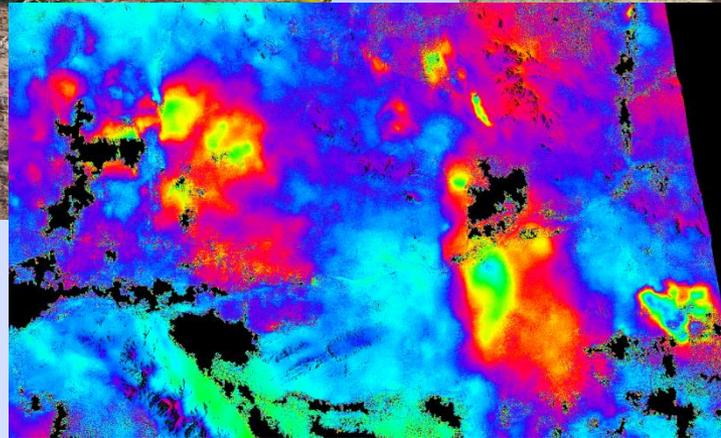


Arizona Department of Water Resources Land Subsidence Monitoring Program Interferometric Synthetic Aperture Radar (InSAR)



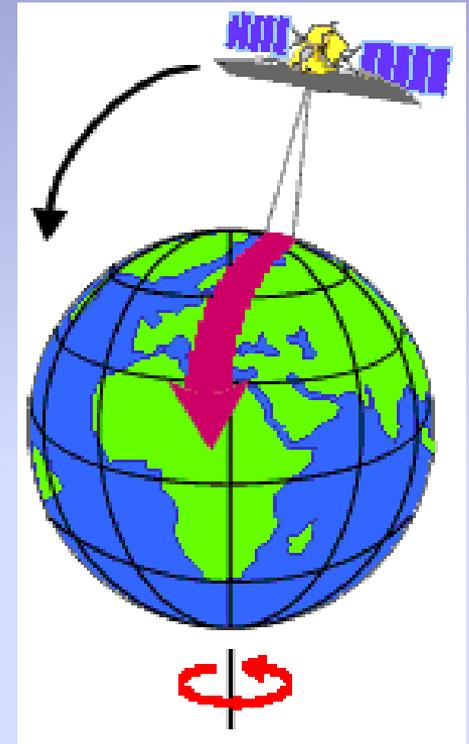
Brian D. Conway
Hydrologist/Supervisor
Geophysics-Surveying Unit



Phoenix AMA GUAC Meeting, September 10, 2015

Synthetic Aperture Radar (SAR)

- Active sensor (day/night/clouds)
- Near Circular, Polar Orbit
- Repeat cycle 8-46 days
- Satellites need to be tasked

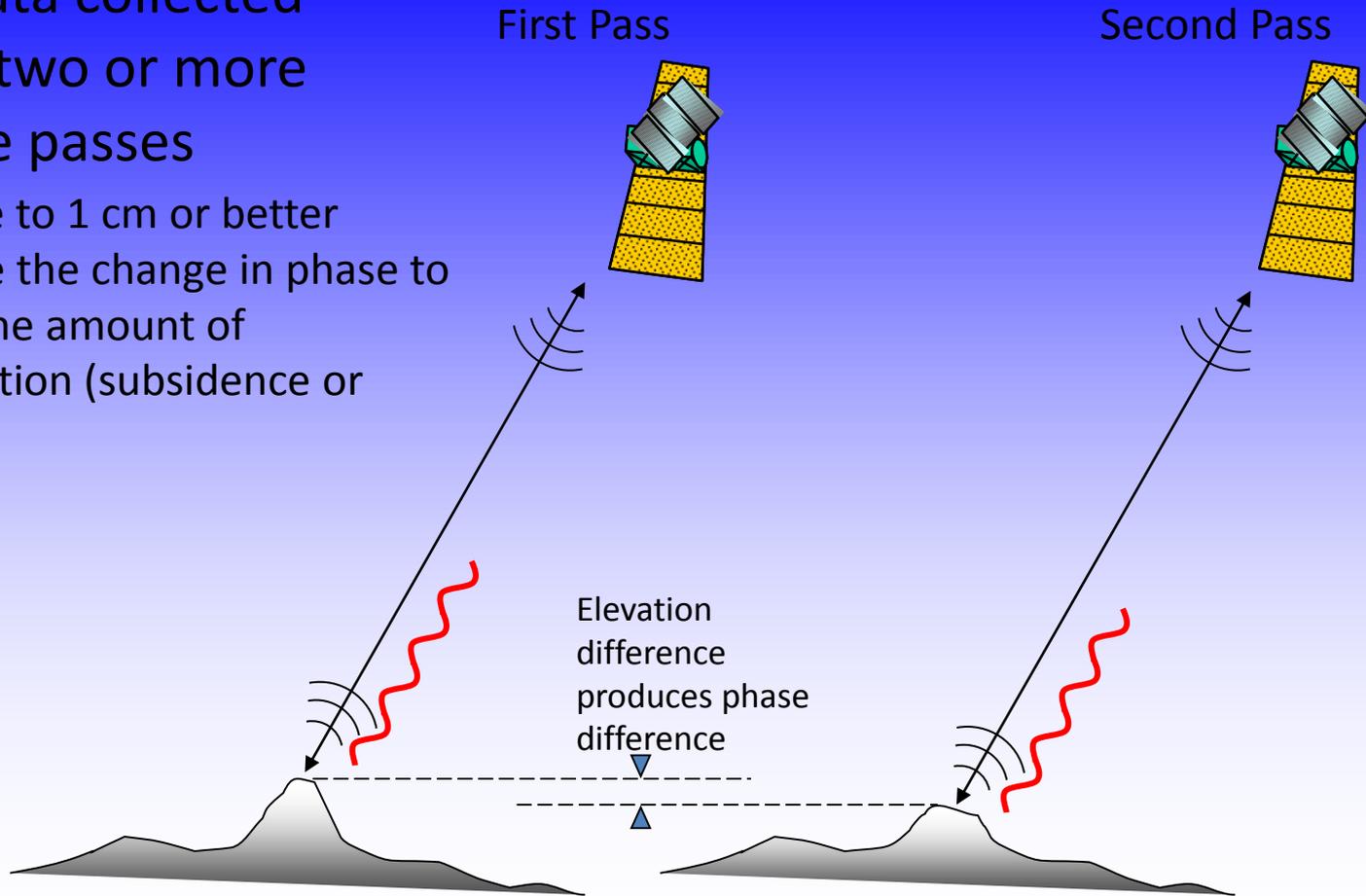


Differential Synthetic Aperture Radar (DiffSAR)

