Needs Assessment
Tuscan Aquifer Monitoring, Recharge, and Data Management Project

This needs assessment summarizes the current understanding of the Lower Tuscan Formation aquifer system, ongoing programs to further characterize and manage the aquifer, and the studies needed to understand the aquifer so that proposed water management programs can proceed while minimalizing third party impacts. Attached to this needs assessment is a detailed work plan to undertake identified programs to further the scientific and public understanding of the Lower Tuscan aquifer system and it's interaction with other aquifer systems.

Purpose and Need

There is increased interest in utilizing the Lower Tuscan aquifer system to augment the State's overall water supply. Because there has been somewhat limited regional utilization of this resource in the past, limited information is available about how the aquifer system may respond to increased utilization, and what impacts this increased utilization may have on other water users, recharge sources, recharge areas, and the environment.

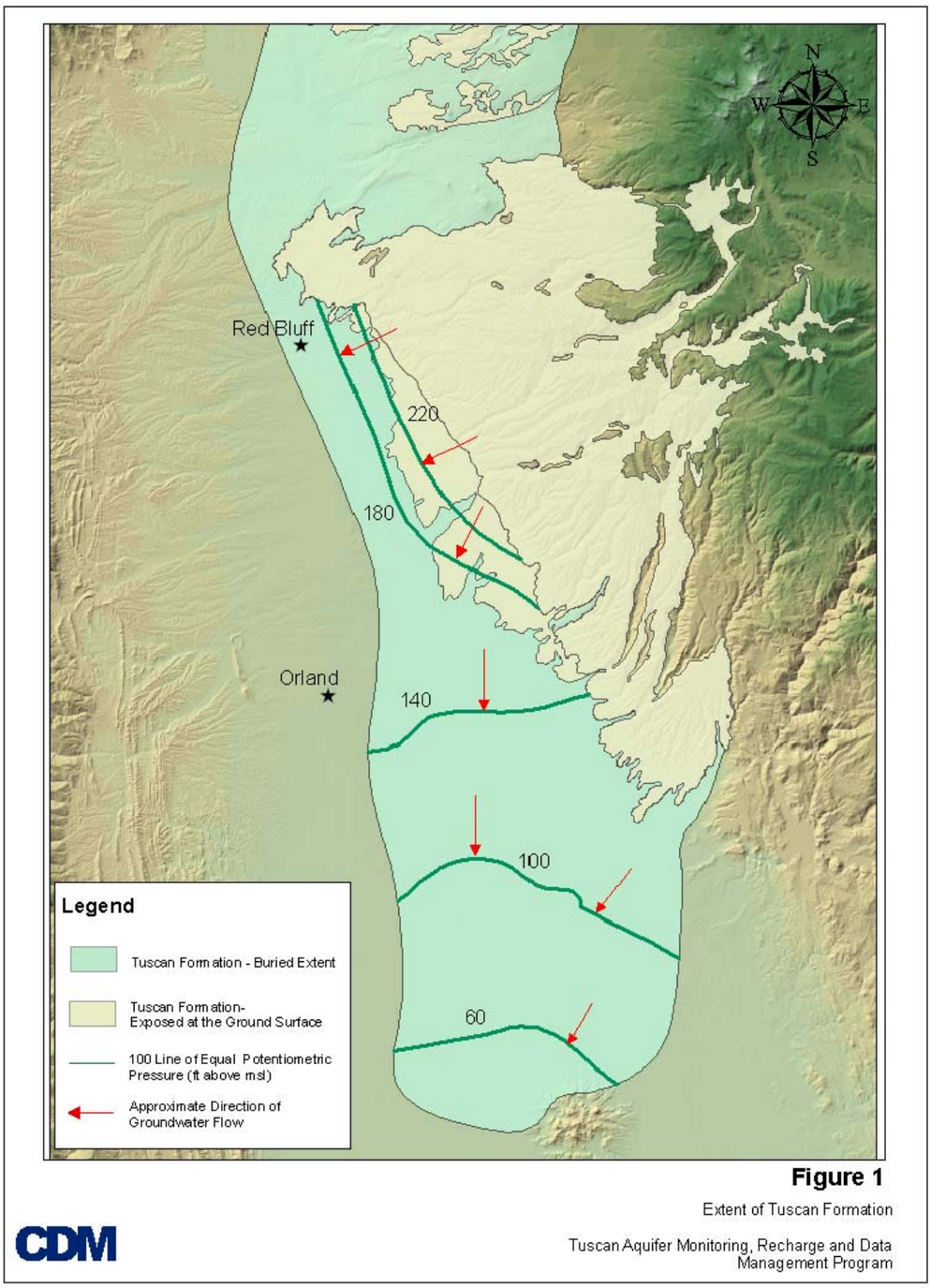
This project provides the needed technical background and develops the needed analytical investigative tools to help understand and assess the impacts to recharge sources resulting from increased utilization of the aquifer system. It also provides additional monitoring infrastructure needed to help assess impacts associated with proposed water management programs that plan to extract groundwater from the Lower Tuscan aquifer system. Finally, this program assists in providing public outreach, education, and coordination for projects that plan to utilize this groundwater resource.

The overall purpose of this program is to bring the individual water management programs utilizing the Lower Tuscan aquifer system into a single coherent integrated plan. Working cooperatively with stakeholders, local governments, and project participants, this program will also explore regional groundwater monitoring and groundwater management specific to this resource.

Tuscan Formation Geology and Hydrogeology

The buried extent of the Lower Tuscan aquifer system in the northern Sacramento Valley is expansive. It extends from the Redding Basin to the Sutter Buttes and from the eastern margin of the valley, westward 10 to 30 miles. In the subsurface, the Lower Tuscan Formation covers an area of about 850 square miles and has an estimated average thickness of about 500 feet. The aquifer system is estimated to contain 30,000,000 acre-feet of groundwater in storage. However, economic and environmental considerations limit the practical annual extraction to a fraction of this total storage estimate.

The Tuscan Formation geologically is divided into four units, Tuscan Formation units A, B, C, and D (Helley and Harwood, 1985). As an aquifer system it is divided into two primary units, the Upper and Lower Tuscan. The Tuscan Formation units C and D define the Upper Tuscan, and the Tuscan Formation units A and B define the Lower Tuscan. The Lower Tuscan aquifer system is the more water bearing of the two and is the focus of this program. Figure 1 shows the estimated extent of the buried portion of the Lower Tuscan aquifer in the northern Sacramento Valley.



Source Data provided by Department of Water Resources, Northern District

The Lower Tuscan aquifer system is also exposed at the ground surface along the east side of the valley. In the central portion of the valley, it is found at a depths ranging from 500 to 1000

feet below the ground surface. This aquifer system consists of gravels, sands, and silts that typically yield moderate volumes of groundwater to wells

Existing and Ongoing Studies

The Tuscan Formation has been investigated by researchers since the early 1900's. The earlier studies helped define the expansive lateral extent of the Tuscan Formation in the subsurface of the northern Sacramento Valley and identify its hydrologic characteristics as a regional aquifer system. They were important building blocks in developing our current understanding of the aquifer system and its hydrology. Listed below is some of the more important geologic literature for the Tuscan Formation.

