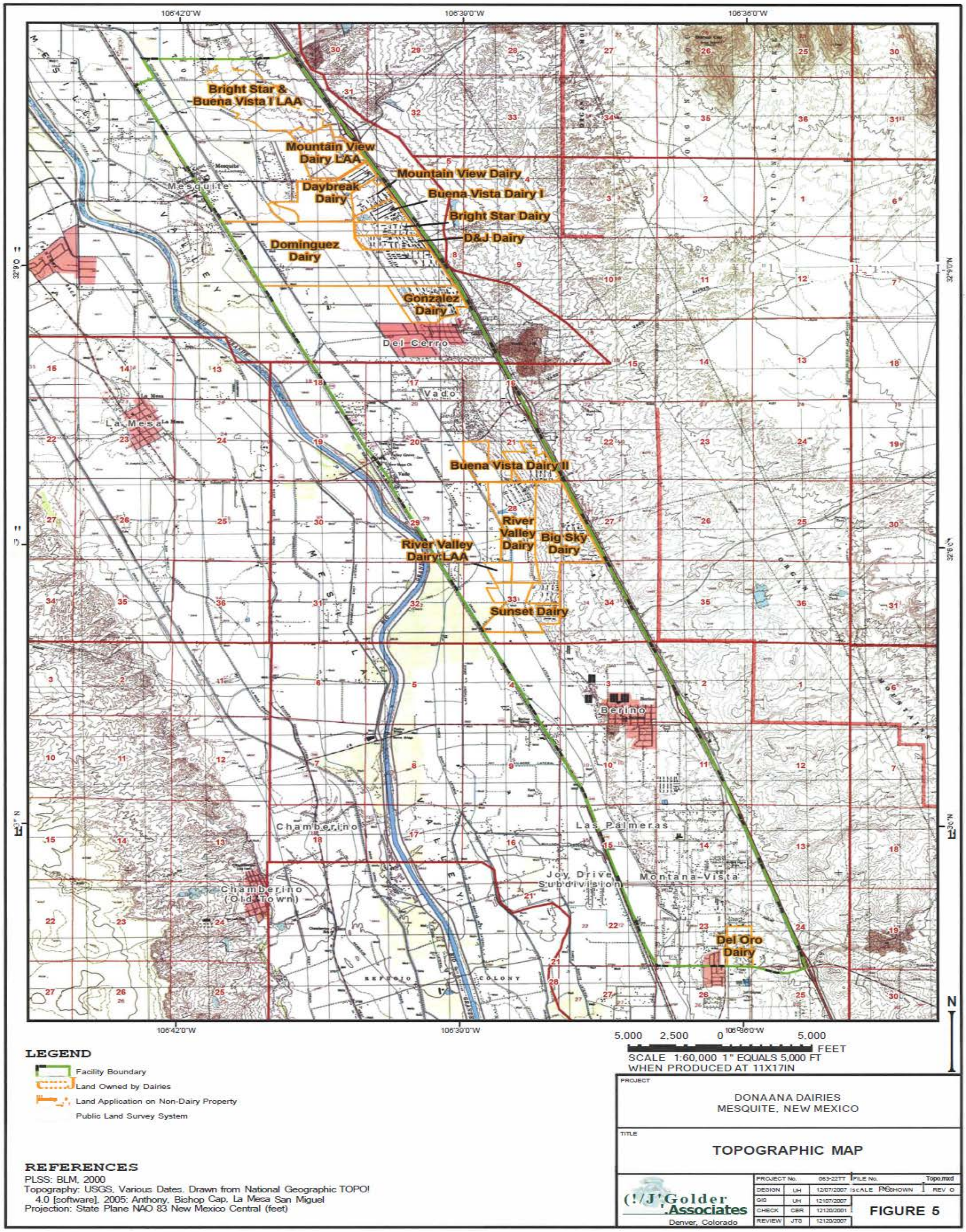


Figure 5 – Topographic Map (Golder, 2008)

III. Climate

The Dairies are situated east of the Rio Grande: elevation ranges between of 3,800 and 3,900 ft above MSL. The area receives approximately 350 days of sunshine annually. Climatological data for Mesilla (elevation 3910 ft above MSL) indicates an average annual precipitation of 6.28 inches, with 3.9 inches of snowfall (WRCC, 2020). Unlike many desert locales, the Mesilla Valley experiences four mildly distinct seasons, with the colder part of the winter occurring during December and January. Light snow does fall in the winter but seldom lasts longer than one day. June is generally the hottest month, with an average high of 96.5 ºF (WRCC, 2020). December is generally the coldest month, with an average low of 28.4 ºF (WRCC, 2020). The monsoon season, when heavy thunderstorms can occur daily, occurs in July and August (WRCC, 2020).

IV. Regional Hydrogeology

Seager et al, (1987) provided the most current mapping of the surficial geology in the vicinity of the Rio Grande south of Las Cruces. Hawley (1984) provided detailed descriptions of the unconsolidated and semi-consolidated basin fill section – the most important from a hydrogeologic standpoint. Surficial geology by Seager et al (1987) and hydrogeologic cross sections from Hawley (1984) in the vicinity of the Doña Ana Dairies are presented in Figure 6. This figure shows that the Doña Ana Dairies are situated on east margin of the Rio Grande Valley. The valley in the area of the dairies is a structural graben bounded by high angle normal faults (Golder, 2008). The valley margin to the east is formed by uplifted dense bedrock units consisting of Paleozoic, Cretaceous and Early Tertiary sedimentary rocks, as well as Tertiary intrusive and volcanic rocks. The valley margin to the west is formed by dense bedrock units of lower Paleozoic sediments and Tertiary volcanics (Golder, 2008). Hawley's (1984) cross sections were prepared using surficial geologic maps, as well as lithologic and geophysical data from deep exploratory wells and surface geophysical soundings (Zhody et al, 1976). Sections A-A' and B-B' (Figure 6) indicate that the Rio Grande graben contains more than 4,000 feet of fill in the vicinity of the Doña Ana Dairies (Golder, 2008). Shallowest fill materials consist of generally less than 100 feet of Quaternary-age surficial fluvial deposits associated with the active channel of the Rio Grande River. The basin contains up to 2,500 feet of Tertiary and Quaternary age unconsolidated and semi-consolidated sediments (Younger Basin Fill) and variable thicknesses (up to 2,000 feet or more) of semi-consolidated Tertiary sediments (Older Basin Fill). Lithologic logs from deep well drilling indicate that the floor of the graben is formed by Tertiary andesitic to rhyolitic volcanic flows (Golder, 2008).

Hawley (1984) identified a number of subdivisions of the Santa Fe Group in the vicinity of Las Cruces based upon texture, lithology, sorting and mineral make-up. These units are identified on the hydrogeologic cross sections Figure 6.

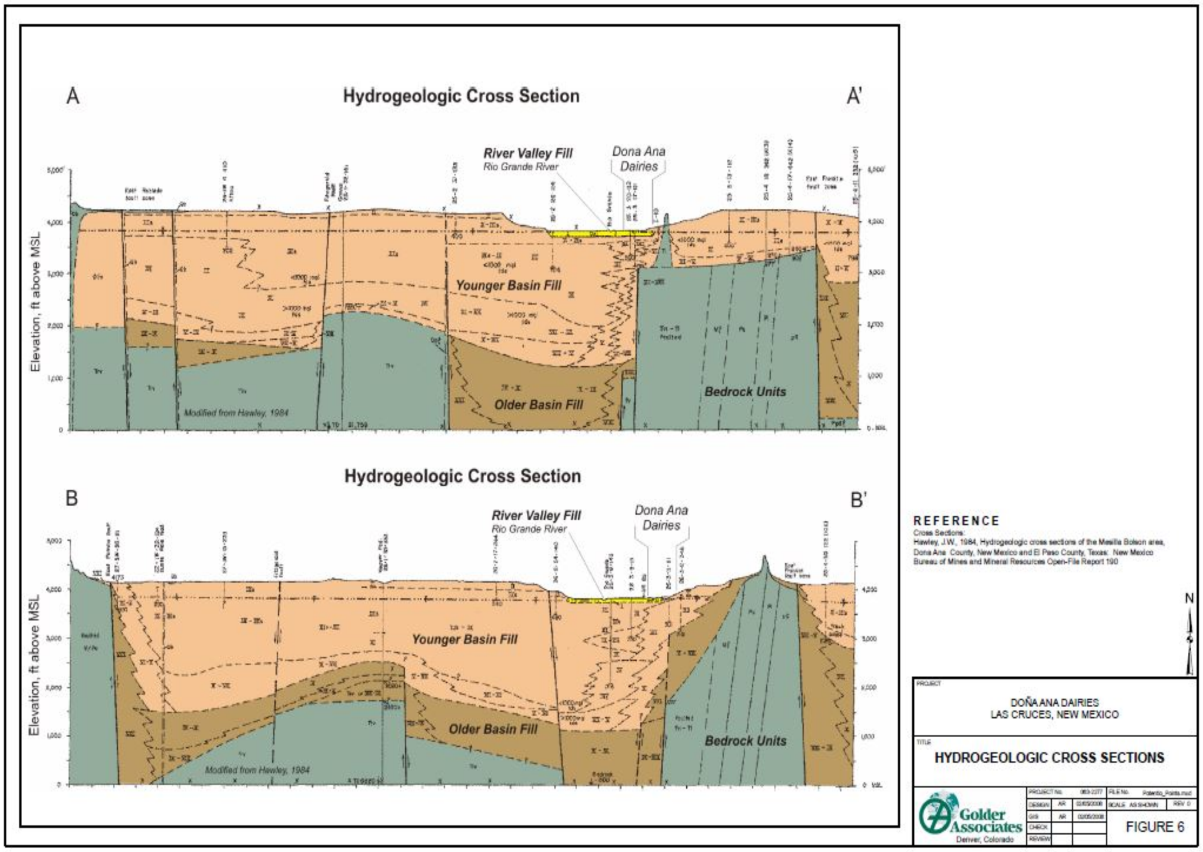


Figure 6 – Hydrologic Cross Sections (Golder, 2008)

Unconsolidated materials in the Santa Fe Group are roughly divided into Older and Younger Basin Fills. The Younger Basin Fill is further divided into Fluvial to Deltaic, Piedmont Slope and Basin Floor facies. The Older Basin Fill is divided into the Piedmont Slope and Basin Floor facies. Hawley's (1984) subunits of the Santa Fe Group and their hydrogeologic significance are summarized below:

Hawley (1984) Stratigraphic Unit	Aquifer
I. Valley Fill Unit	Shallow aquifer (Leggat, et al., 1962) Flood plain alluvium (Wilson, et al., 1981)
II. Younger Basin Fill Unit	Mesilla Bolson aquifer (Wilson, et al, 1981)
III. Younger Basin Fill Unit IV. Younger Basin Fill Unit	Medial aquifer (Leggat, et al, 1962) Deep aquifer (Leggat, et al, 1962)

Figure 7– Hawley 1984

In general, shallower water-bearing units within the Santa Fe Group are texturally coarser grained and more prolific groundwater producers than the deeper units.

King et al (1971) described groundwater conditions in the Mesilla Bolson in the areas east, west and in the Rio Grande valley portions of the bolson. Figure 7 is a potentiometric surface map of shallow groundwater taken from King et al (1971); this map shows the locations of the Doña Ana Dairies relative to significant groundwater surface features of the area. King et al (1971) noted a prominent northwest to southeast trending groundwater flow divide in the area approximately three miles west of the Rio Grande River; this feature was attributed to enhanced recharge and lower permeability of underlying Santa Fe Group sediments in this area. Groundwater flow direction is roughly toward the river on the east flank of this divide and toward the southwest on the west flank of the divide. King et al (1971) described shallow groundwater conditions in the piedmont slope area east of the inner valley area. In this area groundwater flow is toward the Rio Grande on the west flanks of the Organ Mountains, Bishop’s Cap and the Franklin Mountains. In the area between the Organ Mountains and the Franklin Mountains known as Fillmore Pass, significant thickness of saturated Santa Fe Group is present. This area is shown on Hydrogeologic Cross Section A-A’ (Hawley 1984) and on the potentiometric surface map of King et al (1971). Based upon well control described by Knowles and Kennedy (1956) at least 550 feet of saturated unconsolidated sediments are present in this area and little if any head difference exists between the Mesilla Bolson and the Hueco Bolson at this location.

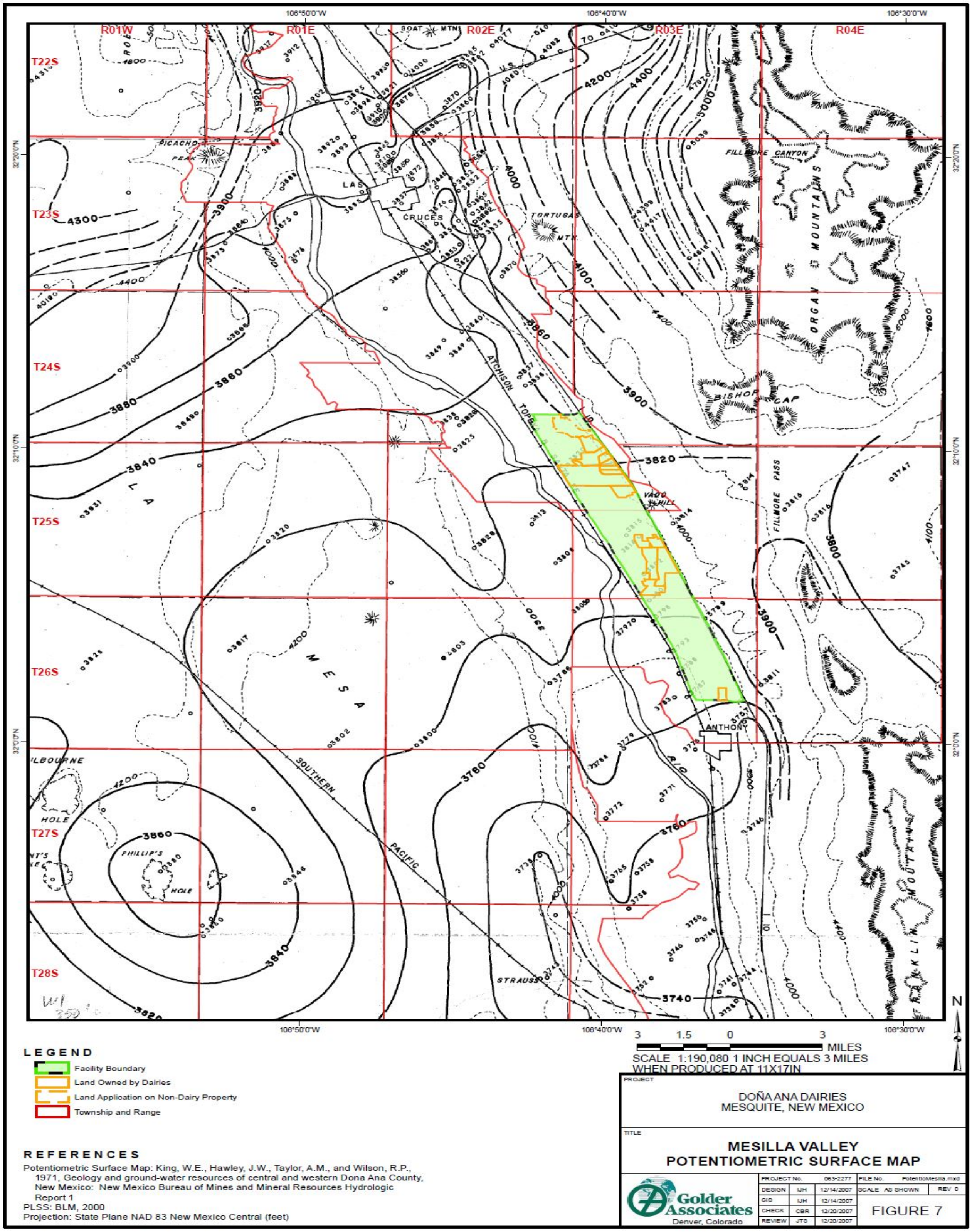


Figure 8 – Potentiometric Surface Map (Golder, 2008)

The Doña Ana Dairies are situated in a transition area spanning the east flank of the inner Rio Grande Valley and the piedmont slope on the east side of the valley (Golder, 2008). Approximately the western half of the Doña Ana Dairies area lies within Elephant Butte Irrigation District (EBID) west of the Mesquite Drain (Golder, 2008). King et al (1971) described the groundwater conditions in this area as highly influenced by irrigation activities. Wilson et al (1981), noted significant groundwater “troughs” in the inner valley area east of the Rio Grande River southeast of Las Cruces and east of Anthony and attributed these features to a combination of irrigation return flow and potentially higher water-bearing properties of the shallow fill in these areas. Conover (1954) presented detailed potentiometric surface maps and a cross section showing the effects of the irrigation conveyance and drain systems of the EBID on the altitude and configuration of the shallow groundwater in the inner valley area. Conover’s maps showed shallow groundwater configuration prior to construction of drains by the United States Bureau of Reclamation in 1917 and after construction of drains in 1919 in the vicinity of the Doña Ana Dairies (Conover 1954, plate 5 and plate 6).

The northern and central portions have similar subsurface lithology, consisting predominantly of sand. The sand is brown in color, fine to medium grained, and poorly graded (EA Engineering, 2009). The sand may have up to 5% gravel. Interbedded with the sand are minor intervals of either brown clayey silt or clayey sand (EA Engineering, 2009). Groundwater was encountered in the wells at depths between 10 to 85 feet below ground surface (bgs) (EA Engineering, 2009). This large range in depth to groundwater is attributed to the 50 to 70 foot change in topographic elevation from the east to the west side of the site (EA Engineering, 2009). The southern portion (Del Oro Dairy) subsurface lithology consists predominantly of sand and gravel with a perched groundwater aquifer present along the eastern portion of the site (EA Engineering, 2009). Along the western side of Del Oro Dairy sand with minor gravel was encountered to approximately 25 to 35 feet bgs (EA Engineering, 2009). Groundwater was encountered at approximately 50 feet bgs. (EA Engineering, 2009). The subsurface lithology along the eastern portion of Del Oro Dairy is similar to the western portion; however, a clay aquitard (e.g., “perching layer”) was encountered (EA Engineering, 2009). It appears that the shallow groundwater observed at 65 feet bgs constitutes a perched aquifer and that the regional aquifer is present below the silty clay aquitard (EA Engineering, 2009). It is unknown how extensive the clay aquitard is; it appears to dip toward the west-southwest.

V. Site Groundwater

The groundwater flow direction throughout the Doña Ana Dairies (northern, central and southern portions) is toward the south-southeast, and the hydraulic gradient is 0.5 feet per thousand (0.0005 foot per foot). The gradient is very low, which may be in response to groundwater pumping stresses from many irrigation and supply wells throughout the basin. The groundwater flow direction differs slightly at Del Oro Dairy within the perched aquifer where the groundwater flow direction is toward the south-southwest (Golder, 2008).

A large number of monitoring wells (65) are located near the Dairies, two additional wells are located within land application area not owned by dairies used for disposal of wastewater, and one well, installed in the early 1980s by NMED, is located within the county right of way (EA Engineering, 2019). Of these 65 wells, 64 are monitored on a quarterly basis. Quarterly monitoring events include water level measurements and sample collection and laboratory analyses for nitrate, total Kjeldahl nitrogen (TKN), chloride, and TDS.

The directions of groundwater flow are somewhat different in the northern, central, and southern portions. In the northern portion, the direction of groundwater flow is to the southeast (away from Mesquite Drain in this reach), in the central area to the south (parallel to the drain), and in the southern area to the east (away from the East Drain) (Golder, 2008). Also, the gradient is considerably steeper in the southern area, where the potentiometric surface lines are shown at 5 ft intervals, as opposed to the northern and central areas where the lines are at a 1 ft interval (Golder, 2008). This increased gradient in the southern portion is thought to be in response to pumping stresses and perhaps stratigraphic control in the vicinity of Anthony (Golder, 2008).

VI. Waste and Water Management Operations at the Dairies

The Doña Ana Dairies operate by the dry lot method, which means that the cows are confined to the pens unless they are in transit to or from or in the milking parlor. The dairies operate 7 days a week and the milking barns/parlors are in use 24 hours a day. Under this operation set-up, two waste-streams are produced: wastewater containing manure residue and manure waste itself. In addition, a third waste stream – storm water runoff over feed lot areas – constitutes a waste stream that is collected and directed towards lagoons to prevent discharge to surface water (Golder, 2008).

VII. Summary of Existing Data

Existing data for the Doña Ana Dairies consists of groundwater monitoring data collected over the years to satisfy requirements of individual discharge plans, survey data in 2007 to bring all dairy monitor wells to a common datum, well gauging data collected in 2007 by Golder, and surface water survey and gauging data collected in 2007 by Golder (Golder, 2008).

This data includes a descriptive history of each dairy, wastewater storage and disposal practices, irrigated cropland acreages and irrigation practices over time, herd size over time, and groundwater samples collected from each dairy at least semiannually. Groundwater samples were collected from monitoring wells with the following protocols:

a. Groundwater sample collection, preservation, transport and analysis shall be performed according to the following procedure:
    i. Measure the depth-to-most-shallow groundwater from the top of the well casing to the nearest hundredth of a foot.

ii. Purge three well volumes of water from the well prior to sample collection.
iii. Obtain samples from the well for analysis.
iv. Properly prepare, preserve and transport samples.

Groundwater samples were analyzed for chloride (Cl), total Kjeldahl nitrogen (TKN), nitrate as nitrogen (NO3-N), and Total dissolved solids (TDS) using U.S. Environmental Protection Agency, Methods for Chemical Analysis of Water and Waste.

All data in this study were obtained from the GWQB of NMED. Water samples from each dairy are submitted in Quarterly Monitoring Reports that are required by their Ground Water Discharge Permit. Data will be extracted from these reports and entered into Excel for trend analysis.

Analysis and Results

I. Northern Portion – Consisting of former Day Break Dairy (Organ Dairy), Mountain View Dairy, Buena Vista Dairy I, Bright Star Dairy, former D&J Dairy (Dominguez 2), Dominguez Dairy, and Gonzalez Dairy

   C. Organ Dairy DP-126

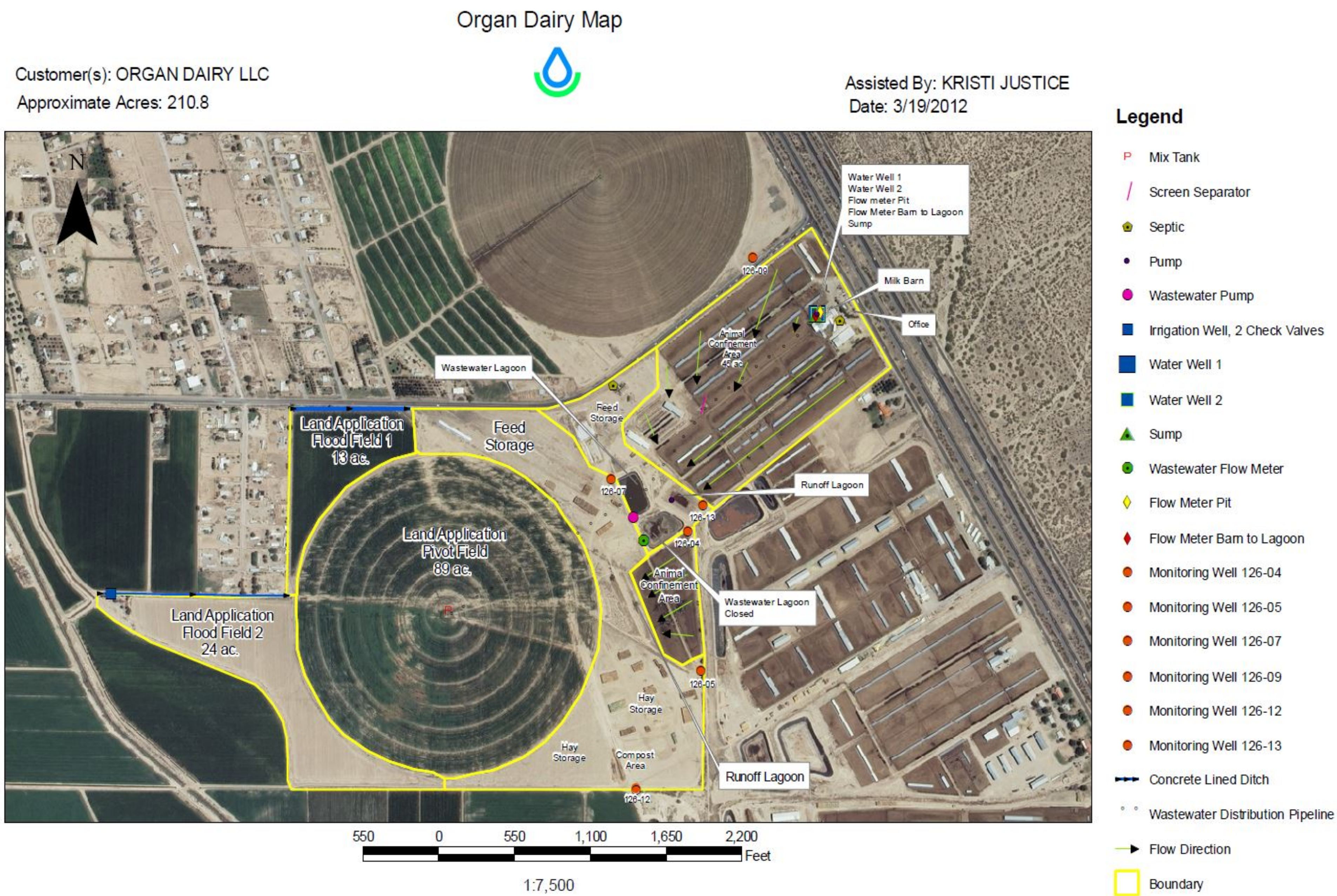


Figure 9 – Organ Dairy Site Map (NMED, 2012e)

The GWQB administrative record for DP-126 states that when Gorzeman #2 Dairy began production in around 1981 wastewater was stored in two manure lined ponds. It also states that a synthetic lined pond was constructed in 1990 and replaced with a HDPE liner in 2008. MW 126-07 is located upgradient of the old wastewater pond and MW 126-04 is located downgradient of it. These two wells track almost identically so a leaking pond is not obvious in the data. A CWA violation was issued in late 2006 noting a leaking wastewater pond and over application to the flood fields (EPA, 2006), adjacent to MW 126-05. The sudden spike in 2006 in 126-05 could be correlated to the prior growing seasons and the cited over irrigating with manure slurries. Groundwater is at a depth of ten feet below the ground surface (NMED, 2019i). The following monitoring wells supply data representative of groundwater quality for Organ Dairy (NMED, 2019i):

- 126-07 – hydrologically upgradient of the Wastewater Ponds
- 126-04 - hydrologically downgradient of the Old Wastewater Pond and located off the southeast corner of the pond
- 126-12 - hydrologically cross gradient of the land application area and located at the southern boundary of the dairy
- 126-05 - hydrologically downgradient of the land application area and located along the eastern boundary of the facility

Nitrate concentrations in mg/L in two monitoring wells near the land application area are graphed in Figure 10. The yellow trendline of the most downgradient well shows a slight upward trend most likely due to past over application to crop land at the dairy facility.

