

Ambient Groundwater Quality of the McMullen Valley Basin: A 2008-2009 Baseline Study – June 2011



Figure 1 - McMullen Valley occasionally has prolific surface water flows such as when the ephemeral Centennial Wash, with flows peaking at 9,938 cubic feet per second, flooded the nearby community of Wenden during heavy precipitation in mid-January, 2010.

INTRODUCTION

A baseline groundwater quality study of the McMullen Valley basin was conducted in 2008-2009 by the Arizona Department of Environmental Quality (ADEQ) Ambient Groundwater Monitoring Program. ADEQ conducted this monitoring pursuant to Arizona Revised Statutes §49-225 that calls for ongoing monitoring of waters of the state including its aquifers. This fact sheet is a synopsis of the ADEQ Open File Report 11-02.¹

The McMullen Valley groundwater basin encompasses approximately 591 square miles in west-central Arizona.² The western portion of the basin is located in La Paz County, the southeastern portion is in Maricopa County, and a small northeastern portion is in Yavapai County. Salome, Wenden and Aguila are small communities located within McMullen Valley where agriculture is the major industry. Approximately 14,600 acres were farmed in 2007.³ There are two irrigation districts: the Aguila Irrigation District and the McMullen Valley Water Conservation District. All wells and ditches are privately owned in both districts as neither has a consolidated distribution system. Groundwater is the primary source for agricultural, municipal,

stock and domestic water supply within the basin; it's estimated that 15.1 million acre-feet of groundwater is contained in the basin.³

The McMullen Valley basin is one of the few groundwater basins in Arizona designated for out-of-basin transport of groundwater. The City of Phoenix has purchased or leased 16,000 acres of agricultural land to obtain the water rights for potential future transport of groundwater to the Phoenix Active Management Area for municipal uses.³ Until this groundwater transfer occurs, the city is managing these agricultural properties by leasing them to farm operators.⁴

GROUNDWATER CHARACTERISTICS

McMullen Valley is located within the Basin and Range physiographic province and is a kidney-shaped basin, oriented northeast-to-southwest and about 15 miles wide and 48 miles long. At the southwest end of McMullen Valley is Harrisburg Valley, oriented perpendicular to the axis of McMullen Valley. The basin is drained by Centennial Wash (Figure 1), an ephemeral tributary of the Gila River that heads about 20 miles east of Aguila and discharges from the basin through "the Narrows" into the Harquahala basin.²

The main source of groundwater in the basin is the Regional aquifer.⁴ Found throughout McMullen Valley, stratigraphic data suggest it's composed of coalescing heterogeneous deposits of poorly sorted, coarse gravel and sand. Although thought to be hydrologically connected, the sediment's heterogeneous nature results in highly variable hydraulic properties throughout the aquifer. Intergranular cementation also impacts the aquifer's hydraulic properties. In general, cementation increases in the basin from west to east, around the basin's margins, and in proximity to bedrock.⁴

For the purposes of this study, the Regional aquifer is subdivided into five aquifers based on partial structural controls and groundwater quality differences. Heavy pumping for agriculture in two areas, in the vicinity of Aguila (Figure 2) and around Wenden/Salome, have produced a groundwater divide near the La Paz-Maricopa County line creating Eastern and Western Regional aquifers.² In terms of spatial extent and groundwater storage these are the largest aquifers in the basin.²



Figure 2 - Well #23 pumps groundwater for use on the nearby irrigated fields of cantaloupe near the town of Aguila. Like many wells in the Eastern Regional aquifer, samples from the well exceeded aesthetics-based standards for fluoride.

Low hills east of Aguila that minimize groundwater movement divides the Eastern Regional aquifer from the Forepaugh aquifer.⁵ A subsurface extension of the Harquahala Mountains that limits groundwater movement separates the Western Regional aquifer from the Southern Regional aquifer located in Harrisburg Valley.² Another subsurface geologic feature separates the Harcuvar aquifer from the Southern and Western Regional aquifers lying to the east.⁴

Groundwater movement between the Western Regional aquifer and the overlying Perched aquifer (Figure 3) is restricted by the Lake-bed Unit, a layer of fine-grained sediments.⁴ These lake-bed deposits, however, are absent in a small area one mile northeast of Salome where the merging of the Regional and Perched aquifers are termed the Mixed aquifer.⁴

METHODS OF INVESTIGATION

To characterize regional groundwater quality in the McMullen Valley basin, samples were collected from 124 sites consisting of irrigation, domestic, municipal and stock wells located throughout the basin. Inorganic constituents and oxygen and deuterium isotopes were collected at all sites. At selected sites, radon (79 sites), radiochemistry (50 sites) and pesticide (2 sites) samples were also collected. Twelve (12) additional sites were sampled for field parameters and nitrate.