- Diller, 1906, USGS Redding Folio
- Kirk, 1923, USGS Water Supply Paper 495
- Anderson, 1933, UC Geological Sciences Bulletin 23
- Olmsted and Davis, 1961, USGS Water Supply Paper 1497
- Lydon, 1969, GSA Memoir 116
- Redwine, 1972, Unpublished PhD thesis
- DWR,1978, Bulletin 118-6
- Helley and Harwood, 1985, USGS Miscellaneous Field Studies Map MF-1790
- DWR, 2003-2006, M&T Chico Ranch Conjunctive Use Investigation
- DWR, 2005, Butte County Groundwater Inventory Analysis

Current ongoing efforts to understand the hydrologic characteristics of the Lower Tuscan Formation aquifer system includes:

- DWR Local Assistance Investigations
- DWR Integrated Storage Investigations
- DWR Deer Creek Conjunctive Use Investigation
- Stony Creek Fan Partnership Investigations
- NHI Water Management Study
- Butte County Integrated Water Resources Program
- County AB3030 Grants
- Sacramento Valley Regional Water Management Program
- USGS GAMA Program

Literature pertaining to the Lower Tuscan Aquifer Formation investigations is presented in the References.

The investigations undertaken by DWR, Division of Local Assistance, focused on providing technical and financial assistance to local irrigation districts to evaluate the feasibility of utilizing the Lower Tuscan aquifer system to improve their water supply reliability. The information collected from these efforts was then used to advance the overall understanding of the groundwater resources for the Sacramento Valley. The Integrated Storage Investigation program complemented and supported the investigations of the Division of Local Assistance.

The Deer Creek Conjunctive Use Investigation looked at utilizing water from the Lower Tuscan aquifer system to replace a portion of Deer Creek Irrigation District's surface water supply to increase fish bypass flows in Deer Creek. This investigation has developed important information about the Lower Tuscan aquifer system in the eastern portion of the Valley. The

Stony Creek Fan Partnership looked at potential water management programs near the western edge of the Lower Tuscan aquifer system in Glenn County. These investigations have developed considerable information on the Lower Tuscan aquifer system. This program is also responsible for the installation of numerous dedicated monitoring wells to monitor conditions in the aquifer system.

GCID along with The Natural Heritage Institute is looking at how the Lower Tuscan aquifer system could be operated conjunctively with State and Federal water projects, thereby allowing the Shasta and Oroville Reservoirs to be re-operated to provide certain environmental benefits.

The Butte County Integrated Water Resources Program focused on a wide array of water management options for Butte County, some of which involved the Lower Tuscan aquifer system. Butte, Glenn, and Tehama Counties have received AB303 grants. Each county has used a part of their grant funding to install dedicated monitoring wells, which has provided much additional valuable information about the Lower Tuscan aquifer system.

Most of these ongoing studies focus on areas where water management programs are being proposed. Currently a coordinated effort to evaluate the overall groundwater resources of the northern Sacramento Valley is lacking.

Need - Regional organization of data through a coordinated data management system.

Tuscan Aquifer Analytical Modeling

The full geographic extent of the Lower Tuscan aquifer system is currently represented through the use of two different analytical groundwater flow models. The area to the east of the Sacramento River, including the recharge zone, is modeled with the Butte County IWFM (CDM, 2005). The area to the west of the Sacramento River is covered in the Stony Creek Fan IGSM (WRIME, 2003). Together, these models can be used to understand groundwater movement with respect to the Lower Tuscan aquifer system. A few studies exist that help characterize properties for this aquifer system. Significant regional information on the hydrogeologic properties (e.g. hydraulic conductivities, vertical interformational leakance factors, aquifer storage terms) of the Lower Tuscan aquifer system is lacking.

Need - A regional program of testing in the Lower Tuscan Formation aquifer system would benefit both the Butte County and Stony Creek Fan groundwater models. The data determined from this testing would provide additional information to both groundwater models to aid in confirming conceptual models, improving calibration, and providing additional confidence in using the models for groundwater management decision making.

Tuscan Aquifer Recharge

It is hypothesized that under current hydrologic conditions the Lower Tuscan aquifer system recharges along the eastern margin of the northern Sacramento Valley, where the Lower Tuscan Formation crops-out at the ground surface (UCCE, 2003). However, it is not clearly understood how the area and source of recharge may change if the groundwater gradients in the Lower Tuscan aquifer system become altered due to increased groundwater extraction. Regional studies to identify stream losses and general soil infiltration rates have been limited. Without proper understanding of aquifer recharge and development of appropriate mitigation

measures, increased groundwater extraction could result in environmental impacts through increased stream depletion or dewatering of important wetland habitat on the valley floor. Investigation of the recharge areas is required to fully understand the implications of increased groundwater usage.

Throughout the valley information is needed at the county government level to provide the basis for informed land-use planning in the recharge corridor. As counties move forward with their General Plan updates, this data will provide decision makers the information necessary to take appropriate measures that can be included in the plan to ensure protection of the recharge areas.

Surface Water in Recharge Zone

The outcropping of the Lower Tuscan Formation is transected by a number of perennial streams which feed the Sacramento River. The Department of Water Resources and the US Geological Survey operate gauging stations on a number of creeks in the area. These stations provide short-term historical data, dating back to 1997. Figure 2 shows the location of existing stream gauging stations. The data provided by the stations indicate the availability of surface water, but the information provided by the existing stations is inadequate for use in quantifying aquifer recharge in the recharge zone. Expansion of stream gauging locations has the potential to document changes in stream-aquifer interactions with increased utilization of water resources in the area.

In addition to the stream gauging, a series of shallow dedicated monitoring wells with temperature sensors will be installed along stream courses in the recharge corridor and downstream to the Sacramento River to help identify what sections of streams are losing or gaining. Information from the stream gages and shallow monitoring wells will be particularly useful for model calibration.

Need- Field testing and monitoring equipment installation to understand the recharge rates and stream losses in the recharge zone.