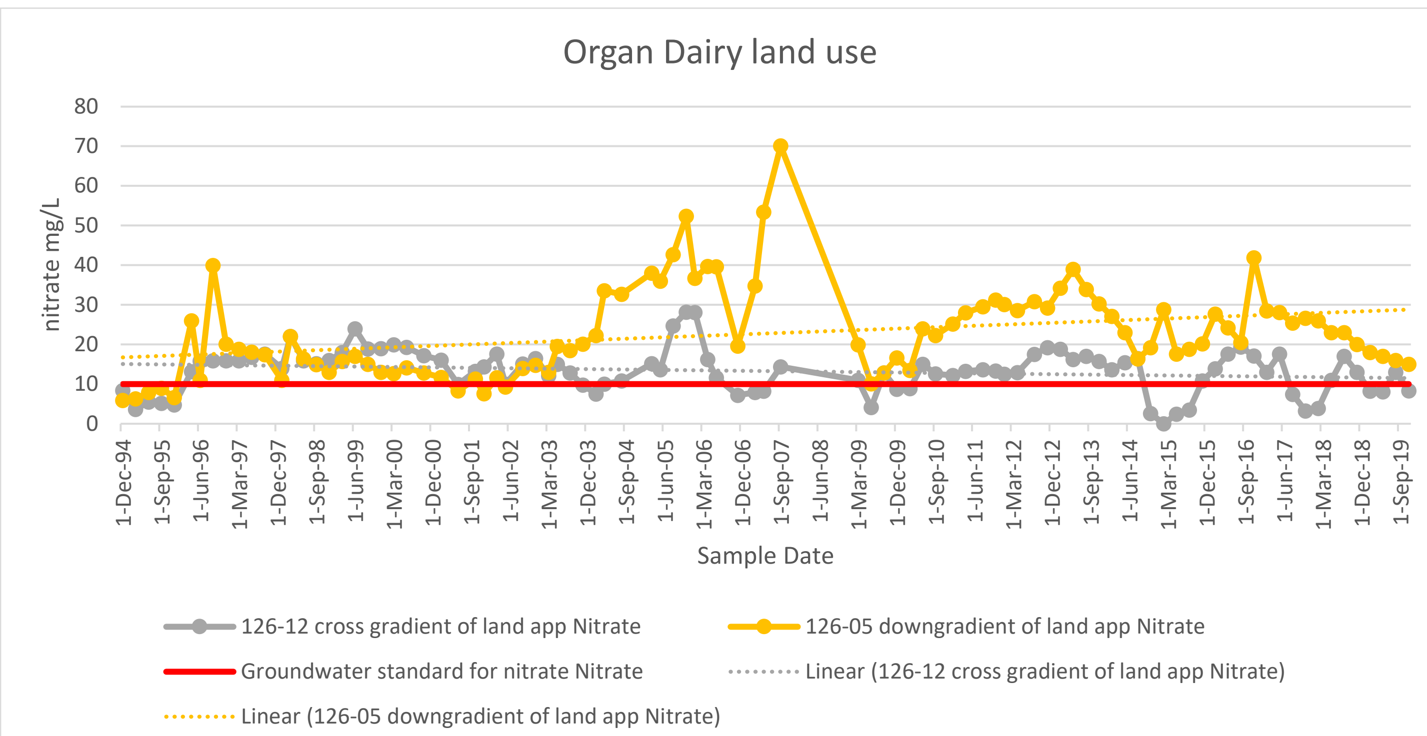


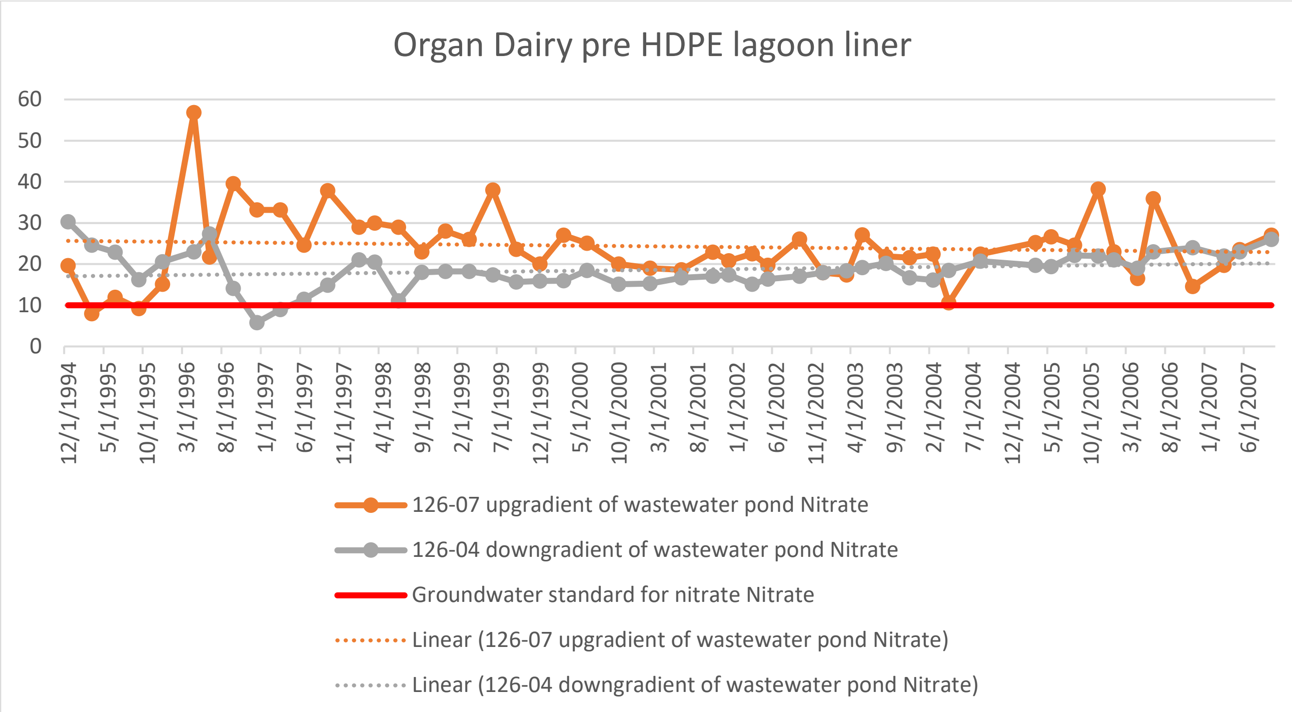
Figure 10 – Organ Dairy Groundwater Nitrate Concentrations near land application area (NMED, 2019i)

Organ Dairy History

From the GWQB administrative record for DP-126, the date of operations inception not available but likely sometime after February 1981. A public notice dated May 21, 1982, mentions that the previously approved DP was for the disposal of 24,000 gpd of milking center wastes to two manure lined evaporation ponds (NMED, 2019i). The proposed modification in the May 21, 1982, public notice mentions land application of wastewater to 221 acres located adjacent to and west of the Gorzeman dairy and south of NM-228 and the manure lined ponds were to be taken out of service (NMED, 2019i). The April 15, 1992 DP approved the discharge of 35,000 gpd through a solids separator to a Hypalon lined holding pond and then land applied to 164 acres of cultivated land (NMED, 2019i). On January 22, 2001 the DP approved up to 40,500 gpd of dairy wastewater discharged to a synthetically lined pond. From the pond, the wastewater is discharged to 164.8 acres of cropland. Manure and solids are removed from the facility biannually (condition 5 of DP mentions solids application to cropland) (NMED, 2019i).

On August 30, 2007 the DP authorized up to 24,000 gpd of wastewater to be discharged to a synthetically lined lagoon for storage, from where it is discharged to 119 acres of center-pivot irrigated cropland under cultivation. Manure is to be removed off site or applied in a manner and frequency that is protective of groundwater (NMED, 2019i). Stormwater is diverted to two stormwater impoundments from where it is transferred to the wastewater lagoon (NMED, 2019i). On August 29, 2019 the permit authorized up to 30,000 gpd of wastewater from the production area to a synthetically lined wastewater impoundment for storage. Stormwater is diverted to two stormwater impoundments from where it is transferred to the wastewater lagoon (NMED, 2019i). Wastewater is land applied by flood and center pivot irrigation to up to 126 acres of irrigated cropland under cultivation (81 acres of flood irrigation and 45 acres irrigated by center pivot) (NMED, 2019i).

The groundwater gradient is relatively flat at Organ Dairy as shown by the potentiometric surface lines drawn at a 1 ft interval (Appendix A) (Golder, 2008). Nitrate concentrations in two monitoring wells near the wastewater storage ponds are graphed in Figure 11. The time prior to the installation of the HDPE liner is plotted in the first graph and post HDPE liner installation in the second graph. The trendlines of the most downgradient well shows a slight upward trend prior to the liner upgrade. The post liner groundwater data shows an upward trend in nitrate concentration, showing that the liner had little to no effect on improving the groundwater quality.



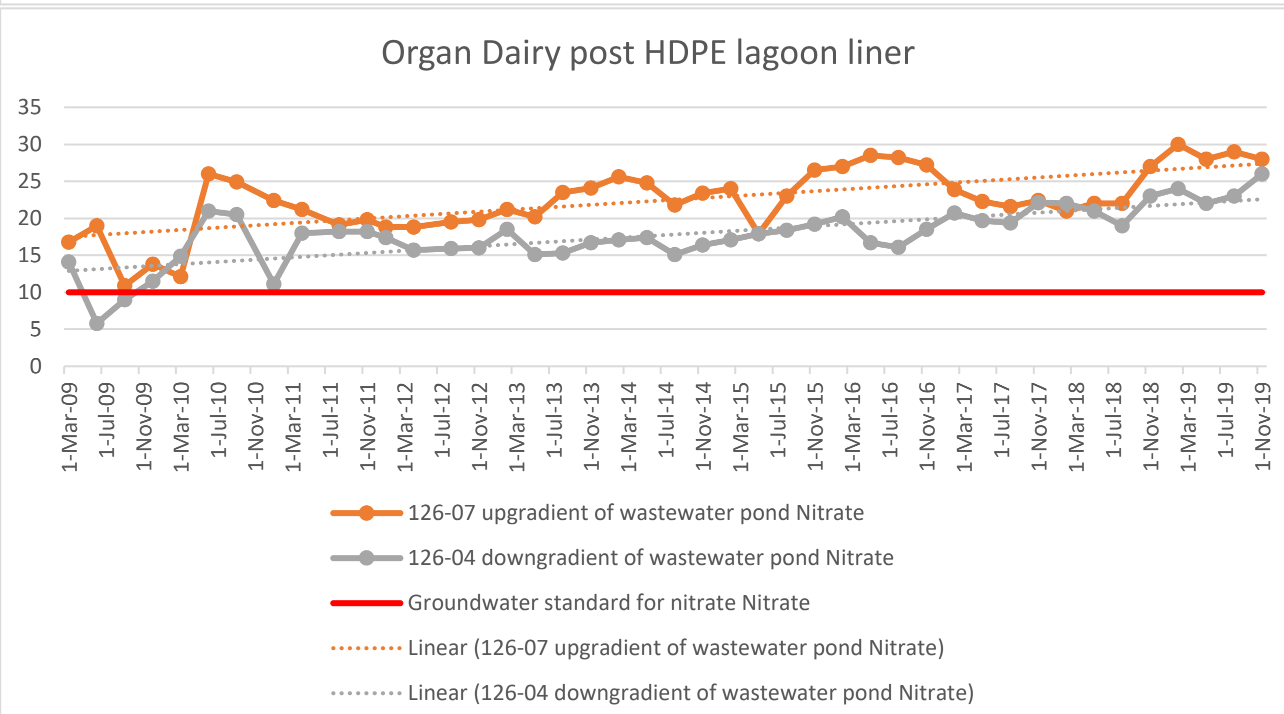


Figure 11 – Organ Dairy Groundwater Nitrate Concentrations near wastewater ponds Prior to installation of an HDPE liner and after installation of an HDPE liner (NMED, 2019i)

Discussion of the Organ Dairy

When Gorzeman #2 Dairy began production in around 1981 wastewater was stored in two manure lined ponds. The discharge volume and land application area has varied over the years but not significantly. A synthetic lined pond was constructed in 1990 and the liner was replaced with a HDPE liner in 2008 (NMED, 2019i). MW 126-07 is located upgradient of the old wastewater pond and MW 126-04 is located downgradient of it. These two wells track almost identically so the liner seems to have little to no impact on groundwater quality.

The CWA violation issued in late 2006 notes over application of dairy wastewater to the flood fields (EPA, 2006), adjacent to MW 126-05. The sudden spike in 2006 in 126-05 could be correlated to the prior growing seasons and the cited over irrigating with manure slurries. The land application practices over time as shown in Figure 10 seem to have more immediate and substantial groundwater quality impacts for nitrate than the wastewater storage ponds do. Herd size in 1990 was 1,000 head and is currently 1,100 (NMED, 2019i), so since there has been no significant change in herd size, it cannot be correlated to a change in groundwater quality.

D. Mountain View Dairy DP-70

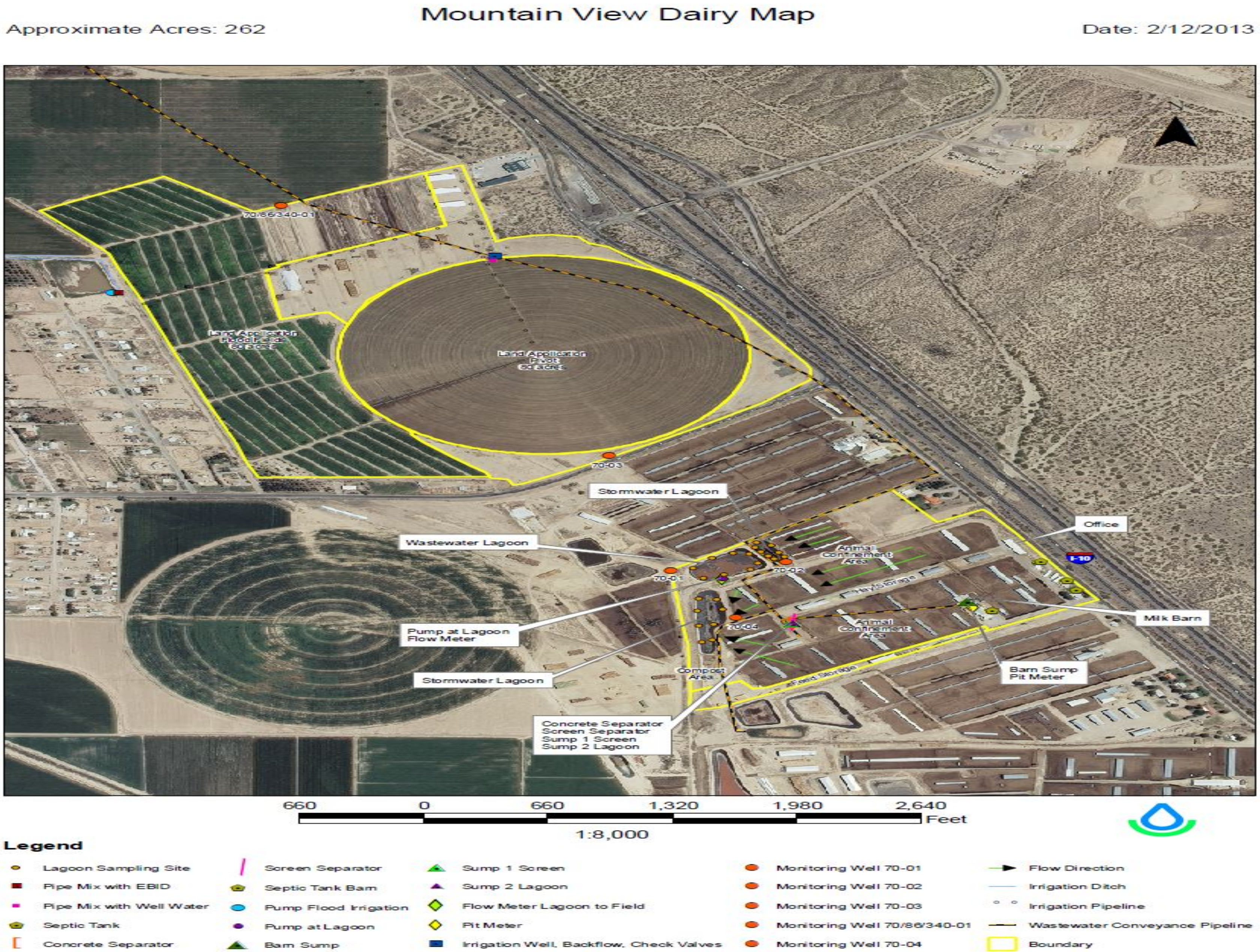


Figure 12 – Mountain View Dairy Site Map (NMED, 2012d)

The high concentrations of nitrate, 70.4 mg/L and 65.1 mg/L respectively appear in MW 70-01 first in late 2001 and then in MW 70-02 in early 2003 (NMED, 2019h). The pond was synthetically lined in 1998 (NMED, 2019h). MW 70-01 is upgradient of the pond and MW 70-02 is downgradient of the pond, so it is likely that the influx of nitrate in 2002 came from the prior manure lined pond. Groundwater is at a depth of approximately 35 feet below the ground surface (NMED, 2019h). The following monitoring wells supply data representative of groundwater quality for Mountain View Dairy (NMED, 2019h):

- MW-70-01 – hydrologically upgradient and northwest of the Wastewater Pond
- MW-70-02 - hydrologically downgradient of the ponds, located approximately 98 feet east of the Wastewater Pond and 16 feet south of the North Stormwater Pond
- MW-70/86/340-01 - hydrologically upgradient of all contamination sources at the dairy facility and northwest of the Flood Field.
- MW-70-03 - hydrologically downgradient of the LAA, located approximately 76 feet south of the Pivot Field.

Nitrate concentrations (mg/L) in two monitoring wells near the pond are graphed in Figure 13. The yellow trendline of the most downgradient well shows a slight downward trend in nitrate concentrations in the groundwater at Mountain View Dairy.

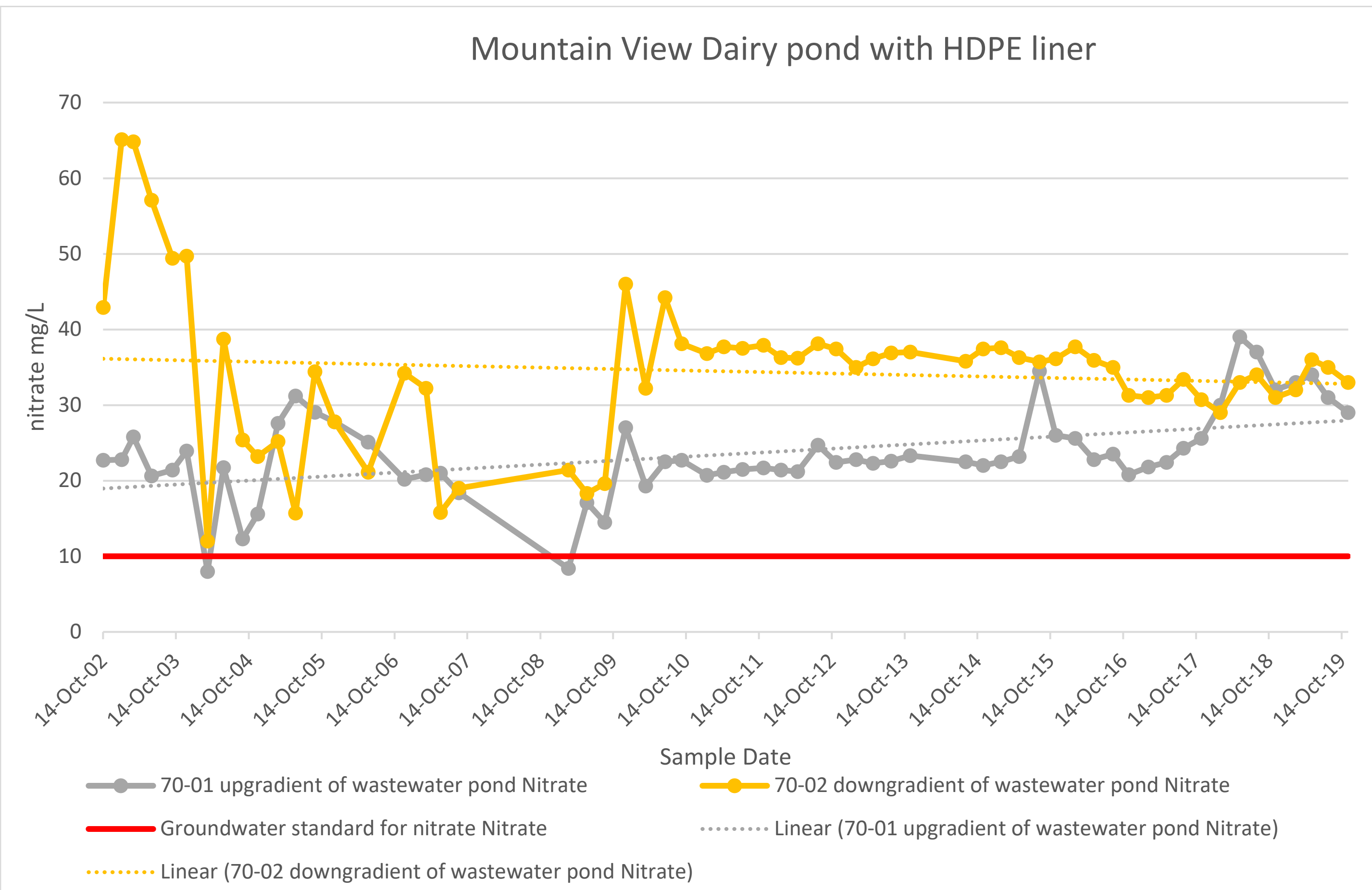


Figure 13 – Mountain View Dairy Groundwater Nitrate Concentrations near wastewater pond (NMED 2019h)

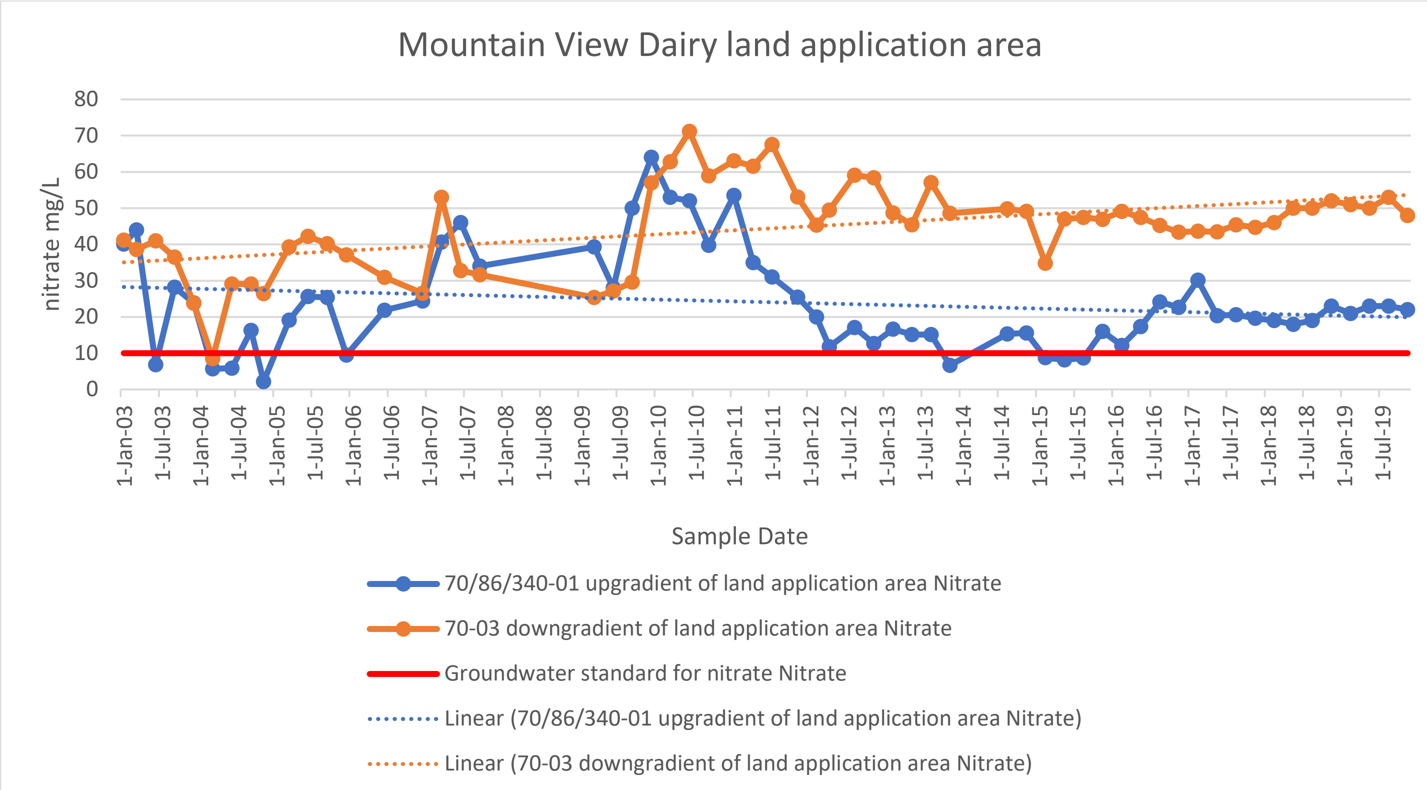


Figure 14 – Mountain View Dairy Groundwater Nitrate Concentrations near land application areas (NMED 2019h)

Mountain View Dairy History

From the GWQB administrative record for DP-70, operations started in 1980, on June 15, 1979, the original DP approval for the Ed DeRuyter dairy (as it was known at that time), was issued. The public notice dated April 30, 1979, indicated a discharge of 16,000 gallons per day (gpd) of dairy barn wastes and manure-contaminated runoff to a manure-lined lagoon (NMED, 2019h). The public notice dated February 21, 1983, indicates a modification to increase discharge to 50,000 gpd and apply to 20 acres of cropland (NMED, 2019h). On December 18, 1991 NMED authorized discharge of 25,000 gpd of milking center and wash pen water to a manure solids separator for removal of solids and then to 35 acres of cropped land (NMED, 2019h). On October 9, 2001, the DP approved up to 60,000 gpd of wastewater from the milking barn through a manure separator to a synthetically lined lagoon from where it is land applied to 160 acres of cropland. Manure is hauled off-site for disposal. Stormwater is collected in a pond, from where it is transferred in the wastewater collection pond for land disposal (NMED, 2019h).

On June 28, 2017, the DP authorized up to 35,000 gpd of effluent from the production area to a synthetically lined impoundment for storage prior to land application by center pivot and flood irrigation to up to 160 acres of irrigated cropland under cultivation (NMED, 2019h).

Discussion of Mountain View Dairy

In the fall of 2005, EPA obtained sampling data from groundwater monitoring wells located adjacent to the wastewater retention pond and land application areas (NMED, 2019h). The data consistently showed nitrate concentrations over 10 milligrams per liter (mg/L) which is the national maximum contaminant level (MCL) for drinking water and the state groundwater nitrate standard. The maximum nitrate concentration from the well adjacent to the pond was 70.4 mg/L in 2001 and the maximum concentration adjacent to the land application areas was 65.1 mg/L in 2003 (NMED, 2019h). These concentrations of nitrate in the groundwater suggest that the wastewater retention pond was leaking, and that wastewater was not being applied to cropland at an agronomic rate (EPA, 2007).

