Flood Risk Analysis: Potential Impacts of Climate Change on the Upper Calabacillas Arroyo

Prepared by Gerhard Schoener, Watershed Scientist
Southern Sandoval County Arroyo and Flood Control Authority

1. Background

The *Central New Mexico Climate Change Scenario Planning Project*, led by the Mid-Region Council of Governments (MRCOG) and the U.S. Department of Transportation's Volpe Center, analyzed strategies to prepare for the impacts of climate change in the greater Albuquerque area. One of the anticipated impacts of climate change is an increase in the magnitude and frequency of extreme precipitation events, leading to an increase in extreme floods. The Southern Sandoval Country Arroyo Flood Control Authority (SSCAFCA) conducted a case study to assess potential implications for existing and future urban development, infrastructure, and public safety, in the upper Calabacillas Arroyo.

The first step in this study was to determine if a link could be established between climate change and increased flood risk based on general circulation models. Once established, SSCAFCA applied factors by which the 100-year flood event may increase over time and modeled the assumed increase in storm magnitude through hydrologic and hydraulic models for the Calabacillas Arroyo watershed.

Baseline Climate Model Data

Global climate models, or general circulation models (GCM) are global scale atmospheric and ocean circulation models used to estimate changes in temperature and precipitation, among other variables, as a result of increased greenhouse gas concentrations in the atmosphere. The World Climate Research Programme's Coupled Model Intercomparison Project Phase 5 (CMIP 5) represents an archive for output from GCM runs by different models for different emissions scenarios. These results (typical spatial unit of one or two degrees square) have been bias corrected and spatially downscaled to 1/8th degree square (approximately 56 square miles) based on historic point observations. Downscaled CMIP 5 data for one grid cell in the SSCAFCA/ City of Rio Rancho area was obtained from the website http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/ (see Figure 1).