Process SAR Data Using Interferometry

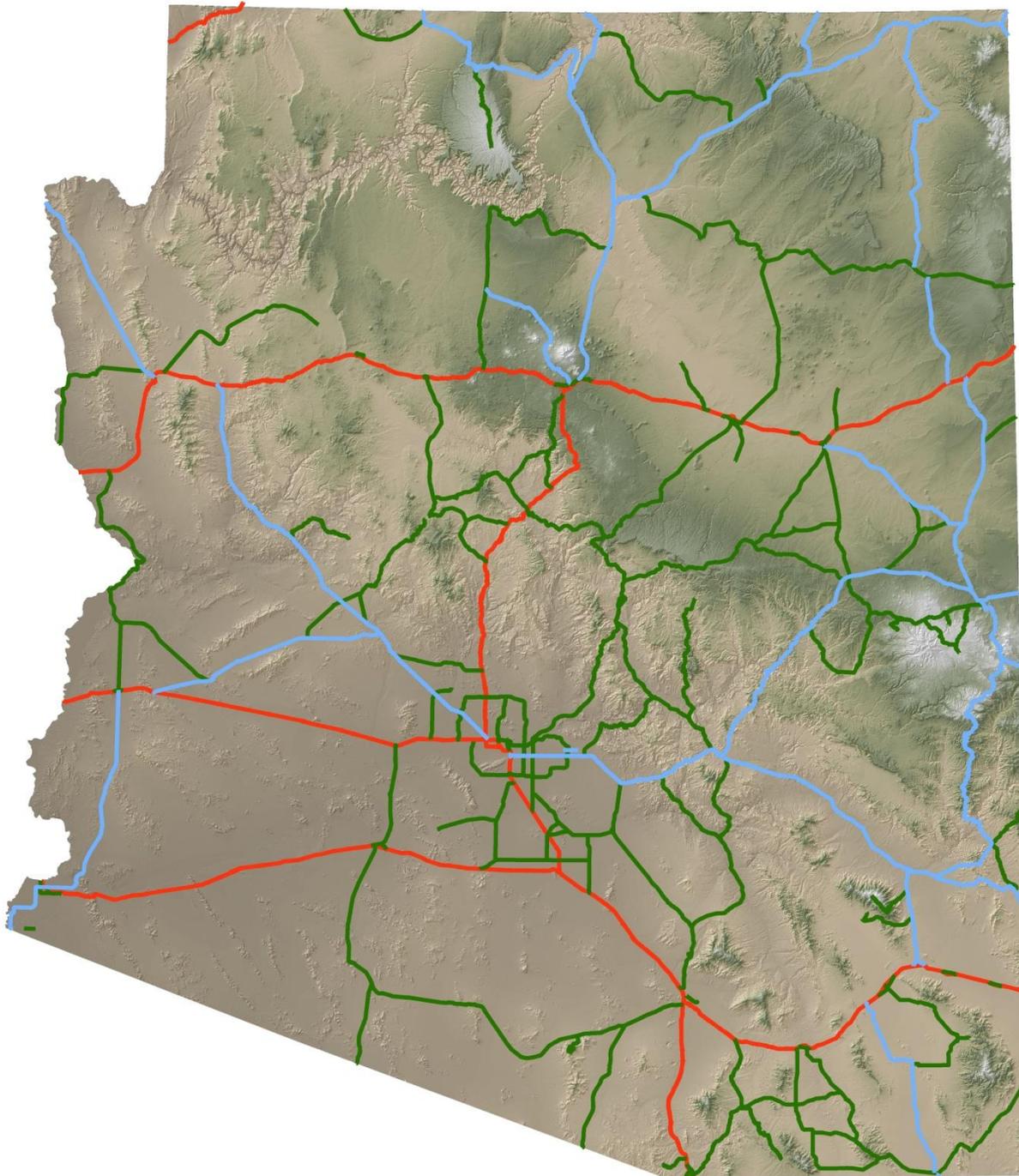
Uses data collected during two or more satellite passes

- Accurate to 1 cm or better
- Measure the change in phase to determine amount of deformation (subsidence or uplift)



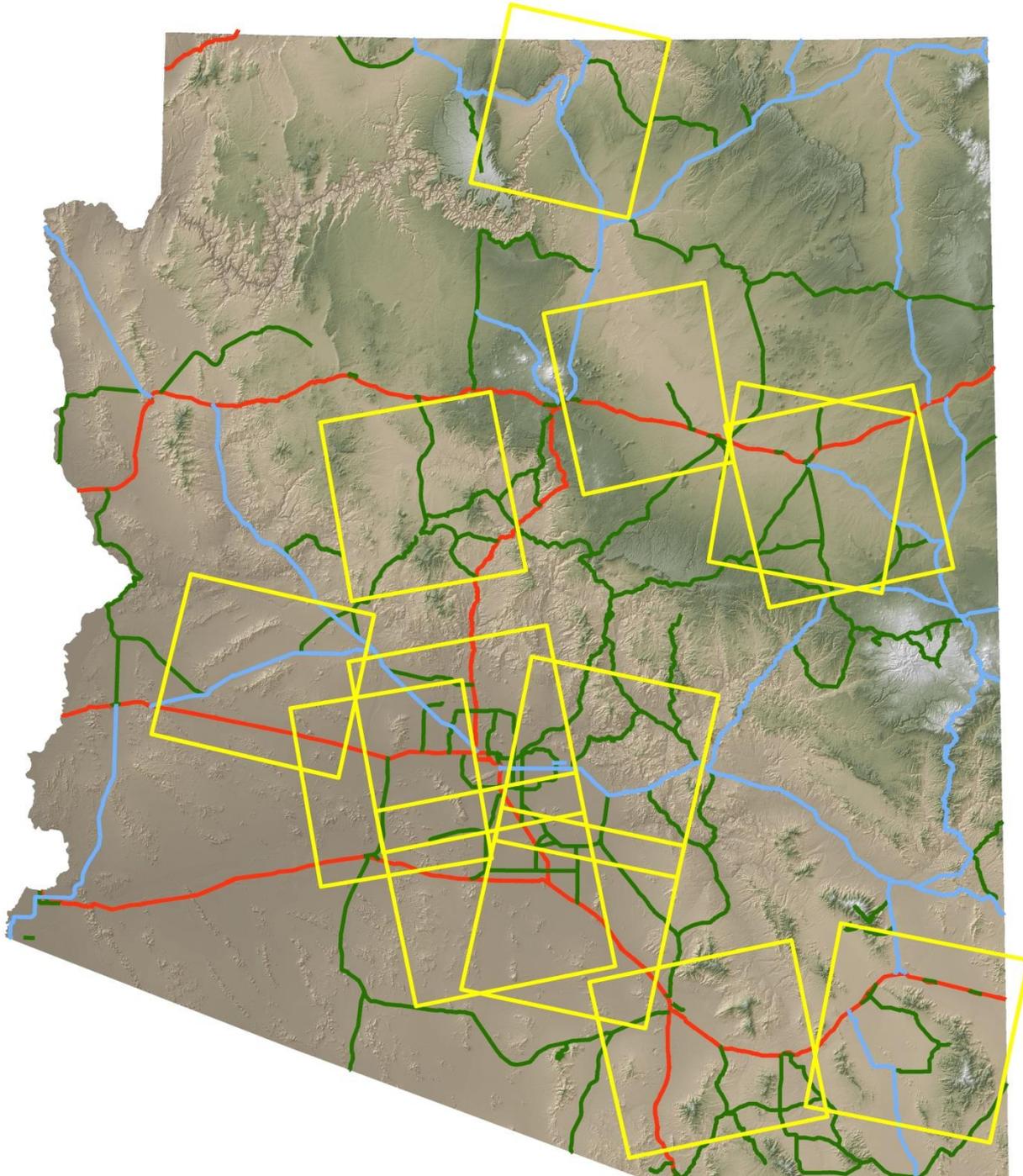
ADWR InSAR Program

- Fully Operational in 2005 (Completion of 3-Year NASA Grant)
- Started collecting data over the Phoenix and Tucson AMA's
- Program has been expanded to cover the entire state through external cooperative funding