The groundwater gradient is relatively flat at Mountain View Dairy as shown by the potentiometric surface lines drawn at a 1 ft interval (Appendix A) (Golder, 2008). The pond was synthetically lined in 1998 (NMED, 2019h). MW 70-01 is upgradient of the pond and MW 70-02 is downgradient of the pond, so the graph above in Figure 13 shows that the downgradient well is slowly trending down and the concentrations for nitrate in MW 70-01 and MW 70-02 are nearing the same concentration in 2019. The liner, while still allowing some leaching of residual nitrate, seems to have reduced the impact of leachate on groundwater quality.

MW 70/86/340-01 upgradient of the facility and MW 70-03 downgradient of the land application area are graphed in Figure 14. The discharge and land application area has remained constant since 2001 but irrigation practices seem to continue to impact nitrate concentrations in the groundwater beneath the crop fields irrigated with wastewater. Herd size was ~ 1000 head in 1990 and is currently 2,400 head, so the increase in herd size cannot be directly correlated to the impact on groundwater quality for nitrate, but the increase in discharge volume directly related to milking more cows and the direct application of this wastewater on crop land for irrigation is shown to be an indirect impact.

E. Bright Star Dairy DP-340

Figure 15 – Bright Star Dairy Site Map (NMED, 2012b)

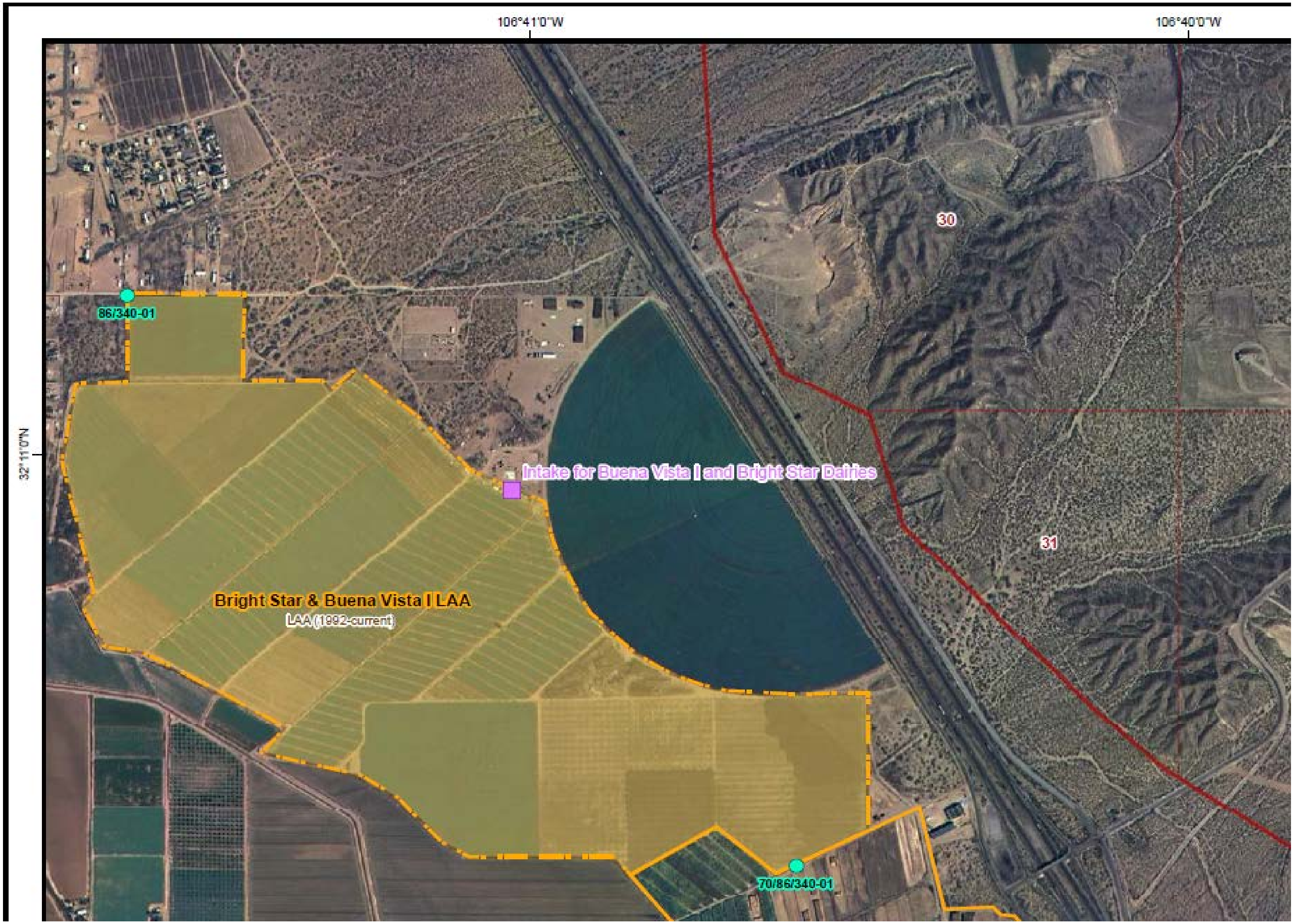


Figure 16 – Bright Star Dairy Land Application Area Map (Golder 2008)

Bright Star Dairy had manure lined ponds for wastewater storage from 1973 to 1993 (Golder, 2006). MW 340-02 located directly adjacent to the main pond which was manure lined and the newer clay lined pond constructed in 1995 (NMED, 2019b). The ponds were noted to be leaking until 2008 when a synthetic liner was installed (NMED, 2019b). Groundwater is a depth of approximately 36-54 feet below the ground surface (NMED, 2019b). The following monitoring wells supply data representative of groundwater quality for Bright Star Dairy (NMED, 2019b):

- 126-12 - hydrologically upgradient of all contamination sources at the facility and located adjacent to Farmland Road
- 340-02 - hydrologically downgradient of main pond and located approximately 500 ft southeast of pond
- 86/340-01 - hydrologically upgradient of the former land application and located along Missionary Ridge Road.
- 70/86/340-01 - hydrologically downgradient of the former land application and located along the property boundary of the Mountain View Dairy land application area.

Nitrate concentrations (mg/L) in two monitoring wells near the pond are graphed in Figure 17. The trendlines show an increasing trend in nitrate concentrations near the wastewater pond.

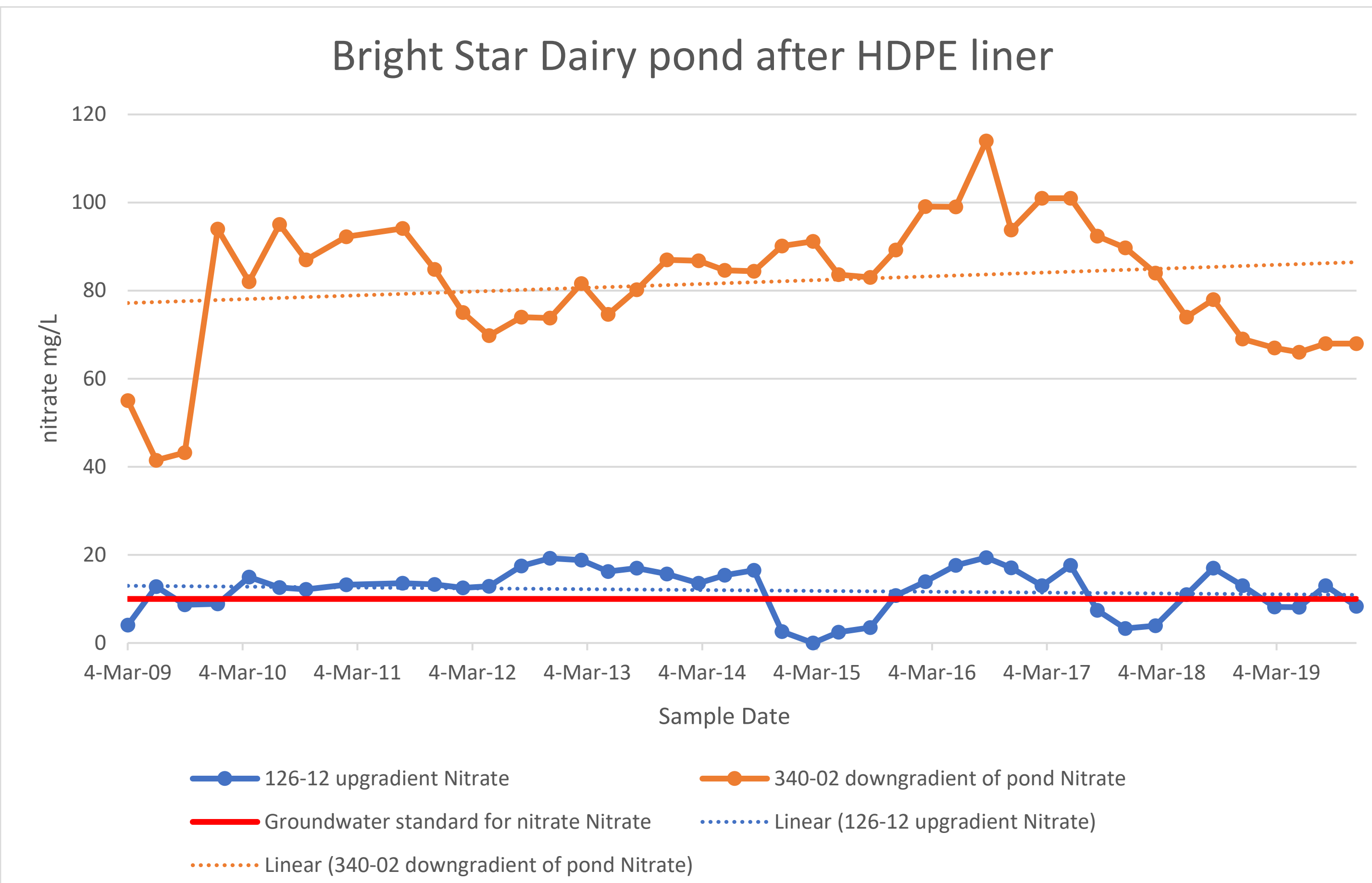


Figure 17 – Bright Star Dairy Groundwater Nitrate Concentrations near pond (NMED 2019b)

Bright Star Dairy History

From the GWQB administrative record for DP-340, operations started in 1973, but on July 8, 1987 NM EID approved the original permit. The August 11, 1986, public notice states that the dairy previously discharged approximately 32,000 gallons per day (gpd) of milking center effluent to 20 acres of pastureland (NMED, 2019b). In a modification it was proposed that effluent be applied to 96 acres cropland located at the adjacent Isaac Dominguez farm (NMED, 2019b). The August 7, 1991 DP approved the discharge of 15,000 gpd of milking center wash water and wash pen wastewater to a screen type manure solids separator mounted on a concrete-lined pad. The clarified wastewater was then gravity fed to a clay-lined holding pond and from there it was pumped to 96 acres of cropland (NMED, 2019b). On December 18, 1991 a permit modification increased the approved discharge volume from 15,000 gpd to 25,000 gpd (NMED, 2019b).

On October 9, 2001 the DP approved up to 60,000 gpd wastewater from the milking barn, to a clay-lined lagoon and then applied to 438 acres of non-dairy land by flood, sprinkler, and drip irrigation, called the Northern LAA; this LAA also receives 60,000 gpd from Buena Vista I (NMED, 2019b). Manure was to be removed from property (NMED, 2019b). On April 3, 2015 the DP authorized a maximum daily discharge volume of 60,000 gpd of wastewater from the production area, to a synthetically lined combination wastewater and stormwater impoundment for storage then land applied by flood and center pivot irrigation to up to 160 acres of irrigated cropland under cultivation (NMED, 2019b). On May 23, 2019 NMED authorizes a discharge up to 20,000 gpd of wastewater from the production area to a synthetically lined combination wastewater and stormwater impoundment for storage prior to transfer to second synthetically lined impoundment for disposal by evaporation. On an as needed basis, wastewater can be transferred from Bright Star Dairy, LLC to Impoundment 3, located adjacent to the Bright Star Dairy, LLC at R-Qubed Energy, Inc (NMED, 2019b).

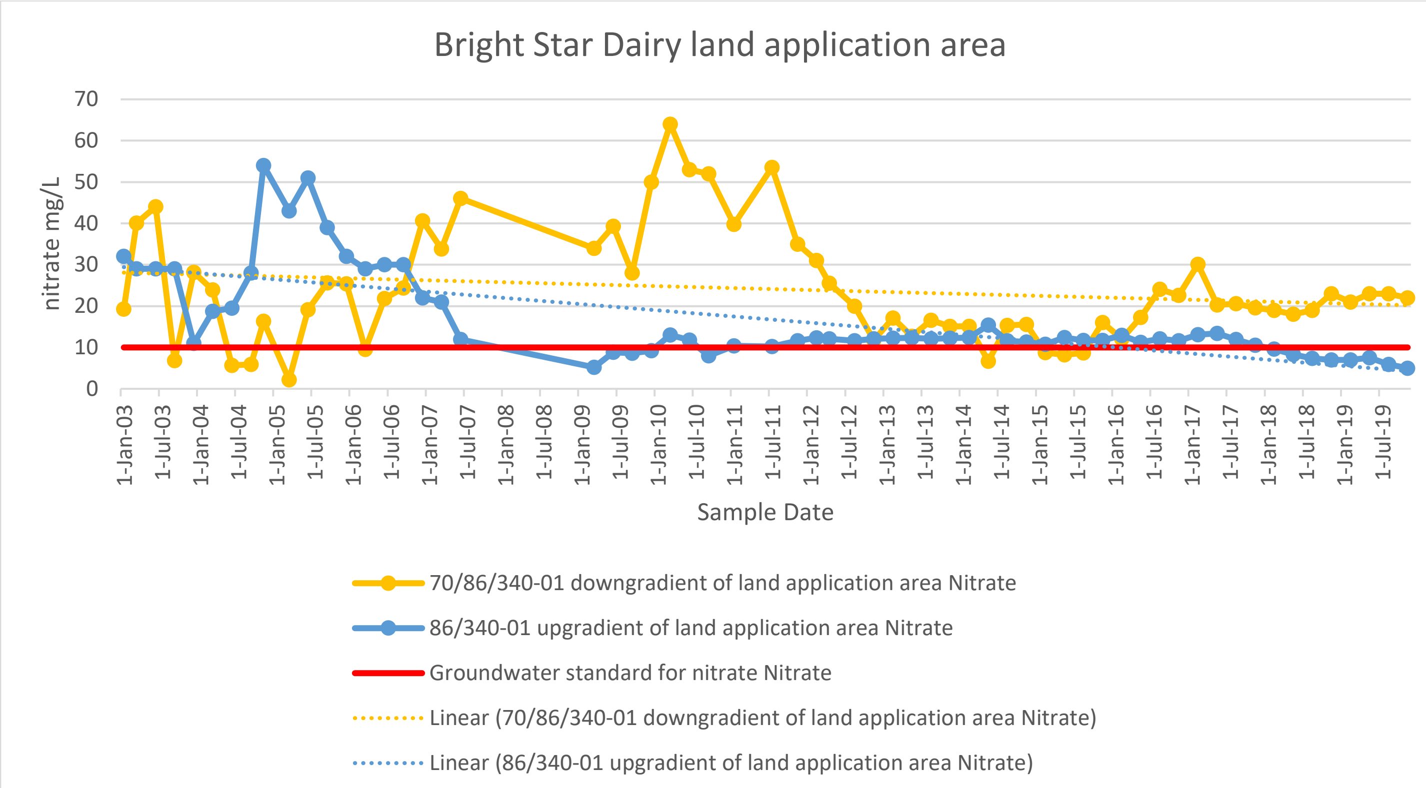


Figure 18 – Bright Star Dairy Groundwater Nitrate Concentrations near land application area (Golder 2008)

Discussion of the Bright Star Dairy

Bright Star Dairy had manure lined ponds for wastewater storage from 1973 to 1993 (Golder, 2006). MW 340-02 located directly adjacent to the main pond which was manure lined and the newer clay lined pond constructed in 1995 (NMED, 2019b). The synthetic liner installed in 2006 (Golder, 2008) seems to have no impact on groundwater quality.

The groundwater gradient is relatively flat at Bright Star Dairy as shown by the potentiometric surface lines drawn at a 1 ft interval (Appendix A) (Golder, 2008). The two monitoring wells near the land application area are graphed in Figure 18. The nitrate concentration in the downgradient well has been less than the upgradient well most of the time since 2006. The use of these flood irrigated fields has not had caused nitrate concentrations in groundwater to increase. Herd size was 1,000 milking head in 1990 and 2,400 milking head in 2018 (NMED, 2019b). The herd size increase does not directly correlate to a groundwater quality impact.

F. Dominguez 2 (Formerly D&J Dairy) DP-42

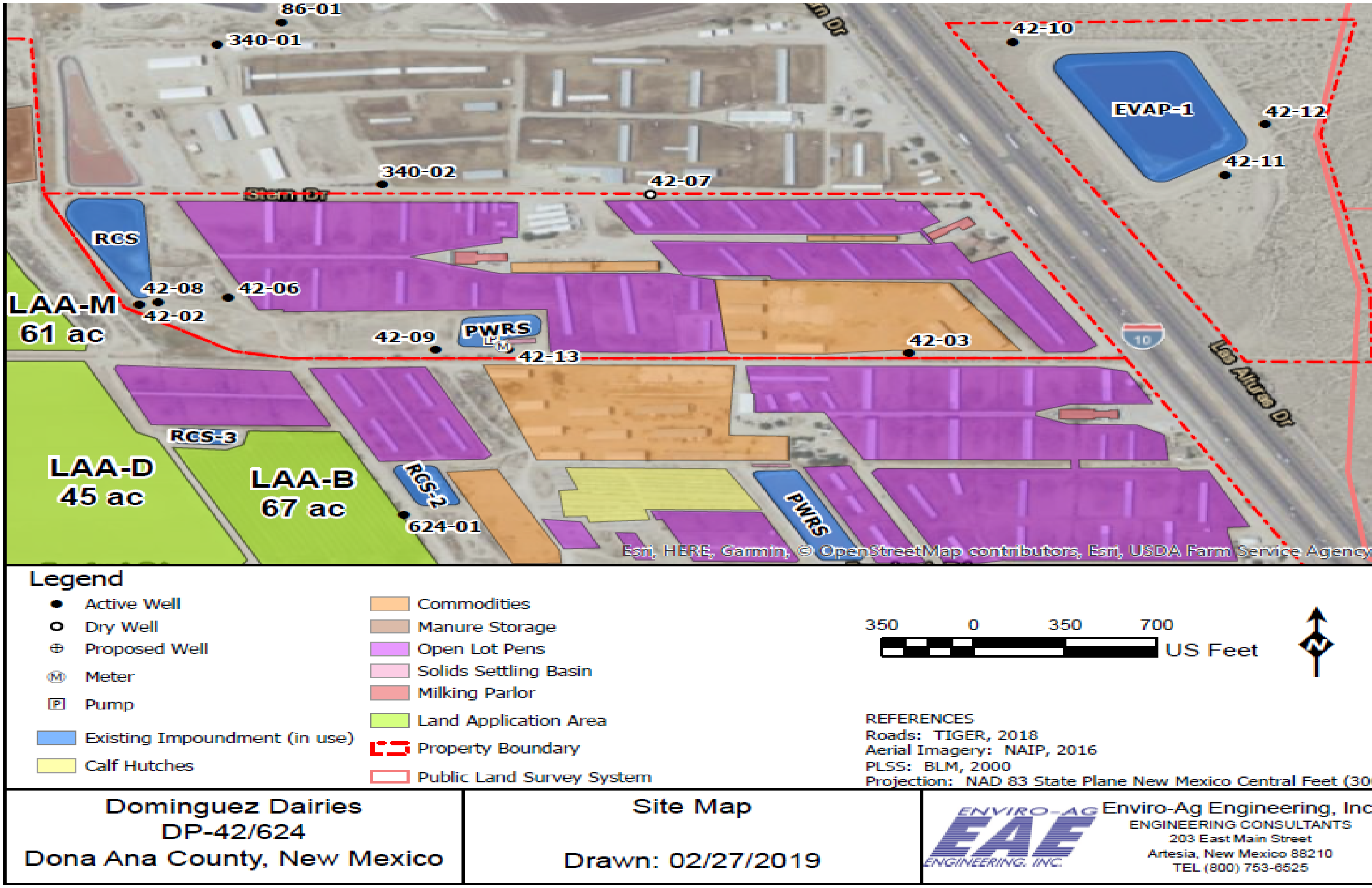


Figure 19 – Dominguez 2 Dairy Site Map (NMED, 2019e)

MW 42-02 is hydrologically upgradient of a stormwater runoff pond that was unlined until 2002 (Golder, 2006). Groundwater quality data for nitrate indicates that possible storm events caused some small spikes and more recently the nitrate concentration in the groundwater has begun to trend down. Groundwater is a depth of approximately 16 feet below the ground surface (NMED, 2019e). The following monitoring wells supply data representative of groundwater quality for Dominguez 2 Dairy (NMED, 2019e):

- MW-42-02 - located south of the Runoff pond and upgradient of the production area
- MW-42-08 - hydrologically downgradient Runoff pond and located near the southeast corner the pond

Nitrate concentrations (mg/L) in two monitoring wells near a pond are graphed in Figure 20.

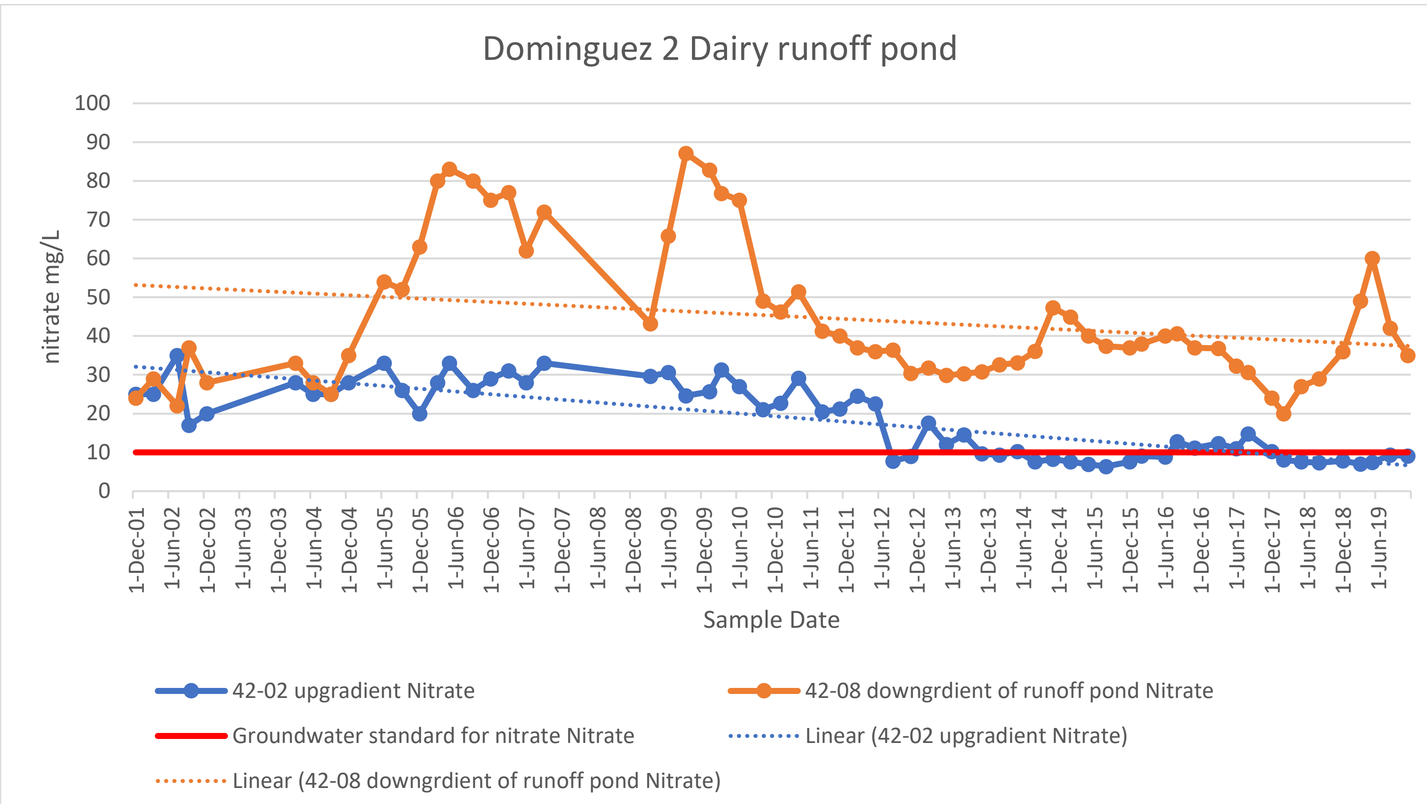


Figure 20 – Dominguez 2 Dairy Groundwater Nitrate Concentrations near runoff pond (NMED 2019e)

Dominguez 2 Dairy History

From the GWQB administrative record for DP-42, operations started in 1973. On December 8, 1978 NM EID approved the original permit In the September 7, 1978, public notice for the BJZ Dairy (as D&J Dairy was known at that time) says approximately 21,000 gpd of wastewater will be used to irrigate 102 acres of cropland (NMED, 2019e). On August 31, 1984 the DP conditionally approved the DP application which proposed 72,000 gpd to be managed in 6 new manure-lined lagoons followed by discharge to approximately 196 acres of terraced fields at two dairies and to crops on land belonging to Dominguez Farms (NMED, 2019e). NMED requested that the existing holding pond be drained once the proposed manure-lined waste retention ponds were constructed and on May 3, 1985, NM EID approved this DP. On June 5, 1989 the DP renewal was approved with no changes to quantity of waste disposal or the application area (NMED, 2019e).

On April 25, 2000 NMED approved the discharge of up to 60,000 gallons per day of dairy wastewater from two milking barns to a synthetically lined primary lagoon at BJZ Dairies, and then transferred via a pipeline under Interstate 10 for disposal in a secondary synthetically lined lagoon for total evaporation (NMED, 2019e). The DP was renewed on September 17, 2007. On December 31, 2018 NMED authorized a discharge up to 60,000 gpd of wastewater from two milking parlors to a synthetically lined wastewater impoundment for storage. Wastewater is either transferred via a pipeline to a synthetically lined lagoon for disposal by evaporation or transferred to Dominguez Dairy #1 for land application by flood irrigation up to 661 acres of irrigated cropland under cultivation in accordance with the conditions of Discharge Permit, DP-624, effective December 31, 2018 (NMED, 2019e).

Discussion of the Dominguez 2 Dairy

The groundwater gradient is relatively flat at Dominguez 2 Dairy as shown by the potentiometric surface lines drawn at a 1 ft interval (Appendix A) (Golder, 2008). MW 42-02 is hydrologically downgradient of a stormwater runoff pond that was unlined until 2002 (Golder, 2008). Groundwater quality data for nitrate indicates that possible storm events caused some small spikes but the nitrate concentrations in the groundwater do have a downward trend. MW 42-08 is downgradient of a runoff area that was used to construct a synthetically lined runoff pond in 2001. The liner had little to no effect on improving the groundwater quality. The slopes of the trendlines are very similar to each other as shown in Figure 20 and a slow downward trend is visible. Herd size was 700 milking head in 1975, 1,400 in 1978, 1,800 in 1984 and 2,000 milking head in 2018. The increase in herd size over time is not directly correlated to any groundwater impacts.