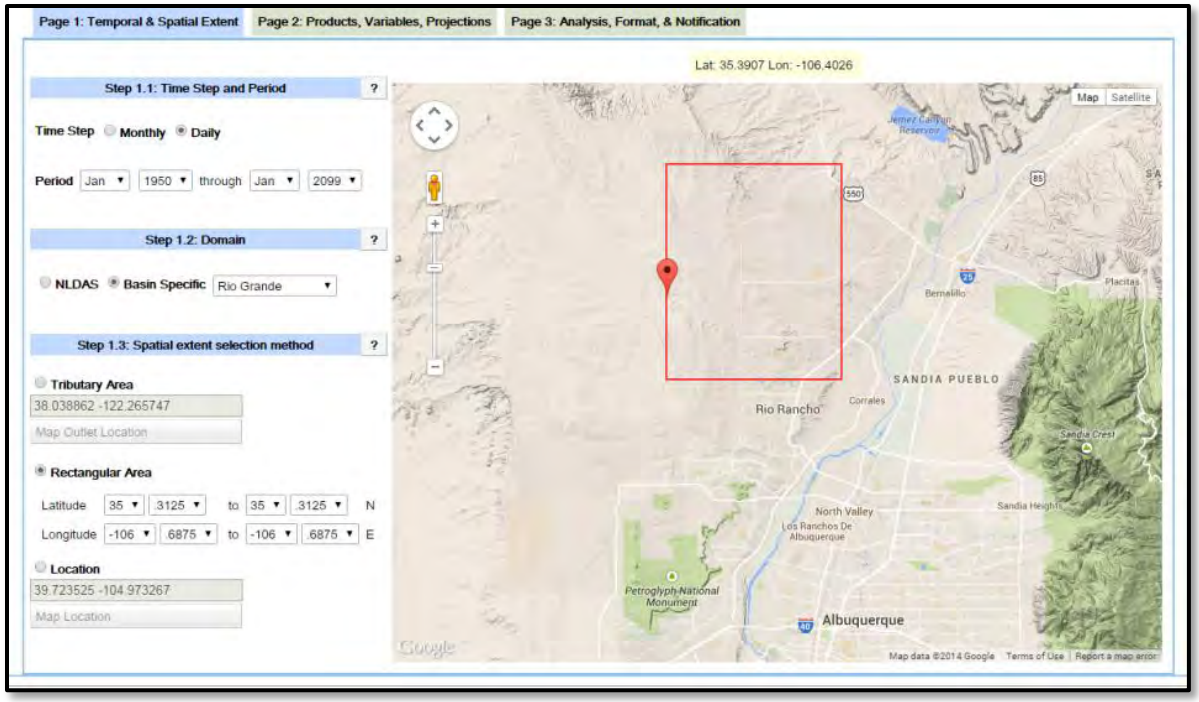
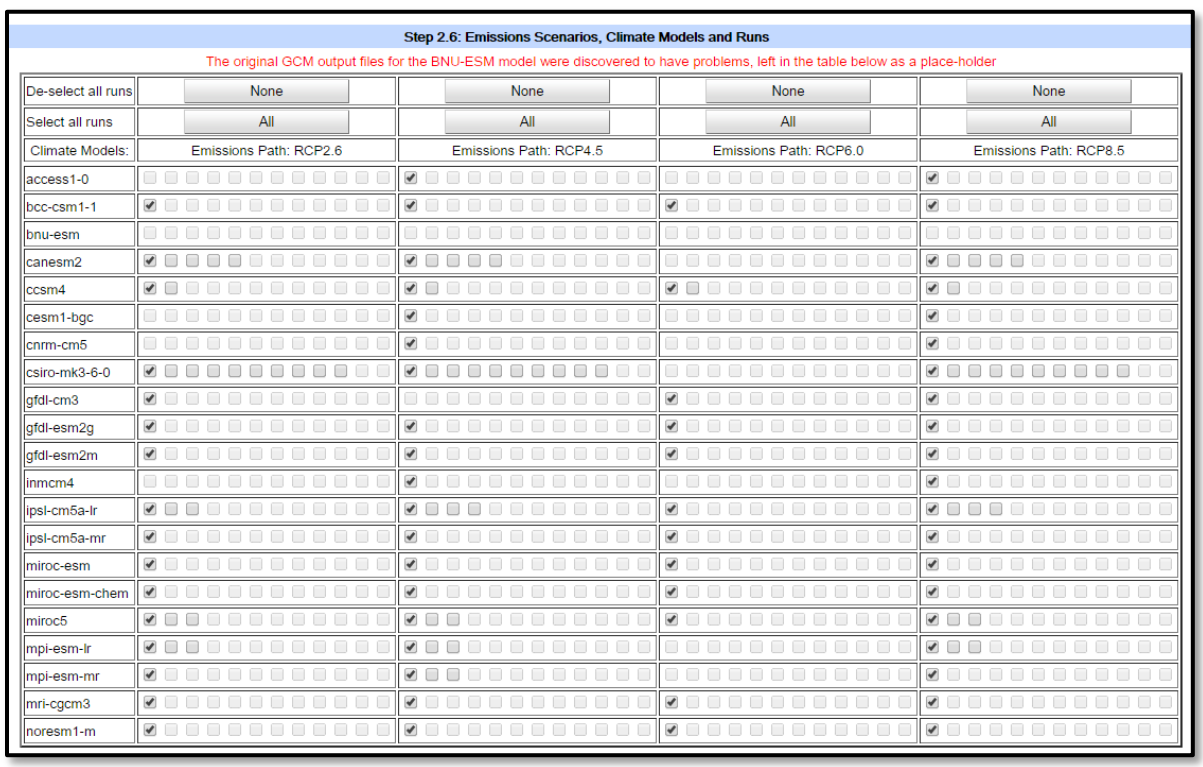


Figure 1: Spatial extent of the 1/8th degree model grid cell analyzed in this study

A total of 67 different GCM model runs with precipitation data at a daily time step were available for the time period 1950-2099 (see Figure 2).



