Project Number:
Date Received: October 5, 2016
Date to be presented to the WQB: October 26, 2016

# WATER QUALITY BOARD
# REQUEST FOR HARDSHIP PLANNING GRANT TO PREPARE GROUNDWATER QUALITY STUDY
# AUTHORIZATION

| | |
|---|---|
| APPLICANTS: | Division of Water Quality<br>195 North 1950 West<br>Salt Lake City, Utah 84114<br>801-536-4300<br><br>U.S. Geological Survey<br>Utah Water Science Center<br>2329 Orton Circle<br>Salt Lake City, UT 84119-2047<br>801-908-5048 |
| CONTACT: | Daniel Hall, Manager, DWQ Ground Water Section |
| TREASURER: | N/A |
| PRINCIPAL INVESTIGATOR: | Corey Angeroth<br>Hydrologist/Chief<br>Surveillance Section<br>2329 Orton Circle<br>Salt Lake City, UT 84119-2047<br>801-908-5048 |
| CITY ATTORNEY: | N/A |

## APPLICANT'S REQUEST:

The Division of Water Quality (Division) requests a **Hardship Planning Grant in the amount of $68,100** to complete a groundwater quality study in conjunction with the U.S. Geological Survey (USGS) and the Division of Drinking Water (DDW). The study will evaluate trends in water quality data from the DDW Safe Drinking Water Information System (SDWIS) and USGS National Water Information System (NWIS). These two data sets provide an opportunity to analyze spatial patterns in ground water quality in parts of Utah to evaluate changes in ground water quality over time. Based on the findings the Division will work with DDW to identify additional resources to seek solutions in partnership with the identified local community or county.

## APPLICANT'S LOCATION

The applicant for this grant is the Division of Water Quality. Funds from the grant will be combined with committed funds from the USGS and the Division of Drinking Water to support this project.

## BACKGROUND

Since the 1960s, ground water quality data have been collected and recorded across Utah by the USGS and by public water suppliers, providing information on changing conditions in the State. To date, there has not been a comprehensive analysis of temporal trends in these water quality data. Given the long period of record (50+ years) at many sites, an opportunity exists to quantify changes in ground water quality and investigate regional trends.

Two water quality databases exist for trend analysis: 1) SDWIS and 2) NWIS. These databases provide an opportunity to analyze spatial patterns in ground water quality in parts of Utah and to evaluate changes over time. The area along the Wasatch Front was selected to test the assessment of ground water quality trends because of significant levels of ground water development that occur in several of the basins (Figure 1 in attachment). Study Area Basins include the Cache Valley, Utah and Goshen Valleys, Tooele Valley, Juab Valley, Sevier Desert, Pahvant Valley, Escalante Valley, Cedar Valley, Parowan Valley and the Beryl-Enterprise area.

The existing ground water quality data represents a major investment in understanding the ground water resources of the State. The need for good quality water increases as the population increases, but growth can also adversely affect water quality through the addition of new contaminants or the movement of existing ones. A better understanding of long term trends in concentration will help water mangers evaluate possible management scenarios and better plan for potential future changes.

Information on water quality trends will help water managers assess and plan for potential changes in ground water quality and will also provide a better understanding of how changes in water quality may relate to natural processes or land uses, such as urban development and agricultural activities. The available data also provide current, baseline information on which future water quality changes may be evaluated. Future changes could result from natural climate variability or human activities, including land-use changes and water development

## PROJECT DESCRIPTION:

The proposed study will be conducted by the United States Geological Survey under direct contract with the Division. The proposed grant would be issued to the Division, at the request of the USGS, to facilitate (simplify) fund management and disbursement of payment requests. The study incorporates ground water data analysis that will evaluate and identify the relation between trends and selected factors to indicate areas where the ground water system is susceptible or vulnerable to the effects of natural variation or human activities.

The study shall include the following tasks and deliverables:

- Compile existing information for water-quality parameters of interest;
- Use grid-based approach to de-cluster and extrapolate ground water quality data;

- Time series trend analysis of ground water quality data using the Regional Kendall statistical test;
- Spatial analysis of ground water quality trends;
- Evaluate the relation between trends and selected factors to indicate areas where the ground water system is susceptible or vulnerable to the effects of natural variation or human activities;
- Project approach and progress will be reviewed quarterly per USGS Utah Water Science Center QA/QC plans. Report review will follow USGS peer-review procedures and policies;
- Results of the study will be presented in a USGS Scientific Investigations Report. The report will be published electronically in digital PDF format available free to the public on the internet through the USGS Publications Warehouse website (*http://pubs.er.usgs.gov/*). Data and any relevant GIS coverages (if any) with metadata will be transferred to cooperators and made available online through NWIS and the Geo spatial One-Stop site at URL: *http://geodata.gov/* .

## IMPLEMENTATION SCHEDULE:

The study is planned to be completed in 24 months. The final report will be issued on or before December 31, 2018.

## PROJECT PRIORITY LIST

A construction project is not anticipated at this time; therefore, the study is not given a priority listing. The study results are expected to inform decision makers for community planning, including the impacts that the community is having, e.g., by septic tank densities, on its groundwater.

## COST ESTIMATE:

The proposed study will cost $208,100. The USGS plans to share the cost of their labor and expenses in the amount of $80,000. The balance of $128,100 would be paid by the Utah Division of Drinking Water, and the grant requested from the Water Quality Board.

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|---|---|---|
| Data compilation and analysis | $ | 108,100 |
| Data analysis and writing | $ | 90,000 |
| Publication Costs | $ | 10,000 |
| **Total** | **$** | **208,100** |

**Cost Sharing:**

| | | |
|---|---|---|
| U.S. Geological Survey | $ | 80,000 |
| Division of Drinking Water | $ | 60,000 |
| Water Quality Board Grant | $ | 68,100 |
| **Total** | **$** | **208,100** |

## STAFF COMMENTS AND RECOMMENDATION:

This project is being presented as an authorization request to the Water Quality Board. Staff recommends the Board authorize the $68,100 requested for Hardship Planning Grant to the Division. The grant is needed to assist water planners and providers in analyzing this important data.

## SPECIAL CONDITIONS:

1. The Division of Water Quality must approve the plan of study before the grant agreement will be executed.
2. This Planning Advance is a grant and will not be repaid.

