Contract Number: CT-FC-14 * 368
Effective Date : 3-6-14
Term Date : 9-30-16
Cost : $60,000.-
Revenue :
Total : NTE:
Action
Renewal By : 7-1-16
Term : 9-30-16
Reviewed by: JK

BOARD OF SUPERVISORS AGENDA ITEM SUMMARY

Requested Board Meeting Date: 04-08-14

ITEM SUMMARY, JUSTIFICATION &/or SPECIAL CONSIDERATIONS:

Approval of Joint Funding Agreement with the United States Geological Survey for *Aquifer-Storage Change and Land-Surface Elevation Change Monitoring in the Tucson Active Management Area.*

The United States Geological Survey has requested authorization to enter into a Joint Funding Agreement with the Pima County Regional Flood Control District to continue to monitor the capacity of the aquifer and change in land subsidence. The cost to Pima County will be $20,000/yr for three years. Other jurisdictions and the Arizona Department of Water Resources, will also contribute to the project. Pima County has helped jointly fund this work since the 1980s. It is integral to understanding the capacity of aquifers in Pima County, and the potential for land subsidence and associated infrastructure damage.

*CONTRACT NUMBER (If applicable): CT 14 *368*

STAFF RECOMMENDATION(S):

Recommend approval of the Joint Funding Agreement

Procure Dept 03/19/14 PM02:25

CORPORATE HEADQUARTERS:
USGS Arizona Water Science Center
520 N. Park Ave.
Tucson, AZ 85719

Ver. 1
Vendor - 1
Pgs. 10

To: COB - 3-26-14
Agenda - 4-8-14
(2)

CLERK OF BOARD USE ONLY: BOS MTG. _____

ITEM NO. _____

PIMA COUNTY COST: *$60,000* ***and/or REVENUE TO PIMA COUNTY:$***

FUNDING SOURCE(S): *Flood Control Tax Levy*
(i.e. General Fund, State Grant Fund, Federal Fund, Stadium D. Fund, etc.)

Advertised Public Hearing:

		YES	***X***	***NO***

Board of Supervisors District:

1		*2*		*3*		*4*		*5*		*All*	*X*

IMPACT:

IF APPROVED:

Pima County will have a better idea of the quantity of groundwater in its aquifers, and the potential for infrastructure damage related to declining ground surfaces associated with groundwater overdraft.

IF DENIED:

Pima County will not know the full extent of the quantity of groundwater in its aquifers, and will not understand the potential for infrastructure damage related to declining ground surfaces associated with groundwater overdraft.

DEPARTMENT NAME:

CONTACT PERSON: *Evan Canfield* *TELEPHONE NO.:* *520 724-4636*

Form 9-1366
(Oct. 2005)

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Customer #:	6000000793/AZ012
Agreement #:	14WSAZ00600
Project #:	ZF009EF
TIN #:	86-6000543
Fixed Cost Agreement	YES

CONTRACT
NO. CT-FC-140000000000000368
AMENDMENT NO. _____
This number must appear on all invoices, correspondence and documents pertaining to this contract.

JOINT FUNDING AGREEMENT

FOR

WATER RESOURCES INVESTIGATIONS

THIS AGREEMENT is entered into as of the, 6th day of March, 2014 by the U.S. GEOLOGICAL SURVEY, UNITED STATES DEPARTMENT OF THE INTERIOR, party of the first part, and the PIMA COUNTY REGIONAL FLOOD CONTROL DISTRICT, party of the second part.

1. The parties hereto agree that subject to availability of appropriations and in accordance with their respective authorities there shall be maintained in cooperation an investigation of aquifer storage change and land subsidence in the Tucson Basin and Avra Valley as described in the attached workplan, herein called the program. The USGS legal authority is 43 USC 36C; 43 USC 50; and 43 USC 50b.

2. The following amounts shall be contributed to cover all of the cost of the necessary field and analytical work directly related to this program. 2(b) includes In-Kind Services in the amount of $0.00

   (a) by the party of the first part during the period

Amount	Date	to	Date
$45,000.00	October 1, 2013		September 30, 2016

   (b) by the party of the second part during the period

Amount	Date	to	Date
$60,000.00	October 1, 2013		September 30, 2016

   Total = $105,000.00

   (c) Additional or reduced amounts by each party during the above period or succeeding periods as may be determined by mutual agreement and set forth in an exchange of letters between the parties.