Step 2.6: Emissions Scenarios, Climate Models and Runs

The original GCM output files for the BNU-ESM model were discovered to have problems, left in the table below as a place-holder

De-select all runs	None	None	None	None
Select all runs	All	All	All	All
Climate Models:	Emissions Path: RCP2.6	Emissions Path: RCP4.5	Emissions Path: RCP6.0	Emissions Path: RCP8.5
access1-0	☐	☑	☐	☑
bcc-csm1-1	☑	☑	☑	☑
bnu-esm	☐	☐	☐	☐
canesm2	☑	☑	☐	☑
ccsm4	☑	☑	☑	☑
cesm1-bgc	☐	☑	☐	☑
cnrm-cm5	☐	☑	☐	☑
csiro-mk3-6-0	☑	☑	☐	☑
gfdl-cm3	☑	☐	☑	☑
gfdl-esm2g	☑	☑	☑	☑
gfdl-esm2m	☑	☑	☑	☑
inmcm4	☐	☑	☐	☑
ipsl-cm5a-lr	☑	☑	☑	☑
ipsl-cm5a-mr	☑	☑	☑	☑
miroc-esm	☑	☑	☑	☑
miroc-esm-chem	☑	☑	☑	☑
miroc5	☑	☑	☑	☑
mpi-esm-lr	☑	☑	☐	☑
mpi-esm-mr	☑	☑	☐	☑
mri-cgcm3	☑	☑	☑	☑
noresm1-m	☑	☑	☑	☑

Figure 2: GCM models and emissions scenarios used for the analysis.

2. Methods

To analyze changes in precipitation patterns over time, an annual maximum series (highest annual 24-hour rainfall) was assembled for each GCM run for the historic period (1950-1999). The annual maximum series were utilized to estimate the 100-year 24-hour storm using the Extreme Value Type I Distribution. Using the same approach, 100-year 24-hour precipitation values were estimated for each GCM run for the periods 2000-2049 and 2050-2099.[1]

Figure 3 shows boxplots of the percent change in the 100-year 24-hour precipitation value for both future time periods compared to the historic period for each of the 67 GCM model runs.