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File: SRF-Central Utah Public Health Department/Planning/Section 1

# Quantifying trends in water quality from selected wells in Utah

Prepared by U.S. Geological Survey Utah Water Science Center, May 5, 2016

## Problem

Groundwater is an important part of the water supply in many parts of Utah, with annual withdrawals estimated over 1,000,000 acre-feet (Burden and others, 2015). Groundwater is used mostly for irrigation (597,000 acre-feet in 2014), public supply (268,000 acre-feet in 2014), and industrial uses (129,000 acre-feet in 2014) (Burden and others, 2015), and acts as an important buffer for water supplies when climatic conditions (i.e. drought) limit surface water availability. Since the 1960s, groundwater-quality data have been collected and recorded across Utah by the U.S. Geological Survey (USGS) (Burden and others, 2015) and by public-water suppliers, providing information on changing conditions in the State. To date, there has not been a comprehensive analysis of temporal trends in these water-quality data. Given the long period of record (50+ years) at many of these sites, an opportunity exists to quantify changes in groundwater quality and investigate regional trends.

Water-quality data from a network of more than 400 wells, primarily used for irrigation in areas with significant groundwater development (figure 1), have been collected by the USGS as part of an annual groundwater monitoring program done in cooperation with the Utah Divisions of Water Quality and Water Rights. Several of these wells have analyses dating back to the 1960s, some with data since the 1930s. Wells sampled in 2014 as part of the annual groundwater monitoring program are shown on figure 2. Additional water-quality data have been collected for regional studies or smaller localized studies addressing specific areas in the State. The water-quality data collected by the USGS resides in the National Water Information System (NWIS) database. While plots of dissolved-solids concentration with time for selected wells are included in the Groundwater Conditions in Utah report (figure 3; Burden and others, 2015), no comprehensive analysis of water-quality changes in the network wells in the NWIS database has been done.

The Utah Division of Drinking Water (UDDW) maintains a water-quality database consisting of analyses of samples collected from water sources used for public supply in Utah (figure 4). The UDDW Safe Drinking Water Information System (SDWIS) database contains millions of sample results from public-supply sources in Utah. For example, the SDWIS data set contains more than 70,000 nitrate concentrations for groundwater used for public supply collected from 1977 to 2012 (Wallace and Inkenbrant, 2013). Water samples are required to be collected from public-supply wells and analyzed every 3 years for inorganic constituents and selected metals (antimony, arsenic, barium, beryllium, cadmium, chromium, copper, cyanide, fluoride, lead, mercury, nickel, selenium, sodium, sulfate, thallium, and dissolved solids), unless a waiver is issued and the sampling frequency is reduced to once every nine years. The sampling frequency for nitrate and nitrite is annually, unless advised otherwise by the Utah Division of Drinking Water (Utah Division of Drinking Water, 2013).

The NWIS and SDWIS data sets provide an opportunity to analyze spatial patterns in groundwater quality in parts of Utah and to evaluate changes in groundwater quality over time. The area along and near the Wasatch Front was selected to test the assessment of groundwater

quality trends because of significant levels of groundwater development that occur in several of the basins (figure 1). Groundwater basins in the study area include the Cache Valley, lower Bear River area, East Shore area, Salt Lake Valley, Utah and Goshen Valleys, Tooele Valley, Juab Valley, Sevier Desert, Pahvant Valley, Escalante Valley, Parowan Valley, Cedar Valley in Iron County, and Beryl-Enterprise area.

Assessment of groundwater quality trends at the basin scale is complicated because of the long time frames for groundwater movement in basin-fill aquifers, sparse or uneven data coverage, and the wide variety of well types, well depths, and data sources. The proposed evaluation of changes in groundwater quality is facilitated by the availability of the NWIS data set, which contains quality-assured data collected using documented and consistent methods, and the SDWIS data set, which stores analyses from mandated periodic sampling of public-supply wells.

Information on water-quality trends will help water managers assess and plan for potential changes in groundwater quality and will also provide a better understanding of how changes in water quality may relate to natural processes or land uses, such as urban development and agricultural activities. The available data also provide information on which future water-quality changes may be evaluated. Future changes could result from natural climate variability or human activities, including land-use changes and water development.

## Objectives

The overall goal of the proposed study is to use the NWIS and SDWIS data sets to provide information on if and how groundwater quality has changed over time in areas along and near the Wasatch Front in Utah. Groundwater samples collected from wells from about 1960 to 2015 will be studied using the water-quality parameters dissolved solids, nitrate and nitrite, and selected major ions and trace elements. Specific study objectives are to:

1. Determine the significance and magnitude of decadal-scale trends in groundwater quality for aquifers along the Wasatch Front and in selected nearby basins.
2. Examine how temporal trends in groundwater quality vary spatially at the study area and basin scale.
3. Evaluate the relation between trends and selected natural and human-related factors.

## Relevance and Benefits

The existing groundwater quality data set represents a major investment in understanding the groundwater resources of the State. The need for good quality water increases as the population increases, but growth also can adversely affect water quality through the addition of new contaminants or the movement of existing ones. A better understanding of long-term trends in concentration will help water managers evaluate possible management scenarios and better plan for potential future changes.

This study is consistent with the national USGS mission and goals and to water-resource issues identified in the USGS Water Science Strategy. The study will contribute to meeting the USGS goal "Assessment of Water Resources and their Suitability to Meet Human and Ecosystem Needs" (goal 1, objective 3) (Evenson and others, 2013). This study is appropriate for inclusion in the USGS Cooperative Water Program because it will "provide reliable, impartial, and timely

information needed to understand the Nation's water resources" (U.S. Geological Survey, 2015), and will be eligible for supplemental funding available through that program.

# Approach

## Task 1: Compilation of existing information

Water-quality parameters of interest for this study include dissolved solids, nitrate and nitrite (and variations), and selected major ions and trace elements. Groundwater-quality data and ancillary information will be compiled from the NWIS and SDWIS databases for the aquifers along the Wasatch Front and from nearby areas. The Utah Geological Survey will gather, format, and quality assure the SDWIS data to be combined with the NWIS data for trend analysis. The combined data sets will be screened for duplicate sites and the water-quality values recensored to a common value for each constituent, generally the highest detection limit. Additionally, the studied areas will be analyzed for gaps or redundancy in the NWIS and SDWIS data sets. Concentrations for the selected water-quality parameters will be retained in the study data set so that there is not more than one value per well per year. If there is more than one constituent result available in a year, a sample collected in the summer or irrigation season will have a higher priority because this is typically when most wells are pumped and sampled.