G. Dominguez 1&3 Dairies DP-624

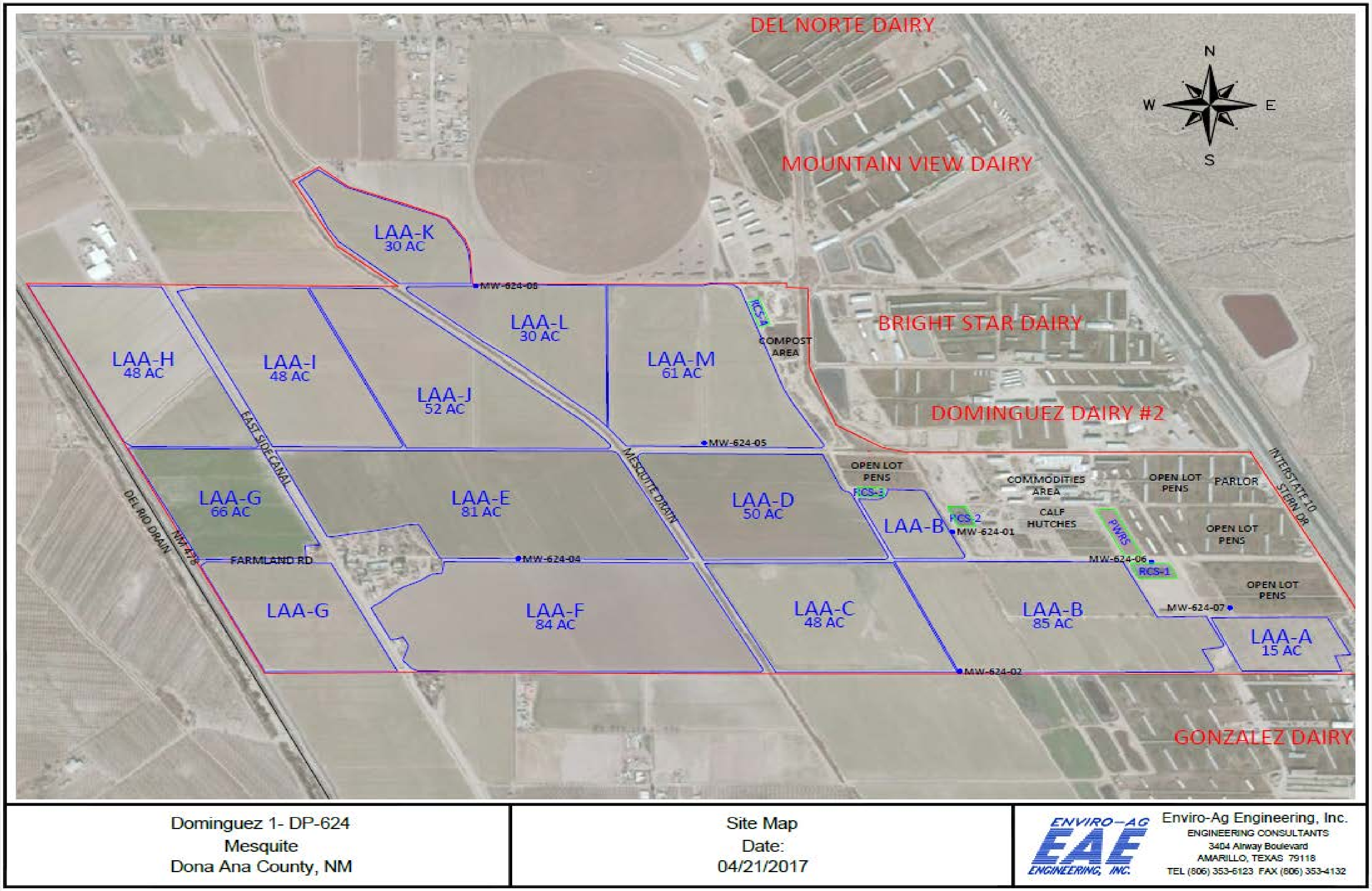


Figure 21 – Dominguez 1 & 3 Dairies Site Map (NMED, 2017c)

This dairy facility does not have an upgradient well (NMED, 2019f). Many of the historic monitoring wells have gone dry. The current Discharge Permit requires replacement wells and they have only recently been installed (NMED, 2019f). Groundwater is a depth of approximately 15 to 55 feet below the ground surface (NMED, 2019f). The following monitoring wells supply data representative of groundwater quality for Dominguez 1&3 Dairies (NMED, 2019f):

- 624-01 - hydrologically downgradient of the land application area and located southwest corner of RCS-2
- 624-02 - hydrologically side gradient to the facility and located off the southeast corner of LAA-C

Nitrate concentrations in two monitoring wells are graphed in Figure 22. The trendlines are almost identical, showing a downward trend in nitrate concentrations in groundwater at Dominguez 1&3 Dairies.

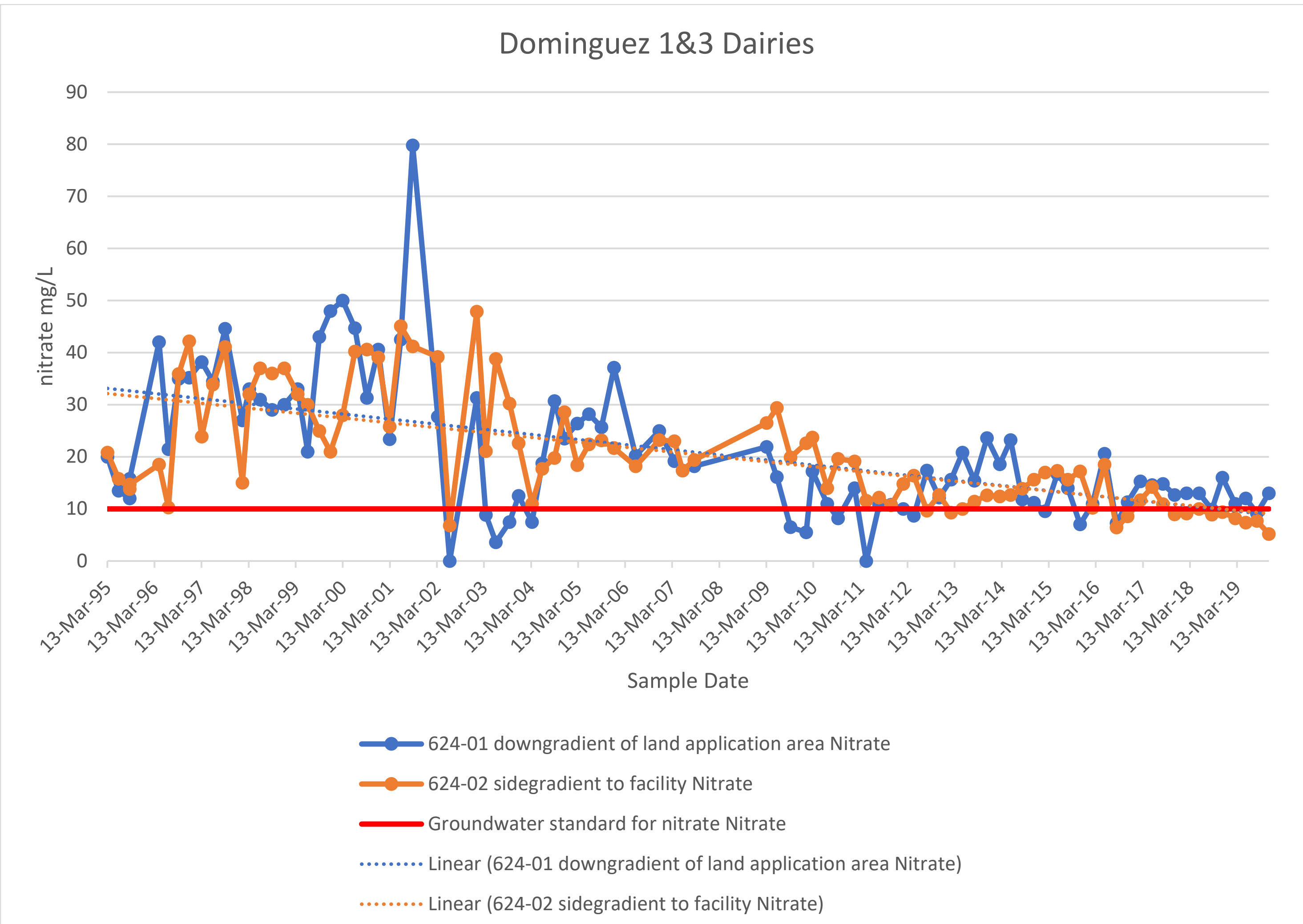


Figure 22 – Dominguez 1&3 Dairies Groundwater Nitrate Concentrations (NMED 2019f)

Dominguez 1 & 3 Dairies History

From the GWQB administrative record for DP-624, operations started in 1979; based on internal correspondence of the NM EID, as of March 21, 1989, the dairy was using a lagoon occasionally but in general was land applying the wastewater (NMED, 2019f). On February 1, 1990 The DP authorized a discharge of 33,000 gpd of wastewater to a manure and clay-lined holding lagoon, from where it was used for irrigation of 200 acres of cropland (NMED, 2019f). On February 28, 2001 the DP authorized up to 37,000 gpd of wastewater discharged to a synthetically lined pond from where it is applied through furrow and flood irrigation to 259 acres of cropland. Manure solids are applied to an additional 155 acres of cropland. On an emergency basis, Dominguez Dairy could accept wastewater from BJZ dairy (currently Dominguez 2 Dairy). Manure to be removed in a manner protective of the environment (NMED, 2019f).

On January 2, 2019 the DP authorized a discharge of up to 47,000 gpd of wastewater from the production area into the synthetically lined wastewater impoundment for storage prior to land application. Additionally, the permittee is authorized receive up to 60,000 gpd of wastewater from the production area of Dominguez 2 Dairy managed under DP-42. Wastewater from both facilities is land applied by flood irrigation up to 661 acres of irrigated cropland under cultivation (NMED, 2019f). Figure 23 shows the monitoring wells downgradient of the land application area and an area overlay of land use acres over time. It shows that as land use area increased, that nitrate concentrations in the groundwater decreased.

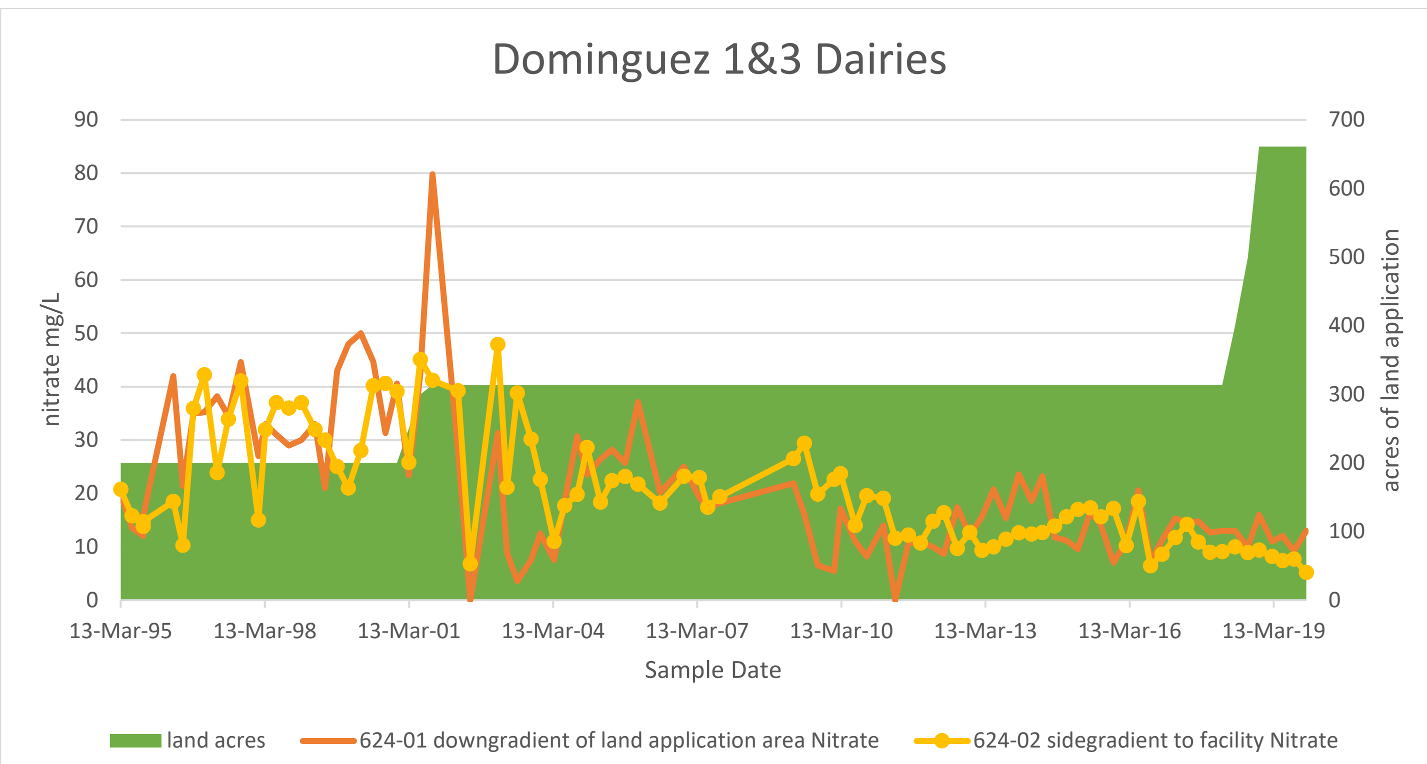


Figure 23 – Dominguez 1&3 Dairies Groundwater Nitrate Concentrations overlaid with land acres (NMED 2019f)

Discussion of Dominguez 1 & 3 Dairies

The land use practices are not contributing to the nitrate concentrations in groundwater at Dominguez 1 & 3 Dairies. The slope of the linear trend lines of the downgradient well compared to the side gradient well are exactly the same as shown in Figure 22. The increase in land application area from 200 acres in 1990 to 314 acres in 2001 separating dry manure on 155 acres and wastewater on 259 acres, to 661 acres in 2019 seem to help control the potential contamination of groundwater by allowing wastewater to be spread over more area shown in Figure 23. The groundwater gradient is relatively flat at Dominguez 1&3 Dairies as shown by the potentiometric surface lines drawn at a 1 ft interval (Appendix A) (Golder, 2008), so impacts from upgradient wells to downgradient wells take time. The herd size did not change significantly and does not directly correlate to a groundwater quality impact.

H. Gonzalez Dairy DP-177

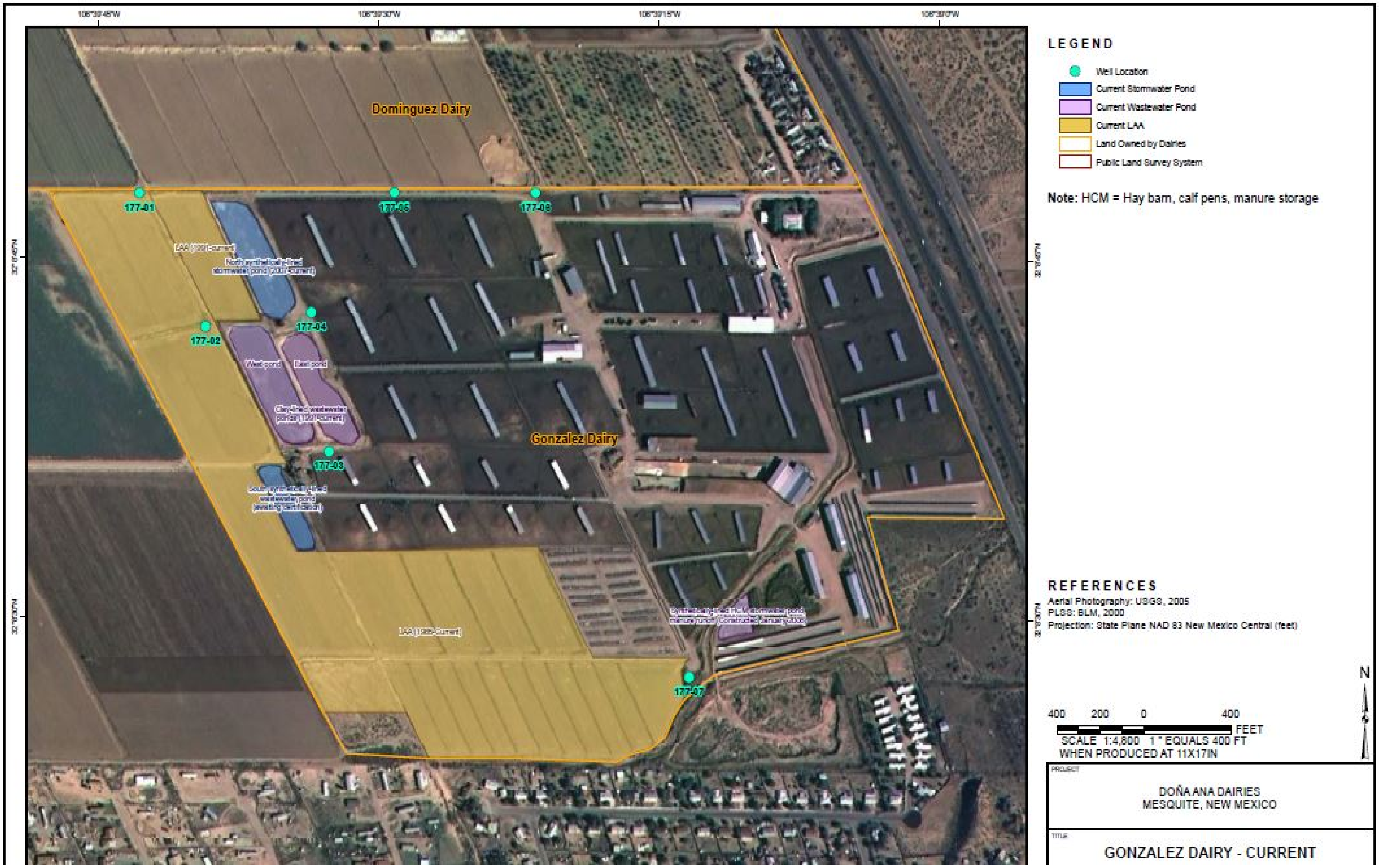


Figure 24 – Gonzalez Dairy Site Map (Golder 2008)

The two Lagoons were originally constructed prior to 1990 and manure lined, they were re-lined in 2004 with 18 inches of clay (NMED, 2019g). Groundwater is at a depth of approximately 15 feet below the ground surface (NMED, 2019g). The following monitoring wells supply data representative of groundwater quality for Gonzalez Dairy (NMED, 2019g):

- 177-01 – intended to be hydrologically upgradient of all contamination sources at the dairy facility and located along the northwest corner of the facility.
- 177-02 – hydrologically downgradient of the land application area and located off the northwest corner of West Lagoon.

Nitrate concentrations (mg/L) in two monitoring wells are graphed in Figure 25. The trendlines show decreasing trends of nitrate concentrations in both the upgradient well and the well downgradient of the clay lined ponds.

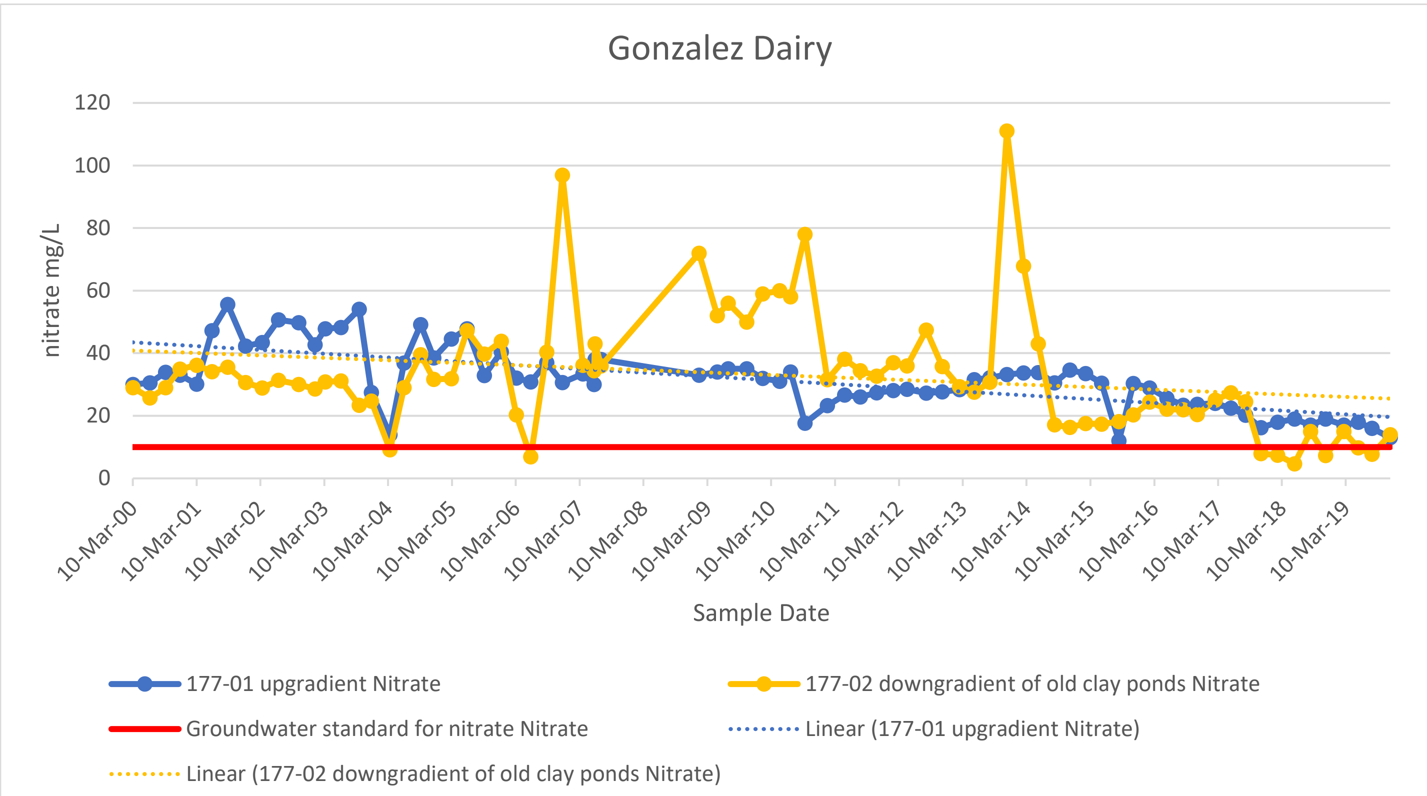


Figure 25 – Gonzalez Dairy Groundwater Nitrate Concentrations (NMED 2019g)

Gonzalez Dairy History

From the GWQB administrative record for DP-177, operations started in 1969, on June 25, 1981 NM EID approved the original permit for an estimated 33,600 gpd discharged to a series of manure-lined evaporation ponds and to cropland. On October 15, 1999 NM EID approved up to 49,000 gpd of wastewater is discharged through a manure/solids separator to a clay-lined facultative pond, a clay-lined evaporative pond, and then land applied to 45 acres of cropland (NMED, 2019g). Manure solids are to be hauled off site for disposal. The dairy has been closed since 2016 (NMED, 2019g).

Discussion of the Gonzalez Dairy

The original dairy had 4 milking barns and by 2012 on one barn was being used. The two Lagoons (East and West) were originally constructed prior to 1990 and were manure lined, they were re-lined in 2004 with 18 inches of clay (NMED, 2019g). The integrity of the clay liner is suspect as indicated by nitrate concentration fluctuations in the groundwater in MW 177-02. The herd size was 3,000 milking head in 1999 and 1,800 head in 2012 (NMED, 2019g). The herd size does not correlate directly with groundwater quality impacts. The land application size has always been 45 flood irrigated acres, so the groundwater quality changes observed cannot be correlated to land use practices or acreage.

II. Central Portion – Consisting of Buena Vista Dairy II, River Valley Dairy, Big Sky Dairy, and Sunset Dairy

A. Buena Vista II Dairy DP-74

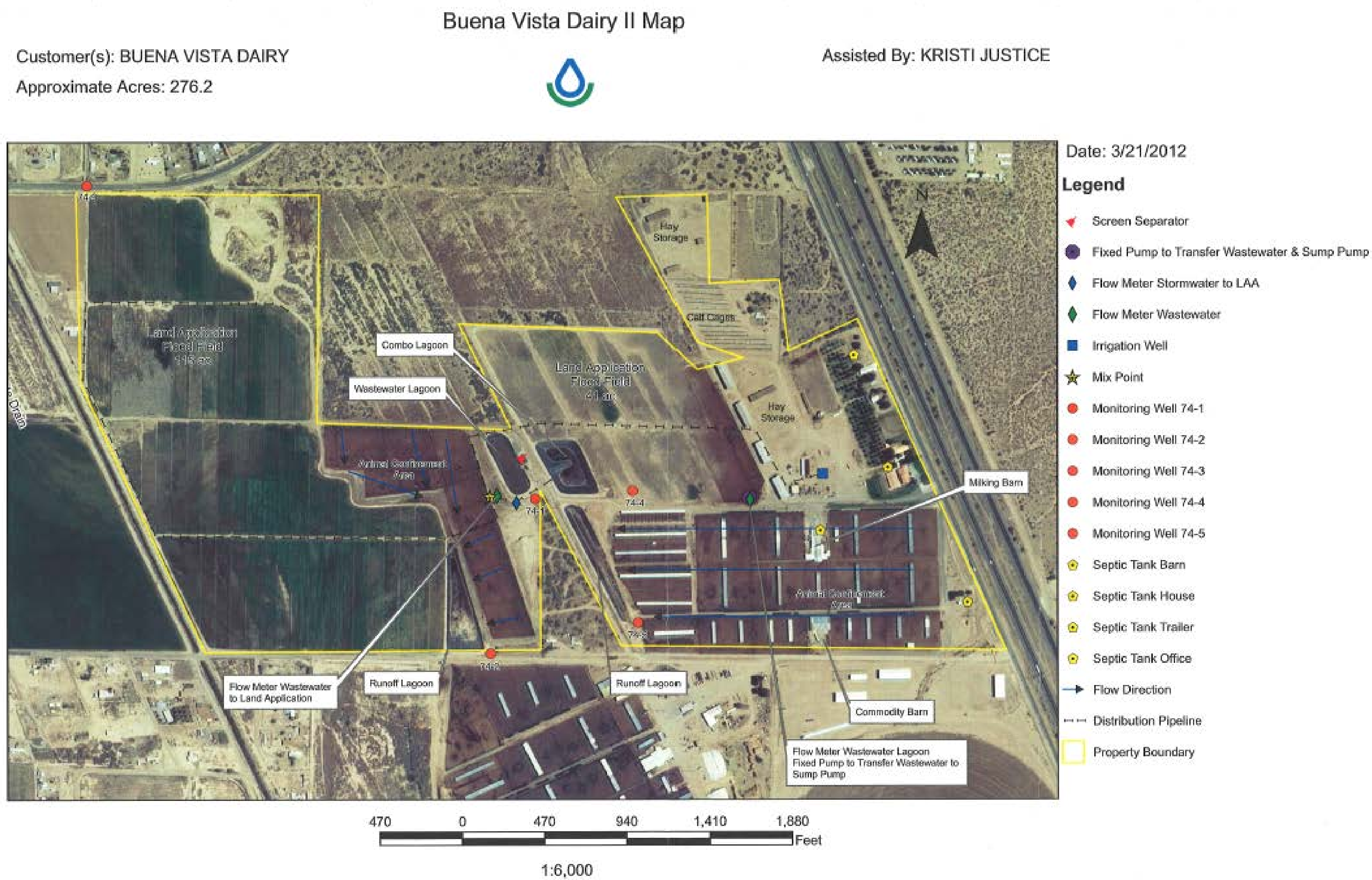


Figure 26 – Buena Vista II Dairy Site Map (NMED, 2017b)

From the GWQB administrative record for DP-74, dairy operations ceased in January 2008 and groundwater contamination has decreased in all wells except MW 74-01 which is hydrologically downgradient of the Wastewater Lagoon (synthetically lined in 2008) (NMED, 2019c). The groundwater gradient is relatively flat at Buena Vista II Dairy as shown by the potentiometric surface lines drawn at a 1 ft interval (Appendix B) (Golder, 2008), so downgradient water quality impacts are not immediate. Groundwater is a depth of approximately 14 feet below the ground surface (NMED, 2019c). The following monitoring wells supply data representative of groundwater quality for Buena Vista II Dairy (NMED, 2019c):

- MW-74-03 - hydrologically upgradient of all contamination sources at the dairy facility and located at the northwest corner of Field 1
- MW-74-01- hydrologically downgradient of the Wastewater Lagoon and located off the southeast corner of Wastewater Lagoon

Nitrate concentrations (mg/L) in two monitoring wells near the pond are graphed in Figures 27 and 28. The orange trendline of the downgradient well data pre-synthetic liner shows almost no variability. The other orange trendline in Figure 28 shows a slight downward trend in well MW 74-01 downgradient of the pond post-liner but some seasonal variability could be correlated to rain events that have the potential to flush out the residual nitrate still present in the soil beneath the liner.