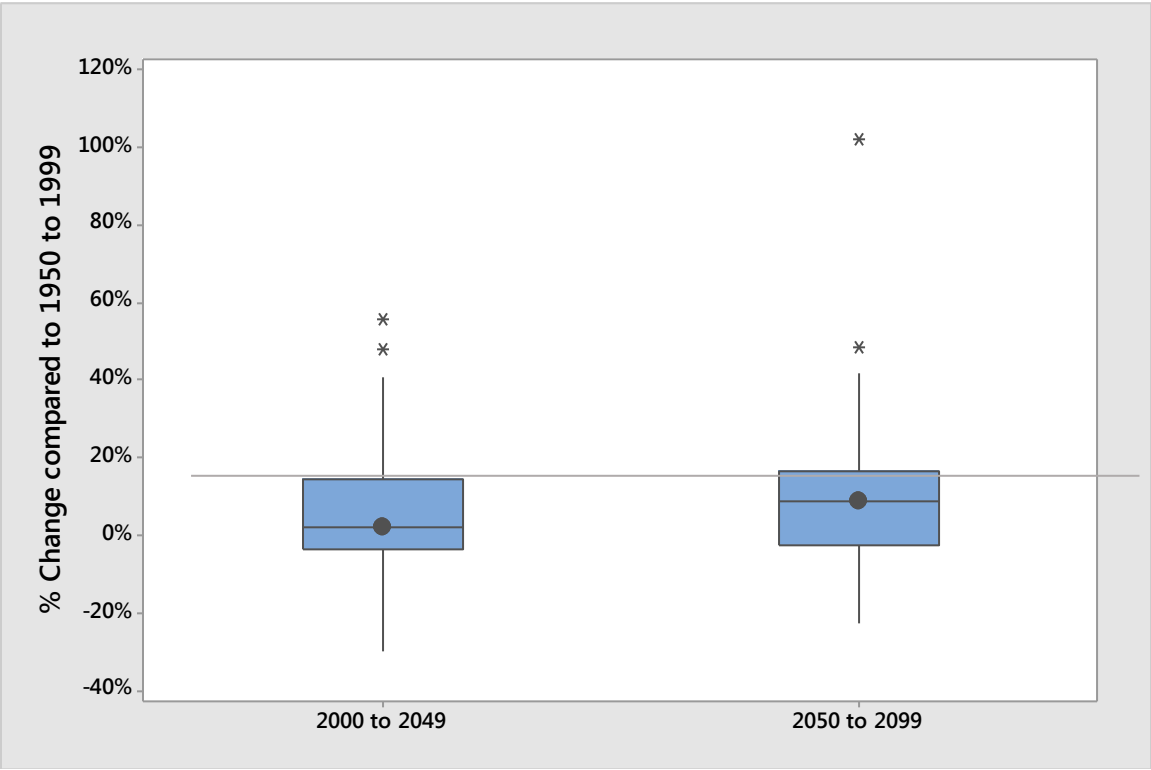


Figure 3: Box plots of the percent change in 100-year 24-hr precipitation from 67 GCM runs for one 1/8 degree grid cell (56 square miles) in Sandoval County.

The comparison shows a small increase in the median 100-year 24-hour precipitation value for the period ending in 2049 (not statistically significant), and a significant increase for the latter time period. The median percent increase for the time period 2050-2099 was 10 percent, with the 95 percent confidence interval ranging from approximately 1 percent to 15 percent (confidence interval based on the non-parametric sign test).

Precipitation projections based on climate models are associated with large uncertainties; rather than focus on the absolute magnitude of the increase, it is noteworthy that many of the GCM runs predict an increase in precipitation variability and extreme events. It is also worth noting that this case study

[1] This methodology was devised by Jesse Roach, at the time with Sandia National Labs, for use in the analysis of CMIP data in the Central New Mexico Climate Change Project.

analyzed only one model grid cell (56 square miles), but results predicting increased magnitude of extreme events are consistent with other studies (Bureau of Reclamation, 2013).

In short, CMIP-5 data establishes that there is a need to prepare for more extreme precipitation events, even though the exact magnitude of increase cannot be determined due to uncertainty in the data. To assess the impacts of climate change on variable precipitation and greater flood risks, SSCAFCA assessed the impacts of hypothetical storm events on the Calabacillas Watershed.

Case Study of Potential Climate Change Impacts

Potential impacts of increasing extreme events were explored using the Calabacillas Watershed, located in Sandoval and Bernalillo Counties, New Mexico (see Figure 4).