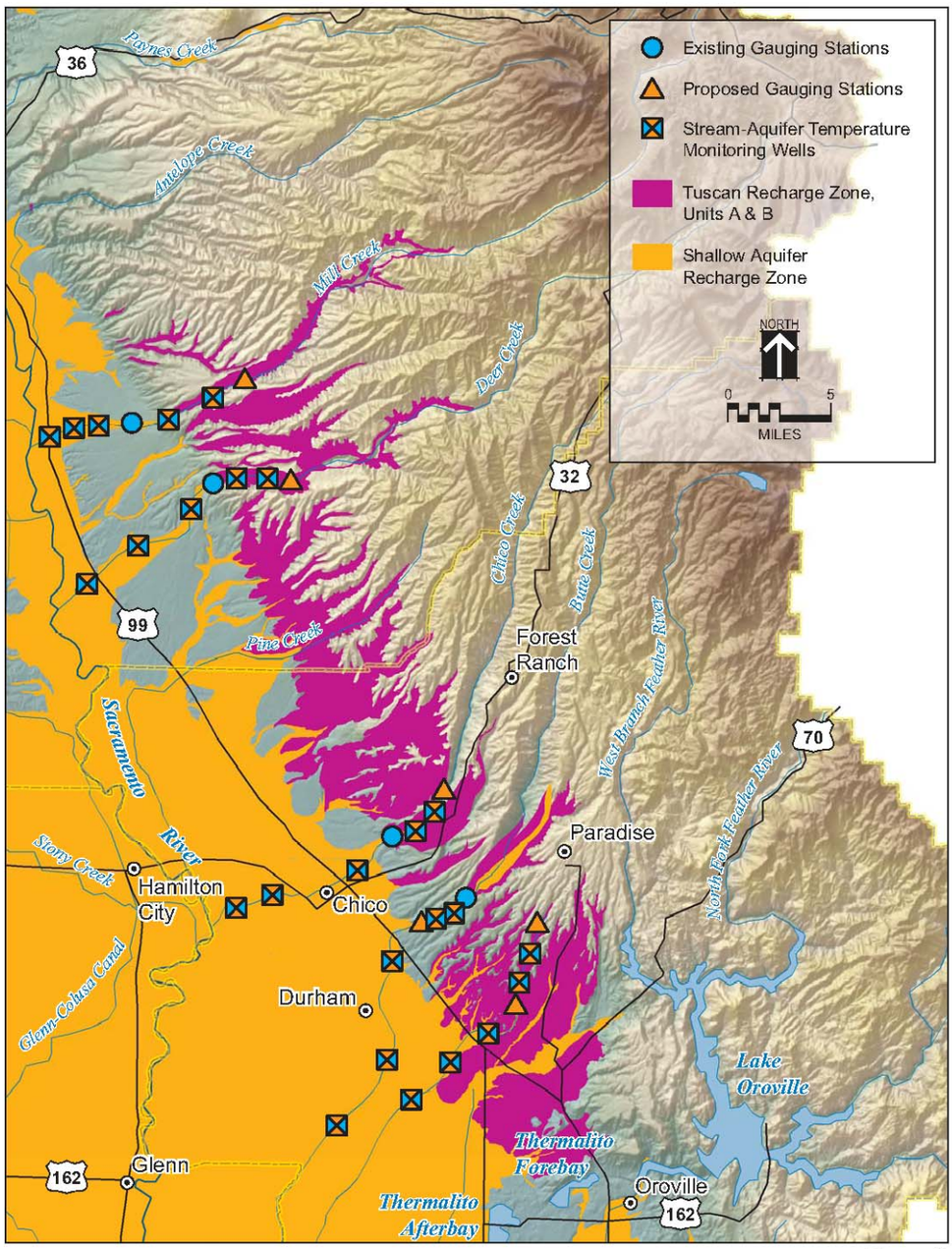


Figure 2
Lower Tuscan Aquifer
Surface Water Monitoring

CDM

Source Data provided by Department of Water Resources, Northern District

Groundwater Monitoring

The Department of Water Resources and their cooperators perform most of the existing groundwater level and groundwater quality monitoring in the northern Sacramento Valley.

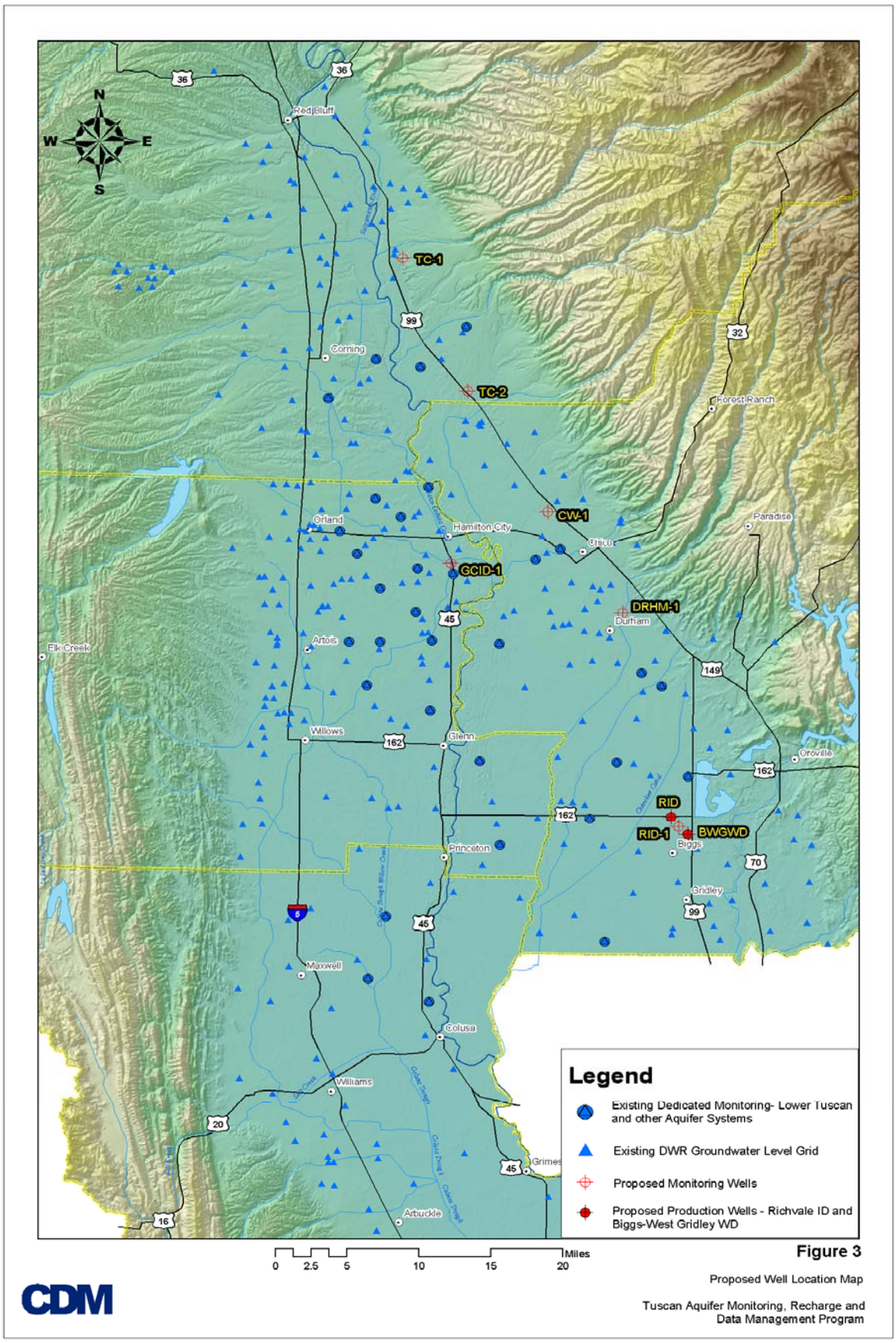
DWR typically conducts groundwater level monitoring a minimum of three times a year, spring, summer, and fall. In several areas, county cooperators assist by conducting the summer measurement.

In the four-county region there are about 400 wells that are being monitored, with approximately 60 dedicated monitoring wells which monitor about 150 zones. Many of the wells are perforated in multiple aquifers so groundwater levels are a composite head of all the aquifers penetrated. Moreover, most of the wells are relatively shallow, in relation to the thickness of the freshwater column, and few are sufficiently deep to monitor groundwater levels in the Lower Tuscan aquifer system, with the exception of wells along the northeastern margin of the valley.

Over the past few years, DWR and others have installed a series of dedicated monitoring wells that are screened in individual aquifer systems. This has resulted in an uneven spatial distribution of dedicated monitoring wells for the Lower Tuscan aquifer system, leading to only a localized rather than a regional understanding of the aquifer system. Figure 3 shows the locations of dedicated monitoring wells that monitor the Lower Tuscan and other aquifer systems. The lack of dedicated monitoring wells is particularly apparent along the recharge corridor.

Need - Additional dedicated monitoring infrastructure and groundwater level monitoring so impacts from continued utilization of the Lower Tuscan aquifer system can be adequately evaluated on a regional basis.

The monitoring infrastructure installed as part of the project will be incorporated into the existing monitoring network as described above



Source Data provided by Department of Water Resources, Northern District

Outreach-Education-Coordination

Each of the four counties that overlie the Lower Tuscan aquifer system has their own and separate regulatory structure relating to groundwater management. Tehama County, Colusa, and Butte Counties each have their own version of an export ordinance to protect the citizens from transfer-related third party impacts. Glenn County does not have an export ordinance because it relies on Basin Management Objectives (BMOs) to manage the groundwater resource, and subsequently to protect third parties from transfer related impacts. Recently, Butte County also adopted a BMO type of groundwater management ordinance. Butte County, Tehama County and several irrigation districts in each of the four counties have adopted AB3030 groundwater management plans. All of these groundwater management activities were initiated prior to recognizing that a regional aquifer system exists that extends over more than one county and that certain activities in one county could adversely impact another. Clearly the current ordinances, AB3030 plans, and local BMO activities, which were intended for localized groundwater management, are not well suited for management of a regional groundwater resource like that theorized of the Lower Tuscan aquifer system.