Sampling protocol followed the ADEQ *Quality Assurance Project Plan*. The effects of sampling equipment and procedures were not found to be significant based on seven quality assurance/quality control tests.⁶

WATER QUALITY SAMPLING RESULTS

Groundwater sample results were compared with the Safe Drinking Water Act (SDWA) water quality standards. Public water systems must meet these enforceable, health-based, water quality standards, called Primary Maximum Contaminant Levels (MCLs), when supplying water to their customers. Primary MCLs are based on a daily lifetime (70 years) consumption of two liters of water.⁷

Of the 124 sites sampled, 54 sites (44 percent) had concentrations of at least one constituent that exceeded a Primary MCL (Map 1). Constituents exceeding Primary MCLs include arsenic (24 sites) (Map 2), fluoride (27 sites), nitrate (25 sites), and selenium (2 sites). Primary MCLs for radionuclides were exceeded at 9 of the 50 sites (18 percent) including gross alpha (9 sites) and uranium (4 sites).

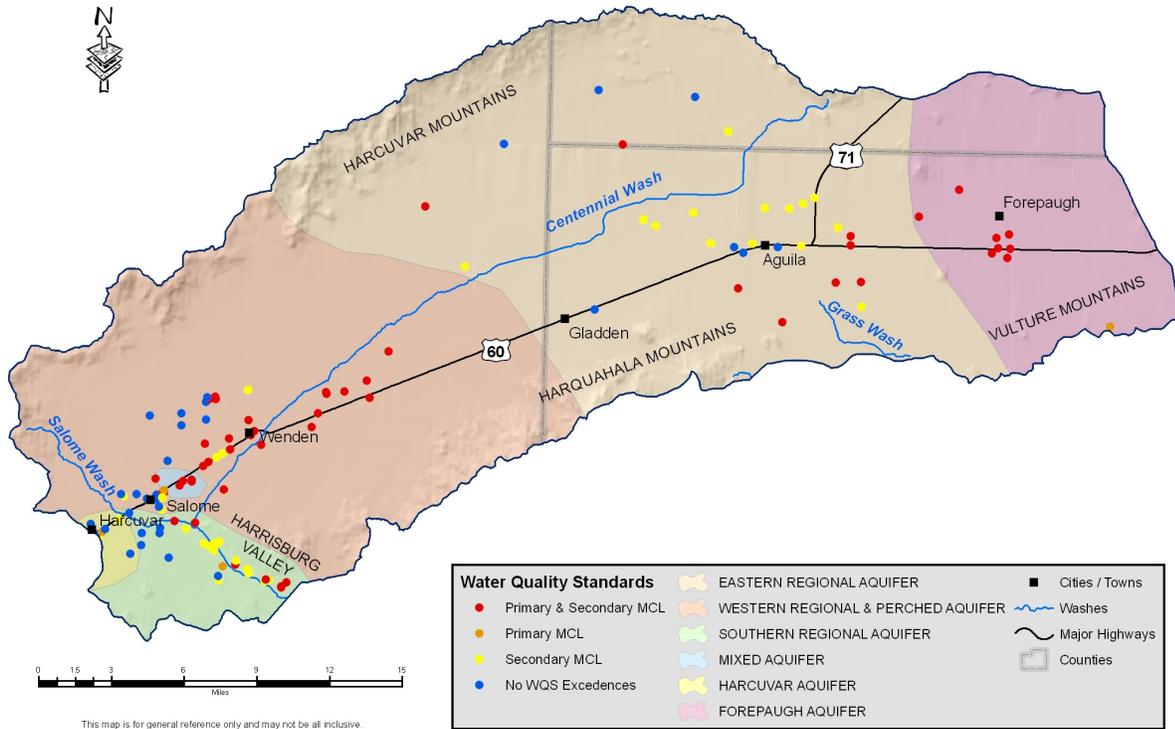
Groundwater sample results were also compared with SDWA water quality guidelines. Public water systems are encouraged to meet these unenforceable, aesthetics-based water quality guidelines, called Secondary MCLs, when supplying water to their customers. Water exceeding Secondary MCLs may be unpleasant to drink and/or create unwanted cosmetic or laundry effects but is not considered a health concern.⁷