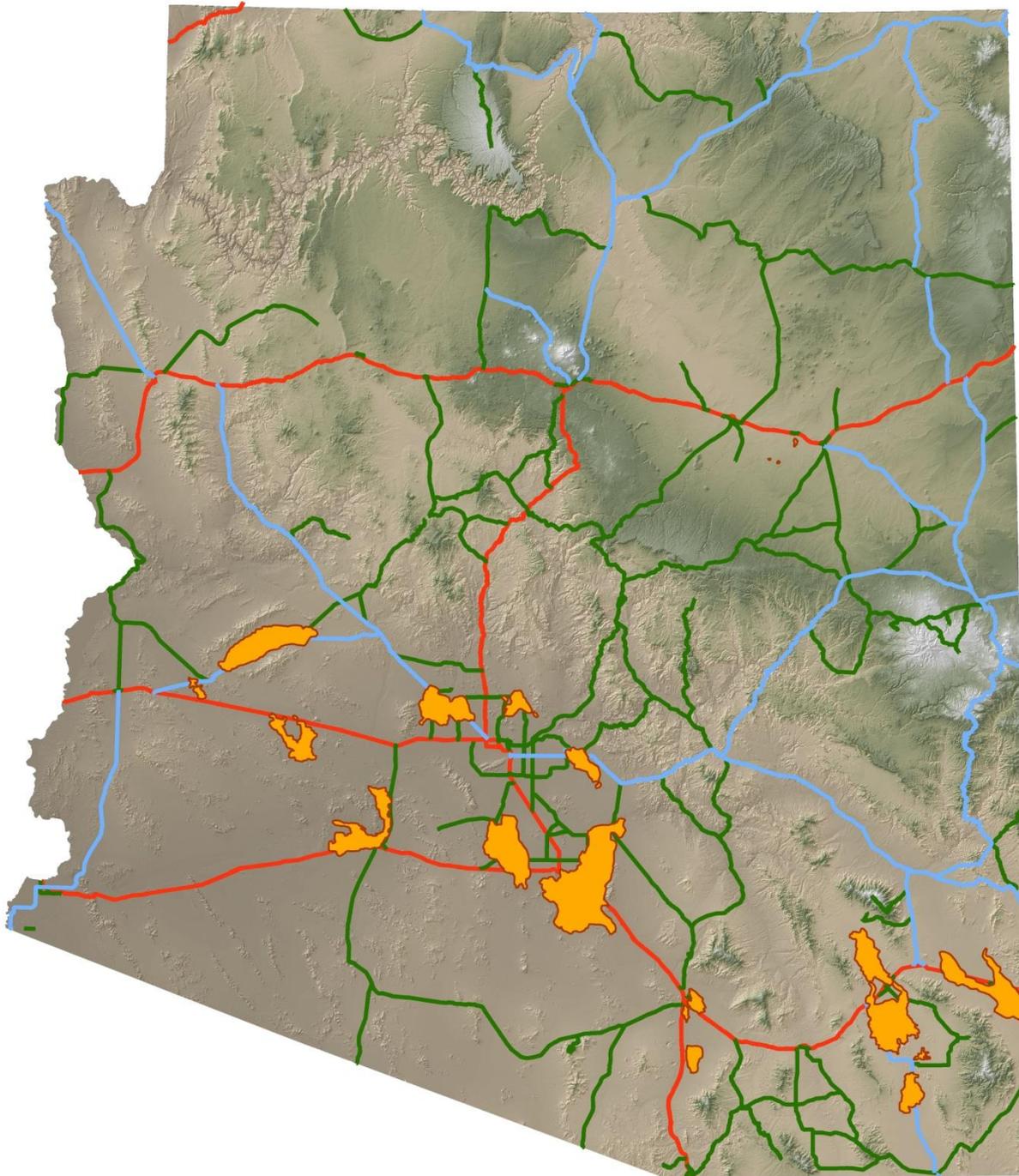
ADWR InSAR Program

- Program has been expanded to cover the entire state and fully funded through external cooperative agreements with 14 Federal, State, County, and Local Agencies
- Collect InSAR data over more than 50,000 square miles



ADWR InSAR Program

- Identified more than twenty-five individual land subsidence features that cover more than 2,800 square miles
- Provide land subsidence maps covering various periods of time on ADWR's website