   (d) The performance period may be changed by mutual agreement and set forth in an exchange of letters between the parties.

3. The costs of this program may be paid by either party in conformity with the laws and regulations respectively governing each party.

4. The field and analytical work pertaining to this program shall be under the direction of or subject to periodic review by an authorized representative of the party of the first part.

5. The areas to be included in the program shall be determined by mutual agreement between the parties hereto or their authorized representatives. The methods employed in the field and office shall be those adopted by the party of the first part to insure the required standards of accuracy subject to modification by mutual agreement.

6. During the course of this program, all field and analytical work of either party pertaining to this program shall be open to the inspection of the other party, and if the work is not being carried on in a mutually satisfactory manner, either party may terminate this agreement upon 60 days written notice to the other party.

7. The original records resulting from this program will be deposited in the office of origin of those records. Upon request, copies of the original records will be provided to the office of the other party.

8. The maps, records, or reports resulting from this program shall be made available to the public as promptly as possible. The maps, records, or reports normally will be published by the party of the first part. However, the party of the second part reserves the right to publish the results of this program and, if already published by the party of the first part shall, upon request, be furnished by the party of the first part, at costs, impressions suitable for purposes of reproduction similar to that for which the original copy was prepared. The maps, records, or reports published by either party shall contain a statement of the cooperative relations between the parties.

9. USGS will issue billings utilizing Department of the Interior Bill for Collection (form DI-1040). Billing documents are to be rendered quarterly. Payments of bills are due within 60 days after the billing date. If not paid by the due date, interest will be charged at the current Treasury rate for each 30 day period, or portion thereof, that the payment is delayed beyond the due date. (31 USC 3717; Comptroller General File B-212222, August 23, 1983).

U.S. Geological Survey **United States** **Department of the Interior**		Pima County Regional Flood Control	
USGS Point of Contact		**Customer Point of Contact**	
Name:	James M. Leenhouts	Name:	Suzanne Shields
Address:	520 N. Park Ave., Suite 221 Tucson, AZ 85719	Address:	97 E. Congress, 3rd Floor Tucson, AZ 85701
Telephone:	520-670-6671 x278	Telephone:	520-243-1800
Email:	leenhout@usgs.gov	Email:	Suzanne.Shields@rfcd.pima.gov

Signatures and Date

Signature:	Date: 03/06/14	Signature:	Date:
Name: James M. Leenhouts		Name:	
Title: Director		Title:	

Contractor shall comply with all applicable provisions of the Americans with Disabilities Act (Public Law, 101-336, 42 U.S.C. 12101 12213) and all applicable Federal Regulations under the Act including 28 CFR Parts 35 & 36

"THIS CONTRACT IS SUBJECT TO THE PROVISIONS OF A.R.S. § 38-511"

THIS CONTRACT IS SUBJECT TO ARIZONA EXECUTIVE ORDER NO. 99.4. AND 2009.09

APPROVED AS TO FORM:
Deputy County Attorney

HAL GILBREATH

Aquifer-Storage Change and Land-Surface Elevation Change Monitoring in the Tucson Active Management Area

FY 2014-2016

Introduction

Aquifer-storage change has been monitored by the U.S. Geological Survey (USGS) within the Tucson Active Management Area (AMA) since 1996. The USGS began a cooperative study with Metropolitan Domestic Water Improvement District and the town of Oro Valley in 1996 to monitor aquifer-storage change in the Lower Cañada del Oro subbasin. In 1998, the USGS began a cooperative study with the Arizona Department of Water Resources (ADWR), Pima County, and the City of Tucson to monitor land-surface elevation change and aquifer-storage change in the Tucson AMA. In 2003, these two monitoring studies were combined, and the town of Marana joined the study. This proposal outlines a scope of work for continued and expanded monitoring of both aquifer-storage change and land-surface elevation change in the Tucson AMA for the period of October 1, 2013 through September 30, 2016.