Of the 124 sites samples, 87 sites (70 percent) had concentrations of at least one constituent that exceeded a Secondary MCL water quality guideline (Map 1). Constituents above Secondary MCLs include chloride (13 sites), fluoride (69 sites), manganese (2 sites), pH (19 sites), sulfate (8 sites), and TDS (31 sites).



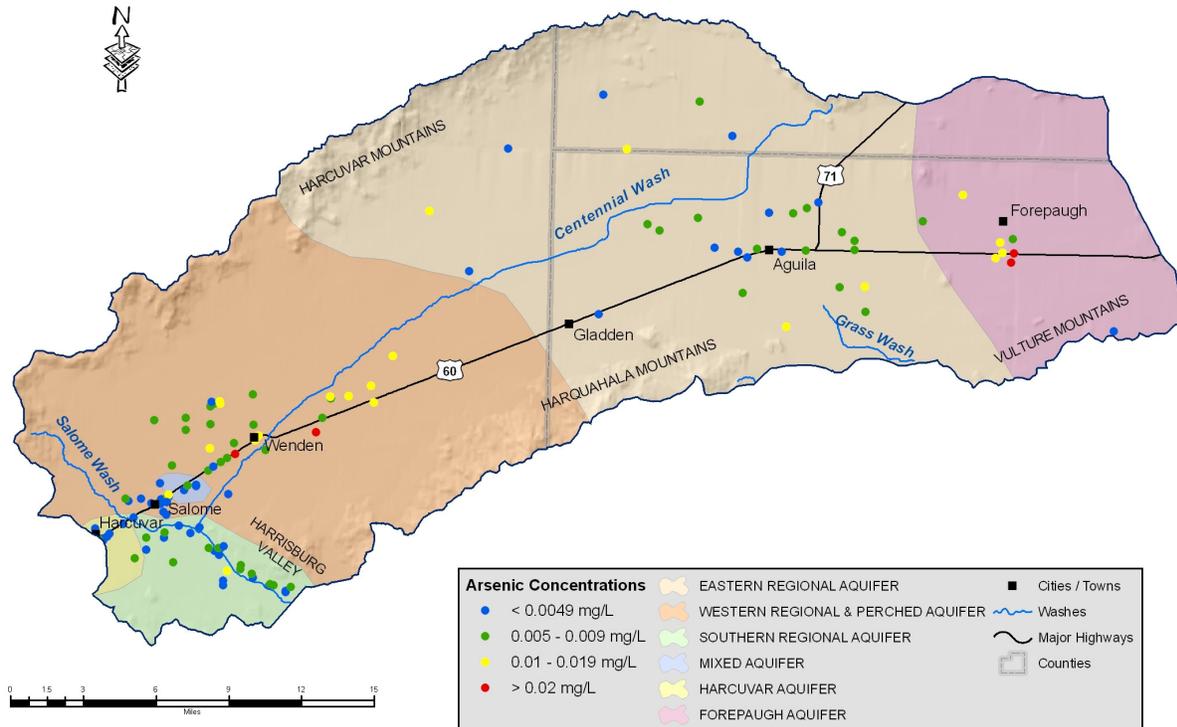
Figure 3 - A 180-foot-deep domestic well located near farmland north of the town of Salome. Like all samples from wells drawing water from the Perched aquifer, it exceeded health-based water quality standards for at least one constituent.

Map 1: Water Quality Standards



Map 1 - Sample sites in the McMullen Valley basin are color-coded according to their water quality standard status.

Map 2: Arsenic
Primary MCL for Arsenic = 0.01 mg/L



Map 2 - Sample sites in the McMullen Valley basin are color-coded according to their arsenic concentrations.