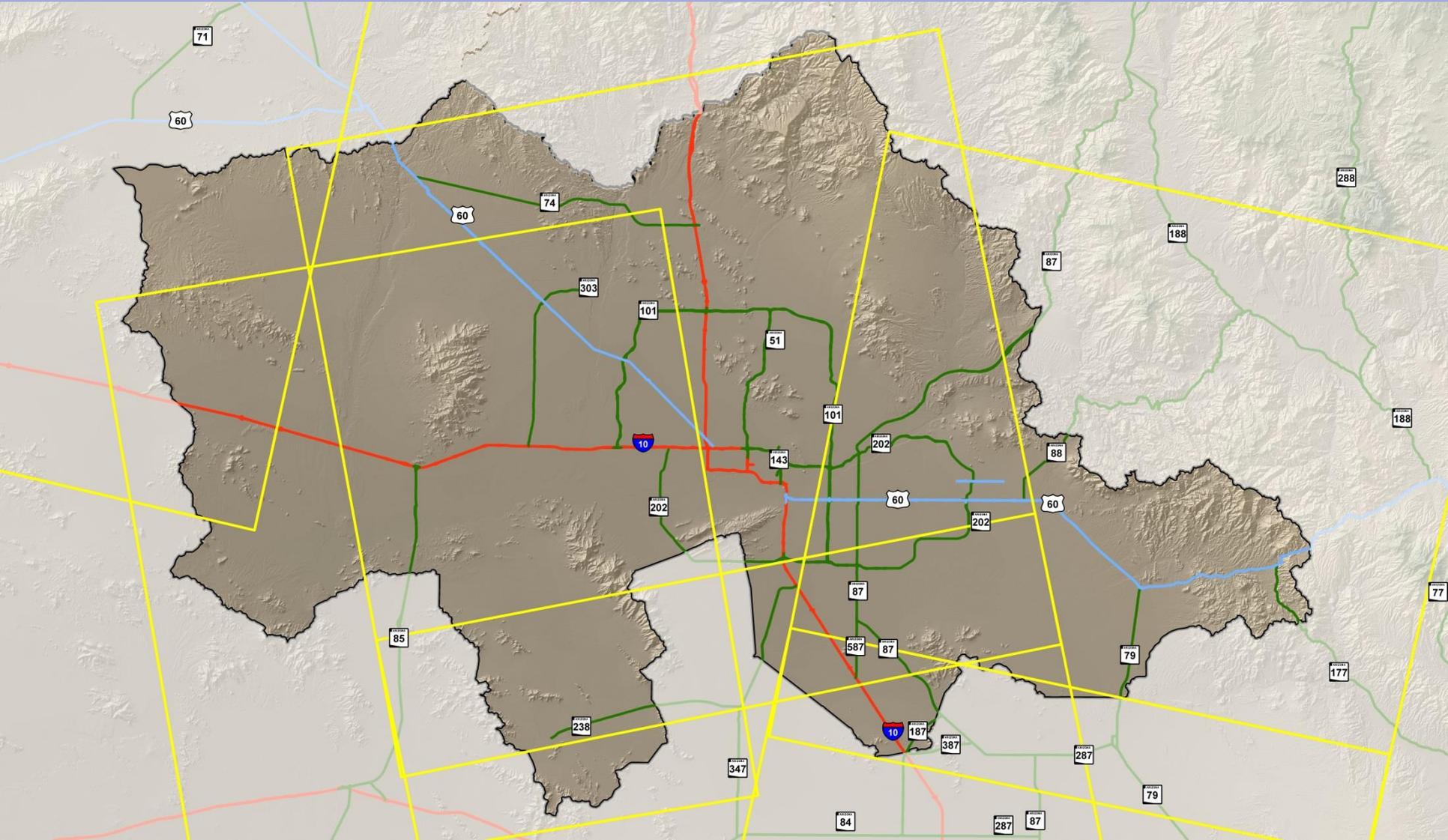


ADWR InSAR Program Cooperators

- **Flood Control District of Maricopa County**
- **Pinal County Flood Control District**
- **Arizona Department of Transportation**
- **Arizona State Land Department**
- **Central Arizona Project**
- **Metropolitan Domestic Water Improvement District**
- **Salt River Project**
- **Community Water Company**
- **City of Scottsdale**
- **Cochise County**
- **Arizona Geological Survey**
- **Petrified Forest National Park**
- **City of Phoenix**
- **City of Mesa**

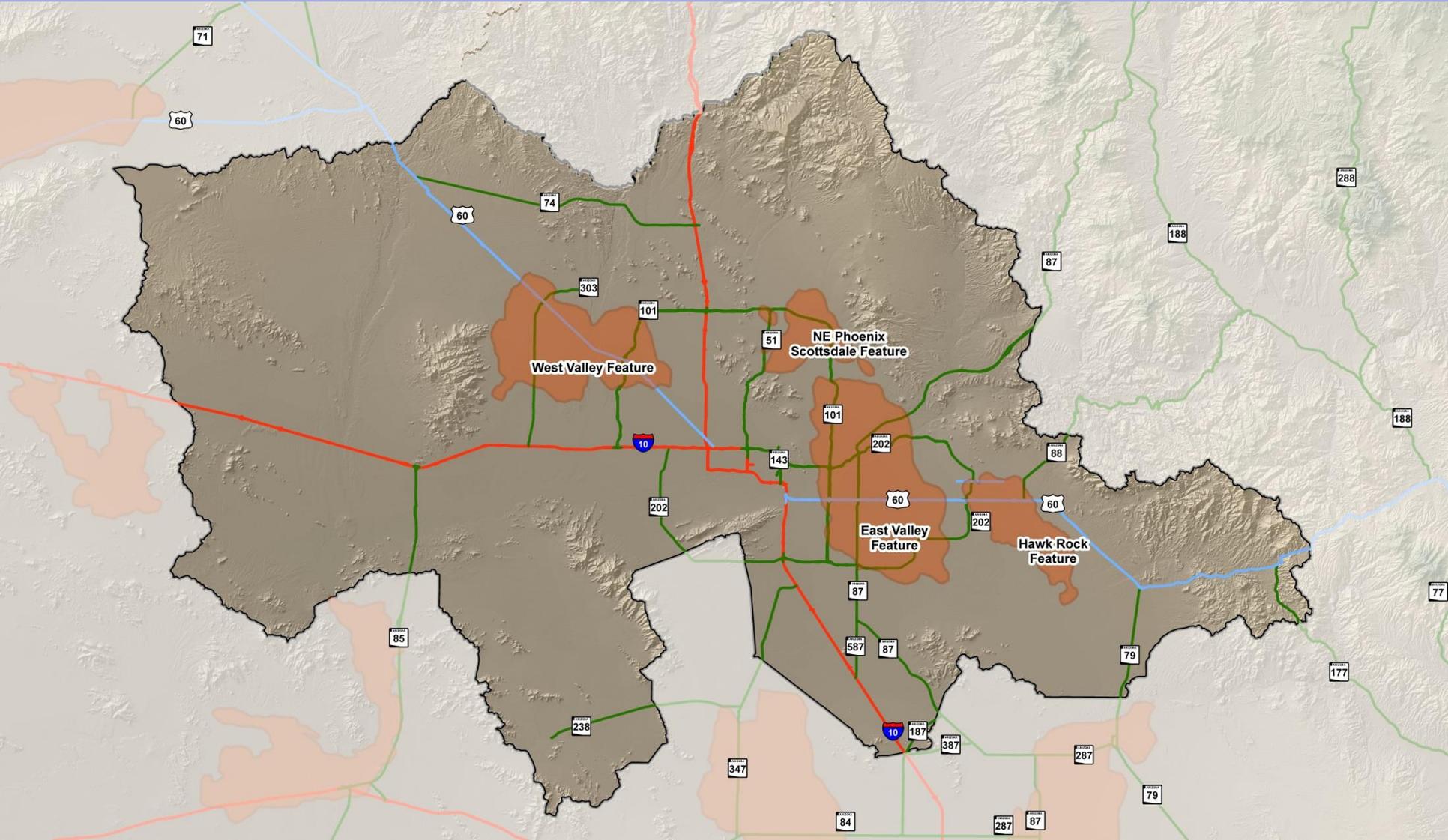
Land Subsidence Monitoring in the Phoenix AMA

InSAR Frames That Cover the Phoenix AMA



Land Subsidence Monitoring in the Phoenix AMA

Four Land Subsidence Features Identified and Being Monitored



ADWR's Land Subsidence Website

NEW! [Interactive Arizona Land Subsidence Map](#)

Arizona Land Subsidence Areas

Scottsdale/NE Phoenix	McMullen Valley	Picacho/Eloy	Fort Grant Rd
West Valley	Harquahala Valley	Maricopa-Stanfield	Kansas Settlement
Hawk Rock	Ranegras Valley	Tucson	Elfrida
Buckeye	Gila Bend	Green Valley	Bowie/San Simon
Holbrook Sinks	East Valley		

What is Land Subsidence



Active Land Subsidence Areas in Arizona
Based on ADWR InSAR Data

Land subsidence has been occurring across Arizona since the early 1900's. Millions of people around the world live in active land subsidence areas and are unaware. Most of the time, there is no clear and identifiable sign that land subsidence has occurred in an area. Areas in Maricopa and Pinal Counties have subsided more than eighteen feet since the early 1900's.

Land subsidence in the basins of Arizona is generally due to compaction of the alluvium caused by lowering of the water table. As the water table declines, pores in the alluvium once held open by water pressure are no longer supported and collapse. Collapse and subsequent lowering in elevation of the land surface is defined as land subsidence. This subsidence is generally not recoverable. If this subsidence occurs over areas of bedrock, differential subsidence can occur.