The sample collection, processing, and analysis methods used for analyses in the NWIS and SDWIS data sets will be described and compared. Limitations of each data set and those resulting from combining the data sets will be evaluated. For example, public-supply wells generally are not used if the water quality is not suitable for consumption. This would skew the SDWIS data set toward water that meets drinking-water standards. The extent of the groundwater basins is available as a geographic information system (GIS) data layer. Other GIS layers needed to be compiled include water use, land use, and surrogate information used to estimate recharge, constituent loading, and aquifer susceptibility to contamination.

## Task 2: Use grid-based approach to decluster and extrapolate groundwater-quality data

The methods used to analyze decadal-scale trends in nitrate in groundwater in the Central Valley, California (Burow and others, 2013) will be used in this study. The aquifers along the Wasatch Front and nearby areas are in unconsolidated basin-fill deposits, most with recharge areas near the mountain fronts and discharge areas in the lower parts of the basins. There is a gradient in land use in the study area basins from mostly urban to mostly agricultural with varying amounts of undeveloped or range land areas. Public-supply wells are more common in urban areas and irrigation wells are more prevalent in agricultural areas. Because some areas have a high density of wells and other areas have few, a spatially unbiased, grid-based approach will be used to decluster the densely spaced data and extrapolate the sparse data (Belitz and others, 2010). A minimum of 30-50 equal area cells will be computed with a GIS-based program to form a grid covering the study area. The actual number of cells to be generated is dependent on the spatial distribution of wells with long-term water quality data. Wells also can be stratified by well depth into shallow and deep zones within the same grid. Domestic-supply and stock wells generally are completed in the shallow zone and public-supply and irrigation wells typically are completed

in the deep zone. A median concentration for the constituent of interest will be computed for each cell for each decade using available well data for that cell. This analysis will allow for statistical tests of trends in water quality across multiple decades through aggregation of the data in a cell and provides a consistent means to compare trends by basin and depth. As an example, the distribution of grid cells within each physiographic subregion in the Central Valley, California is shown in figure 5.

### Task 3: Time-series analysis of groundwater-quality data for trends

The Regional Kendall statistical test (Helsel and Frans, 2006) will be used to analyze the magnitude and significance of trends in water quality for selected constituents within the gridded area. The Regional Kendall Test will be applied to the grid-cell decadal median concentration for the constituent of interest. The test will determine whether or not there is a significant increase or decrease in the dependent variable over time in each cell and depth zone (Helsel and Frans, 2006). Data analysis routines using the R statistical package will be used (R Core Team, 2015).

Cells or groups of cells in a particular basin that show a statistically significant trend in water quality can be further examined using time-series plots of constituents prepared for wells with adequate data to better present patterns of concentration change over time and the spatial distribution of the change. Figure 6 illustrates how dissolved-solids concentrations vary over time for wells in Salt Lake Valley (Thiros and Spangler, 2010), and indicates that consistent increases in concentration occurred across the area. Results of the time-series analysis using statistical and graphical methods will be summarized and described using tables, maps, and diagrams as shown in Burow and others (2013).

### Task 4: Spatial analysis of trends in groundwater quality

How decadal trends in groundwater-quality vary spatially along the Wasatch Front and nearby areas will be examined using maps depicting changes in median concentrations of the constituent of interest by cell. The spatial patterns can be studied and used to identify areas and (or) depth zones with the highest rates of change in groundwater-quality constituent concentration. An example of a map of change in median decadal nitrate concentrations in the Central Valley, California, is shown in figure 7.

The percentage of wells with a concentration greater than an arbitrary threshold value for the constituent can be computed for each cell for each decade to provide an estimate of the areal proportion of the aquifer impacted by elevated concentration of the constituent. For example, a threshold of 5 mg/L for nitrate as nitrogen would represent concentrations well above background levels. The percentage of aquifer with nitrate concentrations greater than 5 mg/L would be computed for each decade to provide an estimate of the areal proportion of the study area affected by elevated nitrate over time.

### Task 5: Evaluate the relation between trends and selected factors

Trends in existing water-quality data can indicate areas where the groundwater system is susceptible or vulnerable to the effects of natural variation or human activities. Decadal trends in groundwater quality in areas and depth zones will be related to various factors, such as water and land use and other surrogate information used to estimate recharge, geochemical redox condition, constituent loading, and aquifer susceptibility. Several of these factors are available as GIS layers that can be compared to the grid cell decadal concentration changes and used to develop hypotheses to explain the changes in groundwater quality.

## Quality Assurance/Quality Control

No new field data will be collected during this study. Much of the water-quality data in the NWIS data set was collected and processed as described in the USGS National Field Manual (*http://water.usgs.gov/owq/FieldManual/index.html*) and analyzed by the USGS National Water Quality Laboratory. Much of the data in the SDWIS data set was collected and processed as described by the Utah Division of Drinking Water (*http://www.deq.utah.gov/Compliance/monitoring/drinkingwater/docs/2014/03Mar/lab_costs_and_sampling_procedures.pdf*) and analyzed by a state certified laboratory. Project approach and progress will be reviewed quarterly per USGS Utah Water Science Center QA/QC plans. Report review and processing will follow USGS peer-review procedures and policies.

## Products

Results of this study will be presented in a USGS Scientific Investigations Report. The report will be published electronically in digital PDF format available free to the public on the Internet through the USGS Publications Warehouse website (*http://pubs.er.usgs.gov/*) in perpetuity. Data and relevant GIS coverages (if any) with metadata will be transferred to cooperators and made available online through NWIS and the Geospatial One-Stop site at URL: *http://geodata.gov/.*

## Personnel

A USGS hydrologist will act as project chief and principal investigator.The project chief will be responsible for project planning, coordination of activities, data management, and design and preparation of the report. Assistance will be provided for spatial and statistical analysis and interpretation and for GIS layer development and manipulation.