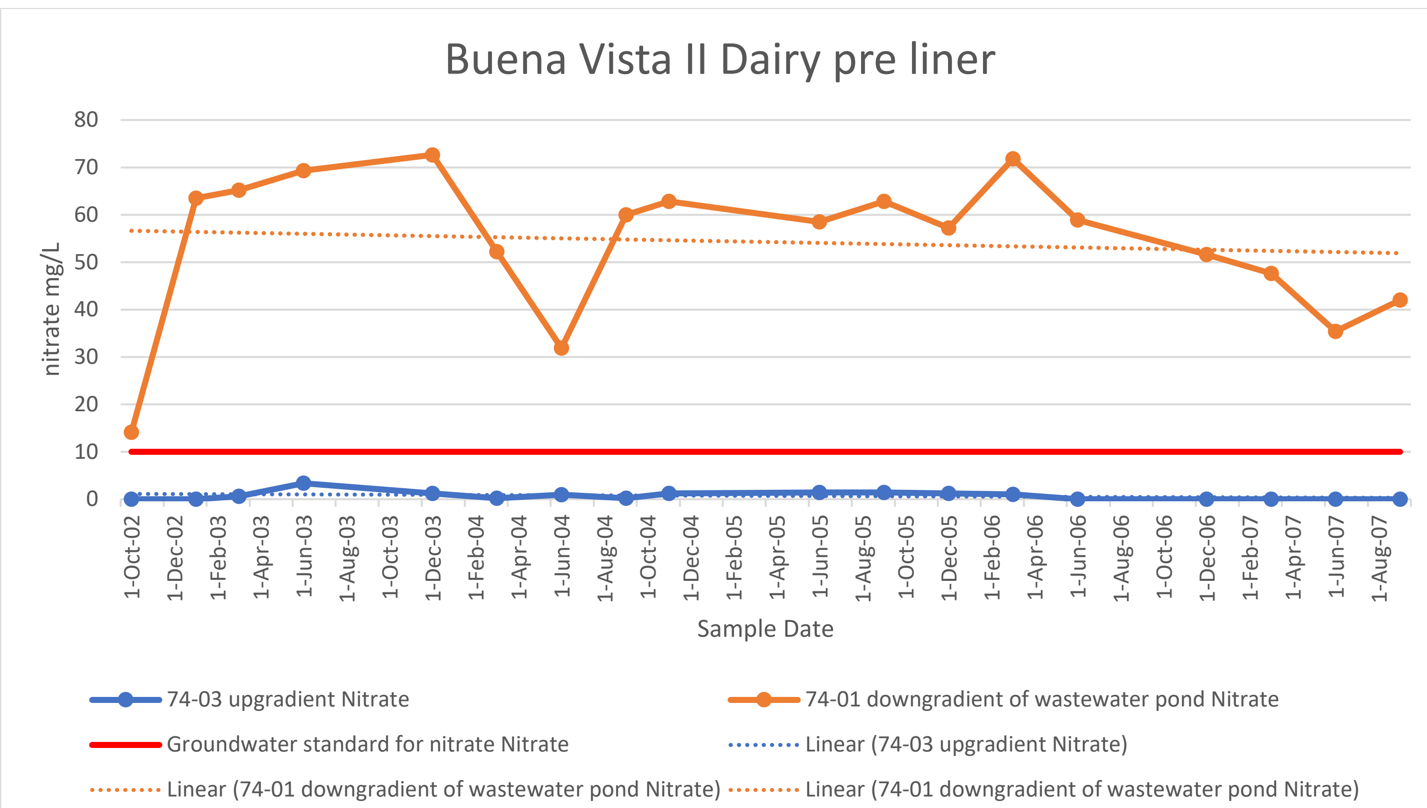


Figure 27 – Buena Vista II Dairy Groundwater Nitrate Concentrations near pond pre HDPE liner (NMED, 2019c)

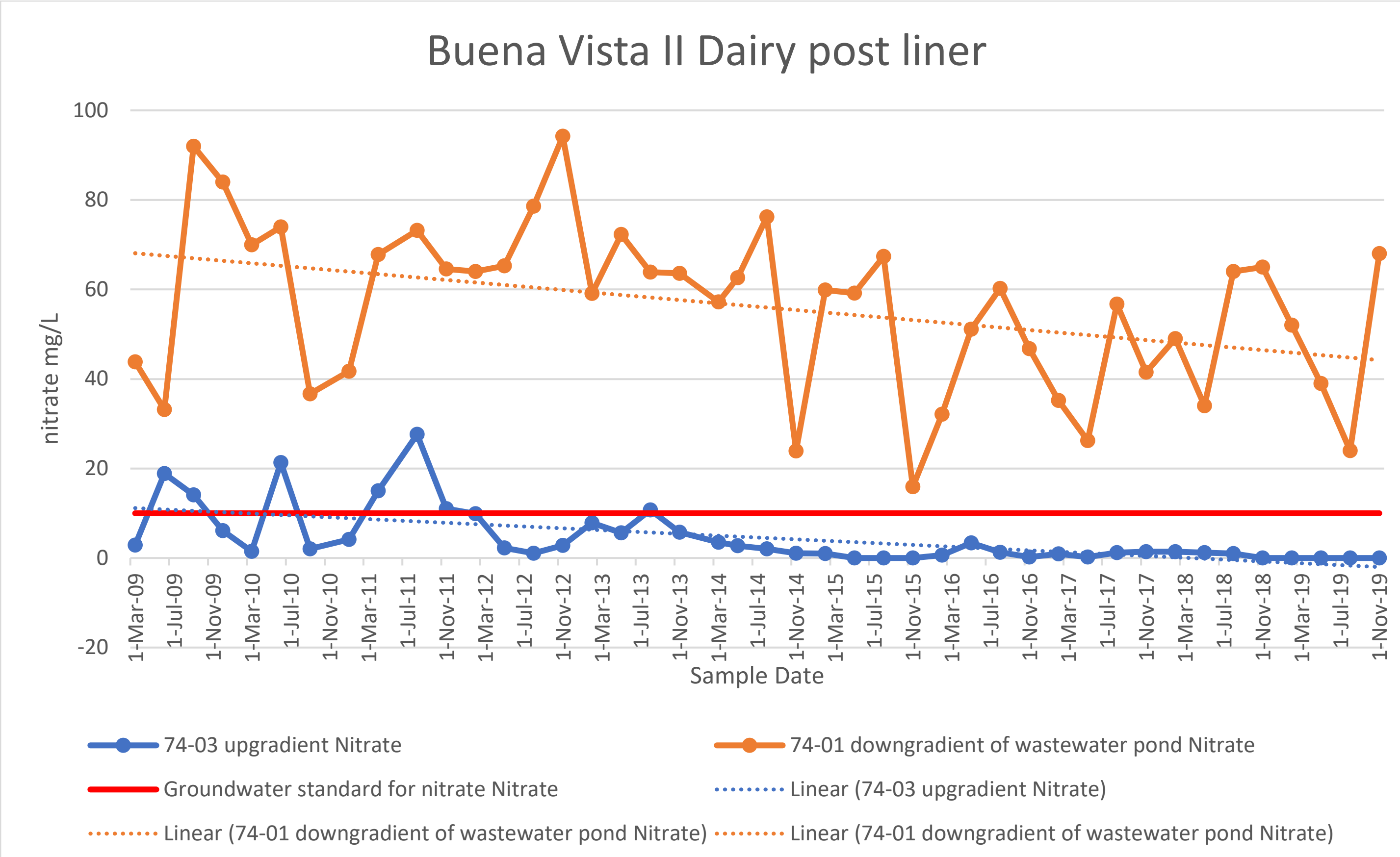


Figure 28 – Buena Vista II Dairy Groundwater Nitrate Concentrations near pond post HDPE liner (NMED, 2019c)

Buena Vista II Dairy History

From the GWQB administrative record for DP-74, operations started in 1979, on July 10, 1979 NM EID approved the original permit, for an estimated 17,500 gpd, to go into two manure-lined lagoons, located in the southwest corner of the property, or to irrigate 41 acres of cultivated land. On December 21, 1991, NMED approved a discharge of 26,000 gpd dairy wastewater after mixing with irrigation water to be applied to up to 165 acres irrigated cropland (NMED, 2019c). On July 18, 1994 the DP approved the discharge of approximately 40,000 gallons per day of milking center wastewater from a 750-cow dairy; wastewater was diluted with fresh water in an 18-inch pipeline and land applied on 41 acres of cultivated terraced pasture (NMED, 2019c).

On April 6, 2001 the DP approved a discharge of up to 26,000 gallons per day of dairy wastewater collected in a synthetically lined lagoon, mixed with irrigation water and applied via flood irrigation to up to 115 acres cropland (NMED, 2019c). The August 30, 2007 the DP authorized up to 55,000 gpd wastewater is discharged from the dairy parlor through a solids separator to a synthetically lined combination wastewater/stormwater lagoon and an additional synthetically-lined wastewater lagoon for storage. Wastewater is land applied by flood irrigation to 156 acres of cropland under cultivation

(NMED, 2019c). Manure is either land applied or removed off site. The new permit requires the completion, within a year from permit approval, of a synthetically lined combination wastewater/runoff lagoon (NMED, 2019c). Runoff is to be managed by storage in two synthetically lined runoff ponds and one combination wastewater-stormwater pond. Although a DP was issued December 31, 2019 to authorize to discharge up to 55,000 gpd of wastewater from the production area, the dairy has been closed since January 2008 (NMED, 2019c).

Discussion of the Buena Vista Dairy

Dairy operations ceased in January 2008 (NMED, 2019c) and groundwater contamination has decreased in all wells except MW 74-01 which is hydrologically downgradient of the Runoff Pond which was synthetically lined in 2008. The herd size went from 1,100 milking head in 1991 to zero in 2008. The nitrate concentrations in groundwater are not directly impacted by herd size at Buena Vista II Dairy.

B. River Valley Dairy DP-167

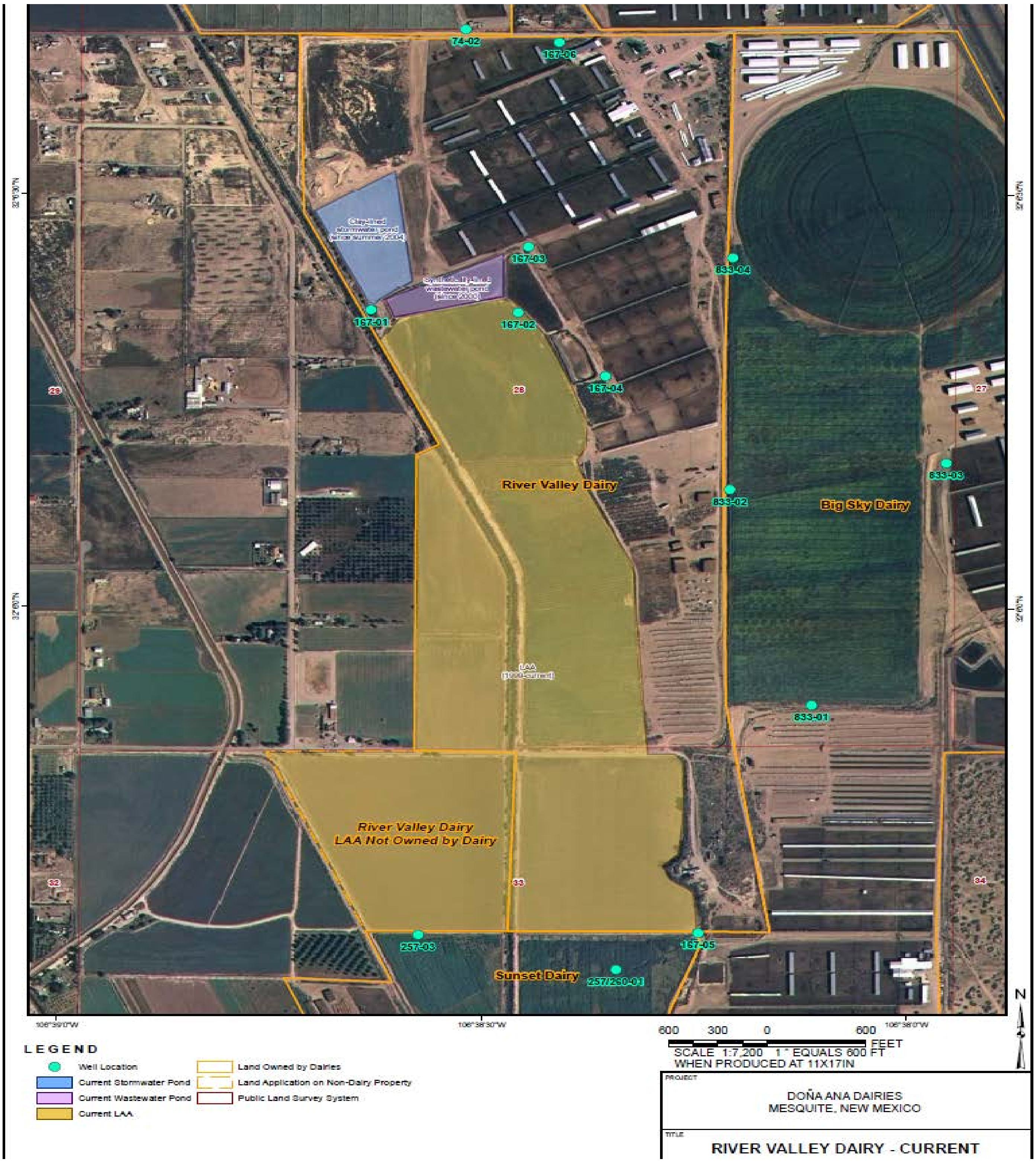


Figure 29 – River Valley Dairy Site Map (Golder 2008)

River Valley Dairy is located in the center of the Central portion of the plume. Downgradient monitoring wells at River Valley Dairy have had a nitrate concentration less than the upgradient well (MW 167-06) since 2005, except 167-04 which is cross gradient of the facility. This shows that the contamination at River Valley Dairy is exacerbated by surrounding dairies and the effect is long lasting. The groundwater gradient is relatively flat as shown by the potentiometric surface lines drawn at a 1 ft interval (Appendix B) (Golder, 2008), so downgradient water quality impacts are not immediate. Groundwater is a depth of approximately 14 feet below the ground surface (NMED, 2019j). The following monitoring wells supply data representative of groundwater quality for River Valley Dairy (NMED, 2019j):

- 167-01 - hydrologically upgradient of all contamination sources at the dairy facility and located west of the PWRS.
- 167-06 - hydrologically upgradient of all contamination sources at the dairy facility.
- 167-02 - hydrologically downgradient of Pond and located centrally along the southside of Pond.
- 167-05 - hydrologically downgradient of the land application area and located in the southeast corner of LAA-C.

Nitrate concentrations in the two monitoring wells near the pond are graphed in Figure 30. The graph shows that the wells at River Valley Dairy since 2003 have had a nitrate concentration less than the upgradient well (NMED, 2012f).

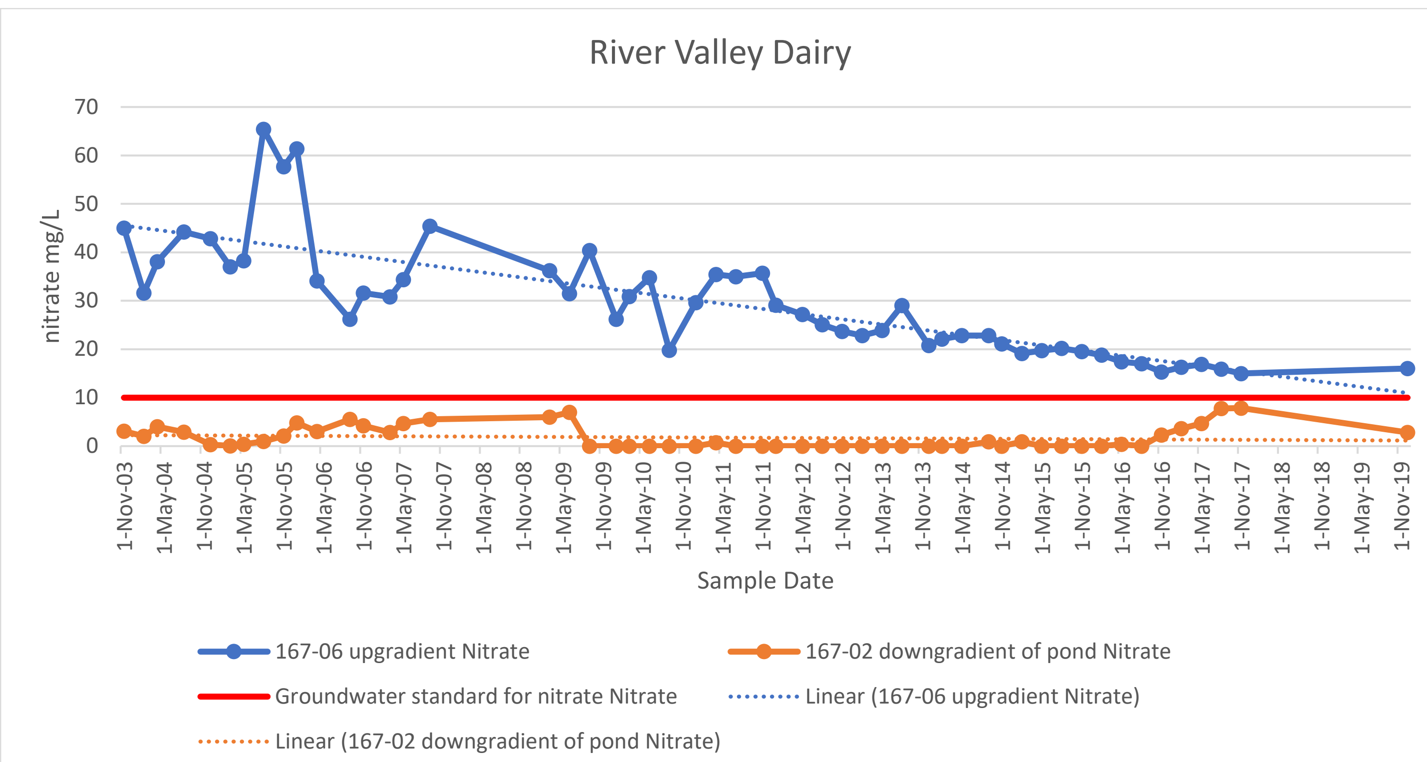


Figure 30 – River Valley Dairy Groundwater Nitrate Concentrations near pond (NMED, 2019j)

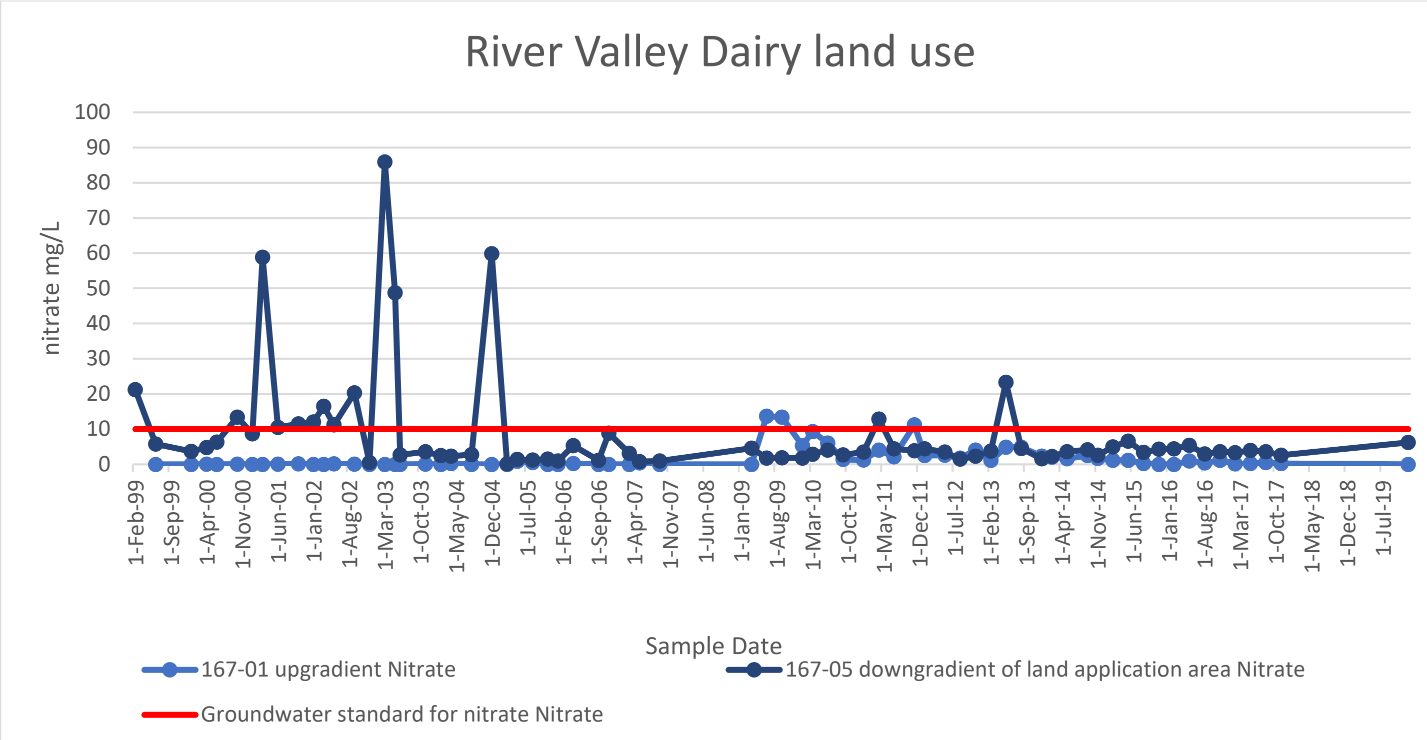


Figure 31 – River Valley Dairy Groundwater Nitrate Concentrations near land application area (NMED, 2019j)

River Valley Dairy History

From the GWQB administrative record for DP-167, operations started in 1981, on June 10, 1981 the original permit approved wastewater being stored in ponds followed by land application. On June 10, 1986 NM EID approved a permit with a discharge of 57,000 gpd of milking center wastes and manure contaminated runoff to holding ponds from where it was to be land applied to 83 acres of cropland (NMED, 2019j). On May 22, 1990 the DP was modified to authorize a discharge 27,000 gpd of wastewater followed by land application to 104 acres of cultivated land (NMED, 2019j). April 8, 1992 NM EID approved the discharge of 27,000 gpd of milking center wash water through a manure separator to a clay-lined evaporation lagoon. Excess water was applied by irrigation to 104 acres of cropland (NMED, 2019j). On August 20, 1997 NMED approved the discharge of up to 27,060 gpd of dairy wastewater through a solids separator to three clay-lined evaporation lagoons. From the lagoons, the wastewater was to be land applied to up to 85 acres of cropland (NMED, 2019j). The modification of the system consisted of enlargement of one of the two existing lagoons, dividing it into two lagoons (thereby creating 3 lagoons total), and relining all lagoons with 12 inches of compacted clay (NMED, 2019j). The clay lagoons were abandoned in 2004 and a new synthetically lined lagoon was constructed (NMED, 2019j).

In the August 28, 2007 DP authorized up to 35,000 gpd wastewater is discharged from the milking parlor to a synthetically lined lagoon. Wastewater applied through flood irrigation to 129 acres of cropland under cultivation (NMED, 2019j). Manure and solids are managed by either off-site disposal or land application in a manner protective of the environment. Stormwater is collected in stormwater ponds, from where it is transferred to the wastewater ponds for land disposal (NMED, 2019j).

Discussion of the River Valley Dairy

The pond berms were breached in early 2003 and ran over into the land application area (NMED, 2019j). The spike in groundwater nitrate concentrations in 2003 could be correlated to this event. Heavy rains also occurred in 2004 (NMED, 2019j), which are also shown to flush out large amounts of nitrate into the groundwater as shown in Figure 31.

Monitoring wells at River Valley Dairy since 2005 have had a nitrate concentration less than the upgradient well (MW 167-06) except 167-04 which is cross gradient of the facility. This shows that the contamination at River Valley Dairy is impacted by surrounding dairies and the effect is long lasting. The land application area increased from 83 acres in 1986 to 129 acres in 2007. The nitrate concentrations in groundwater do not correlate directly with the acreage used for wastewater application. The herd size was 1,000 milking head in 1990 and 1,800 milking head in 2017 (NMED, 2019j). No nitrate groundwater quality impact is directly correlated to changes in herd size.