Current County Groundwater Management Authority

Butte County – Chapter 23(B), 33, 33(A) Butte County Code, AB3030
Tehama County – Chapter 9.40 Tehama County Code, AB3030
Glenn County – Title 20, Chapter 3, Section 10 Glenn County Code
Colusa County – Chapter 43 Colusa County Code

Public outreach and education is a critical component to the overall success of the entire project, particularly in the northern Sacramento Valley. Increased utilization of the Lower Tuscan aquifer system and potential groundwater transfers are politically charged issues. Therefore, it is necessary to ensure that the public is adequately informed regarding these programs.

The current outreach efforts include:

- Presentation to Boards of Supervisors
- Presentations to Board of Directors for Water Districts
- Northern Sacramento Valley Water Forum Meetings

Although this is a start, much more public outreach efforts are needed to provide information about the various projects, to a broader spectrum of the public.

Need - A program that establishes a formalized network of dedicated monitoring wells in the Lower Tuscan aquifer system and identifies a process for disseminating data to the general public. Education of the general public on how the resource functions and can be utilized without adverse impacts.

References:

Anderson, C.A., 1933, The Tuscan Formation in Northern California: University of California, Department of Geological Sciences, Bulletin 23.

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Helley, E.J., and Harwood, D.S., Geologic map of the late Cenozoic deposits of the Sacramento Valley: USGS Miscellaneous field studies: Map MF-1790.

Wrime, 2003, Stony Creek Fan IGSM Model, Model Development Calibration and Analysis, Volume 3: Final report to the Stony Creek Fan Partnership.

Work Plan

Tuscan Aquifer Monitoring, Recharge, and Data Management Project

Local governments play a vital role in water and resource management through their land-use authority. In the Sacramento Valley, local governments are very concerned about the preservation of the agricultural economy, which is dependent on a reliable source of high-quality water. In addition, available water sources must meet the needs of future developments, which are rapidly moving north into the northern Sacramento Valley. Planning decisions made today by local governments will help to shape the use of water within and outside of the region. Identifying the potential yield and geological make-up of the Lower Tuscan Formation aquifer system, as well as access to a comprehensive database of aquifer information, will be invaluable for the above-mentioned local uses and its connectivity to the basin as a whole.

Coordinated Surface and Groundwater Management Programs should consist of recharge, recovery, monitoring, and management components that all coordinate to maximize the regional project yield while at the same time providing long term protection of the groundwater resources, third parties, and the environment. These programs also need to include extensive public outreach and education components to reduce potential local and regional conflict and to help foster regional coordination and cooperation. In the Northern Sacramento Valley there are several proposed groundwater recovery components that will utilize, to some degree, the regional Lower Tuscan Formation aquifer system. Described below are the project components that will monitor conditions in the Lower Tuscan Formation aquifer system and direct the methods used to manage and recharge the aquifer. Together the project tasks will:

- Identify the geological make-up of the Lower Tuscan Formation aquifer system
- Further define inter-connectivity of the Lower Tuscan with other geologic layers
- Quantify the potential yield of the Lower Tuscan Formation aquifer system
- Determine aquifer system's ability to meet the water needs of the local agricultural economy
- Examine potential for conjunctive water management programs
- Educate the public to reduce potential local and regional conflict
- Foster regional coordination of water management

To provide technical oversight for the various components of this project, a Technical Steering Committee will be formed early-on in the project implementation to review progress and results from the various project components as outlined below. The committee will be broad-based and include representatives from the State, Counties, academic community, and various special districts throughout the Northern Sacramento Valley. The anticipated representatives that will make-up the Technical Steering Committee are as follows:

- DWR, Northern District Groundwater Section
- DWR, Northern District Water Quality Section
- UC Cooperative Extension – Butte County
- UC Cooperative Extension – Tehama County
- Butte County
- Glenn County
- Colusa County
- Tehama County

- Special districts
- Agricultural groundwater user organization

This committee will meet on a regular basis, as needed, throughout the duration of the program and will act solely in an advisory capacity to the project manager.

TASK 1: GIS Data Base Development of Lower Tuscan Formation Aquifer System

The creation of a GIS Database of the Lower Tuscan Formation aquifer system, the neighboring aquifer systems, surface water sources, and geologic interactions will enhance the understanding of the recharge mechanisms of the Lower Tuscan aquifer system. A database will integrate available data and provide a library in which to compile new information collected in the course of monitoring the aquifer system. A database will allow qualification and quantification of aquifer properties, including:

- Transmissivity and permeability
- Aquifer storage values
- Surface and groundwater temperature
- Stream infiltration capacities
- Monitoring well location
- Extraction well location

A database will encourage interaction between concerned parties by making full aquifer information available for future land-use decisions in the four counties (Butte, Glenn, Tehama and Colusa) overlying the Lower Tuscan Formation aquifer system. Comprehensive information on the aquifer system will provide the counties with the ability to monitor conditions in the aquifer system and promote an educated use of its resources.

1.1 GIS Database Development Activities

The first step in creating a database of aquifer system information is the acquisition of additional hardware and software to support the input data. This includes the purchase of additional disk storage capacity for the GIS-supporting server and additional software. To make the best use of existing data, the new database will compile the existing GIS layers and information on the aquifer systems and the four counties region. Information in hard copy will be digitized for addition to the database.

1.1.1 Purchase additional GIS server storage capacity and associated software.

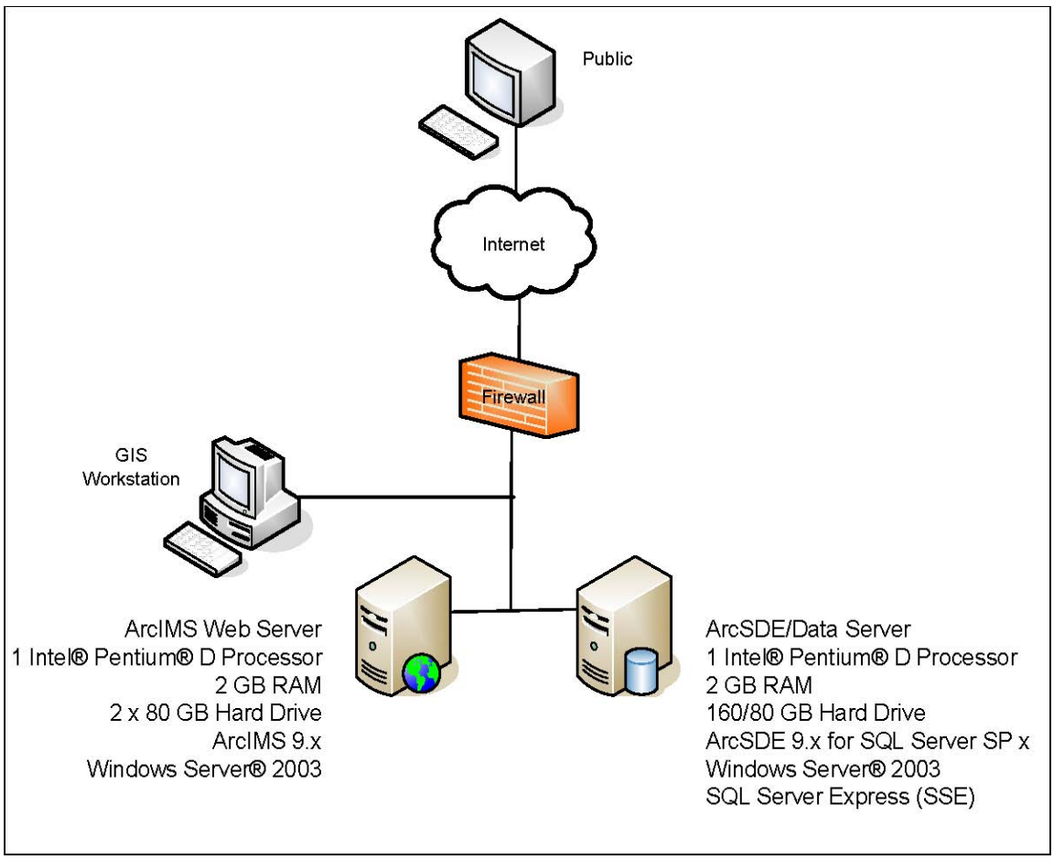
Establishing a web presence is necessary to support the GIS spatial data management requirements of the project. The infrastructure required will support the forecasted usage of the system with expandability for future growth. It will enable streamlined access to data, which can be queried and allow for the production of basic mapping.