The Utah Geological Survey (Paul Inkenbrandt) will support efforts of the U.S. Geological Survey (USGS) by modifying data from the Safe Drinking Water Information System (SDWIS) to match the standard schema of the USGS National Water Information System (NWIS) database. To make the SDWIS schema match that of NWIS, UGS will alter existing Python programming language scripts he has created for similar projects will provide support on the SDWIS data set and possibly on providing ancillary data for the public-supply wells.

## Budget and Schedule

The study is planned to be completed in approximately 24 months. The project as described in this proposal is budgeted for a total cost of $200,000 over two fiscal years (FY). The USGS will provide Cooperative Water Program matching funds to cover 40 percent of the cost ($80,000). The State of Utah, Division of Water Quality will contribute the remaining 60 percent ($120,000).

| Tasks and gross cost | FY2017 | FY2018 | Total |
|---|---|---|---|
| Data compilation and analysis | $100,000 | | $100,000 |
| UGS data compilation | $6,000 | $2,100 | $8,100 |
| Data analysis and writing | | $90,000 | $90,000 |
| Publication costs | | $10,000 | $10,000 |
| **Total:** | **$106,000** | **$102,100** | **$208,100** |
| **Utah Division of Water Quality contribution** | **$66,000** | **$62,100** | **$128,100** |
| **USGS Cooperative Water Program contribution** | **$40,000** | **$40,000** | **$80,000** |

(FY, Federal fiscal year)

## Selected References


Belitz, Kenneth, Jurgens, B.C., Landon, M.K., Fram, M.S., and Johnson, Tyler, 2010, Estimation of aquifer scale proportion using equal area grids: assessment of regional scale groundwater quality: Water Resources Research, 46. Accessed May 5, 2016 at: *http://ca.water.usgs.gov/projects/gama/pdfs/Belitz_etal_2010_wrcr12701.pdf*

Burden, C.B. and others, 2015, Groundwater conditions in Utah, spring of 2015: Utah Department of Natural Resources cooperative Investigations Report No. 56, 136 p. Available online at *http://ut.water.usgs.gov/publications/GW2015.pdf*

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Evenson, E.J., Orndorff, R.C., Blome, C.D., Böhlke, J.K., Hershberger, P.K., Langenheim, V.E., McCabe, G.J., Morlock, S.E., Reeves, H.W., Verdin, J.P., Weyers, H.S., and Wood, T.M., 2013, U.S. Geological Survey water science strategy—Observing, understanding, predicting, and delivering water science to the Nation: U.S. Geological Survey Circular 1383–G, 49 p. Available at *http://pubs.usgs.gov/circ/1383g/*

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Wallace, Janae and Inkenbrandt, Paul, 2013, Mapping tool to show trends in groundwater nitrate concentrations in Utah: Utah Geological Survey Open-File Report 610, 23 p. Accessed May 5, 2016 at: *http://files.geology.utah.gov/online/ofr/ofr-610.pdf*

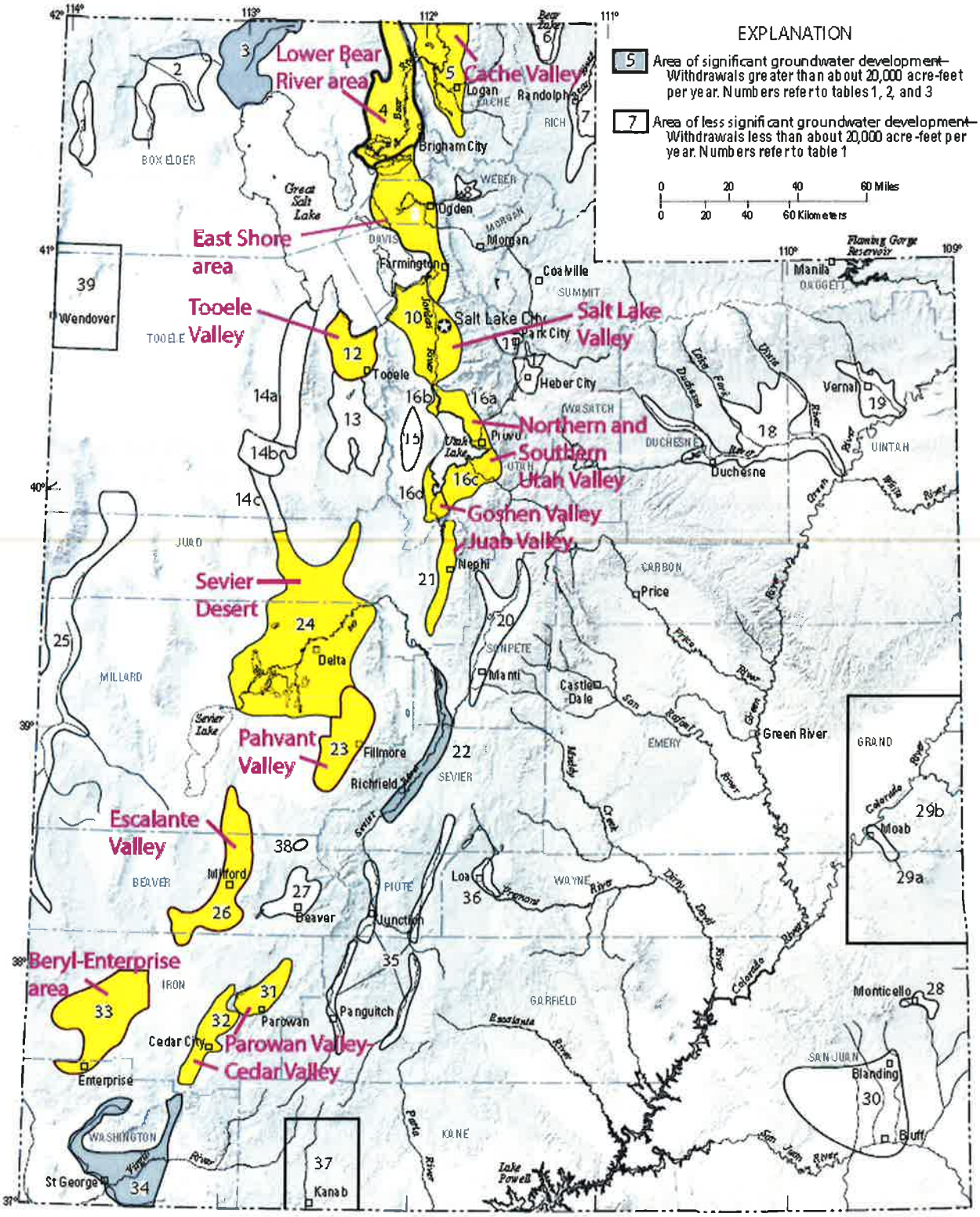


Figure 1. Trends in water quality using the NWIS data set will be determined for the labeled areas along and near the Wasatch Front. These basins are part of the monitored areas discussed in the Groundwater Conditions in Utah report (Burden and others, 2015).