Aquifer-Storage Change

Aquifer-storage change can be monitored by measuring changes in gravity. As water is added or removed from the aquifer, there is a change in mass and a corresponding measurable change in gravity. Gravity also is affected by changes in land-surface elevation, so monitoring of land-surface elevation change is essential for accurate measurement of aquifer-storage change.

Water levels in wells commonly are monitored to estimate aquifer-storage changes. However, use of water-level variations entails significant assumptions about the hydraulic properties of the aquifer system. One difficulty is the heterogeneity of hydrologic properties of the aquifer; the alluvial sediments of the aquifer vary in lithology and texture, both laterally and with depth. Thus, data from individual wells may not represent aquifer characteristics some distance away from the well. A second difficulty is monitor-well design; in Tucson Basin, most water levels are measured in deep wells that tap multiple aquifer layers, most of which are confined and have accordingly low storage properties. Water levels in these deep wells are a composite of water levels from several aquifer units. When these composite water levels are used to estimate storage changes, the hydrologic properties used in the calculation typically do not reflect the range of aquifer materials over which the well is screened. Because of these complexities and requisite assumptions, use of water-level variations as the only indicators of storage change can be uncertain, and cannot be reliably extrapolated beyond the well location.

Monitoring of gravity and water levels in Tucson Basin has shown that large changes in groundwater storage, as much as several feet of water, have occurred that were not reflected in comparable water-level changes. Water levels following intense precipitation

and infiltration, and associated gravity increases, either tend to rise slightly or to cease or slow their declines as gravity declines. These responses generally are manifested up to a year after the storage increase. The extent to which water levels are influenced by storage changes are directly related to the proximity of the well to the recharge area. Closer proximity yields an earlier and more discernible water-level response. Water-level responses also depend on the geometry and lithology of the sedimentary layers in the aquifer system that wells sample. Typically this information is missing, incomplete, or uncertain. All of this points to the need for a combination of storage-change and water-level data, which together enable defensible estimates of aquifer specific yield distribution.

Land-Surface Elevation Change

Permanent land subsidence can occur in alluvial basins when water is removed from aquifer systems (Galloway and others, 1999). Aquifer systems in unconsolidated rocks such as those in the Tucson AMA are supported by the granular skeleton and the pore-fluid pressure. When groundwater is withdrawn and the pore-fluid pressure is reduced, the granular skeleton is compressed, causing some lowering of the land surface. Both the aquifers (sand and gravel) and aquitards (clay and silt) of aquifer systems are deformed as a result of changes to the pore-fluid pressure and skeleton, but to different degrees. Most permanent subsidence occurs due to the irreversible compression of aquitards during the slow process of aquitard drainage (over a number of years).

Permanent subsidence, seasonal elastic deformation, and uplift have been observed in Tucson Basin and Avra Valley. Rates of compaction in Tucson Basin in relation to water-level decline have been less than 0.5 foot per 100 feet of water-level decline. Comparison with the Eloy and Phoenix areas (greater than 1 foot per 100 feet of decline) suggests that compaction to date in the Tucson region has been largely elastic and recoverable. Compaction and land subsidence can be slowed or stopped, and in areas having appropriate geologic conditions, reversed to some extent by eliminating groundwater withdrawals or through artificial recharge.

The City of Tucson has increased delivery of Central Arizona Project (CAP) water, while reducing pumping from the Central Well Field. This has reduced water-level declines; however, subsidence due to previous pumpage may continue for some time into the future. Continued monitoring of areas having the greatest potential for subsidence will provide information that municipalities and resource managers can use in the development and implementation of prevention and mitigation efforts.

Objectives

The objectives of this project are to monitor aquifer-storage change and land-surface elevation change within the Tucson AMA.

Approach

Land-surface elevation change is monitored at a network of benchmarks (figure 1) throughout the Tucson AMA by measuring changes in land surface elevation over time (approximately annually) with Interferometric Synthetic Aperture Radar (InSAR) and targeted GPS surveys. The Arizona Department of Water Resources (ADWR) has an InSAR program in the Tucson AMA. InSAR is a technique that utilizes interferometric processing to compare the amplitude and phase signals received during one pass of the satellite-based SAR platform over the AMA with the amplitude and phase signals received during a second pass of the platform over the same area but at a different time.