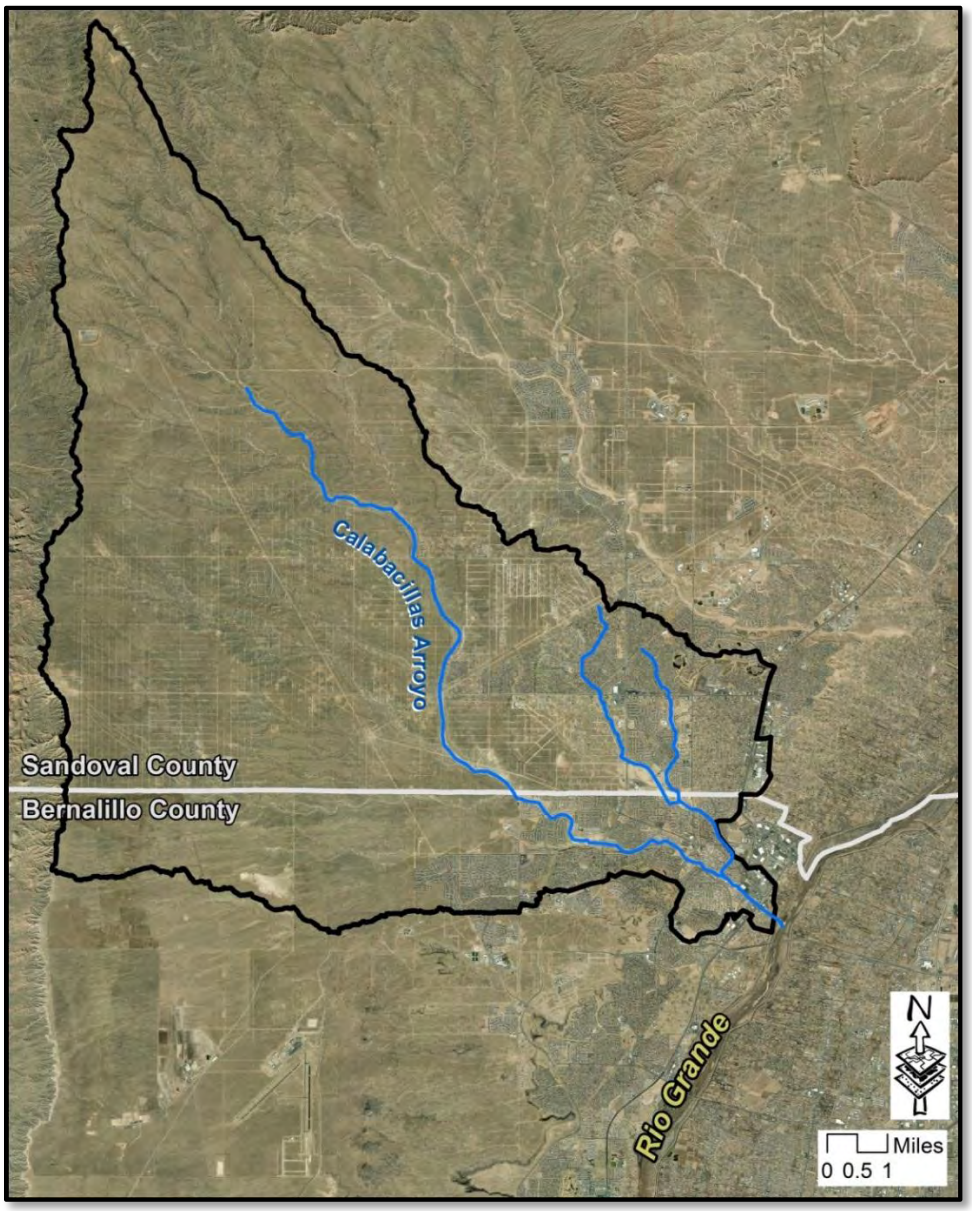


Figure 4: The Calabacillas Watershed (black outline) drains to the Rio Grande from the west.

A hydrologic model for the upper portion of the watershed was developed by SSCAFCA in cooperation with the Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA) as part of a regional watershed management plan (SSCAFCA, 2014).

To assess the potential impacts of increased extreme rain events on the Calabacillas Watershed, the hydrologic model was run using three different scenarios:

- The 100-year 24-hour design storm, a hypothetical storm based on point precipitation estimates from the NOAA 14 Atlas (SSCAFCA, 2009). In the Calabacillas Watershed, current point precipitation estimates for the 100-year 24-hour storm range from 2.6 to 3.1 inches. The design storm is utilized to design drainage infrastructure such as road crossings, channels, ponds and dams, and to delineate floodplains; this is the current standard used by SSCAFCA.
- A hypothetical storm based on 10 percent higher 100-year 24-hour point precipitation; it was assumed that incremental rainfall would increase uniformly by 10 percent for every time increment of the storm.
- A hypothetical storm based on 25 percent higher 100-year 24-hour point precipitation; it was assumed that incremental rainfall would increase uniformly by 25 percent for every time increment of the storm.

3. Results

Impacts of higher magnitude extreme events in the Calabacillas Watershed can be assigned to three general categories: existing flood control infrastructure, floodplains, and erosion.

Existing Flood Control Infrastructure

Due to higher peak flows resulting from higher precipitation extremes, existing flood control infrastructure can be adversely affected by climate change. In the Calabacillas Watershed, the road crossing structure at Southern Blvd already has insufficient capacity under existing conditions.

Figure 5: Storm flows in the Calabacillas Arroyo overtopping Southern Blvd during the flood of September 13, 2013 (Source: koat.com).

Figure 5 shows the Southern Blvd crossing during the storm of September 13, 2013. Storm flows overtopped the roadway resulting in localized flooding upstream due to the ponding effect of the road embankment (Figure 6).