The GIS server will serve as a means of data storage and dissemination of pertinent information. Data will be accessible to our internal GIS team and served to public users while at the same time managing for current, up to date data so that decisions will be reflective of the most accurate information.

Two pieces of software are required to meet the GIS Spatial Data requirements. These include ArcIMS 9.x and ArcSDE 9.x. Each must be placed on a separate server. Therefore, two (2) servers must be utilized to support this environment. Additionally, Microsoft SQL Server Express (SSE), a free version of the database software, is required for ArcSDE to operate.

Figure 1 depicts a schematic of the proposed architecture:

Figure 1
GIS Server Architecture



1.1.2 Obtain readily available GIS layers (topography, hydrology, land use, monitoring well locations for the four county region) and develop skeletal GIS system.

The core datasets required as the basis for the GIS system are readily available. These data sets include topography, hydrology, land use, and monitoring well locations in addition to several base maps of the four-county project area.

GIS data for this study will be housed in a Geodatabase developed specifically for this effort. Data layers will be formatted and standardized for ease of use and integration within the GIS server environment. The data will be made accessible via the ArcIMS site so that users can query, analyze, and make simple maps from remote locations.

1.1.3 Collect available aquifer data, aquifer properties and water quality parameters.

Aquifer properties will be collected and GIS feature classes will be developed and housed in the Geodatabase on the GIS server. These will include the following characteristics: transmissivity, storage values, vertical leakance, and infiltration.

1.1.4 Field verify current geology and soils mapping.

Several datasets are readily available from other studies conducted in the four-county area that can be harnessed for this project. The geology and soils GIS data sets will be formatted and stored in the Geodatabase on the GIS Server.

To field verify the current data, about 100 sites will be visited to truth check the GIS data. Changes to the geology and/or soils classification will be made at these locations and extrapolated throughout the entire study area as appropriate.

1.1.5 Revise existing geologic and soils mapping.

As a result of the field verification in Item 4, the GIS data and resulting maps will be updated accordingly. Since the entire study area can not be field verified, assumptions of the surrounding geology and soils will still be based on the best available GIS data layers.

1.1.6 Digitize geology, soils series, percolation test sites, gauging stations, surface water diversions, aquifer-stream interaction monitoring sites.

Based on completion of Items 1.1.4 and 1.1.5, geology and soil data will be incorporated into the GIS environment. These datasets will be available via the ArcIMS site, desktop GIS applications, and in hard or soft copy format.

In addition, percolation test sites, gauging stations, surface water diversions, and aquifer-stream interaction monitoring sites (see Task 2) will be integrated into the GIS environment. Typically these locations will be surveyed with GPS devises. The GPS coordinates will allow for highly accurate placement in the GIS.

1.1.7 Provide input into Butte County's and other regional General Plan Updates to assist in informed development which protects recharge areas.

The extent of the Lower Tuscan Formation aquifer system recharge areas in Butte and Tehama Counties will be accurately delineated in GIS. Butte and Tehama Counties will use this information in their general plan update to identify the appropriate land use activities in these areas to protect groundwater quality and recharge to the aquifer system.

1.2 Deliverables

GIS database of information pertaining to the four counties further defining the extent of the Lower Tuscan Formation aquifer system.

TASK 2. Lower Tuscan Formation Aquifer System Recharge Assessment.

Following the initial creation of the GIS database for the Lower Tuscan Formation aquifer system, the outcropping (surface exposures) of the Tuscan Formation will be assessed for

direct, in-lieu, and natural recharge potential. The recharge assessment will consist of three subtasks:

- Soils infiltration tests,
- Stream gauging,
- Assess gaining and loosing stream reaches through vertical groundwater temperature profiles.

Subtask 2.1: Infiltration Testing

Field infiltration tests will quantify the recharge potential of formational materials within the Lower Tuscan outcropping. Natural aquifer recharge occurs in part when precipitation and surface runoff infiltrate into the aquifer system. Infiltration rates will be measured through infiltration tests conducted across the area identified as the outcropping of the Tuscan Formation Units A and B using a double-ring infiltrometer.

The infiltrometer tests will be used to assess both the passive and active water infiltration capacity of the Lower Tuscan Formation. Passive infiltration capacity is defined as the potential for water to infiltrate the exposed Lower Tuscan Formation soils across the study area. Active infiltration capacity is defined to address the potential for areas specifically near active streams that hold potential for development as active groundwater recharge areas. Care will be taken at each infiltration test location to ascertain whether there is a near-surface low-permeability layer that may affect the test. This will include clearing the soil infiltration test site of vegetation and the soil organic horizon before each test and by post-hole-digging a pit to ascertain whether a representative formational profile exists within a depth of 3-feet of the ground surface.

2.1.1 Infiltration Testing Activities:

1. Obtain right-of-entry from landowners

2. Purchase 1 double-ring infiltrometers

3. Conduct approximately10 field infiltrometer tests at locations throughout the previously identified extent of the Lower Tuscan Formation outcropping. In order to provide a regional snapshot of the recharge potential of the Lower Tuscan Formation, tests will be conducted in all areas of the identified outcropping with slopes less than 5%. Special attention will be paid to areas where active recharge facilities may be developed in the future such as public land with meandering streambeds or old sand or gravel mines. On slopes greater than 5% infiltration will be limited by precipitation losses to runoff. See Figure 1 in the Appendix for the proposed infiltrometer test locations. Tests will be conducted in accordance with ASTM Standard D-3385-03.

4. Collect soil samples at each testing site for geological classification and mechanical analysis.

5. Analyze and report test data. Infiltration rates, soil classifications, and mechanical analysis test results for all sites investigated during the testing phase of Subtask 2.1 will be entered into the GIS database of Task 1.

2.1.2 Deliverables

Infiltration rates, soil classifications, and mechanical analysis test results for all testing locations within the recharge area. This information will be provided as a layer in the GIS database (Task 1).

Subtask 2.2: Stream Gauging

The objective of the stream gauging is to characterize the stream-aquifer interactions and to monitor riparian habitat by determining the volume and rate of surface water that recharges into or is discharged from exposures of the Lower Tuscan Formation along perennial streams. Measurement of water movement in the aquifer will be used to test the accuracy of the Integrated Water Flow Model, an integrated surface water-groundwater finite-element model developed for Butte County.