The SAR data are used by ADWR to produce a land-surface elevation-change map over the same time period as the targeted GPS surveys in the AMA. The GPS data is then used to compare with and constrain the InSAR deformation information. The annual InSAR product provides a much broader coverage of land-surface deformation information than could be feasibly obtained with GPS alone.

Aquifer-storage change is monitored by measuring changes in gravity over time at the same network of benchmarks. Gravity is affected by mass and distance; a change in mass or a change in elevation will cause a change in gravity. Groundwater depletion is a mass change and land-surface elevation change is a distance change. By removing the effect of change in distance, changes in gravity are used to determine changes in aquifer-storage.

Temporal-gravity surveys are used in the Tucson AMA to detect local changes in the gravitational field of the Earth. The method is readily applied to measurement of aquifer-storage change in the AMA because of the occurrence of significant variations in pore-space storage that result from groundwater withdrawal and periodic (non-continuous) focused recharge. Two instruments are used at the network of benchmarks: the relative gravity meter and the absolute gravity meter. The relative meter is the primary instrument by which differences in gravity are monitored at stable monuments. Much as control benchmarks are used in conventional land surveying, repeated relative gravity surveys for groundwater storage monitoring should include a reference station where gravity is known to vary little, or the absolute acceleration of gravity is monitored. The USGS uses a Micro-g LaCoste A-10 field-portable absolute gravity meter to establish these reference stations as needed. This is particularly valuable in a hydrologic context where a number of absolute stations may be located throughout a basin, thereby serving to constrain a least-squares adjustment of the network of gravity differences from relative gravity surveys.

Gravity surveys are conducted annually at the entire network of benchmarks (figure 1). GPS surveys also are conducted annually at the portion of the network that previous surveys have shown to be the most active areas of land-surface elevation change. The network of benchmarks may be modified and/or expanded in areas of poor coverage to improve resolution. These areas include Avra Valley, Sahuarita, and central Tucson. Gravity measurements will increasingly be made using the A10 portable absolute gravimeter; this will allow for fewer relative gravity measurements, thus improving the

efficiency of data collection.

Fig. 1. Proposed network for aquifer-storage and subsidence monitoring in the Tucson AMA.

Benefits

Aquifer-storage monitoring

Microgravity surveys are an efficient, noninvasive means of measuring changes in the amount of groundwater in Southwestern alluvial basins. Monitoring changes in groundwater storage in the Tucson AMA is a means to monitor the status of the basin aquifers. This will be of value as water-supply entities in eastern Pima County address needs to manage and augment groundwater resources. The most significant value would accrue as the city further implements aquifer storage and recovery efforts at the Clearwater Renewable Resource Facility (CRRF). As the CRRF reaches anticipated capacity, pumping from the Central Well Field will continue to be reduced. This decreased demand will, if withdrawals do not increase, enable the aquifer to slowly refill.

Water-level data entail assumptions about aquifer and well properties; thus, monitoring of gravity changes as pumping decreases in the basin currently is the only way to measure attendant changes in the amount of water in the aquifer and determine if and when aquifer recovery is occurring. This information conceivably will serve as part of a basis for decisions regarding distribution of groundwater withdrawals to help in mitigating land subsidence or aquifer storage losses in particular areas.

Aquifer-storage change is one of the three components of the groundwater budget. The other two are inflow to and outflow from the aquifer system. Measurement of aquifer-storage change and measures and estimates of outflow enable better estimation of recharge and development of a more reliable groundwater budget for the basin. Measures of aquifer-storage change increase the reliability and utility of groundwater flow and management models. Use of storage-change data to improve model calibration enables additional reduction in the uncertainty of model results. The improved understanding of the movement, distribution, volume, and availability of ground water, to which storage monitoring contributes, enables more effective water management in the Tucson AMA and in other areas of the State.