C. Big Sky Dairy DP-833 (with DP-260)

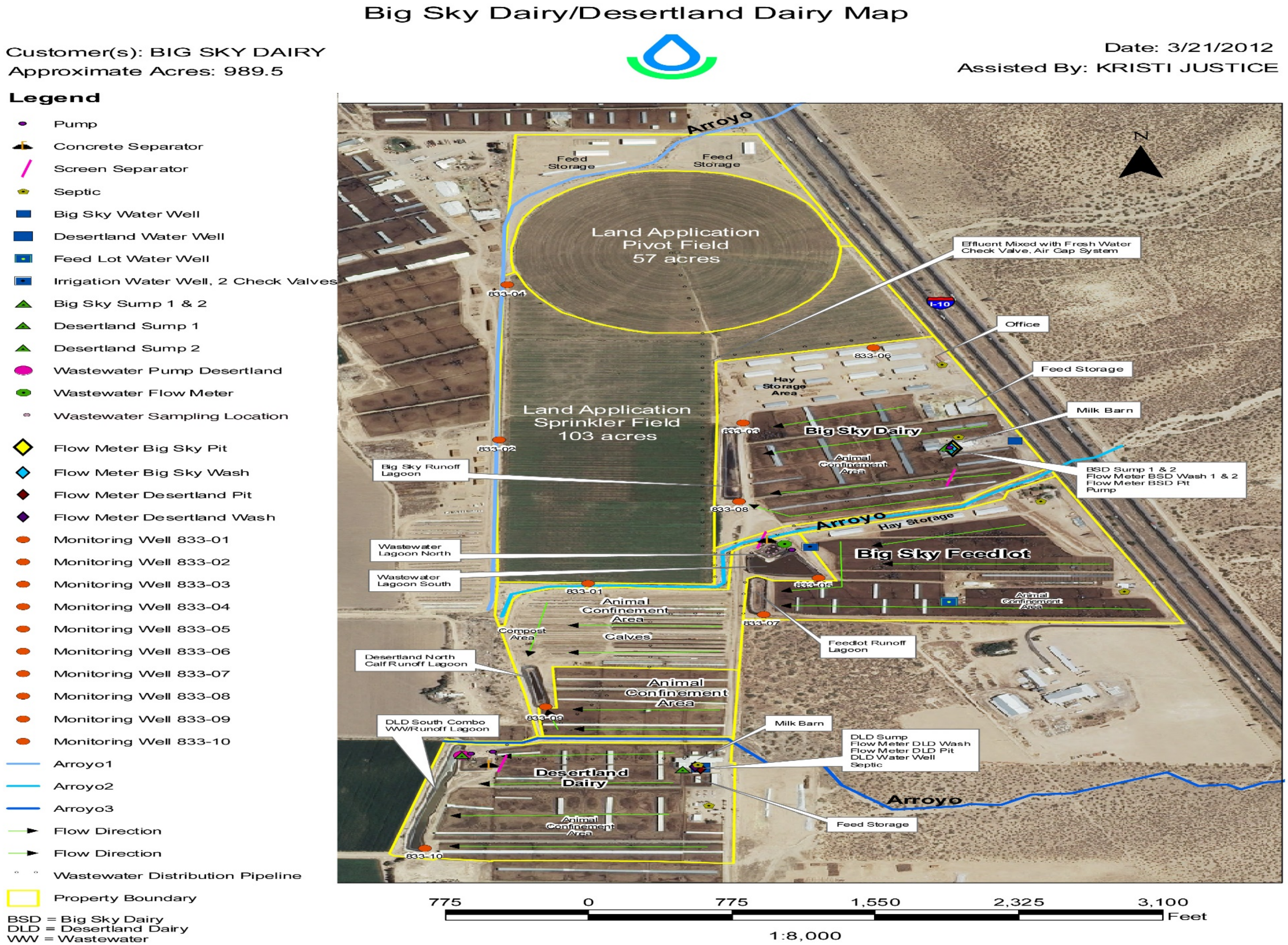


Figure 31 – Big Sky Dairy Site Map (NMED, 2012a)

Big Sky Dairy is also located in the center of the Central portion of the plume. The groundwater gradient is relatively flat at Big Sky Dairy as shown by the potentiometric surface lines drawn at a 1 ft interval (Appendix B) (Golder, 2008), so downgradient water quality impacts are not immediate. Even though the runoff ponds were synthetically lined in 2007 (NMED, 2019a), Figure 33 shows that the liners take a long time to improve the groundwater quality. Groundwater is a depth of approximately 11 feet below the ground surface (NMED, 2019a). The following monitoring wells supply data representative of groundwater quality for Big Sky/Desertland Dairy (NMED, 2019a):

- 833-02 - hydrologically sidegradient (west) of the Sprinkler Field, west of the Big Sky Dairy parlor.
- 833-04 – hydrologically downgradient of the Pivot Field, at the northwest corner of the Sprinkler Field.
- 833-06 – hydrologically downgradient of the east portion of the Sprinkler Field, on the north side of the north Hay Storage Area.
- 833-08 – hydrologically downgradient of the Big Sky Stormwater Pond, west of the Big Sky Dairy parlor.
- 833-09 – hydrologically downgradient of the Desertland North Calf Stormwater Pond, northwest of the Desertland Dairy parlor.

Nitrate concentrations (mg/L) in three monitoring wells near runoff ponds that were synthetically lined in 2007 are graphed in Figure 33.

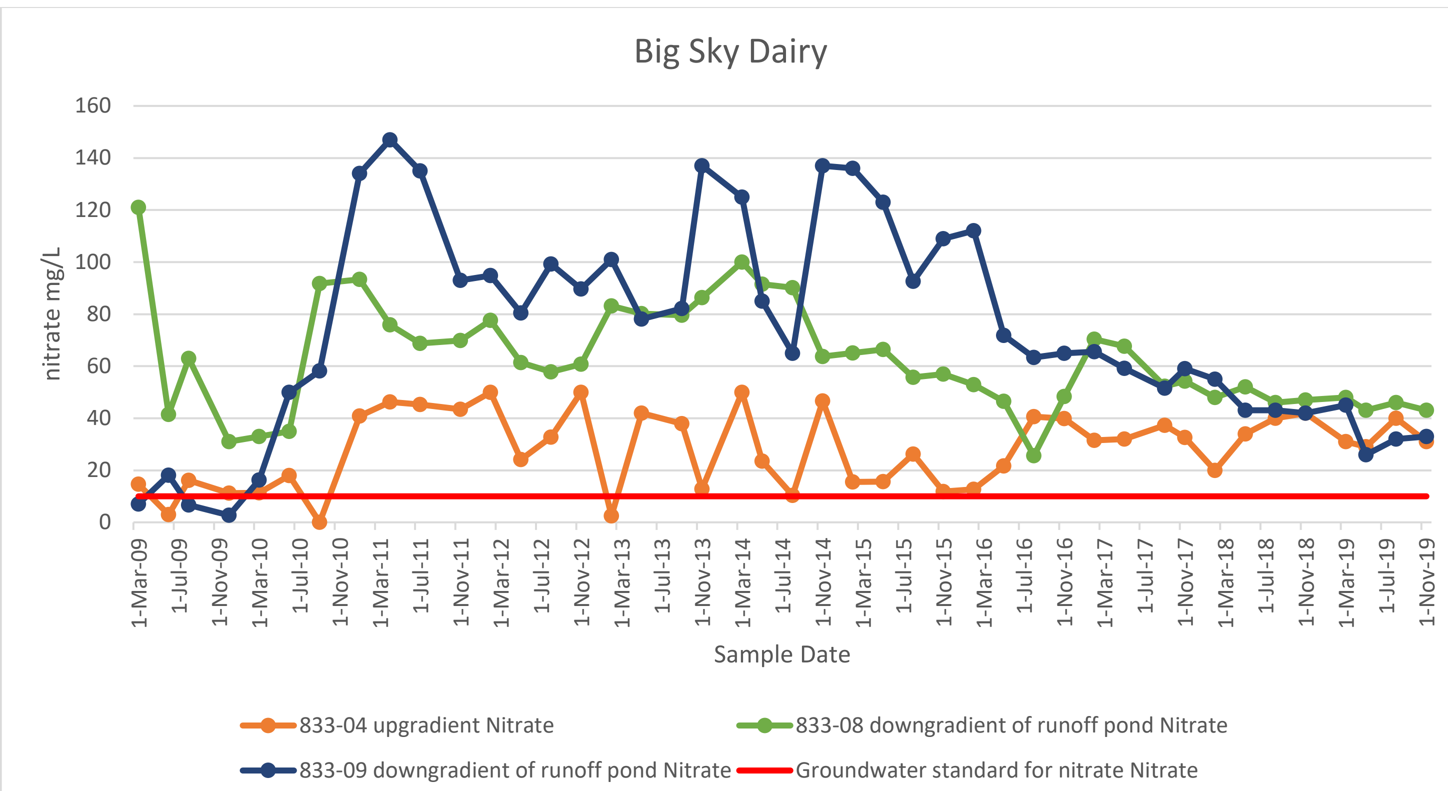


Figure 33 – Big Sky Dairy Groundwater Nitrate Concentrations near runoff ponds (NMED, 2019a)

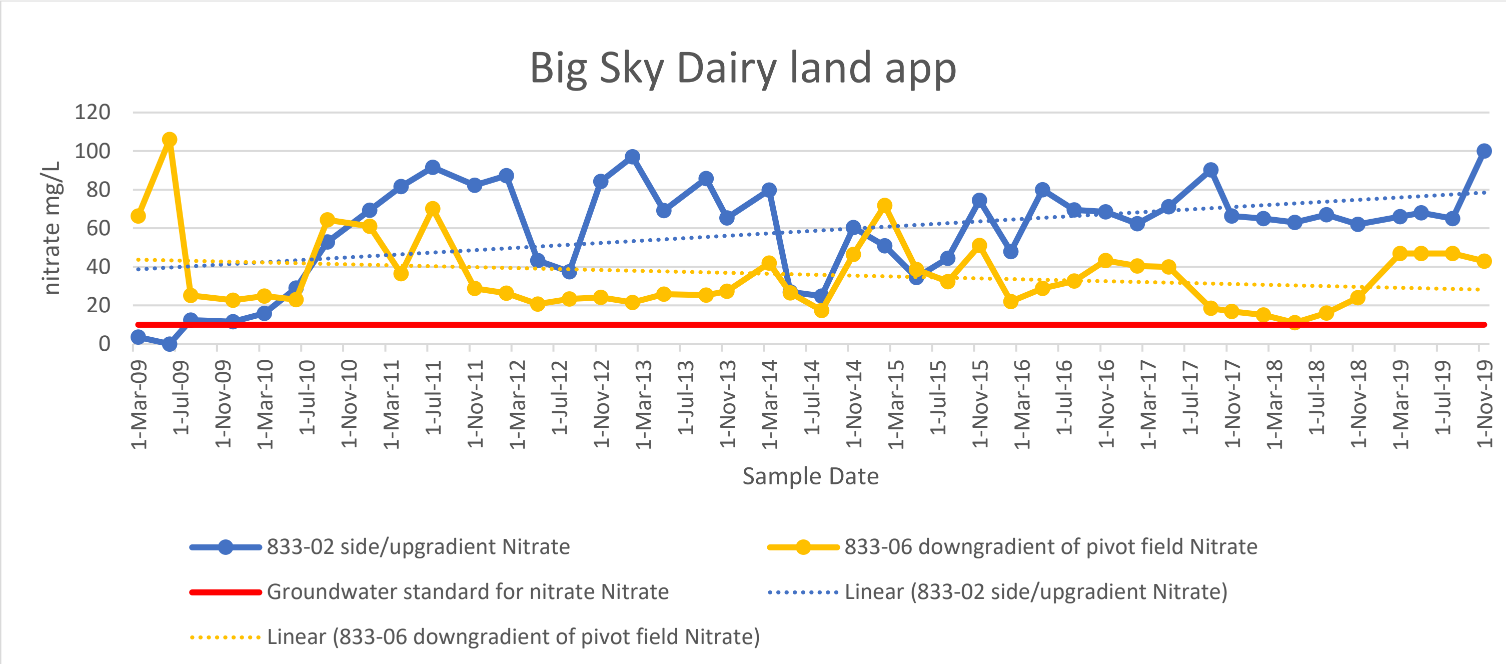


Figure 34 – Big Sky Dairy Groundwater Nitrate Concentrations near land application area (NMED, 2019a)

Nitrate concentrations (mg/L) in two monitoring wells near crop land used for wastewater irrigation are graphed in Figure 34. The graph shows that the pivot field does not have much of an impact on groundwater quality for nitrate.

Big Sky Dairy History

From the GWQB administrative record for DP-833, operations started in around 1983 and on June 29, 1992 the original permit was approved where a discharge of 25,000 gallons per day from the milking center was approved to be pumped through a screen-type solids separator (NMED, 2019a). The screened wastewater was stored in a HDPE lined, holding pond, from where it was used to irrigate 52.7 acres of cultivated cropland (NMED, 2019a). On August 30, 1997 the Permit approved discharge of 36,000 gpd of dairy wastewater through a screen solid separator and a concrete manure separator basin, to a synthetically lined lagoon, then to 101.2 acres of cropland (NMED, 2019a).

Desertland Dairy (previously named Morningside Dairy)

From the GWQB administrative record for DP-260, operations started in 1984, and on February 20, 1984, the original permit was approved. NM EID correspondence indicates a request to discharge 48,000 gpd; approval for discharge to a synthetically lined wastewater lagoon and in 1985, wastewater was land applied to crops located at Sunset Dairy (NMED, 2019a). The February 24, 1989, public notice identifies a discharge of 48,000 gpd into a lined holding pond and then to be used for the irrigation of cropland (NMED, 2019a). The October 15, 1993 the Permit approves a wastewater discharge of 25,000 gpd through a gravity manure separator to a synthetically lined holding pond (NMED, 2019a). From this pond, the water was pumped to a synthetically lined lagoon on adjacent Big Sky Dairy (DP-

833) where it was mixed with the wastewater from Big Sky Dairy. The combined wastewater was land applied to approximately 72 acres of cropland (NMED, 2019a). On March 13, 2007 NMED accepted the request that DP-260 for Desertland Dairy be terminated. The basis for this decision was the fact that the wastewater from Desertland Dairy was being discharged to the lagoon system and the land application area authorized under the DP for Big Sky Dairy, DP-833 (NMED, 2019a).

On April 5, 2007, NMED approved a DP to combine Desertland and Big Sky Dairies. Up to 80,000 gpd wastewater total from one milking parlor at Big Sky and one milking parlor at former Desertland dairies was approved for discharge (NMED, 2019a). From Big Sky, wastewater is pumped to two synthetically lined wastewater ponds. Wastewater from the former Desertland dairy is pumped to a combination wastewater/stormwater pond that is synthetically lined (NMED, 2019a). Wastewater is then pumped to the Big Sky synthetically lined lagoon, from where all combined wastewaters are land applied to 151 acres of cropland under cultivation by both pivot and sprinkler (NMED, 2019a). The permittee is required to either land apply manure solids in a manner protective of groundwater or remove them off the facility. Storm water collected in earthen-lined lagoons is to be pumped in the wastewater ponds within 14 days of storm events (NMED, 2019a). On January 18, 2017 NMED authorized up to 70,000 gpd of wastewater from two production areas (NMED, 2019a). At Big Sky Dairy wastewater flows through a pipeline running from the milking barn to a Wastewater Pond North for storage prior to transfer to Wastewater Pond South for storage prior to land application (NMED, 2019a). At Desertland Dairy, wastewater flows from the barn to a synthetically lined combination wastewater/stormwater impoundment for storage prior to transfer. to the Big Sky Dairy Wastewater Pond South for storage prior to land application (NMED, 2019a). Wastewater from the Big Sky Dairy Wastewater Pond South is land-applied by center pivot, sprinkler irrigation and flood irrigation to 200 acres of irrigated cropland under cultivation (NMED, 2019a).

Discussion of Big Sky Dairy

Even though the runoff ponds were synthetically lined in 2007 (NMED, 2019a), Figure 33 shows that the liners take a long time to improve the groundwater quality. The land application area increased from 52 acres in 1992 to 151 acres in 2017 (NMED, 2019a). The increase could have a small effect on the concentration of nitrate in groundwater. The herd size has remained 1,000 milking head at Desertland Dairy and 1,000 milking head at Big Sky Dairy, so there is no change in herd size to correlate to groundwater quality changes.

D. Sunset Dairy DP-257

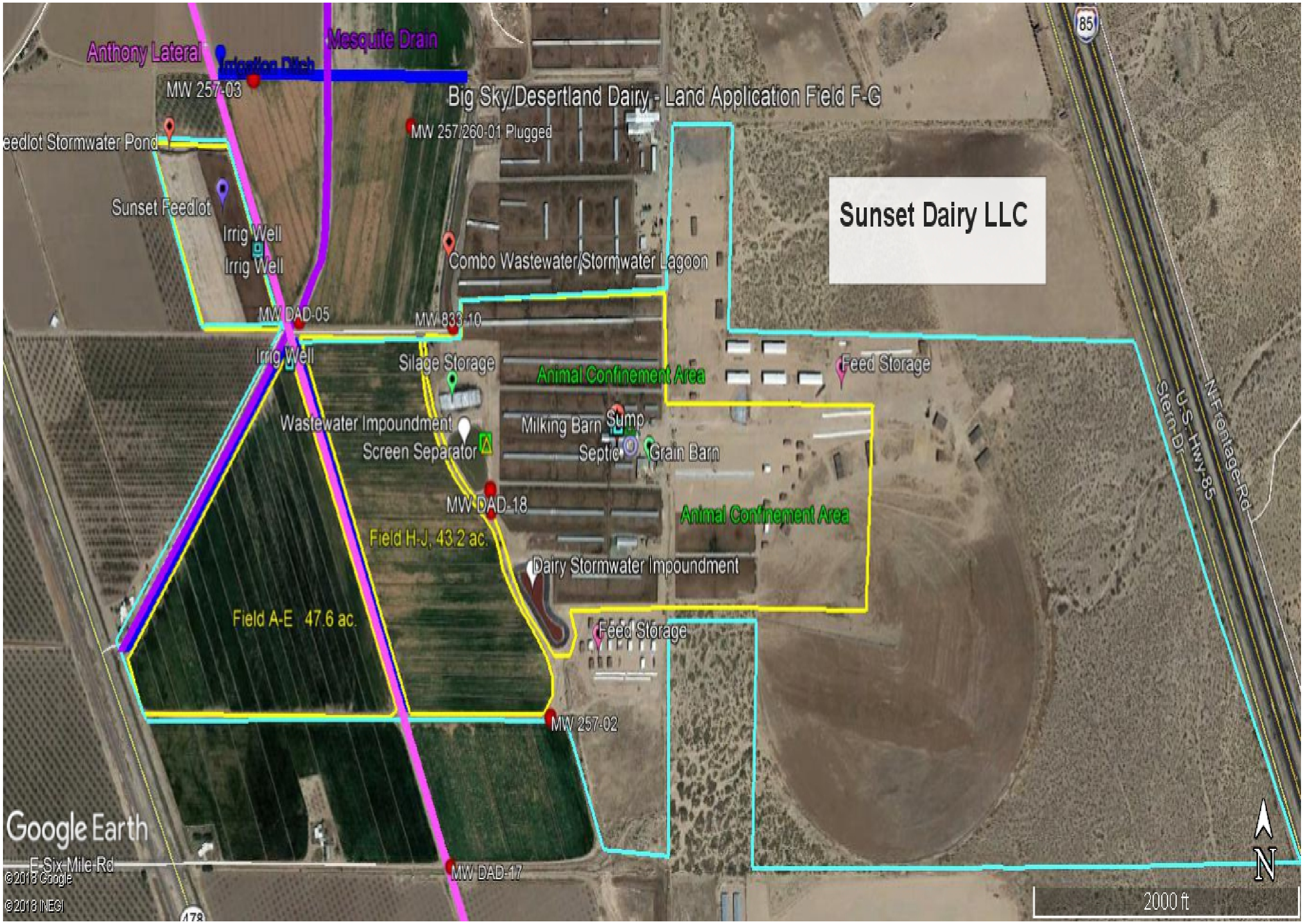


Figure 35 – Sunset Dairy Site Map (NMED, 2017e)

Even though the wastewater pond was installed in 1983 with a synthetic liner, it was damaged and required to be relined in 2001 (NMED, 2019k). Some leak or damage must have occurred in 2009 as shown by the graph in Figure 36. The synthetic liner has improved the groundwater quality. Groundwater is at a depth of approximately 10 feet below the ground surface (NMED, 2019k). The following monitoring wells supply data representative of groundwater quality for Sunset Dairy (NMED, 2019k):

- 257-03 - hydrologically upgradient of all contamination sources at the dairy facility and located northeast of the feedlot.
- 257-01 - hydrologically downgradient of wastewater pond and located off the southeast corner of the wastewater pond.

Nitrate concentrations (mg/L) in two monitoring wells near the pond are graphed in Figure 36. The orange trendline show a downward trend in nitrate concentrations over time.

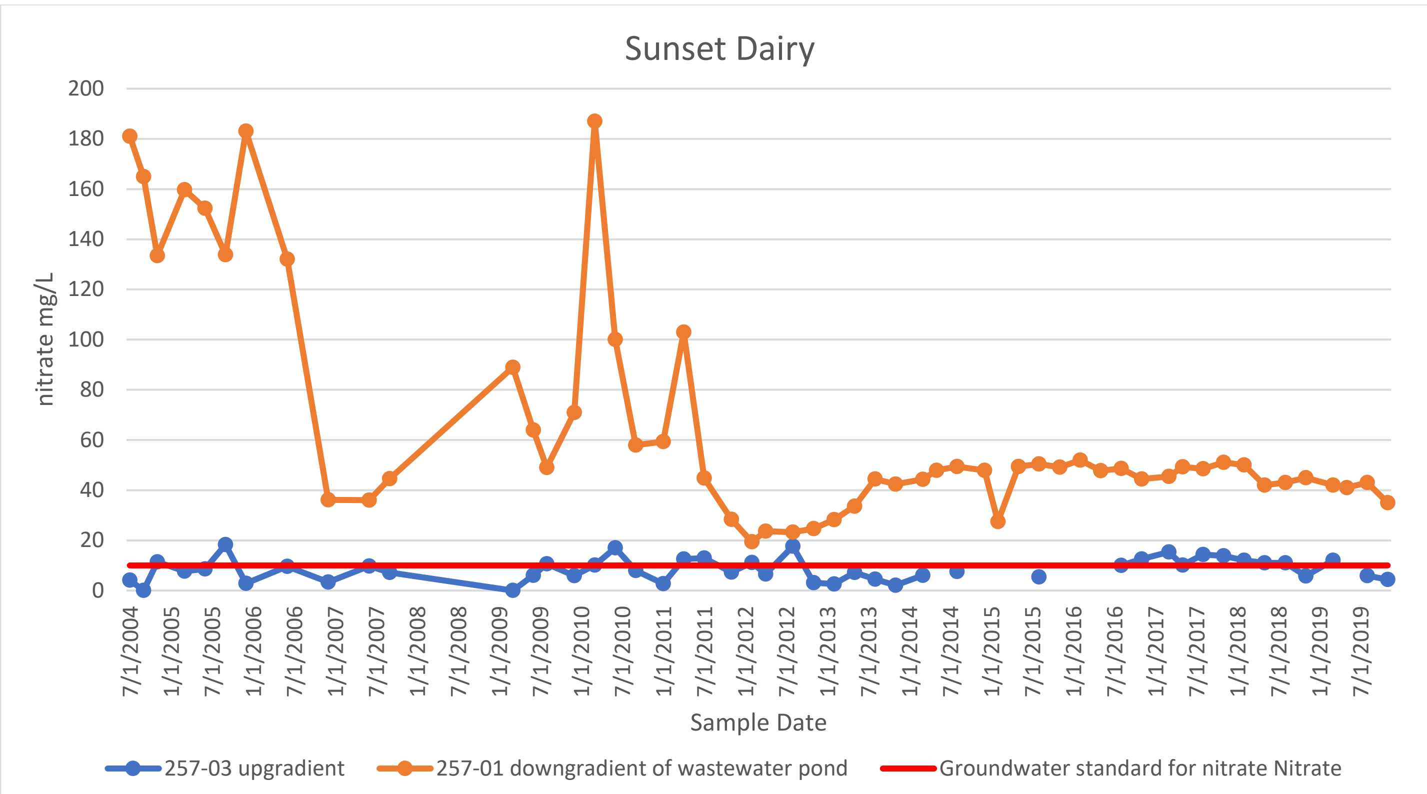


Figure 36 – Sunset Dairy Groundwater Nitrate Concentrations (NMED, 2019k)

Sunset Dairy History

From the GWQB administrative record for DP-257, operations started in 1983, and on December 7, 1983, the original permit was issued to allow the discharge of 48,000 gpd of wastewater to be directly applied to 91 acres of cropland and pasture. This permit was modified on September 20, 1983 to add a synthetically lined lagoon for wastewater clarification prior to land application (NMED, 2019k). On December 13, 1995, the DP approved 84,000 gpd of dairy wastewater discharged through a manure separator to a synthetically lined lagoon, then pumped to a 91acre land application area (NMED, 2019k). On February 1, 2002, the DP approved up to 45,000 gpd of wastewater discharged through a solids separator to a synthetically lined pond from where it is applied by furrow irrigation to 129.7 acres of cropland (NMED, 2019k). Solids are removed from the facility in a manner protective of the environment. Stormwater is diverted to a stormwater pond from where, within 14 days of the storm event, it is to be pumped either to the wastewater pond of the land application area (NMED, 2019k). On August 8, 2014 NMED authorized a discharge up to 45,000 gpd of wastewater from the production area, pumped through a solids separator to a synthetically lined wastewater impoundment for storage prior to being applied by flood irrigation to up to 130.7 acres of cropland under cultivation (NMED, 2019k). The June 26, 2019 DP states: 1. For a period not to exceed three years, to allow for the installation of the proposed evaporative wastewater impoundment, the permittee is authorized to discharge up to 20,000 gpd of wastewater from the production area, pumped through a solids separator to a synthetically lined wastewater impoundment for storage. Wastewater is land applied by flood irrigation to up to 90.8 acres of irrigated cropland under cultivation. 2. Following completion of the evaporative wastewater impoundment, the permittee is authorized to discharge up to 20,000 gpd of wastewater from the production area, pumped through a solids separator to a synthetically lined wastewater impoundment for disposal by evaporation (NMED, 2019k).

Discussion of the Sunset Dairy

Even though the wastewater pond was installed in 1983 with a synthetic liner, it was damaged and required to be relined in 2001 (NMED, 2019k). Some leak or damage must have occurred in 2009 as shown by the graph in Figure 36. The synthetic liner has improved the groundwater quality as shown by the downward trend. The land application area has remained virtually the same so changes cannot be correlated to a groundwater quality impact. Herd size was 1,000 milking herd in 1995 and is currently 2,400 milking head (NMED, 2019k). No nitrate groundwater quality impact is directly correlated to changes in herd size.