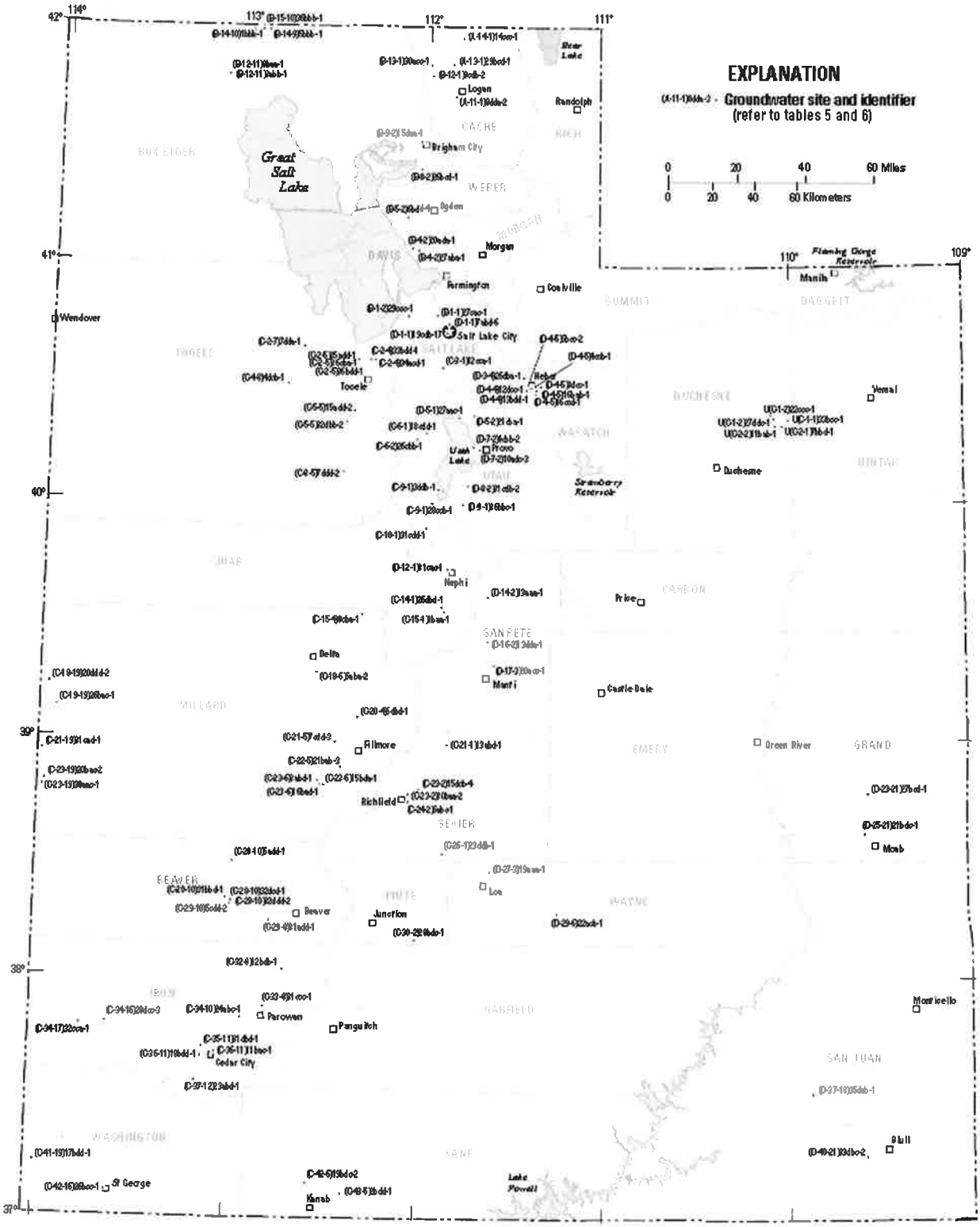


Figure 2. The USGS sampled 104 of the more than 400 wells in its groundwater-quality network during the summer of 2014. These water-quality analyses are stored in the USGS National Water Information System (NWIS) database (Burden and others, 2015).