Radon is a naturally occurring, intermediate breakdown product from the radioactive decay of uranium-238 to lead-206. Of the 79 sites sampled for radon, 3 exceeded the proposed 4,000 picocuries per liter (pCi/L) standard that would apply if Arizona establishes an enhanced multimedia program to address the health risks from radon in indoor air. Sixty-eight (68) sites exceeded the proposed 300 pCi/L standard for states that would apply if Arizona doesn't develop a multimedia program.⁷

There were no positive detections of any of the 20 organochlorine compounds analyzed in the 2 pesticides samples collected from shallow wells near irrigated agricultural fields.

GROUNDWATER CHEMICAL COMPOSITION

Groundwater in the McMullen Valley basin was predominantly of sodium-chloride or sodium-mixed chemistry. Levels of pH-field were *slightly alkaline* (above 7 su); 63 sites had pH-field levels over 8 su and 6 sites had pH-field levels over 9 su. TDS concentrations were considered *fresh* (below 1,000 mg/L) at 108 sites, *slightly saline* (1,000 to 3,000 mg/L) at 14 sites and *moderately saline* (3,000 to 10,000 mg/L) at 2 sites. Hardness concentrations were *soft* (below 75 mg/L) at 57 sites, *moderately hard* (75 – 150 mg/L) at 38 sites, *hard* (150 – 300 mg/L) at 19 sites, and *very hard* (above 300 mg/L) at 10 sites.

Nitrate (as nitrogen) concentrations at most sites may have been influenced by human activities. Nitrate concentrations were divided into natural background (0 sites at <0.2 mg/L), may or may not indicate human influence (53 sites at 0.2 – 3.0 mg/L), may result from human activities (56 sites at 3.0 – 10 mg/L), and probably result from human activities (17 sites >10mg/L).⁸

Most trace elements such as antimony, beryllium, cadmium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, thallium and zinc were rarely—if ever—detected. Only arsenic (Map 2), barium, boron, chromium and fluoride were detected at more than 50 percent of the sites.

GROUNDWATER PATTERNS

Many statistically significant groundwater quality patterns were found between aquifers in the McMullen Valley basin. Generally, concentrations of many constituents, including TDS, magnesium, sodium, chloride, sulfate, and nitrate (Figure 4), were significantly higher in the Perched and Mixed aquifers than in the other five aquifers. In addition, hardness, calcium, potassium, barium and gross beta were significantly higher in the Mixed aquifer than the other aquifers; similarly, turbidity and boron were significant higher in the Perched aquifer than the other aquifers (Kruskal-Wallis with Tukey test, $p \leq 0.05$).

There were a few exceptions to the Perched and Mixed aquifers having the highest concentration of constituents in the McMullen Valley basin. Fluoride concentrations were significantly higher in the Forepaugh aquifer than the other aquifers except for the Perched aquifer (Figure 5).

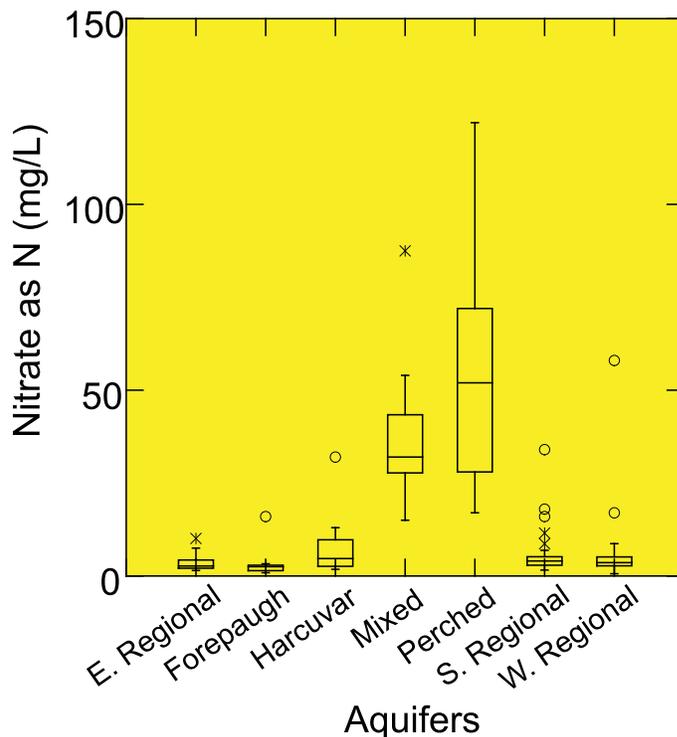


Figure 4 - Samples collected from wells in the Perched and Mixed aquifers have significantly higher nitrate concentrations than well samples collected from the other McMullen Valley aquifers (Kruskal-Wallis with Tukey test, $p \leq 0.01$). The Perched and Mixed aquifers are likely impacted by nitrogen-laden recharge from irrigated fields and, to a lesser degree, septic systems.