Figure 6: Extent of flooding upstream of Southern Blvd during the storm of September 13, 2013 (Source: koat.com).

Any further increase in flows would exacerbate the capacity and flooding problems at Southern Blvd. This example illustrates how increased peak discharge can negatively affect existing drainage infrastructure.

The predicted peak flow rate at Southern Blvd resulting from the 100-year design storm is approximately 8,000 cfs. The hydrologic model for the Calabacillas Watershed predicts that a 10 percent increase in the 100-year precipitation would lead to a 25 percent increase in peak flow at this point (see Table 1); a 25 percent increase in 100-year precipitation would lead to a 75% increase in peak flow at Southern Blvd.

Table 1: Approximate flow rates at Southern Blvd for existing conditions compared to hypothetical increases in the 100-year 24-hour rainfall due to climate change.

Model Scenario	***Southern Blvd Peak Flow Rate***	***Increase***
Existing Conditions 100-year 24-hour design storm	8,000 cfs	--
10 percent increase of 100-year 24-hour rainfall	10,000 cfs	25%
25 percent increase of 100-year 24-hour rainfall	14,000 cfs	75%

Even moderate changes in precipitation can have dramatic impacts on peak discharge during extreme storm events.

Floodplains

Floodplains are areas inundated during peak flow conditions. The extent of a floodplain depends largely on the topography. Minimally incised channels with wide, flat overbank areas are more susceptible to increased flooding, since a small rise in water surface elevation can substantially increase the inundated area. Deeply incised channels on the other hand may only see a small floodplain change, even if the flow rate increases. Susceptibility to flooding therefore has to be analyzed on a case-by-case basis.

Figure 7 shows an area in the Calabacillas Arroyo where an increase in the 100-year storm would dramatically alter the floodplain and impact existing development along the eastern edge of the Arroyo. Approximately 30 homes would be completely in the floodplain with a 10% increase in the 100-year storm (yellow line).

Figure 7: Existing 100-year floodplain (blue) in the Calabacillas Arroyo north of Southern Blvd. Yellow and red lines indicate the estimated flood plain extents for 10% and 25% higher precipitation.

Erosion

Soils in the Calabacillas Watershed are predominantly sandy loams and are highly erosive. Flood waters erode and transport large amounts of sediment, and arroyos migrate laterally over time. Erosion and lateral migration can pose a significant threat to private property and public infrastructure adjacent to arroyos, even in areas that are not within the floodplain.