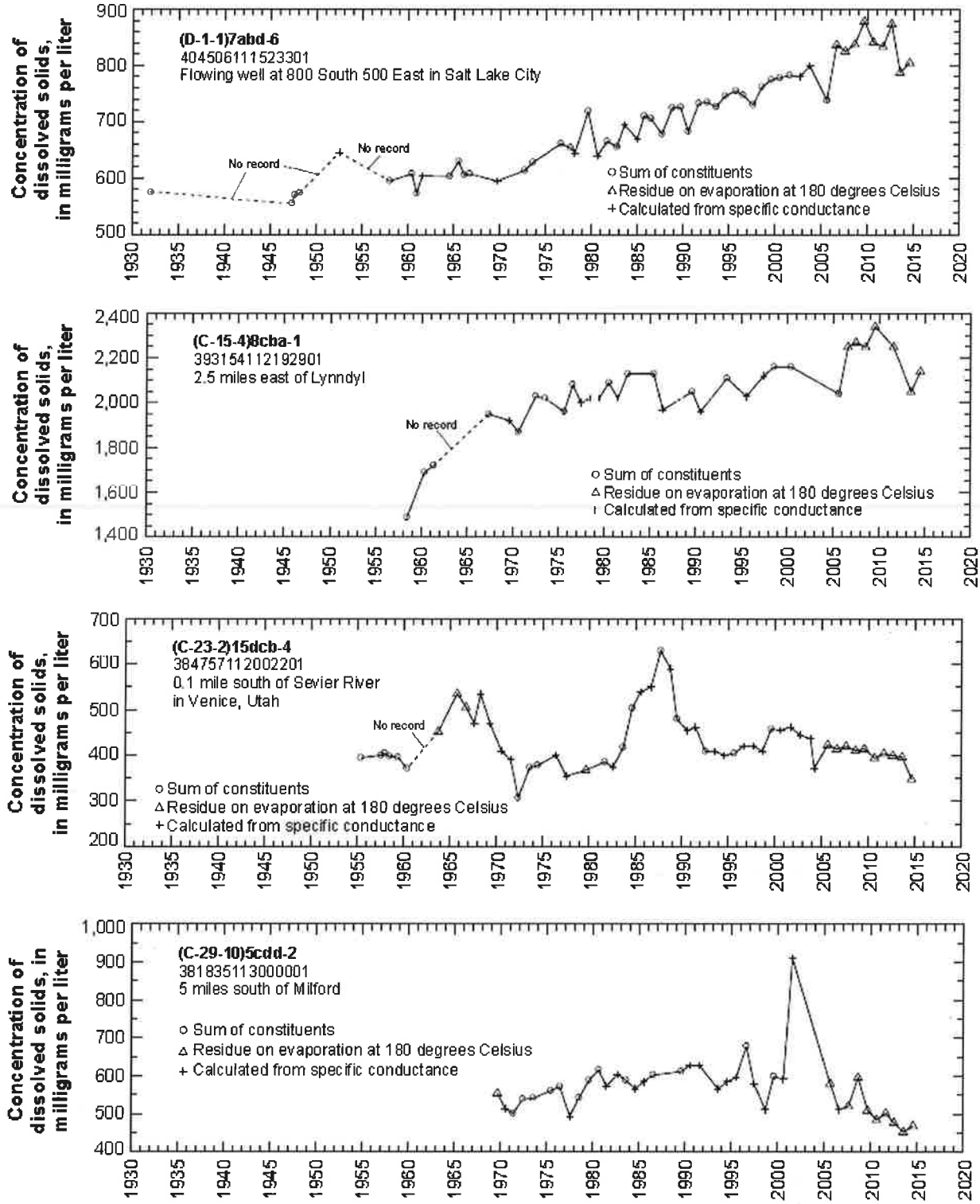


Figure 3. Concentration of dissolved solids in water from selected wells is plotted with time and shown in the Groundwater Conditions in Utah report (Burden and others, 2015).

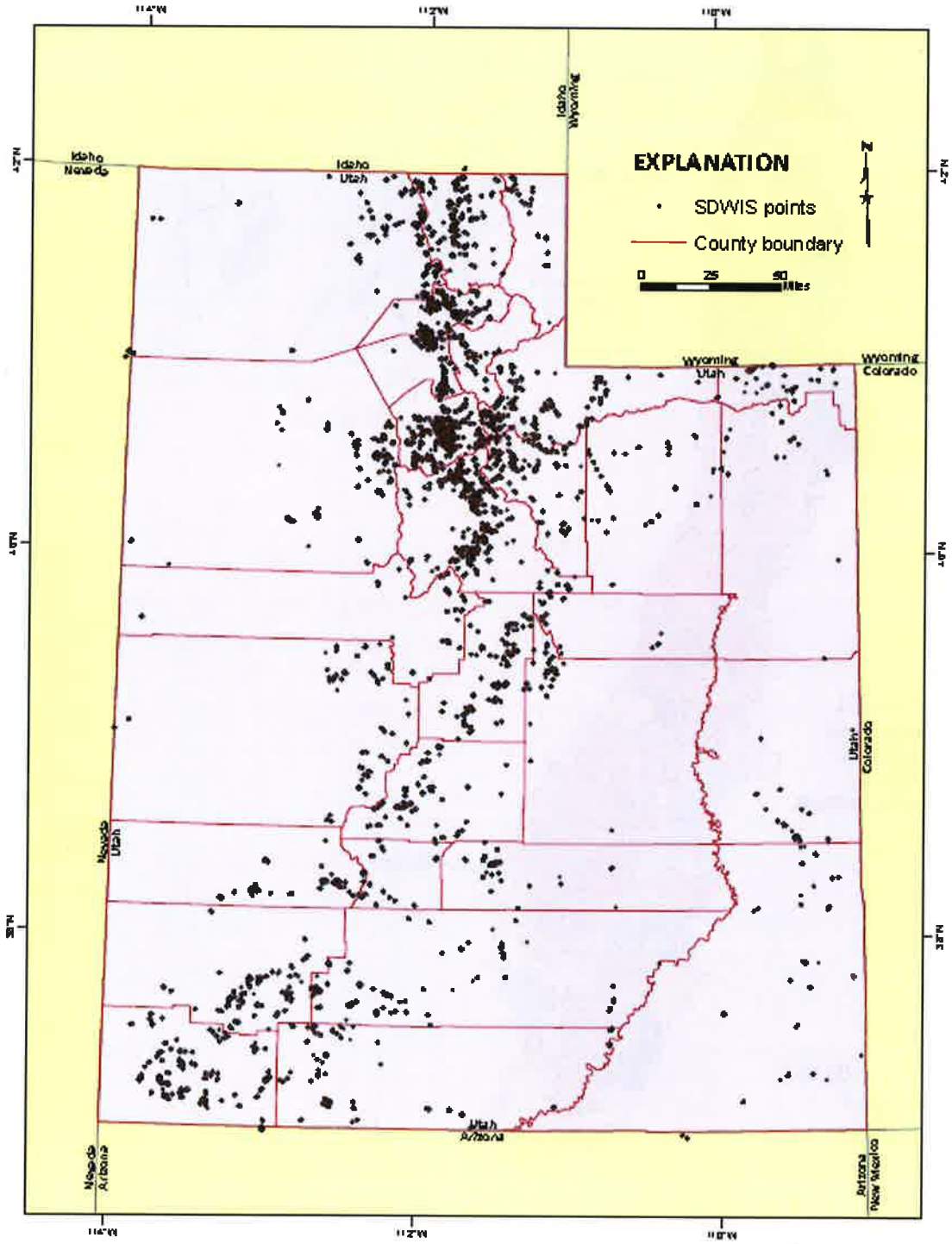


Figure 4. Nitrate data is collected annually from most wells used for public supply in Utah. The data is maintained by the Utah Division of Drinking Water in the Safe Drinking Water Information System (SDWIS) database (Wallace and Inkenbrant, 2013).