Differential subsidence is when adjacent areas subside at different rates. Bedrock will not compress like the surrounding alluvium, creating a subsurface platform. Differential subsidence occurs where shallow bedrock and deep bedrock are adjacent to each other, creating a zone of differential change in surface elevation. Because of these different amounts of subsidence, tension can build in the alluvium layer at this differential subsidence zone, forming an earth fissure.

ADWR's Land Subsidence Website

NEW! Interactive Arizona Land Subsidence Map

Arizona Land Subsidence Areas

Scottsdale/NE Phoenix	McMullen Valley	Picacho/Eloy	Fort Grant Rd
West Valley	Harquahala Valley	Maricopa-Stanfield	Kansas Settlement
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Holbrook Sinks	East Valley		

Click on Land Subsidence Feature

What is Land Subsidence



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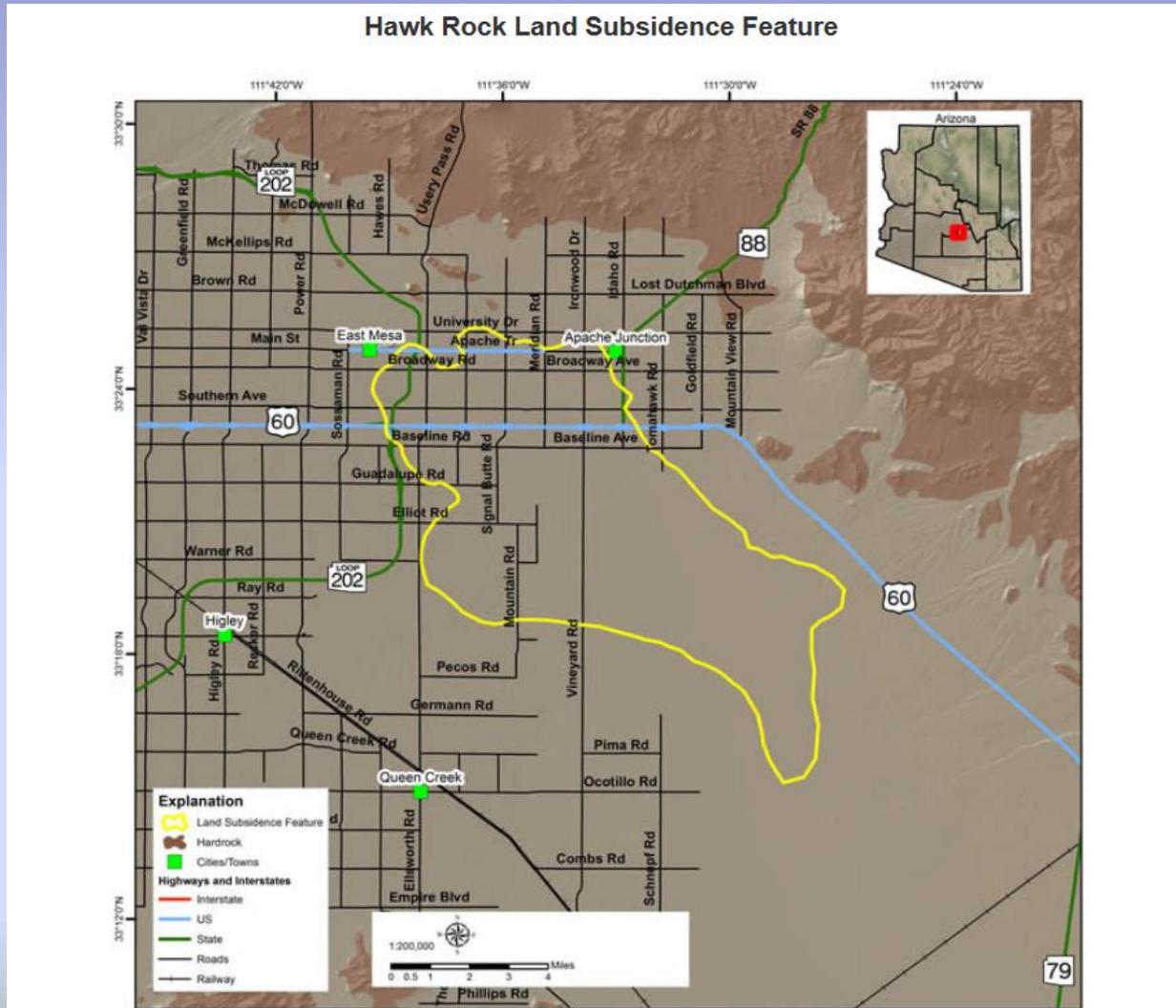
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ADWR's Land Subsidence Website

Example of a Land Subsidence Feature Webpage

Hawk Rock Land Subsidence Feature



The Hawk Rock land subsidence feature is located in Eastern Maricopa and Western Pinal Counties. The cities of Mesa and Apache Junction are located within the land subsidence feature along with unincorporated State Trust and private lands.

ADWR's Land Subsidence Website

Example of a Land Subsidence Feature Webpage

Hawk Rock Land Subsidence Feature

List of Available Land Subsidence Maps

Land Subsidence Rate Maps:

The land subsidence rate maps show the rate of land subsidence per year (cm/yr). These maps are used to illustrate any changes in land subsidence rates over time. All the land subsidence rate maps utilize the same color scale.

MAY-1992 to NOV-2000 	FEB-2009 to MAR-2010 	MAR-2013 to MAR-2014 
MAR-2014 to APR-2015 		

Land Subsidence Maps:

The land subsidence maps show the total land subsidence (cm) over a specific period of time (1-year, 2-year, 4-year, etc). All the land subsidence maps utilize the same color scale.

MAY-1992 to APR-2000 	FEB-2007 to APR-2008 	JAN-2008 to MAR-2010 
JAN-2004 to SEP-2010 	FEB-2007 to MAR-2009 	FEB-2009 to MAR-2010 
FEB-2006 to APR-2008 	JAN-2008 to FEB-2009 	MAY-2010 to MAY-2011 
MAR-2011 to APR-2012 	MAY-2010 to APR-2012 	MAR-2011 to APR-2013 
APR-2012 to APR-2013 	MAY-2010 to APR-2013 	APR-2012 to MAR-2014 
MAR-2013 to MAR-2014 	MAY-2010 to MAR-2014 	APR-2013 to APR-2015 
MAR-2014 to APR-2015 	MAY-2010 to APR-2015 	