Two new stream gage stations will be installed on each of six perennial streams crossing the Lower Tuscan Formation to establish baseline stream flow and infiltration information. The differences between stream flow measurements taken both upstream and downstream of exposures of the Lower Tuscan Formation indicate the stream-aquifer interaction. Losses or gains in stream volume indicate aquifer recharge from or discharge to the surface water sources. Streams of interest include:

- Antelope Creek
- Mill Creek
- Deer Creek
- Big Chico Creek
- Butte Creek
- Little Dry Creek

Currently stream monitoring equipment is installed in Butte Creek, Deer Creek, and Mill Creek. Big Chico and Little Dry Creek each have abandoned stream gauging sites. As a cost saving measure, the first priority will be to attempt to re-establish monitoring in those sites (see Figure 2 in Appendix).

2.2.1 Stream Flow Measurement Activities

Before flow measurements begin, each stream cross-section will be surveyed in detail at the sampling site. Stream gauging equipment will be the USGS standard Price Type AA current meters with sensing instruments coupled with pressure transducer and data loggers. Based on final site selection, vertical control will be established via installation of a cable line or staff gage, as is appropriate. Measurements will be made bi-weekly from April to November for a three-year period.

1. Assess functionality of existing gauging stations on Big Chico Creek, Butte Creek, Deer Creek, and Mill Creek. Determine likelihood of reestablishing sites on Big Chico Creek and Little Dry Creek. See Figure 2 in the Appendix for station locations.

2. Obtain right-of-entry and environmental review for each site.

3. Develop stream flow measurement protocol. Based upon seasonal rainfall averages and times when significant water will be extracted from the aquifer, testing times for the streams will be determined, with each stream monitored.

4. Purchase necessary equipment and supplies.

5. Establish vertical control at each site and install staff gauges, current meters, and pressure transducers.

6. Survey stream cross-section in detail at each site.

7. Make biweekly stream flow measurements at each site from April to November for a three-year period when the dry season in the region limits rainwater infiltration to the Lower Tuscan Formation.

8. Develop stage-flow rating table.

9. Analysis and report.

2.2.2 Deliverables

A quantitative assessment of the volume of water gained or lost by the streams to and from the Lower Tuscan Formation aquifer system. Approximately 8 stream gauging installations for continued monitoring of stream flow in the region. The data collected will be used for refining the IWFM groundwater model and to assess overall recharge of the Lower Tuscan Formation aquifer system.

Subtask 2.3: Stream-Aquifer Temperature Gradient Measurements

The objective of measuring stream-aquifer temperature gradients is to determine how groundwater is influenced by the influx of surface waters to the aquifer or the movement of groundwater toward the ground surface. Monitoring of the temperature gradient adjacent to the streams with temperature-sensing piezometers can determine the vertical direction of water movement and help quantify the amount of water a stream is losing or gaining from an aquifer. Gradient measurements will be taken at several locations where the Lower Tuscan Formation outcrops to gain understanding of surface water-groundwater interaction. Temperature monitoring will take place along six perennial streams identified in Subtask 2.2.

2.3.1 Temperature Gradient Measuring Activities

1. Obtain right-of-entry and environmental clearance for each site
    - Private landowners (Right-of entry)
    - Department of Water Resources (Right of entry)
    - Reclamation Board (Encroachment Permit)

2. Field-verify shallow water temperature gradient monitoring well sites and choose best sites for monitoring. All sites must be accessible by a small truck-mounted drill rig.

3. Purchase and install up to 25 monitoring structures to a depth of 50 feet along each of six monitored streams and in the valley alluvium to determine the stream-aquifer relationship. Using a hollow-stem auger drilling rig, piezometers will be 2-inch diameter continuous wire-wound stainless steel drivepoints. Thermistors (Seistronix TL-300 or equivalent) with a sensitivity of 0.1 degrees Celsius will be used to make the

profile measurements every 2-5 feet below the ground surface. Temperature monitoring sites are identified in Figure 2 in the Appendix.

4. Take temperature profile measurements over 2 years to attempt to interpret stream-aquifer interaction and viewing monthly temperature profiles over several years will indicate whether there are significant changes in the interactions between the stream and the underlying aquifer. Measurements over several years may show how relative percolation rates change to and from the aquifer as a result of changes in system-wide hydrology.

5. Analyze and report data.

6. Calibrate IWFM and perform simulations.

2.3.2 Deliverables

Aquifer depth-temperature tables and plots for 25 stream bank locations within the Lower Tuscan Formation aquifer system recharge area establishing the interaction of surface waters in the stream bed with the movement of water into and out of the aquifer system. The data collected will be used for refining the IWFM model and to assess overall recharge of the Lower Tuscan Formation aquifer system.

TASK 3. Installation of Additional Groundwater Monitoring Infrastructure

Over the past few years much needed dedicated groundwater monitoring infrastructure (monitoring wells) has been installed in the Northern Sacramento Valley. Although this has contributed to a much better understanding and quantification of the hydrogeology of the Sacramento Valley, additional dedicated monitoring infrastructure will be needed to assure future groundwater development in the Northern Sacramento Valley is done in a fashion that will not create unacceptable third party impacts or adversely impact surface water sources or the environment.

Information developed during drilling and construction of these wells will be shared with State and local government agencies, water districts, and will be used in the public outreach and educational components, which are described below.

A reliable baseline of hydrogeologic data is necessary in order to aid in water resource management decisions for the Sacramento Valley. Carefully designed and constructed monitoring wells will provide much of this data. The general objectives of newly proposed monitoring wells include the following:

1. Fill data gaps – Monitoring wells will be sited in areas of present data gaps in order to develop a more complete picture of the Lower Tuscan Formation as it relates to the other aquifer systems within the valley. Well locations have been selected to a) improve coverage of unconfined and confined groundwater level data across the Lower Tuscan Formation, b) to develop a geologic profile of potential production zones aiding in the determination of production well design, c) obtain groundwater quality data.

2. Support aquifer testing – Monitoring wells will be located in order to measure drawdown during aquifer performance tests conducted on new and existing production wells as described in Section 4. The aquifer testing data obtained will be input into the

existing Butte Basin IWFM groundwater model, enhancing knowledge of the spatial distribution of aquifer properties across the basin.

3. Monitor groundwater recharge – Groundwater levels and quality within the recharge corridor will be monitored throughout the year in order to supplement the aquifer recharge findings from Task 2. Data obtained in that study are primarily obtained in shallow horizons. The data collected from the proposed wells will help evaluate the degree of hydraulic connection between the surface water and groundwater systems.

4. Evaluate well performance and pumping impacts – The monitoring wells will be used to develop a monitoring program designed to evaluate overall groundwater basin conditions and the effects of pumping from the new and existing production wells. Water produced and resulting groundwater level decline will be measured in the vicinity of six production wells.

3.1 New Monitoring Well Locations

This project will coordinate with other projects that will utilize the Lower Tuscan Formation aquifer system to assess the adequacy of the local and regional monitoring needs of the region. Where gaps in monitoring are identified, or for aquifer performance testing, this project will install new dedicated monitoring wells as needed. Monitoring wells will also be installed in recharge areas to provide the needed basis for assuring the effectiveness of direct and in-lieu aquifer recharge activities. Up to 12 dedicated monitoring well are proposed under this project. Table 3-1 identifies the proposed wells and the primary objective of each.

Table 3-1
Proposed Monitoring Wells

Proposed Monitoring Well	County	Depth (feet)	Number of Completion Zones	Objectives (a)	Associated Production Well
CW-1	Butte	1000	3	1,2,3,4	Cal Water Service
DRHM-1	Butte	1000	3	1,2,3,4	Durham
RID-1	Butte	500	2	1,2,4	None
BC-1	Butte	1000	3	1,3,4	None
BC-2	Butte	1000	3	1,3,4	None
BC-3	Butte	1000	3	1,3,4	None
BC-4	Butte	1000	3	1,3,4	None
TC-1	Tehama	1000	3	1,3,4	None
TC-2	Tehama	1000	3	1,3,4	None
TC-3	Tehama	1000	3	1,3,4	None
TC-4	Tehama	1000	3	1,3,4	None
GCID-1	Glenn	1000	3	1,2,3,4	GCID-2

(a) Numbers correspond to the Objectives in the previous section.