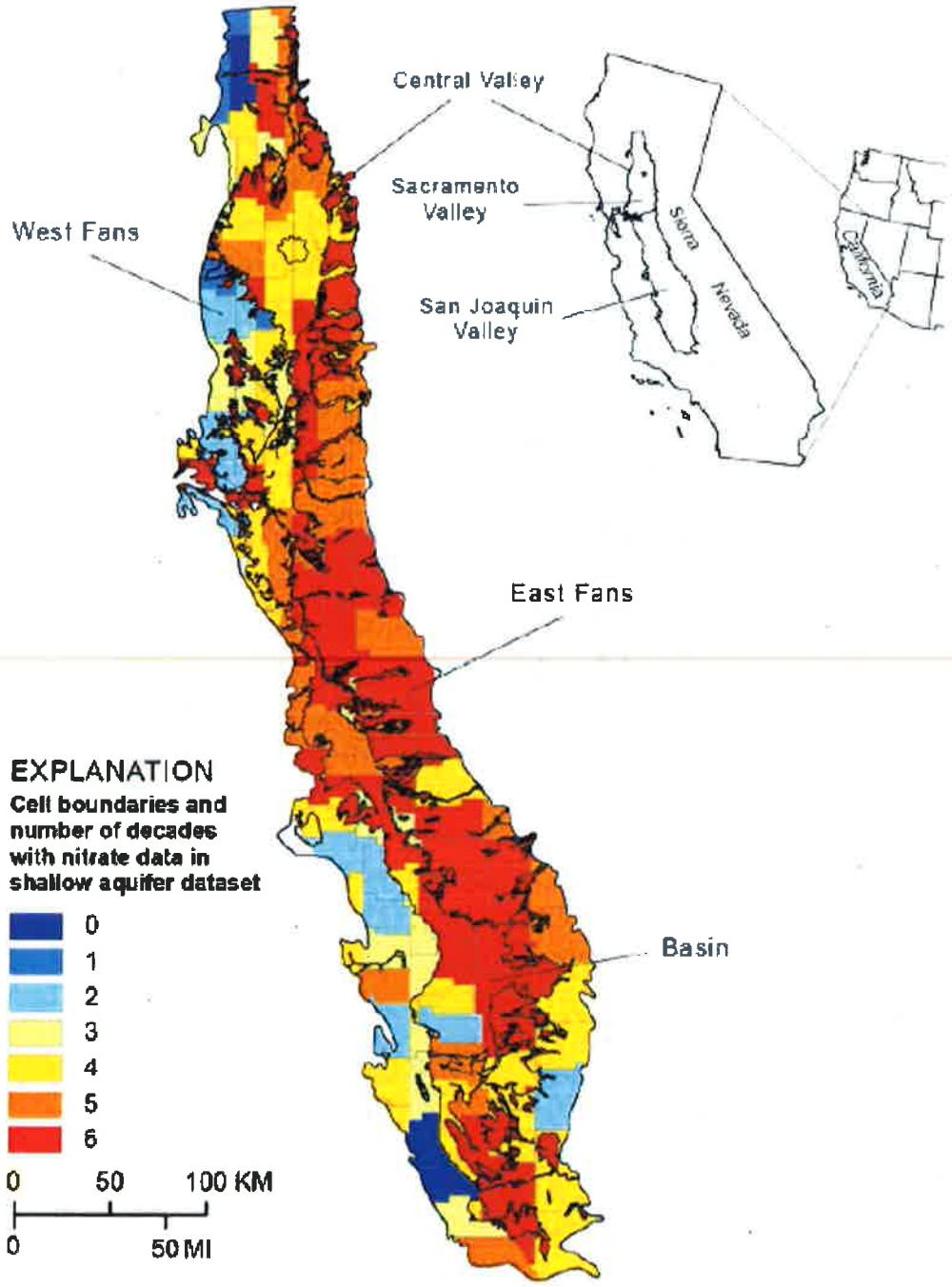


Figure 5. Map of the Central Valley, California, and the distribution of grid cells within each physiographic subregion (Burow and others, 2013).