ADWR's Land Subsidence Website

Example of an Land Subsidence Feature Webpage

Hawk Rock Land Subsidence Feature

List of Available Land Subsidence Maps

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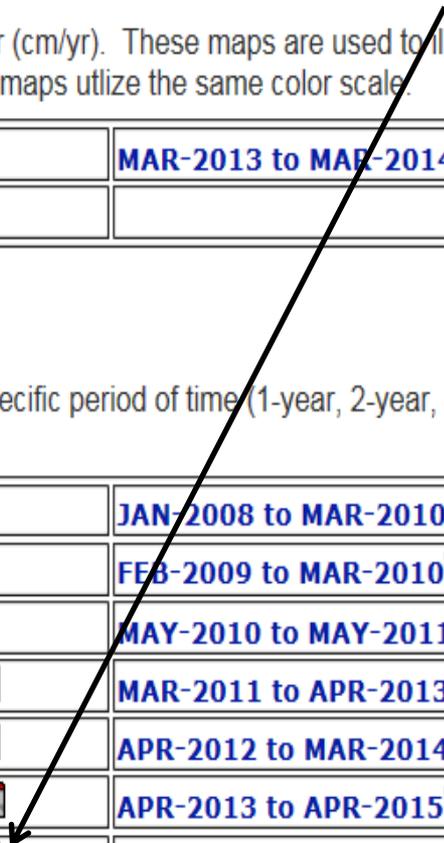
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MAY-1992 to APR-2000 	FEB-2007 to APR-2008 	JAN-2008 to MAR-2010 
JAN-2004 to SEP-2010 	FEB-2007 to MAR-2009 	FEB-2009 to MAR-2010 
FEB-2006 to APR-2008 	JAN-2008 to FEB-2009 	MAY-2010 to MAY-2011 
MAR-2011 to APR-2012 	MAY-2010 to APR-2012 	MAR-2011 to APR-2013 
APR-2012 to APR-2013 	MAY-2010 to APR-2013 	APR-2012 to MAR-2014 
MAR-2013 to MAR-2014 	MAY-2010 to MAR-2014 	APR-2013 to APR-2015 
MAR-2014 to APR-2015 	MAY-2010 to APR-2015 	

Click on Land Subsidence Map



ADWR InSAR Program

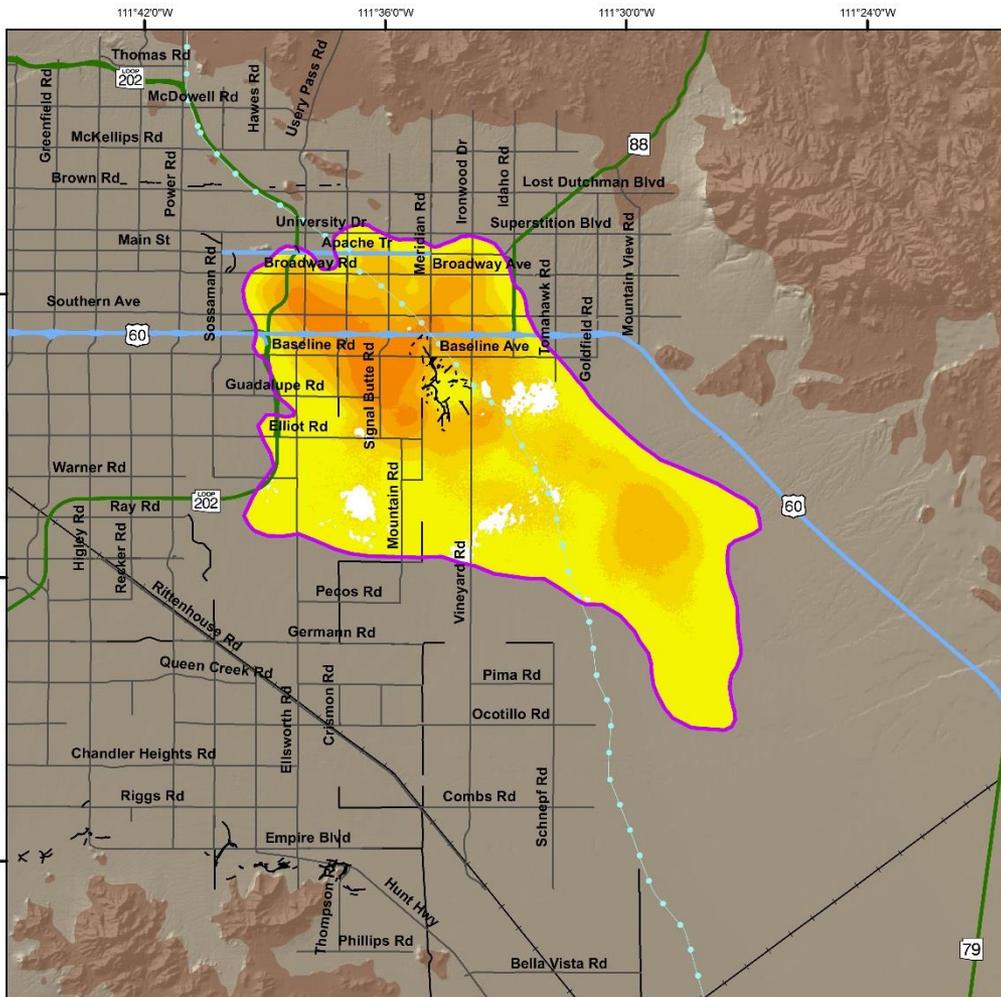
An example of a land subsidence PDF map: Hawk Rock 2010-2015

Land subsidence as high as 8.7 cm in 5-years

Land subsidence rates have been declining when compared to data from the 1990's

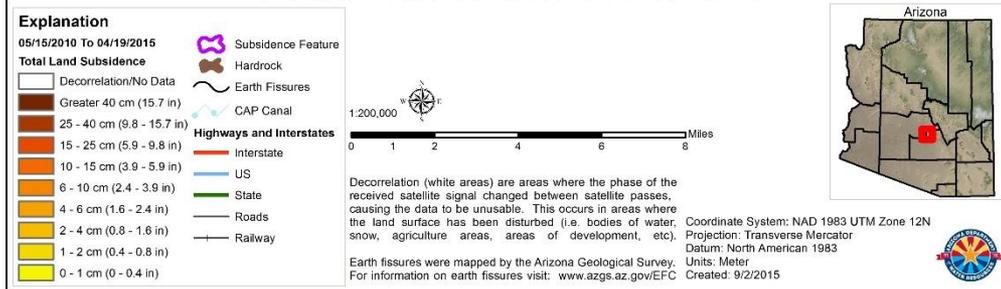
Land subsidence maps are updated annually (late spring/early summer)

As of May 2015, more than 240 land subsidence maps are available online



Total Land Subsidence in the Hawk Rock Area, Maricopa and Pinal Counties
Based on Radarsat-2 Satellite Interferometric Synthetic Aperture Radar (InSAR) Data
Time Period of Analysis: 5.0 Years 05/15/2010 To 04/19/2015