Figure 3 in the Appendix identifies the proposed location of each monitoring well, and associated production wells, where applicable.

3.2 Infrastructure Installation Activities

Specific activities that must be conducted in order to accomplish the above objectives are described in the sections that follow.

3.2.1 Right-of-Entry

Land ownership maps will be consulted for each of the proposed drilling sites, and the owners contacted regarding access agreements for drilling. In most cases, the proposed monitoring well sites are located within existing municipal or agricultural water system operator properties. Off-site access will be required for monitoring wells to be installed near the Cal Water Service -1 and Durham production wells.

Proposed right-of-entry and well maintenance access agreements will be negotiated in good faith with the associated property owners, under the by-laws of County and local ordinances in which the wells are located.

3.2.2 Environmental Compliance

Task-specific environmental compliance activities include the inspection of existing land, land use practices, and conditions at each proposed drill site, and the identification of sensitive species or land uses. Soundproofing requirements, utilities, and discharge locations will be evaluated. Following the inspection, the Department of Health Services (DHS) Proposition 50 Worksheet for CEQA Exemptions will be completed.

The land use designation for the plots to be used is largely agricultural, and their zoning is expected to be General Agriculture. Typical land uses for the agriculture land use designation include crop production, orchards, grazing, pasture, and rangeland; resource extraction activities; facilities that directly support agricultural operations; and necessary public utility and safety facilities. Groundwater monitoring wells are consistent with this designation as facilities that support agricultural irrigation operations. The element will require no change in land use designation or zoning.

For those sites that are not exempt from CEQA, an Initial Study will be conducted in order to further evaluate the land and potential impacts of drilling. Based on current understanding of the proposed sites, it is assumed that a Categorical Exemption will be supported by the findings of the Initial Study.

The wells are not anticipated to have impacts on the waters of the United States or waters of the State; endangered species; or the beds or banks of any streams, levees, public roads, dams, or any other resources for which potential effects may require compliance with the Clean Water Act, federal or state endangered species acts, the California Fish and Game Code, or other applicable state laws or regulations. Similarly, there should be no need for a National Pollution Discharge Elimination System (NPDES) General Construction Activity Storm Water Permit because the total area of disturbance for the project will be less than one acre. Water generated during construction of the wells is not expected to require an NPDES discharge permit.

3.2.3 Permitting

A well drilling permit will be necessary for each well. Permits will therefore be obtained from the Butte, Tehama, and Glenn County Departments of Environmental Health. The departments incorporate the following standards in their process to obtain well permits.

- California Department of Water Resources, 1981, California's Well Standards, Bulletin No. 74-81.
- California Department of Water Resources 1991, California Well Standards, Draft Bulletin No. 74-90.

The monitoring well drilling will be consistent with the respective County General Plans.

3.2.4 Contracting

Butte County Department of Water and Resource Conservation will competitively bid the engineering and environmental design, planning, and construction oversight services needed to accomplish the project. Detailed contract documents will be prepared according to County standards that identify borehole width, well depth, materials to be used for casing, seals, filter pack, screen, and surface completion, well screen, borehole seal, and blank casing intervals, development criteria and the required schedules.

3.2.5 Well Design, Logging and Installation

Plans and specifications are near an 80-percent completion level for the monitoring wells. A schematic design is provided as Figure 4. Following the selection of the C-57 licensed drilling contractor, the work plan will be implemented and each well drilled using direct mud rotary or reverse circulation equipment. Sediment samples will be collected at each target completion depth for mechanical analysis.

Upon completion of drilling, the boring will be conditioned and a down-hole geophysical survey, consisting of resistivity, spontaneous potential, spectral gamma, and caliper, will be performed in the un-cased borehole. The geophysical logs and mechanical analyses will be used by the hydrogeologist to perform the final well design in the field. The construction materials and techniques have been determined for each well prior to drilling, however, the well screen intervals, gravel pack size and gradation, and well screen slot size will be determined by a registered hydrogeologist after review of the logs and sediment samples.

Following completion, each well will be developed by mechanical methods (e.g., surging, swabbing, and air lifting) until the wells have been judged free of suspended material and contain water representative of the formation.

Each monitoring well will be equipped with a pressure transducer-data logger in order to automatically record and store groundwater level data from each well or completion zone at predetermined time intervals. Multi-completion wells will be equipped with multiple loggers. Each data logger will be battery equipped in order to operate remotely without the need for a permanent power supply. Each monitoring well will be surveyed for elevation and location. Data collected will be shared with proponents and agencies as described in section 3.3.

3.2.6 Analysis and Report

Project performance will be documented through quarterly progress reports prepared throughout the design and construction period. After the wells are installed, they will be

included in the cooperative DWR-Butte County monitoring network. Butte County will prepare and submit annual reports to DWR for at least five years. The annual reports will include groundwater level and electrical conductivity measurements recorded during the reporting period. The details of performance monitoring will be presented in a Project Assessment and Evaluation Plan (PAEP) to be developed as part of this task.

3.3 Deliverables

Completed permit applications for each monitoring well. Following approval and well construction, finalized permits, all well logs, and well completion reports will be submitted to the State. The Proposition 50 CEQA Categorical Exemption worksheet will be completed. Progress will be documented in quarterly construction reports and annual monitoring reports. A PAEP will be completed for the project.

Butte County will work cooperatively and share data with other project proponents in the Northern Sacramento Valley to maximize the benefits of this work.

TASK 4. Lower Tuscan Formation Aquifer Performance Testing

As new groundwater recovery projects are implemented throughout the Northern Sacramento Valley, the opportunity exists to obtain valuable information regarding hydrogeologic aspects of the Lower Tuscan Formation aquifer system.

The primary objectives of this task are to 1) collect basic aquifer performance data including transmissivity and storage in a cost effective and consistent manner, and 2) to gain a better understanding of the vertical interformational leakance between the Lower Tuscan Formation aquifer system and other hydraulic units. The results of this task are needed to calibrate and integrate the Butte County Integrated Water Flow Model (IWFM). The IWFM will be used as a regional coordination and management tool to assess local and regional, impacts, as well as potential impacts to surface water source and the environment.

4.1 Aquifer Performance Testing Activities

This task will involve both the re-analyzing of existing aquifer test data and the conducting of new aquifer tests.

4.1.1 Existing Aquifer Test Re-Analysis

In order to cost-effectively develop a network of hydrogeologic data within the Lower Tuscan Formation aquifer system, existing data sets from six previous aquifer performance tests will be obtained and if necessary, re-analyzed using consistent methods. The results of these analyses will ultimately be utilized for the updated IWFM groundwater model. Re-analysis using consistent methods will result in a more uniform interpretation of the data and better understanding of the Lower Tuscan Formation aquifer system's hydraulic performance. Table 4-1 lists six existing wells that have previously been tested, and the agency source of the aquifer test data.

Table 4-1
Existing Wells, Locations, and Monitoring Agencies

Well	County	Data Source
Sun City	Tehama	Tehama County
Deer Creek ID	Tehama	DWR ND

M&T Chico	Butte	DWR ND
GCID-1	Glenn	DWR ND
Orland/Artois	Glenn	DWR ND
Western Canal/Fenn)	Butte	DWR ND

The data review and analysis will be conducted in conjunction with a review of existing and available memoranda or reports.