Surveys in the Tucson AMA since 1998 have provided previously unavailable data quantifying recharge and storage changes. For example, the results of aquifer-storage change monitoring in the Tucson Basin between 1998 and 2012 indicate that storage change and recharge can vary considerably from year to year. It is possible that just a few years may account for the majority of recharge to southwestern aquifers for an entire decade or more. These data are being used to improve the understanding of the aquifer systems and to improve groundwater flow models that will be used in resource planning.

Land-surface elevation change monitoring

Some types of infrastructure are more sensitive to changes in land slope than other types. Sewer systems are largely gravity driven, and are designed and constructed at slopes of about 2 feet per 1,000 feet. Small slope changes can cause operational problems under some conditions. Accurate determination of the rates, amounts, and distribution of land subsidence, together with delineation of higher-risk areas, will provide data upon which mitigation and protection plans can be based.

Subsidence rates will increase when the stress threshold between elastic and inelastic compaction is exceeded. Because it is not possible to reliably estimate when the threshold might be exceeded in the Tucson AMA, and infrastructure damage becomes more likely, subsidence monitoring also provides a means to identify the type of compaction that is occurring.

Groundwater withdrawals from the City's Central Well Field has been substantially decreased as the CRRF reaches full capacity. However, regional subsidence in response to previous pumping is unlikely to end in the near future. It will continue until the aquifer system reaches pressure equilibrium. Observation of the timing and magnitude of aquifer responses will further improve the understanding of land subsidence and of how the aquifer systems function. Monitoring data also will contribute to a better understanding of the responses of the aquifer systems to withdrawals, and will provide additional insight in future plans for well-site selection, recharge efforts, and water-management programs. Additionally, monitoring data will continue to augment and serve as ground truth for satellite-based information that the ADWR is acquiring to enable broad-scale assessments of regional subsidence in the Tucson Basin.

Differential subsidence refers to a relatively large amount of subsidence over a relatively short distance, and can cause focused effects. For example, localized subsidence of as little as one-half inch can necessitate rebuilding a highway overpass. Differential subsidence has the potential to separate pipe joints of sewer and water lines—this can lead to system disruptions and roadway damage. Also vulnerable are the concrete lining sections of engineered channels that rely on the integrity of expansion joints to prevent flood damage. Costs to address such infrastructure failures are high. Awareness of the distribution and magnitude of differential subsidence can help to guide the design and implementation of maintenance and monitoring schedules, selection of monitoring methods, and the design and construction of future infrastructure.

Products

1) Annual interpretive maps of aquifer-storage change and land-surface elevation change in the Tucson AMA (available to all cooperators and to the public on http://az.water.usgs.gov/).

2) Oral presentation of findings to all cooperators each year.

3) Oral presentation of findings at a state or national professional society meeting each year or as funding permits.

Work Schedule and Budget

Fixed-cost funding information for this project is provided in tables 1 and 2. Table 1 presents the schedule of work activities over the project life. Table 2 presents the summary of funding by agency. It is understood that all agency funds in future years are subject to appropriation.

Table 1—Schedule of work activities.

Work Tasks	Year 1				Year 2				Year 3			
1. GPS and InSAR surveys												
2. Gravity surveys												
3. Data post processing, analysis, and interpretation												
4. Preparation of annual digital maps of aquifer-storage change and land-surface elevation change												
5. Oral Report to project cooperators												
6. Oral Presentation at state or national professional meeting												
7. Review, revision and approval of annual maps of aquifer-storage change and land-surface elevation change												
8. Posting of annual maps to http://az.water.usgs.gov/ and distribution to project cooperators												

Table 2—Summary of funding by agency.

Note: Funding distributions shown are proposed for the FY14-16 project period. A table reflecting the final distribution will be provided to all participants following completion of funding agreements.

Agency	Year 1	Year 2	Year 3	Total Share
ADWR	30,000	30,000	30,000	90,000
Marana	7,500	7,500	7,500	22,500
Oro Valley	15,000	15,000	15,000	45,000
Metro Water	7,500	7,500	7,500	22,500
Pima County	20,000	20,000	20,000	60,000
USGS	60,200	60,200	60,200	180,600
Totals	140,200	140,200	140,200	420,600