© MDA 2010 - 2015

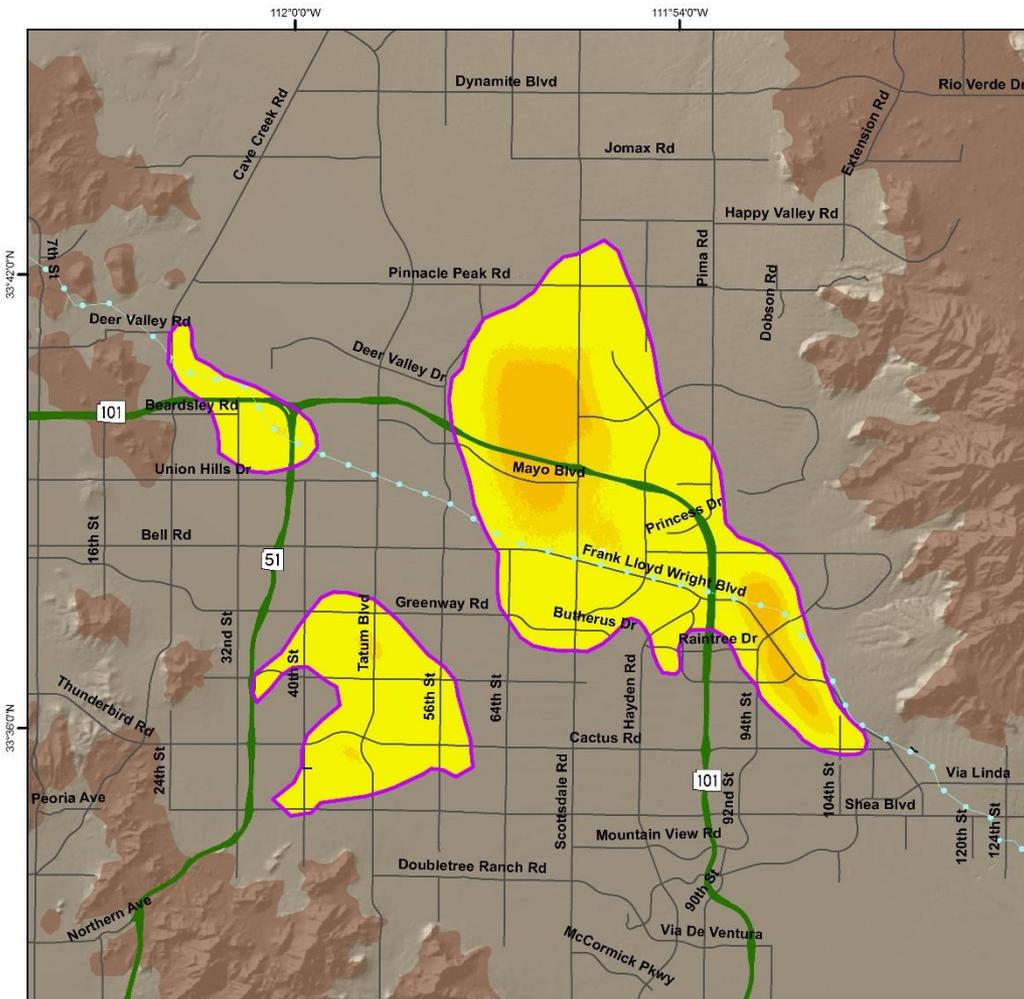


ADWR InSAR Program

Northeast Phoenix/Scottsdale 2010-2015 map

Land subsidence as high as 4 cm in 5-
years

Land subsidence rates have been
declining when compared to data
from the 1990's



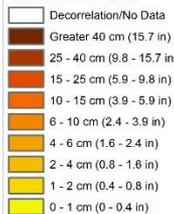
Total Land Subsidence in the Northeast Phoenix and Scottsdale Areas, Maricopa County
Based on Radarsat-2 Satellite Interferometric Synthetic Aperture Radar (InSAR) Data
Time Period of Analysis: 5.0 Years 05/08/2010 To 04/12/2015

© MDA 2010 - 2015

Explanation

05/08/2010 To 04/12/2015

Total Land Subsidence



Decorrelation (white areas) are areas where the phase of the received satellite signal changed between satellite passes, causing the data to be unusable. This occurs in areas where the land surface has been disturbed (i.e. bodies of water, snow, agriculture areas, areas of development, etc).

Earth fissures were mapped by the Arizona Geological Survey. For information on earth fissures visit: www.azgs.gov/EFC

Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Created: 9/2/2015

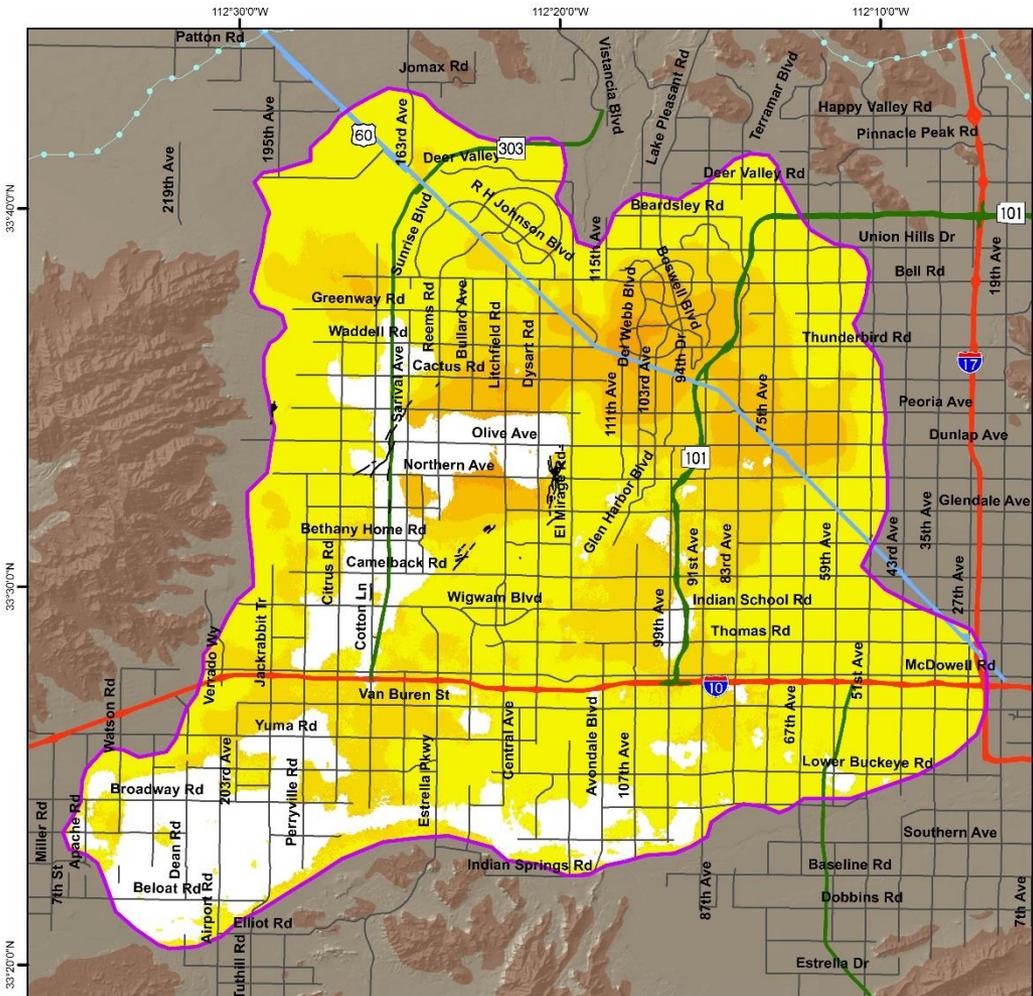


ADWR InSAR Program

West Valley 2010-2015 map

Land subsidence as high as 6.6 cm in 5-years

Land subsidence rates have been declining when compared to data from the 1990's



Total Land Subsidence in Western Metropolitan Phoenix, Maricopa County
 Based on Radarsat-2 Satellite Interferometric Synthetic Aperture Radar (InSAR) Data
 Time Period of Analysis: 5.0 Years 05/08/2010 To 04/12/2015