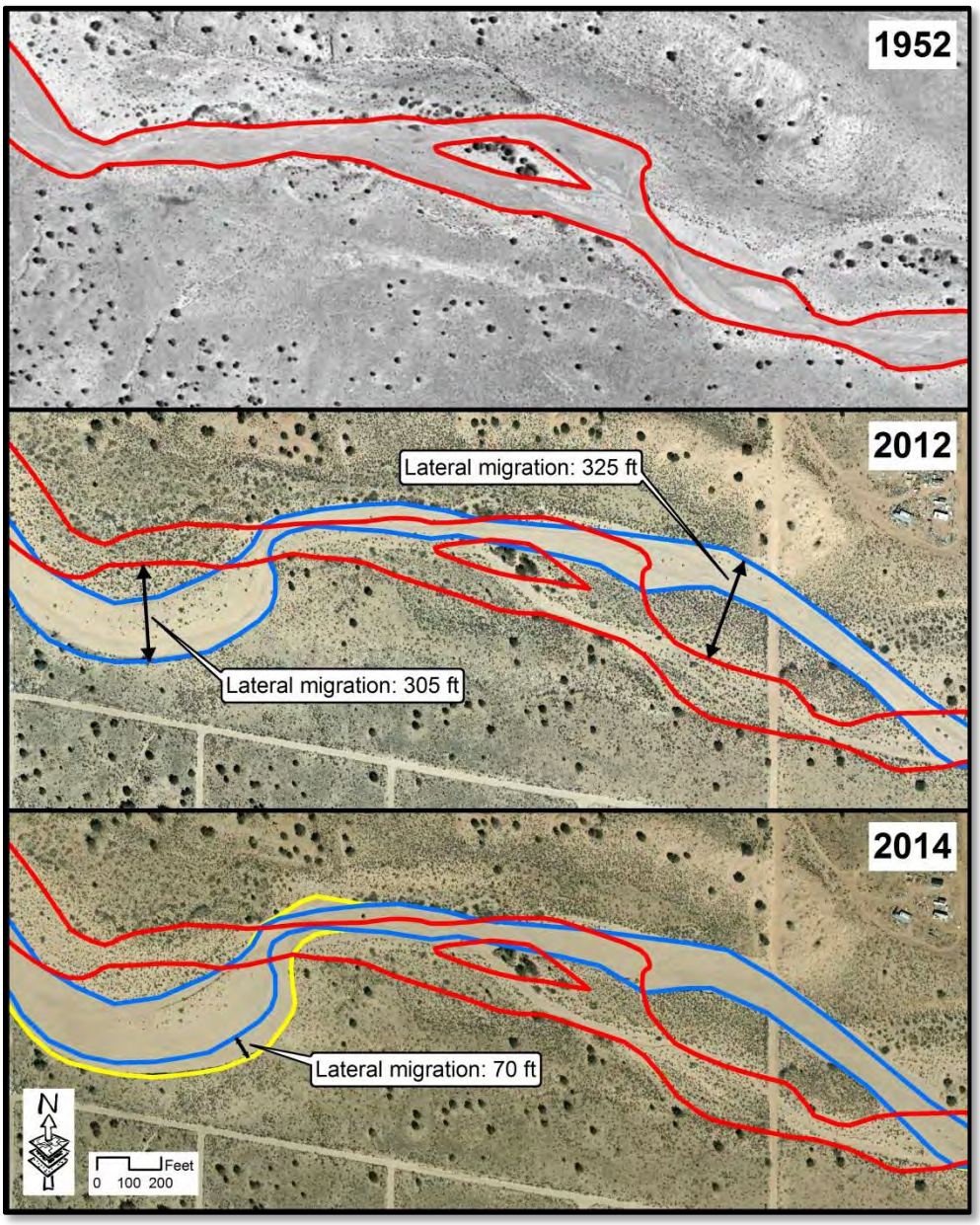


Figure 8: Lateral migration of the Calabacillas Arroyo between 1952 and 2014.

Figure 8 illustrates how one reach of the Calabacillas Arroyo has changed over time. In the 60-year period between 1952 and 2012, the banks of the arroyo moved more than 300 feet. One large storm in 2013 shifted the southern bank 70 feet further to the south (see yellow line, Figure 8). As extreme events become more frequent and greater in magnitude, the rate of lateral migration will likely increase.

4. Conclusions

This case study illustrates how anticipated increases in the magnitude and frequency of extreme rainfall events due to climate change could have detrimental impacts on public health, safety and welfare, particularly adjacent to major natural drainage ways such as the upper Calabacillas Arroyo.

Higher magnitudes of extreme rainfall will lead to increased peak flows. The Calabacillas case study shows that a 10 percent increase in precipitation could lead to a 25 percent increase in peak discharge; a 25 percent increase in precipitation could lead to a 75 percent increase in flow.

Higher peak discharge may overwhelm existing drainage infrastructure, as well as planned facilities designed based on current standards; furthermore, the extent of floodplains in low lying areas will increase. More frequent storm flows and higher peaks will increase bank erosion and accelerate the lateral migration of natural arroyos. Preservation of buffer areas adjacent to natural arroyos that account both for floodplains and lateral migration will therefore become increasingly important in the future.

5. References

Bureau of Reclamation (2013). West-Wide Climate Risk Assessment: Upper Rio Grande Impact Assessment.

SSCAFCA (2009). Final Development Process Manual for Southern Sandoval County Arroyo Flood Control Authority and the City of Rio Rancho, New Mexico.

SSCAFCA (2014). DRAFT Calabacillas Watershed Park Management Plan.