4.1.2 New Aquifer Tests

Up to 12 new monitoring wells are proposed for installation under this application (see Task 3). Whenever possible, the new monitoring wells will be installed in the vicinity of new and existing production wells listed in Table 4-2 below. Following the monitoring well installation and development, aquifer performance tests will be conducted on the 3 or more production wells, using the monitoring wells as observation points.

Table 4-2
New Lower Tuscan Aquifer System Performance Testing

Well	County	Notes
Cal. Water Service-1	Butte	Install Monitoring Well
Durham	Butte	Install Monitoring Well
GCID-2	Glenn	Install Monitoring Well

Figure 3 in the Appendix identifies the proposed location of each of the wells to be tested.

4.2 Aquifer Performance Testing Activities

Specific activities that must be conducted in order to accomplish the above objectives are described in the sections that follow.

Two types of aquifer performance tests will be conducted: a step drawdown test and a constant discharge aquifer test. During both pumping tests, transducers and data loggers will be used, in addition to manual measurements, to monitor the water levels. Prior to stopping the pump, a water sample will be collected and analyzed for physical parameters, standard minerals, minor elements, nutrients, and oxygen isotopes to identify water quality and recharge source. Following the aquifer test, an in-casing flow test (spinner) will be performed in the well if possible.

Monitoring is assumed during these tests to confirm that accurate data are collected. Staff or consultants will monitor the discharge rate to ensure that it remains constant, measure and collect water levels and graph the results. The level of effort assumes an 8-hour step drawdown test, 10-day constant discharge test and a 10-day recovery test. An in-line flow meter with totalized will be installed for this test.

Water levels will be monitored in the pumping well during both tests using electronic pressure transducers located in both the pumping well and the selected nearby monitoring well(s). Data will be recorded in a digital format with an automated data acquisition system (i.e., Troll data logger, or equivalent). Measurements of water levels are expected to be accurate to within 0.1 foot. Manual measurements will also be made using a water level indicator to calibrate and ensure the accuracy of the transducer readings.

Background water level and barometric data will also be collected hourly for approximately 48 hours prior to conducting the pumping tests and during the test duration in order to evaluate potential trends in groundwater level fluctuations using a separate barometer.

4.2.1 Step Drawdown Test

The items below list the basic procedure for administering the step drawdown test.

- The well shall be "step" tested for 2 hours each at rates of ½, ¾, 1 and 1-½ times the estimated design capacity of the well.

- At the conclusion of each step, the water levels will be allowed to recover to within 80 percent of static conditions.

- Discharge rate from the pump shall be controlled at approximately the desired discharge for each step .

- During the test, the time, pumping level, and discharge rate will be recorded. Electrical conductivity, pH and temperature of the discharge water will also be measured.

4.2.2 Constant Discharge Test

The items below list the basic procedure for administering the constant discharge test.

- A long-term, continuous, constant rate, time-drawdown test shall commence not less than 24 hours and not more than 48 hours after completion of the step drawdown test. The rate of pumping shall be set at approximately the design rate for the well. The pumping rate selected will remain constant throughout the test duration of 10 days. When the pump is stopped, water level recovery will be measured for a period of approximately 10 days.

- During the drawdown and recovery tests, the water level in the pumped well will be recorded using continuance data loggers and evaluated using the following schedule.

0-10 minutes once each minute
10-20 minutes once each 2 minutes
20-60 minutes once each 5 minutes
60-120 minutes once each 10 minutes
120-240 minutes once each 30 minutes
240-720 minutes once each hour
720-1440 minutes once each 2 hours
>1440 minutes once each 6 hours

- The discharge rate and temperature, EC, and pH of the discharge water will be measured at least every 24 hours.

- Discharge rate from the pump shall be controlled at approximately the desired discharge for the duration of the discharge portion of the test using an orfice plate and gate valve to control the discharge

4.3 Deliverables

4.3.1 Reporting

The results from both the re-analysis of existing pumping test data and the new pumping test data will be documented in short technical memoranda.

4.3.2 Groundwater Model Update

The information determined as a result of these aquifer test analyses will be incorporated into the regional IWFM groundwater flow model, which is currently under development. This regional IWFM model will be used as a regional coordination and management tool to assess local, regional, and third party impacts and potential impacts to surface water sources and the environment.

The newly estimated parameter values will be compared to the existing values used in the model. Where warranted, model hydraulic property data sets will be changed to reflect the new data. The revised model will be compared to calibration targets to assess consistency of data. Revisions to the model and calibration results will be documented in a technical memorandum or report.

TASK 5. Lower Tuscan Formation Aquifer System Outreach, Education and Coordination.

This task will cover the outreach, educational and regional coordination necessary to implement other projects utilizing the Lower Tuscan Formation aquifer system. Studies indicate that the Lower Tuscan Formation forms a regional aquifer system that is theorized to underlie Tehama, Butte, Glenn, and Colusa Counties. It is important to coordinate management of regional aquifers to help minimize the potential for local scale projects to negatively impact supply and use on a regional scale.

To help promote regional coordination of the Lower Tuscan water supply, this project element would provide the public outreach and education needed to further educate elected officials, media, the academic community, environmental groups, and the community at large on the Lower Tuscan Formation water supply capabilities, and its economic and social values for the counties that overlie it.

Outreach and education will be managed over the three year term of the project and will provide documentation and dialogue by development of five focused informational brochures and five educational public meetings. The objectives of the two-phase program are to produce brochures that identify and discuss key basin management issues regarding the Lower Tuscan Formation aquifer system and to provide a forum in the form of public meetings for discussion and determination of basin management goals.

5.1 Program Development Activities

5.1.1 Production of Informational Brochures on five topics:

- Regional Monitoring Program Review – Evaluation of adequacy of current monitoring of the basin including the Lower Tuscan Formation aquifer system and formalization of a monitoring network for it and other aquifers systems in the region.

- Web-based Storage and Reporting of Monitoring Data - Document the format and function and use of the Basin Management Objective Information Center and the

availability of this data via the web-based storage system. Enhancements to the existing system to include data from the four area counties (Butte, Tehama, Glenn and Colusa) and the Lower Tuscan Formation aquifer system data collected under this Prop. 50 grant.

- Basin Management Objectives – Identify and discuss key basin management issues and objectives for the basin including the Upper and Lower Tuscan Formation, the Alluvial aquifer, the Tehama formation and other layers of the regional aquifer system.

- Regional Management Strategies –Regional issues related to the use of the various layers of the aquifer system. Review of multi-agency decisions and actions and how they can affect the functional use of the aquifer system. Land use issues related to recharge areas, groundwater extraction practices and potential impacts on third parties, review of potential costs and benefits of various water use scenarios, etc.

- Water management strategies for the regional aquifer system – Results of monitoring and management program development should be used to develop sustainable water management strategies for the region.

5.1.2 Organization of Regional Educational Meetings whose content will be refined through project development:

5.1.3 Other Tasks

Other tasks related to the education and outreach project would be to expand the web-based reporting portal developed under the BMOIC to include monitoring data from Tehama, Glenn and Colusa Counties and additional Lower Tuscan Formation aquifer system data collected under this grant. The program would be scheduled to comply with project development and data availability over a three-year span.

5.2 Deliverables

Enhanced web-based monitoring data portal to include the four counties and the Lower Tuscan Aquifer system. Informational brochures (series of 5) associated presentation materials for 5 educational public meetings.

Costs Distribution

Provided in Table 1 is a distribution of costs for each task with respect to the proposal's budget items. This table demonstrates the cost distribution of the project for ease of understanding by reviewers. Table 1 also documents the budget and hours to be devoted to each task.

Insert Appendix