III. Southern Portion – Del Oro Dairy

A. Del Oro Dairy DP-692

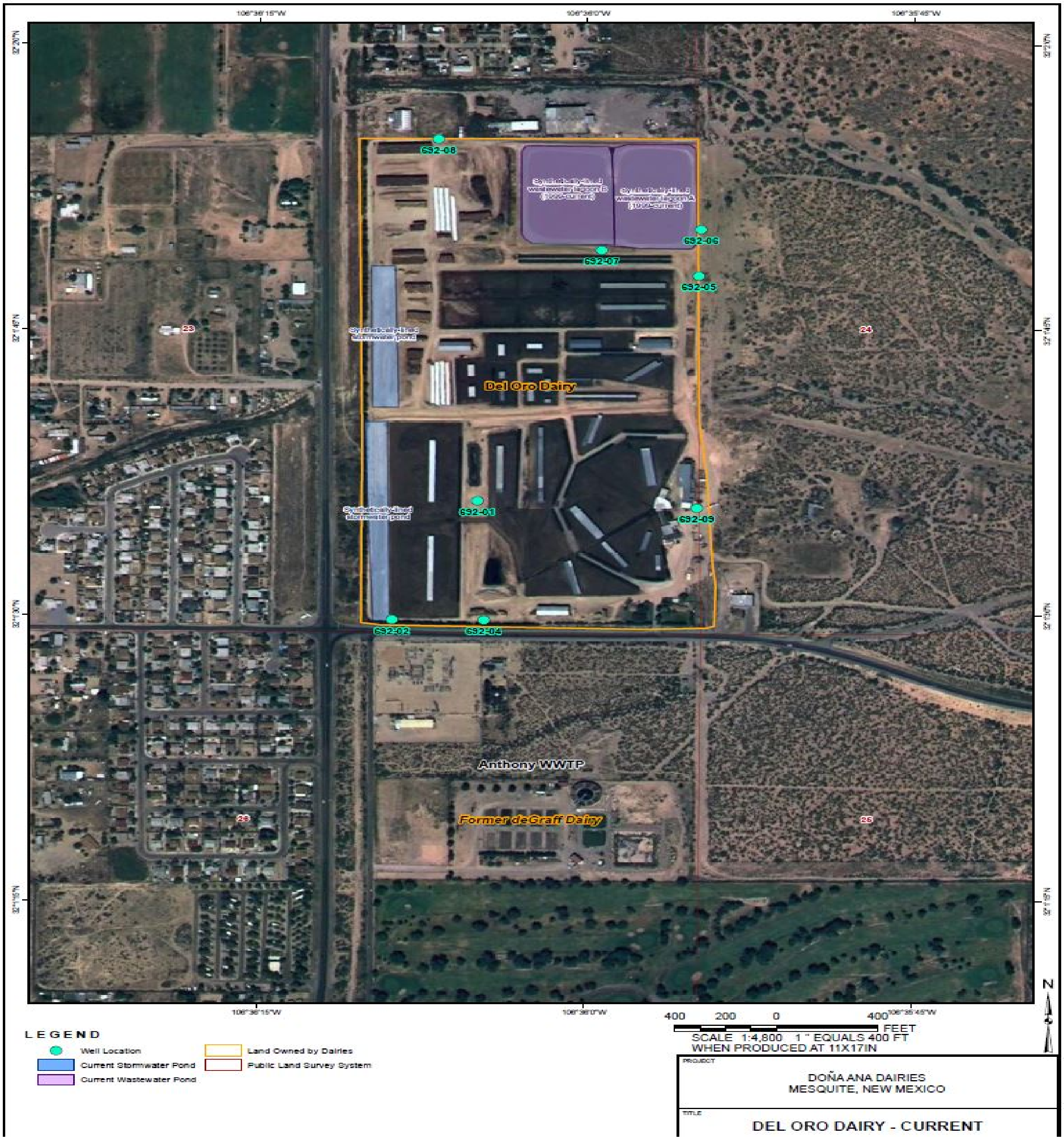


Figure 37 – Del Oro Dairy Site Map (Golder 2008)

Nitrate impacts are observed in the perched aquifer and the regional aquifer at Del Oro Dairy. The gradient is considerably steeper in the southern area, as shown by the potentiometric surface lines drawn at a 5 ft interval (Appendix C) (Golder, 2008). Groundwater is a depth of approximately 50 feet below the ground surface (NMED, 2019d). The following monitoring wells to supply data representative of groundwater quality for Del Oro Dairy (NMED, 2019d):

- 692-02 - hydrologically downgradient of the former wastewater and stormwater impoundments and located in the southwest corner of the facility, on the south property line. 692-02 monitors groundwater quality in the perched aquifer.
- 692-04 - hydrologically downgradient of the former wastewater and stormwater impoundments and located approximately 350 feet east of 692-02. 692-04 monitors groundwater quality in the perched aquifer.

Nitrate concentrations (mg/L) in two perched monitoring wells are graphed in Figure 38.

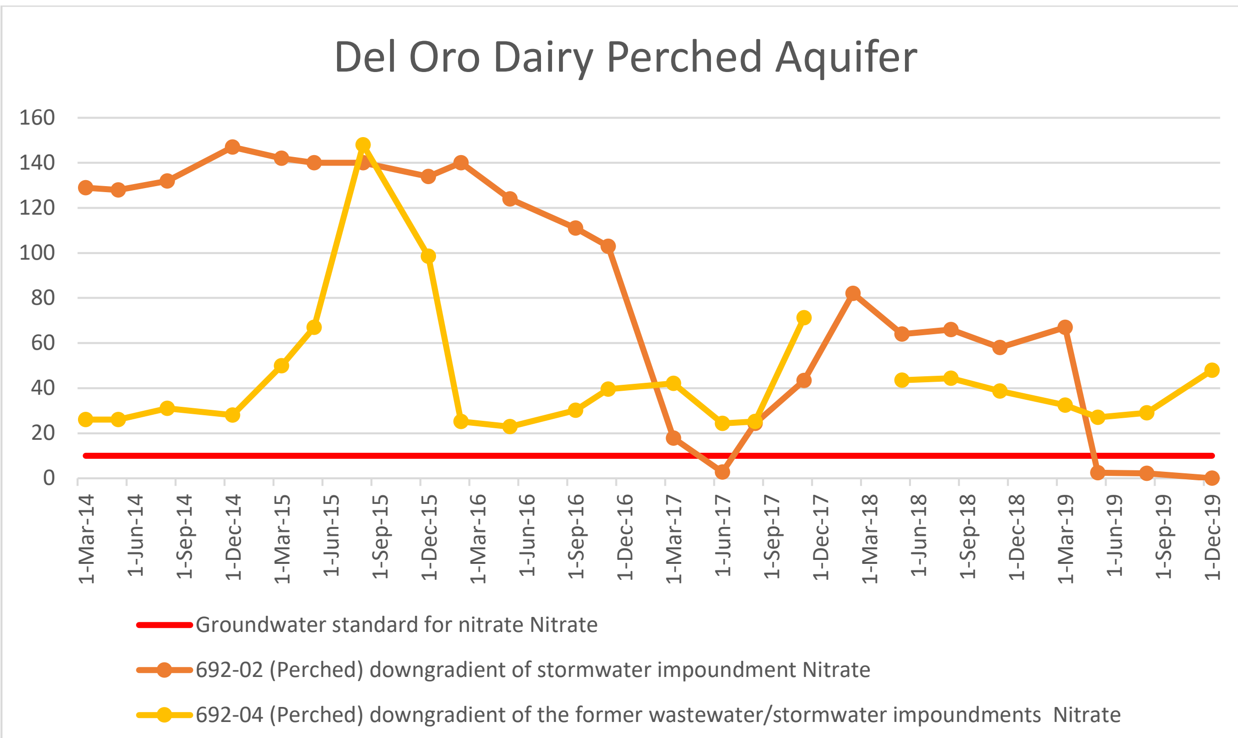


Figure 38 – Del Oro Dairy Perched Groundwater Nitrate Concentrations (NMED, 2019d)

- 692-05 - hydrologically downgradient of Wastewater Lagoon-A and located approximately 120 feet south of the southeast corner of Lagoon-A. 692-05 monitors groundwater quality in the regional aquifer.
- 692-08 - hydrologically upgradient of all contamination sources at the dairy facility and located approximately 275 feet east of the northwest corner of the facility. 692-08 monitors groundwater quality in the regional aquifer.

Groundwater is a depth of approximately 80 feet below the ground surface (NMED, 2019d). Nitrate concentrations (mg/L) in two regional monitoring wells are graphed in Figure 39.

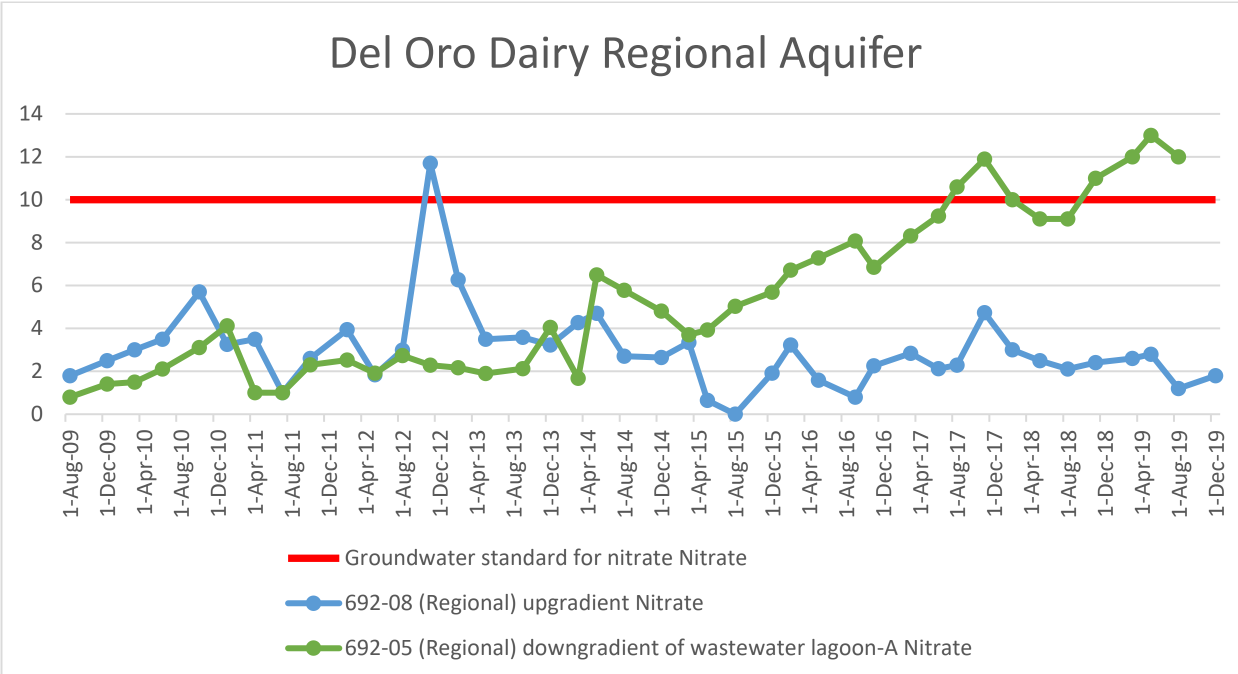


Figure 39 – Del Oro Dairy Regional Groundwater Nitrate Concentrations (NMED, 2019d)

Del Oro Dairy History

From the GWQB administrative record for DP-692, operations started in 1977, and on August 17, 1990 the original permit was approved. On March 19, 1999, NMED approved the discharge of up to 60,000 gpd from the milking parlor to the existing synthetically lined lagoon, then to 3 new synthetically lined lagoons in series. If needed, wastewater could be land applied to 37 acres (NMED, 2019d). On August 15, 2007 the DP authorized up to 60,000 gpd of wastewater discharged from the milking parlor through a screen separator to a concrete sump from which it is pumped to a synthetically lined pond (pond A) in series with a second pond (pond B) for disposal by total evaporation (NMED, 2019d). As needed, wastewater can be discharged to two synthetically lined stormwater ponds (ponds C and D). Manure is transported off the facility. Runoff is directed to two stormwater ponds (ponds C and D), from which it is transferred to the wastewater ponds A and B (NMED, 2019d).

Discussion of the Del Oro Dairy

Nitrate impacts are observed in the perched aquifer and the regional aquifer at Del Oro Dairy. The nitrate is trending down in the perched aquifer. Most of the regional aquifer wells at Del Oro Dairy appear to have been completed and screened within both the perched and regional aquifer (NMED, 2019d). The yellow trendline above shows that the regional aquifer which is used for drinking water by nearby neighbors and the town of Anthony, is starting to be impacted.

IV. Doña Ana Dairies Plume Discussion

Graphical representation of the groundwater data at each dairy highlights the variability of nitrate concentrations. Overall, very few sites show a definitive decreasing trend for every well at each site. The results are typically indicating decreasing concentration trends mixed with stable or increasing trends at each dairy. Some spikes in nitrate concentrations is obviously correlated to a management practice or source control on the ground.

As stated earlier, for ease of discussion and due to groundwater contamination and abatement requirements, the Doña Ana Dairies are divided into three sections:

- Southern Portion – Del Oro Dairy
- Northern Portion – Consisting of former Day Break Dairy (Organ Dairy), Mountain View Dairy, Buena Vista Dairy I, Bright Star Dairy, former D&J Dairy (Dominguez 2), Dominguez Dairy, and Gonzalez Dairy
- Central Portion – Buena Vista Dairy II, River Valley Dairy, Big Sky Dairy, and Sunset Dairy

A. Southern Portion – Del Oro Dairy

Within the southern portion nitrate impacts are observed in the perched aquifer and the regional aquifer. Most of the regional aquifer wells at Del Oro Dairy appear to have been completed and screened within both the perched and regional aquifer (NMED, 2019d).

All wells completed within the regional aquifer were below 10 mg/L nitrate until August of 2017. Del Oro well 692-05 has had nitrate concentrations above the standard, with ranges from 10.6 mg/L to 12 mg/L since August of 2017. Figure 34 shows the nitrate, chloride and TDS concentrations within the southern portion regional aquifer in November/December of 2019. In 2018 since Del Oro well 692-05 in the regional aquifer exceeded 10mg/L for nitrate, NMED required Del Oro Dairy to modify the Stage 2 Abatement Plan (NMED, 2018). Discussions are ongoing to approve an active pumping plan to capture the plume and keep it from migrating toward the town of Anthony.

All but three wells in the perched aquifer have nitrate concentrations above 10 mg/L (Figure 35). Wells DAD-26, DAD-22 and Del Oro Dairy well 692-02 had nitrate concentrations below standards with concentrations in August 2012 of 1.8 mg/L, 6.7 mg/L, and <1.0 respectively. The perched contamination is mostly contained on dairy property except for well DAD-20 which seems to have contributions of nitrate from the Anthony Waste Water Treatment Plant.

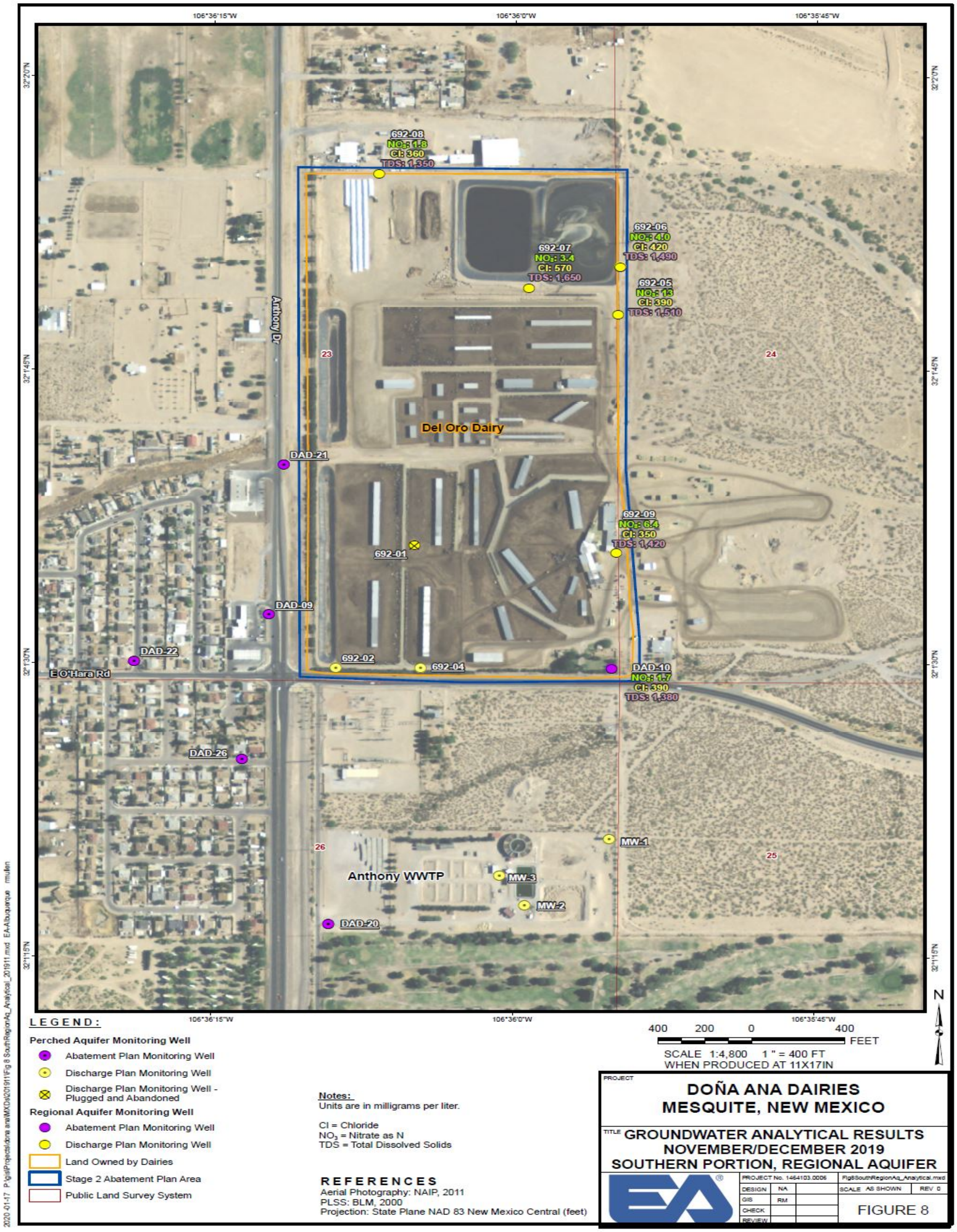


Figure 40 – DAD Southern Portion Groundwater 2019 Regional Aquifer with Nitrate Concentrations (EA Engineering, 2019)

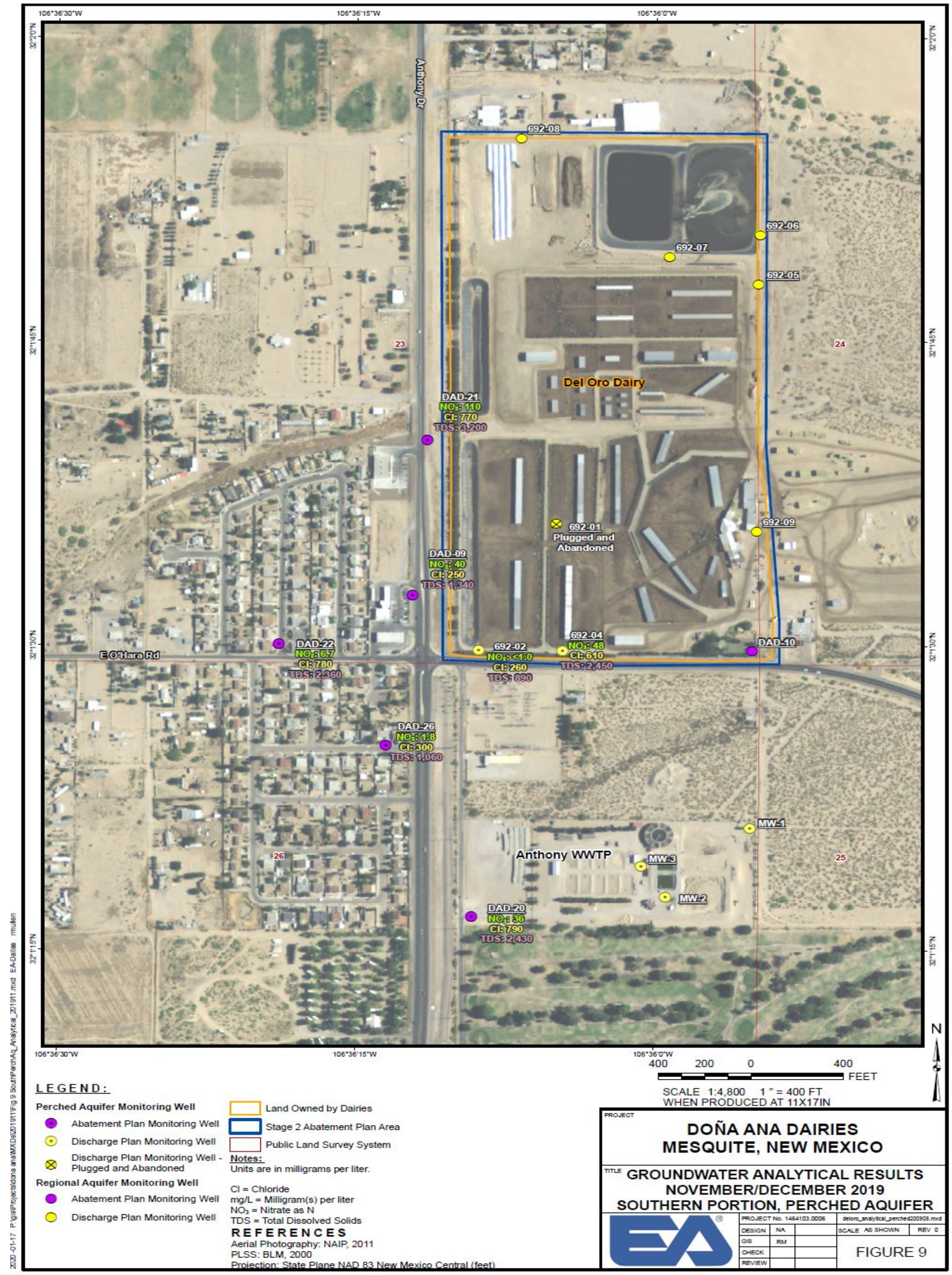


Figure 41 – DAD Southern Portion Groundwater 2019 Perched Aquifer with Nitrate Concentrations (EA Engineering, 2019)

B. Northern Portion

The nitrate concentrations in May 2019 and the estimated extent of the nitrate plume is shown in Figure 42. Nitrate contamination is present from upgradient well 86/340-01 located at the northern end of the northern land application area, which has a nitrate concentration of 7.5 mg/L, to just south of Gonzalez Dairy, where well DAD-02 monitors the downgradient extent of nitrate contamination with a concentration of 7.8 mg/L. The western cross-gradient extent of the plume is monitored by Dominguez Dairy wells 624-05 Gonzalez Dairy well 177-03A, which had nitrate concentrations of 6.6 mg/L, and 15 mg/L respectively. The cross-gradient extent of the plume to the east is monitored by Organ Dairy well 126-09 with a concentration of <1.0 mg/L; well DAD-01 with a concentration of 13 mg/L; Dominguez Dairy 2 wells 42-10, 42-11 and 42-12 with nitrate concentrations of <1.0 mg/L, 1.39 mg/L and 1.15 mg/L, respectively. In addition, well DAD-13 had a nitrate concentration of 13 mg/L in May 2019, completing the cross-gradient delineation of the nitrate plume.

The highest nitrate concentrations are present in the northern area in the area of Dominguez Dairy 2, where nitrate concentrations are greater than 50 mg/L. The highest nitrate concentration is observed in Dominguez Dairy well 42-06 with a concentration of 140 mg/L in May 2019. When compared to 2012 concentrations shown in Figure 37, the nitrate plume has become less concentrated on the outer edges, while the center is smaller it has higher concentrations. The reduced size of the center is thought to be affected by pumping of supply/irrigation wells in the immediate vicinity. Although the abatement has only been highly organized and monitored since 2012 some positive things are happening in the groundwater.

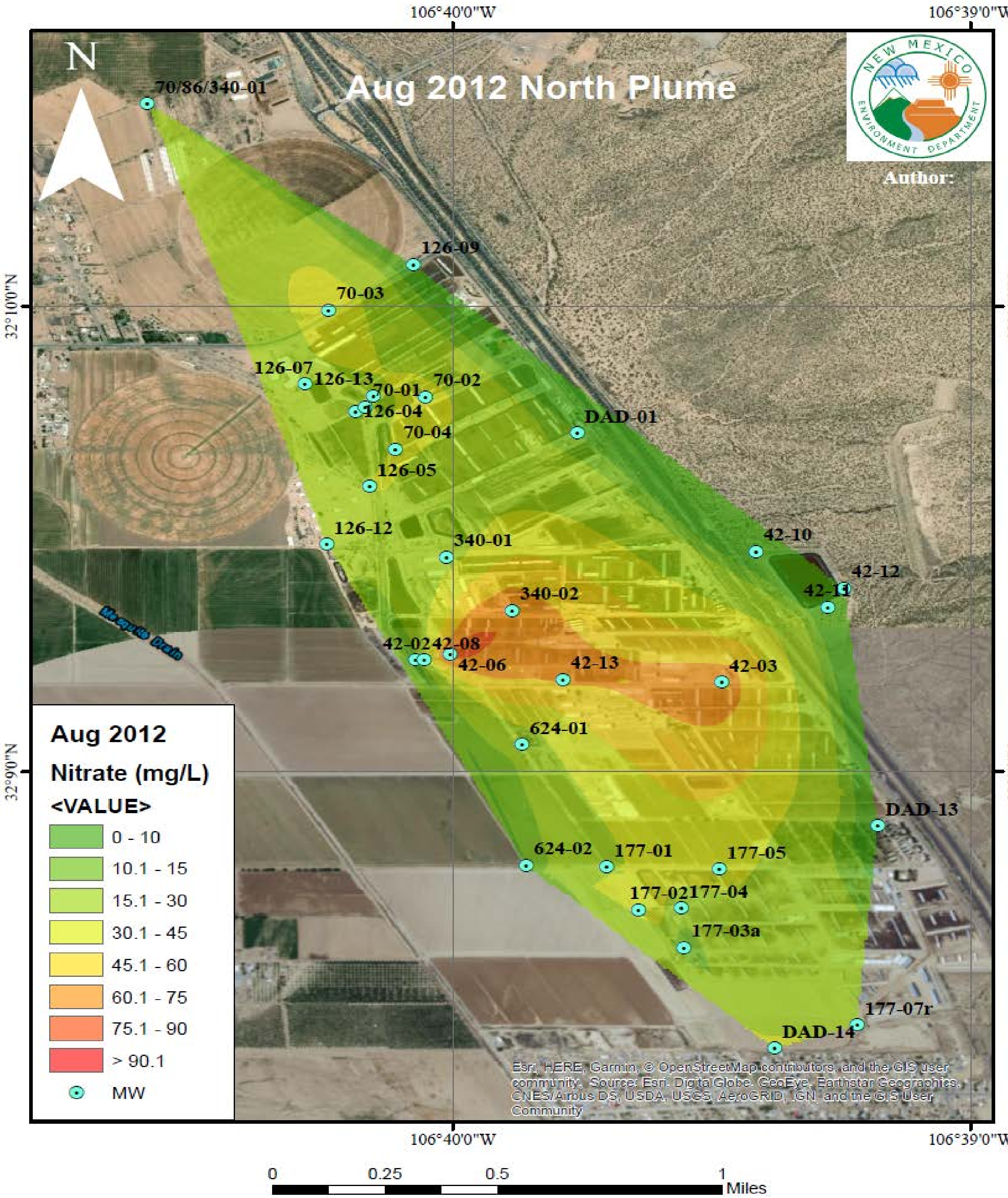


Figure 42 – DAD Northern Portion Groundwater Nitrate 2012 Isoconcentration Map (NMED, 2019)

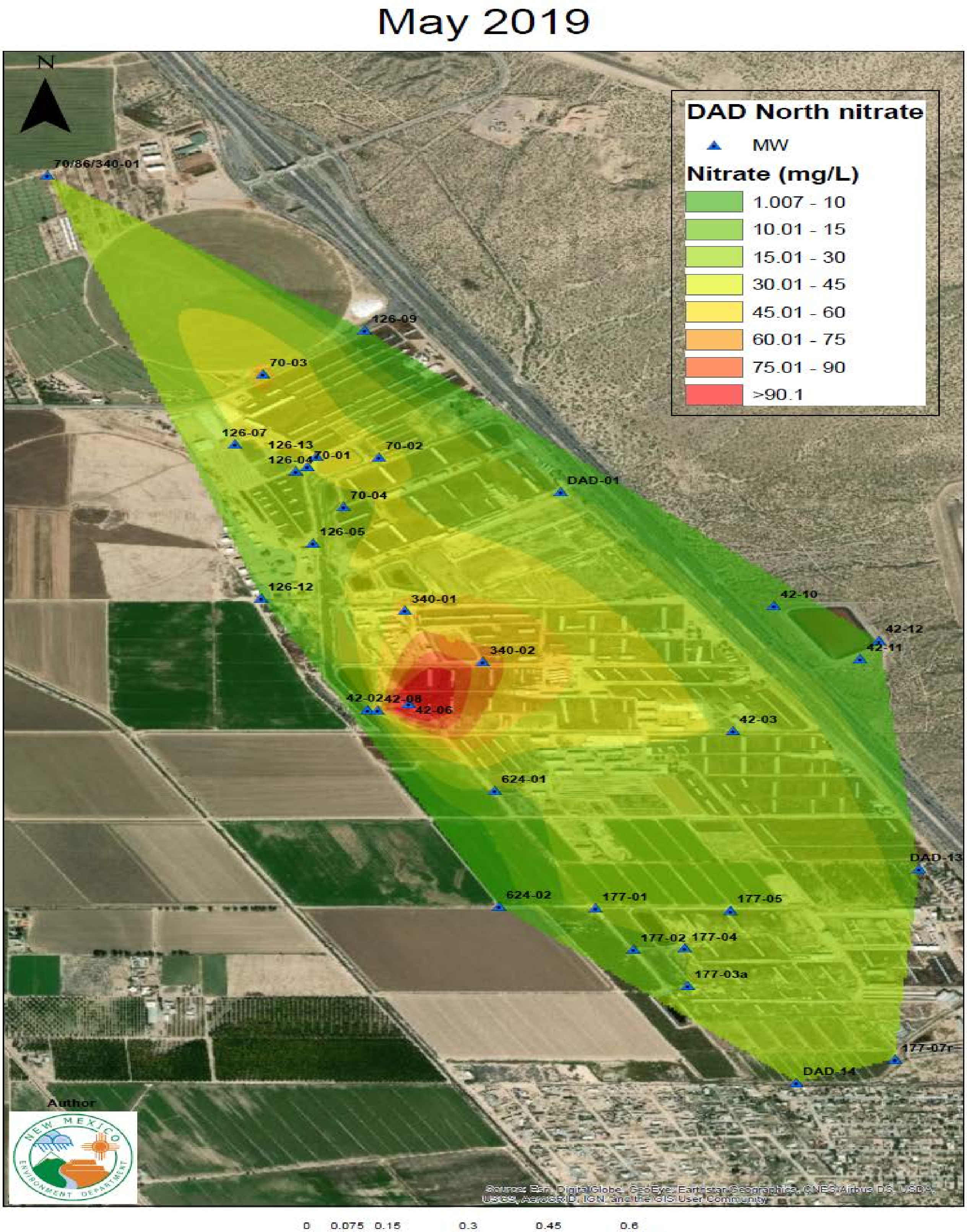


Figure 43 – DAD Northern Portion Groundwater Nitrate 2019 Isoconcentration Map (NMED, 2019)

C. Central Portion

The upgradient extent of nitrate is defined by well DAD-03 (shown in Figure 38) which had a nitrate concentration in May 2019 of <1.0 mg/L. The western cross-gradient extent of nitrate in groundwater is monitored by wells DAD-04, River Valley well 167-07, DAD-16, and DAD-05 all with nitrate concentrations at 1.0 mg/L or below. The eastern cross-gradient extent of nitrate in groundwater is monitored by wells DAD-15 and DAD-07 with concentrations of 9.9 mg/l and 12 mg/L, respectively. The downgradient extent of the nitrate plume is monitored by well DAD-17, which had a nitrate concentration of 1.3 mg/L.