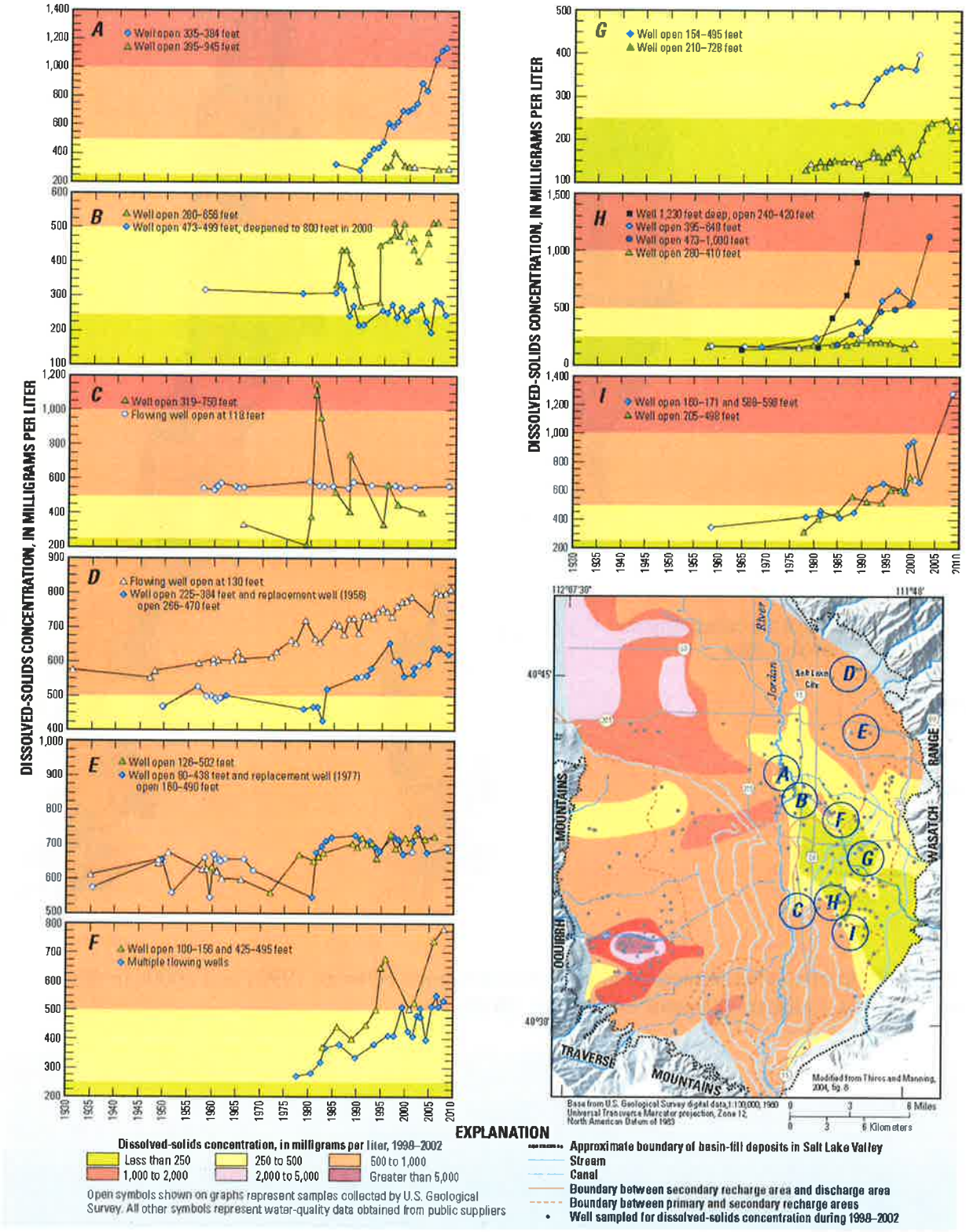


Figure 6. Dissolved-solids concentrations in water from some wells in the principal aquifer in Salt Lake Valley, Utah, have increased to more than 1,000 milligrams per liter (Thiros and Spangler, 2010).

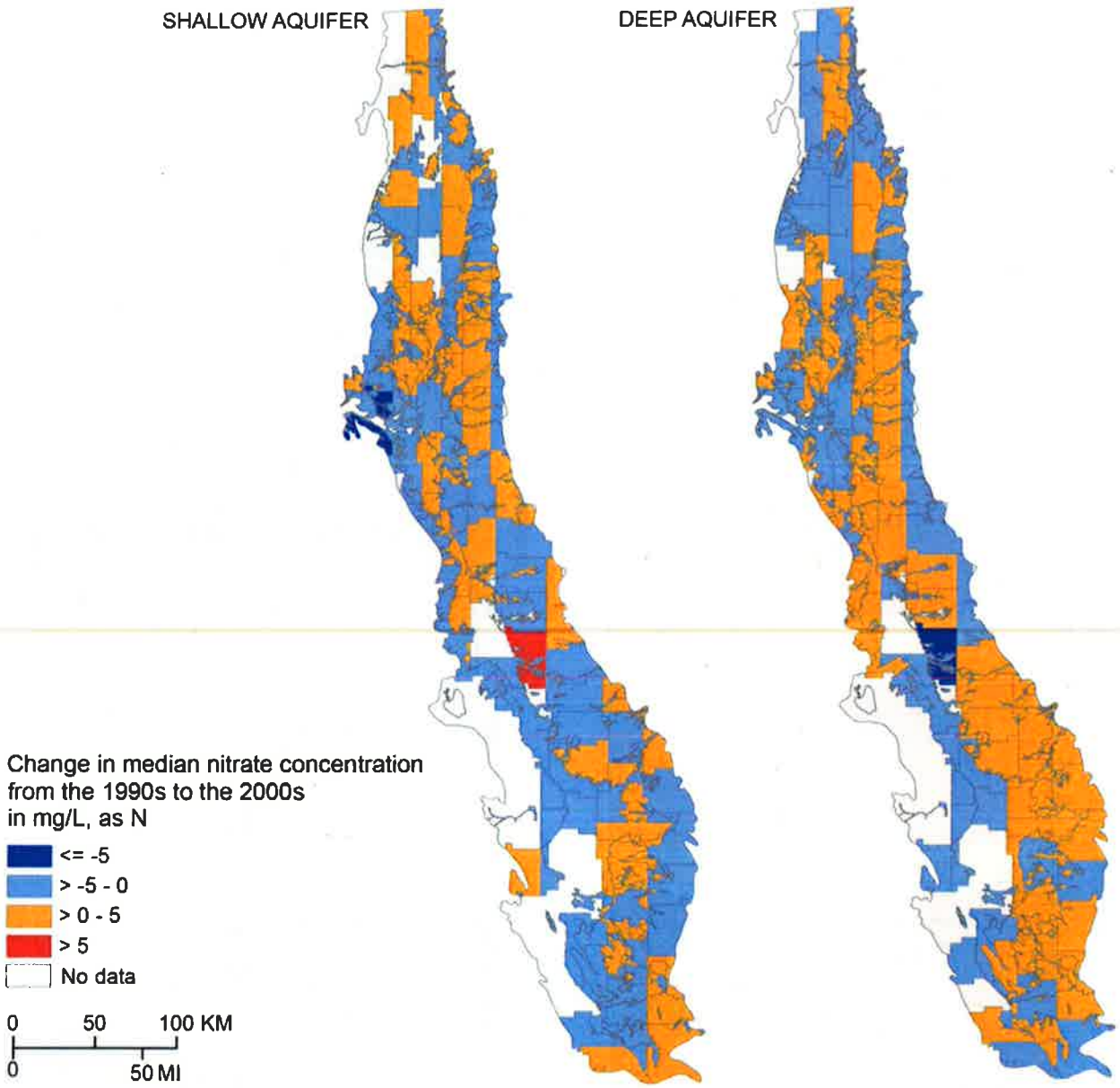


Figure 7. Map of change in median nitrate concentrations between 1990s and 2000s in the Central Valley, California (Burow and others, 2013).