Explanation

05/08/2010 To 04/12/2015

Total Land Subsidence

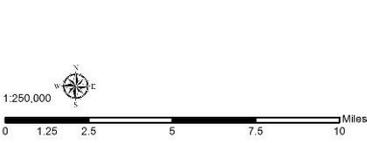
White	Decorrelation/No Data
Dark Red	Greater 40 cm (15.7 in)
Red-Orange	25 - 40 cm (9.8 - 15.7 in)
Red	15 - 25 cm (5.9 - 9.8 in)
Dark Orange	10 - 15 cm (3.9 - 5.9 in)
Orange	6 - 10 cm (2.4 - 3.9 in)
Light Orange	4 - 6 cm (1.6 - 2.4 in)
Yellow-Orange	2 - 4 cm (0.8 - 1.6 in)
Yellow	1 - 2 cm (0.4 - 0.8 in)
Light Yellow	0 - 1 cm (0 - 0.4 in)

Highways and Interstates

- Red line: Interstate
- Blue line: US
- Green line: State
- Black line: Roads

Other Features

- Purple outline: Subsidence Feature
- Brown shape: Hardrock
- Blue dashed line: Earth Fissures
- Blue dashed line: CAP Canal



Decorrelation (white areas) are areas where the phase of the received satellite signal changed between satellite passes, causing the data to be unusable. This occurs in areas where the land surface has been disturbed (i.e. bodies of water, snow, agriculture areas, areas of development, etc).

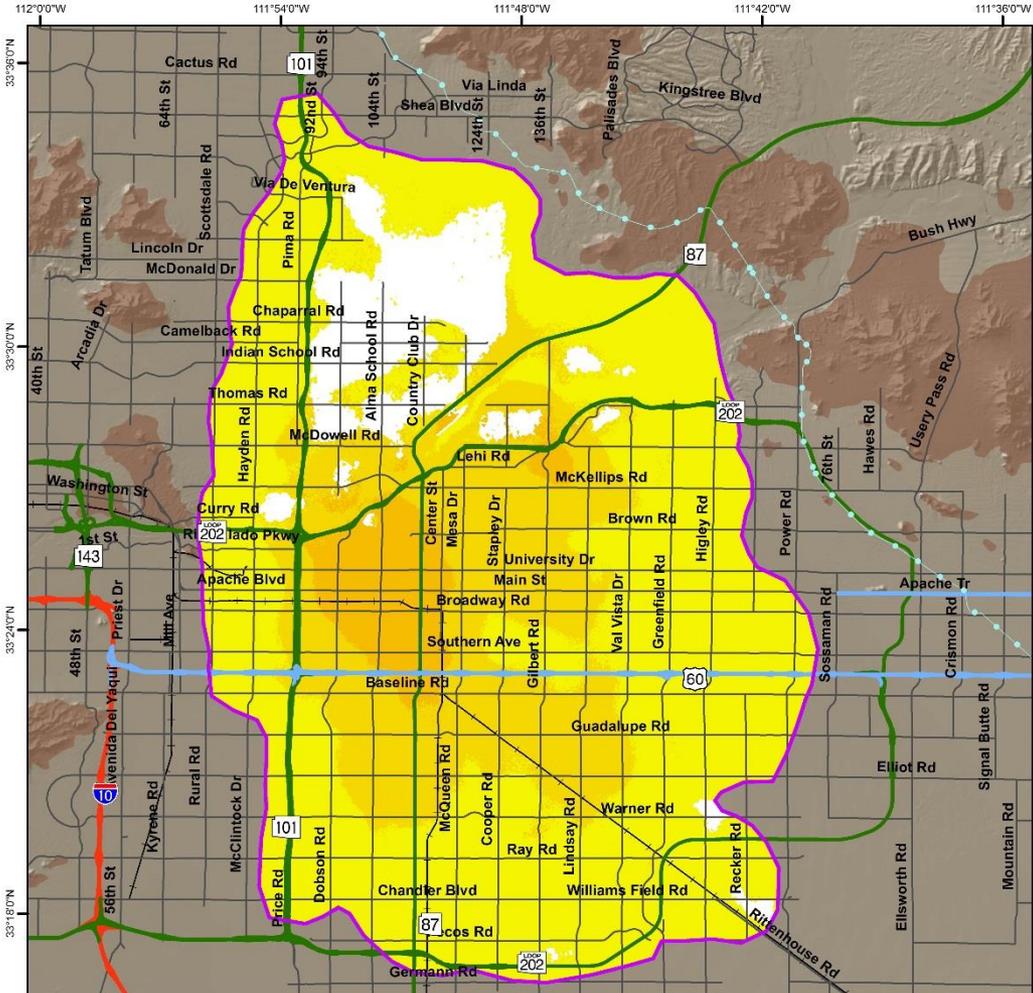
Coordinate System: NAD 1983 UTM Zone 12N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter
 Earth fissures were mapped by the Arizona Geological Survey. For information on earth fissures visit: www.azgs.gov/EFC
 Created: 9/2/2015



ADWR InSAR Program

East Valley 2011-2015 map

Land subsidence as high as 4.4 cm in 3.4-years



Total Land Subsidence in Eastern Metropolitan Phoenix, Maricopa County
 Based on Radarsat-2 Satellite Interferometric Synthetic Aperture Radar (InSAR) Data
 Time Period of Analysis: 3.4 Years 11/11/2011 To 04/12/2015

© MDA 2011 - 2015

Explanation

11/11/2011 To 04/12/2015

Total Land Subsidence

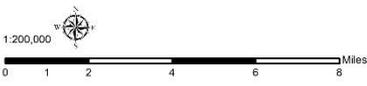
- Decorrelation/No Data
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- 25 - 40 cm (9.8 - 15.7 in)
- 15 - 25 cm (5.9 - 9.8 in)
- 10 - 15 cm (3.9 - 5.9 in)
- 6 - 10 cm (2.4 - 3.9 in)
- 4 - 6 cm (1.6 - 2.4 in)
- 2 - 4 cm (0.8 - 1.6 in)
- 1 - 2 cm (0.4 - 0.8 in)
- 0 - 1 cm (0 - 0.4 in)

Subsidence Feature

- Subsidence Feature
- Hardrock
- CAP Canal

Highways and Interstates

- Interstate
- US
- State
- Roads
- Railway



Decorrelation (white areas) are areas where the phase of the received satellite signal changed between satellite passes, causing the data to be unusable. This occurs in areas where the land surface has been disturbed (i.e. bodies of water, snow, agriculture areas, areas of development, etc).

Coordinate System: NAD 1983 UTM Zone 12N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter
 Created: 9/2/2015



The Future of ADWR's InSAR Program

- ADWR has the largest State operated InSAR program in the U.S. and will continue to collect InSAR data through out State.
- ADWR will continue to work with it's InSAR cooperators and stakeholders, providing land subsidence products for their own monitoring, modeling, mitigation, and planning needs.
- ADWR will continue to update land subsidence maps on it's website each spring using the most recent InSAR data.
- ADWR continues to look for additional InSAR cooperators in the Phoenix AMA to help fund data collection for the AMA.

Questions?

Brian D. Conway

bdconway@azwater.gov

602.771.8667



*NASA UAVSAR Platform on
a Gulfstream III Aircraft*

Image Courtesy of NASA