The central portion is predominantly defined by a hot spot in the vicinity of Big Sky Dairy. There two areas within the central portion where nitrate concentrations are greater than 50 mg/L. The areas are located at Big Sky Dairy, well 833-02 side gradient to a land application area with a nitrate concentration of 68 mg/L in May 2019 and well 833-07 downgradient of a stormwater pond with a nitrate concentration of 69 mg/L in May 2019. In August 2012 shown in Figure 39 nitrate concentrations in groundwater in this area was above 90 mg/L but is decreasing and currently is below 90 mg/L. When comparing the two figures below it is apparent that the nitrate concentrations in the central portion are decreasing.

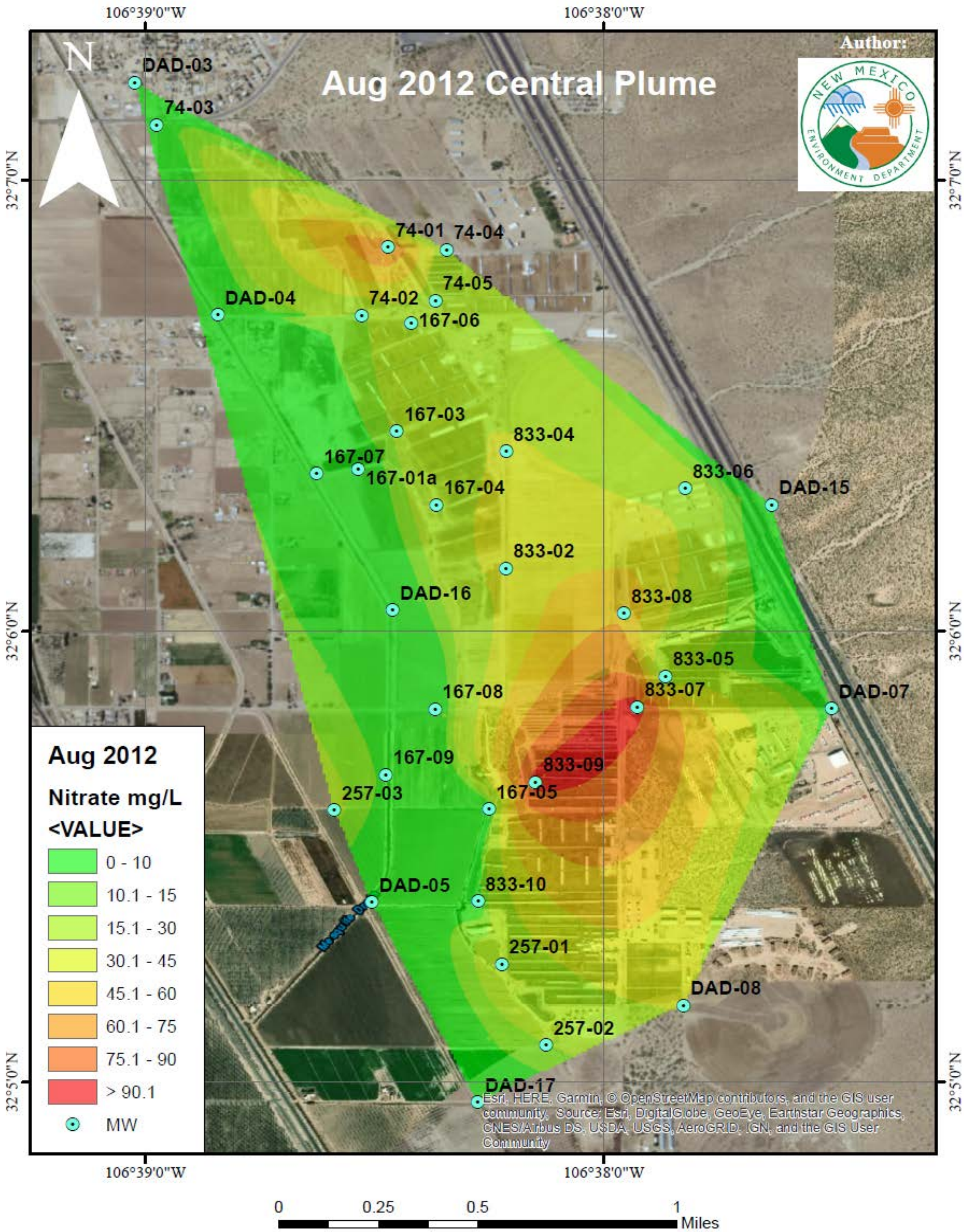


Figure 44 – DAD Central Portion Groundwater Nitrate 2012 Isoconcentration Map (NMED, 2019)

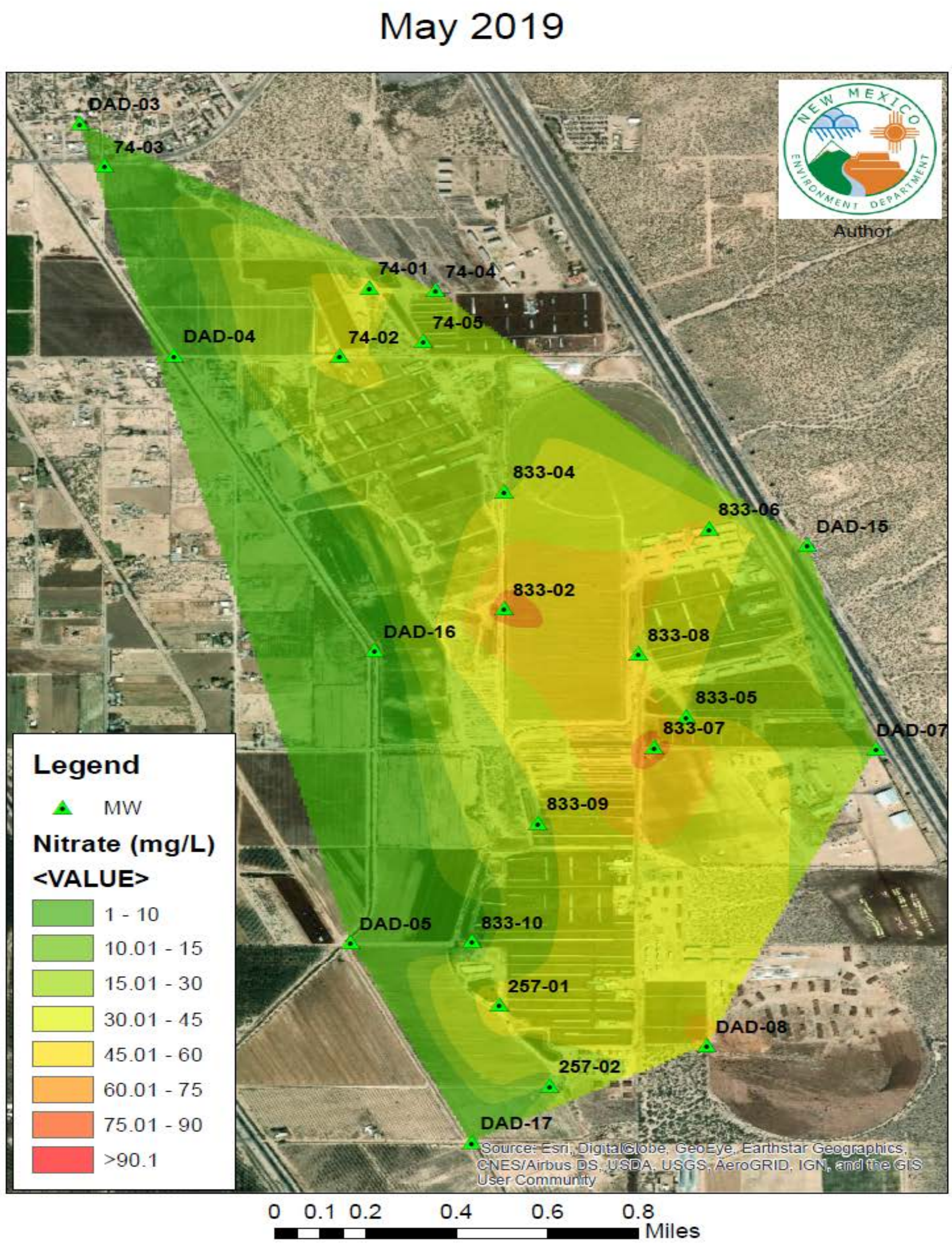


Figure 45 – DAD Central Portion Groundwater Nitrate 2019 Isoconcentration Map (NMED, 2019)

Conclusions

Dairy	Figure	Well ID	Nitrate	Position Relative to Dairy Facility
Organ Dairy	10	126-05	increasing	downgradient of land application area
	11	126-04	decreasing	downgradient of wastewater pond pre HDPE liner
		126-04	increasing	downgradient of wastewater pond post HDPE liner
Mountain View	13	70-02	decreasing	downgradient of wastewater pond post HDPE liner
	14	70-03	increasing	downgradient of land application area
Bright Star	17	340-01	increasing	downgradient of wastewater pond post HDPE liner
	18	86/340-01	decreasing	downgradient of land application area
Dominguez 2	20	42-08	decreasing	downgradient of runoff pond post HDPE liner
Dominguez 1&3	22	624-02	decreasing	downgradient of land application area
Gonzalez	25	177-02	decreasing	downgradient of wastewater clay lined
Buena Vista II	27	74-01	decreasing	downgradient of wastewater pond pre HDPE liner
	28	74-01	decreasing	downgradient of wastewater pond pre HDPE liner
River Valley	30	167-02	decreasing	downgradient of wastewater pond post HDPE liner
	31	167-05	decreasing	downgradient of land application area
Big Sky	33	833-08	decreasing	downgradient of runoff pond post HDPE liner
	33	833-09	decreasing	downgradient of runoff pond post HDPE liner
	34	833-06	decreasing	downgradient of land application area
Sunset	36	257-01	decreasing	downgradient of wastewater pond post HDPE liner
Del Oro	39	692-05	increasing	downgradient of wastewater pond post HDPE liner

Figure 46 – Results Summary

The analysis of groundwater quality data related to past practices and herd size showed that changes in herd size over time has very little impact on groundwater quality. Land application management practices do seem to have an immediate and long-lasting effect on groundwater quality for nitrate. When over application of dairy wastewater to flood irrigated fields occurs, it negatively impacts groundwater quality. The groundwater quality data downgradient of different dairies in this study shows two ways to reduce the amount of nitrate leaching from land application areas, into groundwater are:

1. Use of more land to control the nutrient loading; or
2. Install infrastructure to irrigate with sprinklers or center pivots to allow more precise use of nutrients

Historical groundwater quality data shows that unlined ponds allow nitrate to move directly into shallow groundwater, but the benefit of HDPE liners may not be seen for many years. This is likely because of the large mass of nitrogenous material, both nitrate and TKN that has accumulated in the soil and groundwater, and the slow rate of flushing of these contaminants in a region with little precipitation and very slow groundwater flows due to flat hydraulic gradients If HDPE liners are used from the inception of the dairy the groundwater impacts are greatly diminished (NMED 2019m).

Figure 46 shows a summary of the results depicted in the graphs for each dairy in the study, and although some areas of land use continue to have an increasing trend for nitrate concentrations in groundwater, for the most part the source control and changes in land use and irrigation practices is making a positive impact on the groundwater quality.

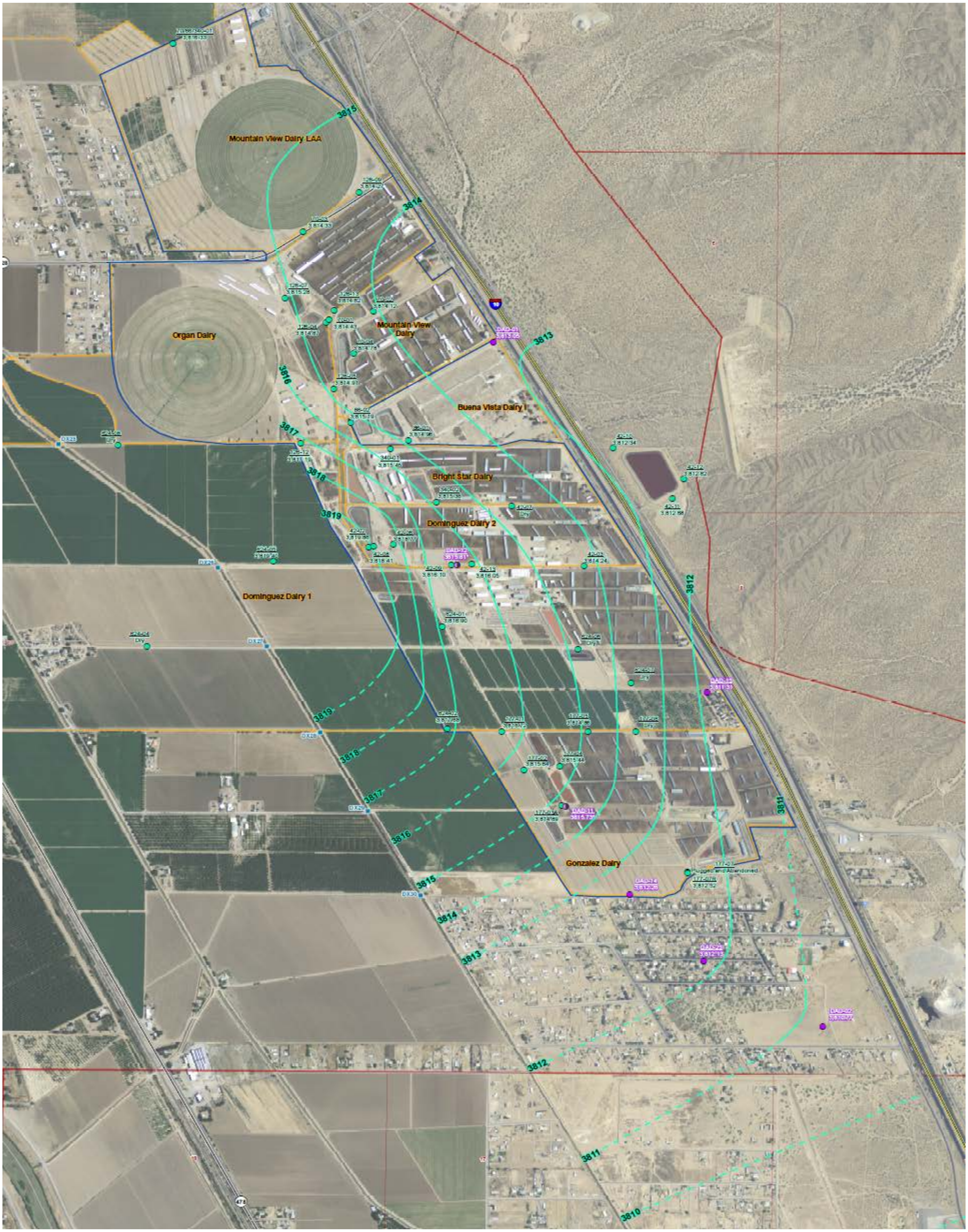
This study shows that pollution of groundwater can happen quickly in shallow basins. Source control measures such as HDPE liners in ponds and better irrigation practices can prevent or control most of these groundwater inputs, if enacted early or as a design of the dairy facility at inception.

In contrast, the cost of groundwater sampling and control measures after the fact, the slow decrease of nitrate concentrations, and resources it takes to report all this effort, show that programs to prevent groundwater pollution are much more effective than cleanup programs for sustaining usable groundwater supplies. Prevention of groundwater pollution is more cost effective than trying to clean up an aquifer after it has become contaminated.

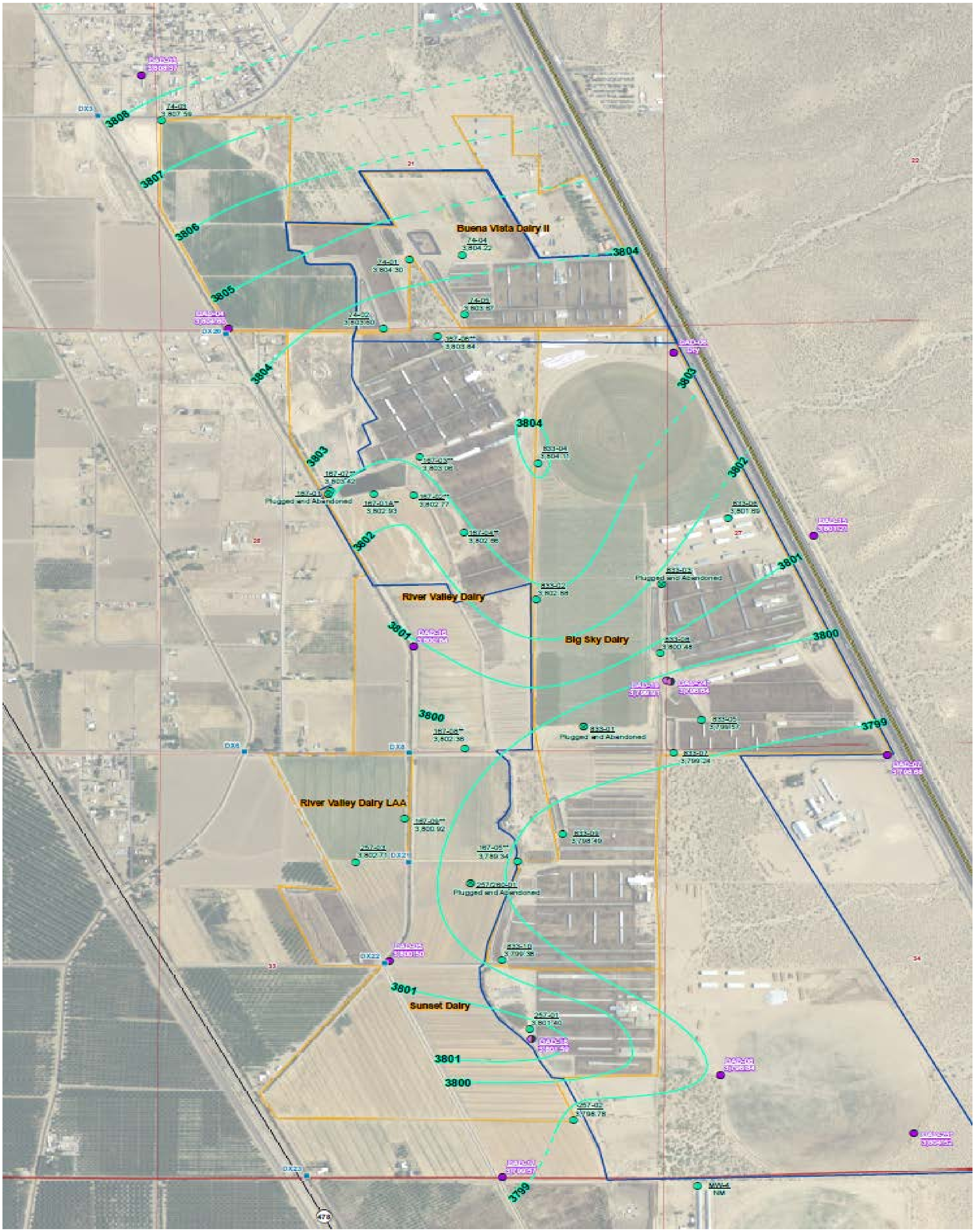
The groundwater pollution prevention provisions of the WQCC regulations 20.6.2 and 20.6.6. NMAC are designed to ensure the long-term protection of New Mexico’s groundwater resources. These groundwater resources are essential to sustaining the state’s populace, business, and agriculture.

Appendices

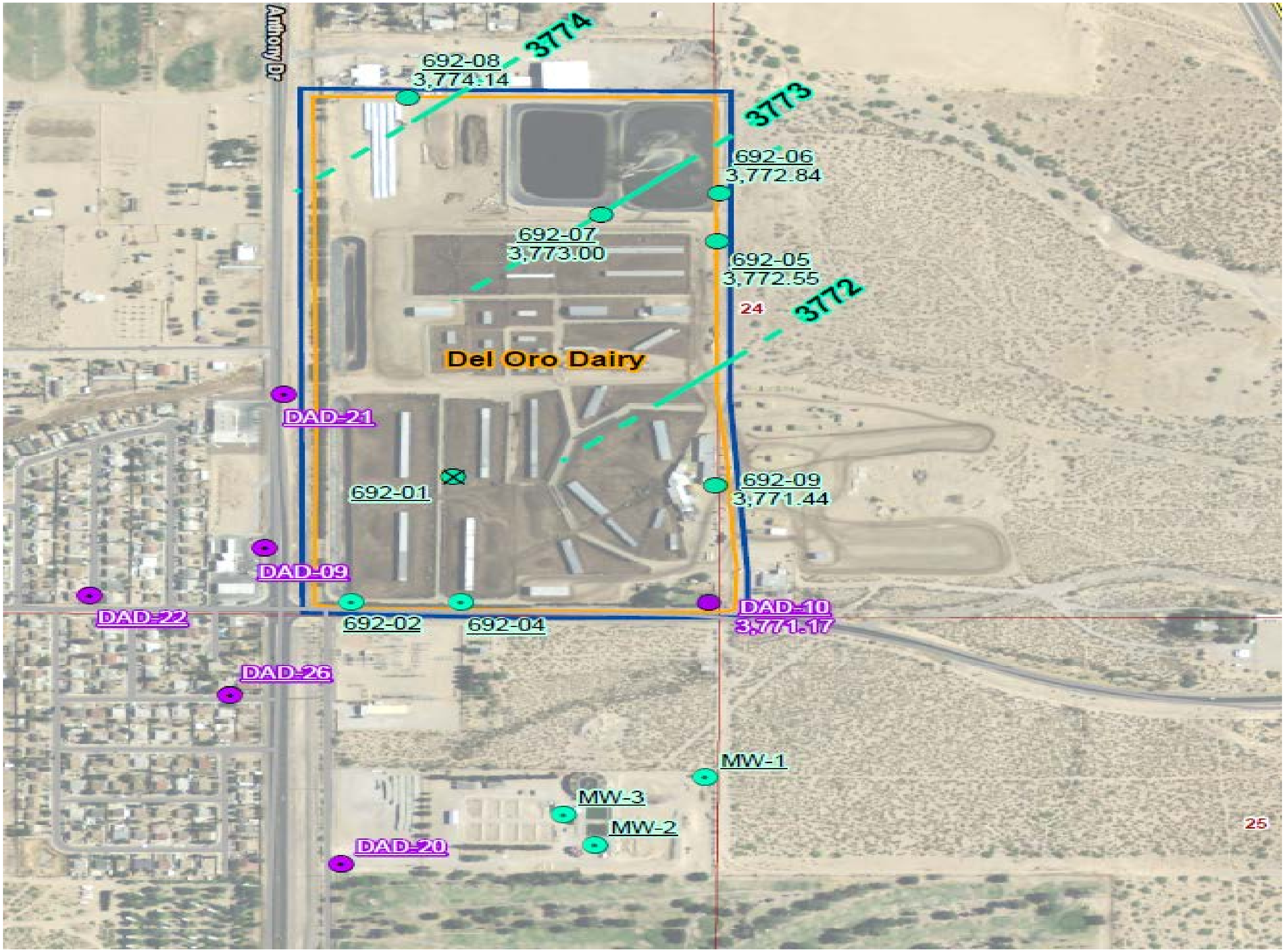
Appendix A – DAD Northern Portion Groundwater Flow Direction Map



Appendix B – DAD Central Portion Groundwater Flow Direction Map



Appendix C – DAD Southern Portion Groundwater Flow Direction Map



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