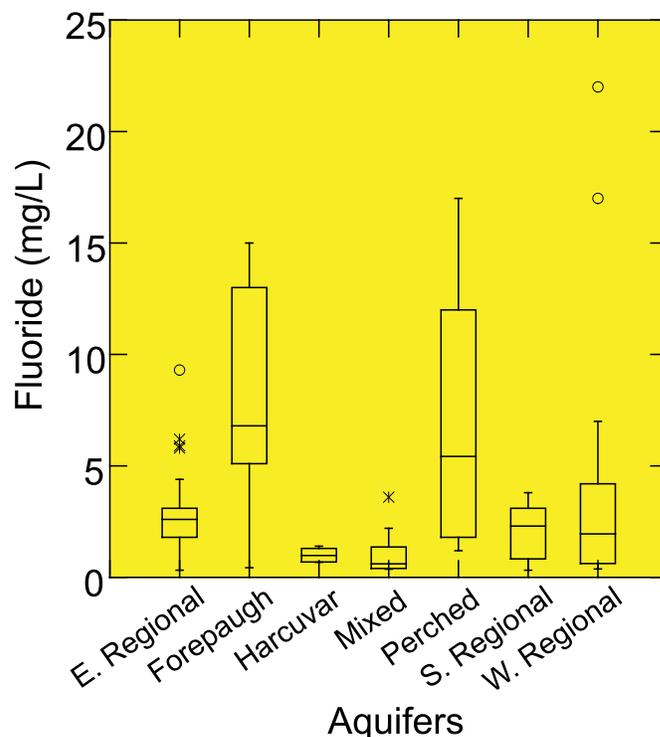


Figure 5 - Samples collected from wells in the Forepaugh aquifer have significantly higher fluoride concentrations than samples collected from all other aquifers except the Perched aquifer. (Kruskal-Wallis with Tukey test, $p \leq 0.05$). The median fluoride concentration for both the Forepaugh and Perched aquifers exceeded the 4.0 mg/L health based water quality standard.

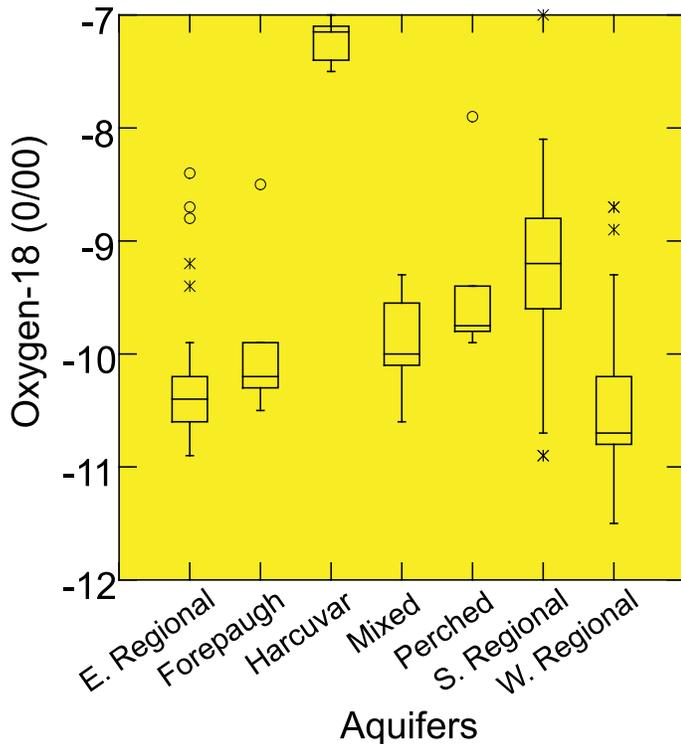


Figure 6 - Samples collected from wells in the Harcuvar aquifer have significantly higher oxygen-18 values than samples collected in other McMullen Valley aquifers (Kruskal-Wallis with Tukey test, $p \leq 0.05$). This pattern indicates groundwater in the Harcuvar aquifer is likely of more recent origin.

Oxygen and deuterium levels were significantly higher in the Harcuvar aquifer than the other aquifers (Figure 6). Well depths and groundwater depths were significantly greater in the Eastern Regional aquifer than the other aquifers (Kruskal-Wallis with Tukey test, $p \leq 0.05$).

CONCLUSIONS

The basin's most important groundwater quality aspect is the absence of the Lake-bed Unit northeast of Salome.⁴ Nearby wells commonly exceed water quality standards and guidelines; nitrate concentrations were elevated up to seven times the 10 mg/L health-based water quality standard. This appears to be the result of percolating irrigation water, and to a lesser degree wastewater from septic systems, recharging the Perched aquifer with high concentrations of salts and nitrate.⁴ With a higher static water level than the Regional aquifer, groundwater drains downward from the Perched aquifer into the Western Regional aquifer.⁴ This impacted area is referred to in this report as the Mixed aquifer. Besides TDS and nitrate water quality exceedances, gross alpha and uranium exceedances also occurred in the Mixed aquifer. The latter two constituents are likely naturally occurring and are related to nearby granite geology or alluvial areas of eroded granite though the elevated levels may be exacerbated by anthropomorphic sources such as the high alkalinity recharge liberating naturally occurring uranium that is absorbed into aquifer sediments.^{9, 10}

Although the plume of degraded water in the Mixed aquifer appears too large to be significantly reduced by pumping, wells in the area should continue to be used for irrigation purposes to minimize the spread of the plume.⁴ Groundwater from wells tapping the Mixed aquifer would require extensive treatment to be used as a municipal or domestic source. The proposed City of Phoenix well field locations should avoid this area.

Another important finding was that all nine sample sites in the Forepaugh aquifer exceeded health-based water quality standards, most commonly for fluoride and to a lesser degree, arsenic (Figure 7). Fluoride concentrations were as high as 15 mg/L, almost four times the health based water quality standard. Concentrations of fluoride above 5 mg/L are controlled by calcium through precipitation or dissolution of the mineral fluorite.¹¹ In a chemically closed hydrologic system such as the McMullen Valley basin, calcium is removed from solution by precipitation of calcium carbonate and the formation of smectite clays. High concentrations of dissolved fluoride may occur in groundwater depleted in calcium if a source of fluoride ions is available for dissolution.¹¹ Arsenic concentrations were as high as 0.022 mg/L, over twice the 0.01 mg/L standard and may have been influenced by exchange on clays or with hydroxyl ions. Other factors such as aquifer residence time, an oxidizing environment, and lithology likely effect arsenic concentrations.¹¹

Although the Eastern and Western Regional aquifers generally produced water acceptable for domestic or municipal uses, both aquifers had areas of water quality concern. Sample sites often exceeded standards for fluoride and, to a lesser degree, arsenic in the Eastern Regional aquifer, south-east of the town of Aguila and in the Western Regional



Figure 7 - ADEQ's Jason Jones samples a domestic well in the Forepaugh aquifer located east of the town of Aguila. Samples from sites in the Forepaugh aquifer commonly had health-based exceedances of fluoride and arsenic.

aquifer near Wenden. These water quality exceedances appear to be naturally occurring from the same processes detailed previously.¹¹

The Eastern Regional aquifer exhibited significantly lower concentrations of TDS, sodium, and boron than in the Western Regional aquifer; the opposite pattern occurs with well depth and groundwater depth (Kruskal-Wallis with Tukey test, $p \leq 0.05$). These water quality differences may result from poor quality irrigation recharge minimally impacting the Eastern Regional aquifer because of the great depths needed to percolate to groundwater.

Few water quality standards were exceeded in the Southern Regional and Harcuvar aquifers; both appear to consist of more recent recharge than the other aquifers. In the Southern Regional aquifer there are occasional exceedances of nitrate in wells located near Centennial Wash; these are probably the result of wastewater disposal from septic systems. In the extreme southern portion of the Southern Regional aquifer near the Narrows, gross alpha and uranium exceedances occurred along with the highest radon concentrations (10,241 pico curies per Liter) ever collected by the ADEQ ambient groundwater monitoring program.

FOR MORE INFORMATION

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Maps by Jean Ann Rodine

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