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Alluvial Fan and Debris Flow

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Alluvial Fan and Debris Flow

The New Mexico All Hazard Mitigation Plan (MHP) addresses major natural hazards identified as presenting substantial risk to human life and private and public property. Alluvial fans are recognized in the HMP as representing risks from "high velocity flow (as high as 15-30 feet per second) producing significant hydrodynamic forces, erosion/scour to depths of several feet, deposition of sediment and debris (to depths of several feet), deposition of sediment and debris (depths of 15 – 20 feet have been observed), debris flows/impact forces, mudflows, inundation, producing hydrostatic/buoyant forces (pressure against buildings caused by standing water), flash flooding with little, if any, warning times (NMHMP 2013:95)." Additionally, FEMA's *Alluvial Fans: Hazards and Management* guidance document discusses the tendency to underestimate the potential and severity of alluvial fan flood events due to infrequent rainfall, gently-sloping terrain and often long time spans between successive flood events. Structures on alluvial fans may be susceptible to damage caused by high velocity water; lateral loading that forces structures off foundations or induces wall collapse; water inundation; scour and undermining of buildings; impact of mud, debris, and boulders; sediment burial; and landscape erosion (FEMA P-259 2012).

The identification and mapping of alluvial fans is an important first step in reducing risk to life and property, especially as communities expand and development increases. In addition to the mapping of alluvial fans, techniques and strategies for avoiding and minimizing losses need to be implemented by communities that are located on or near alluvial fans. FEMA's alluvial fan guidance documents (FEMA 165 and FEMA P-259 Appendix D) outline strategies to manage future development on alluvial fans as well as residential retrofitting measures that can be utilized to reduce flood damage in existing structures.

The New Mexico Bureau of Geology and Mineral Resources has been working on an inventory of alluvial fans for a number of years. However, that data is not available to the public and it has not been incorporated into the New Mexico Hazard Mitigation Plan. The Earth Data Analysis Center, FEMA Region VI CTP, as part of the CTP program has assembled a database of available GIS data on alluvial fans in New Mexico.

Data Sources

The New Mexico Bureau of Geology and Mineral Resources (NMBGMR) is a research and service division of the New Mexico Institute of Mining and Technology (NM Tech). It is a non-regulatory agency that serves as the geological survey for the State of New Mexico. The NMBGMR publishes detailed geologic surveys as they are completed at a scale of 1:24,000

which is equal to the area a 7.5 minute topographic map. The majority of these maps are available for download, only a portion of them have the associated geologic information in a GIS format. Those maps with GIS data were examined for alluvial fan deposits and the data extracted into a separate geodatabase.

The NMBGMR also has a statewide surficial geologic map at a scale of 1:500,000 that identifies surficial alluvial fan deposits (Af). This map was created from geological information from a variety of sources including the New Mexico State Highway Department, New Mexico State Land Office, New Mexico Energy Minerals and Natural Resources Division and unpublished geologic studies (Barker et al. 2006.)

The United States Geological Survey also published geologic reports for several areas of New Mexico with the accompanying GIS data that identified alluvial fan deposits.

The last dataset is alluvial fan deposit information from a series of maps created in 1990 (Cardinali et al.) The landslide information was derived from aerial photograph interpretation and field work. The alluvial fan information on these maps was digitized and added to a geodatabase.

Table 2 shows the geologic map codes for alluvial fan deposits and Figure 1 shows an example of an area of alluvial fan deposits from the Hillsboro 7.5 –Minute Quadrangle in Sierra County, New Mexico with showing map units Qafy, Qayr and Qay.

Table 1 – Alluvial Fans Geologic Map Units.

AF	Qfa	Qfu	Qfy	Qfo
Qf1	Qf2	Qf3	Qf4	Qf6
Qafyh	Qafyr	Qafo	Qfo	Qfu
Q	Qafhm	Qafh	Qafy	

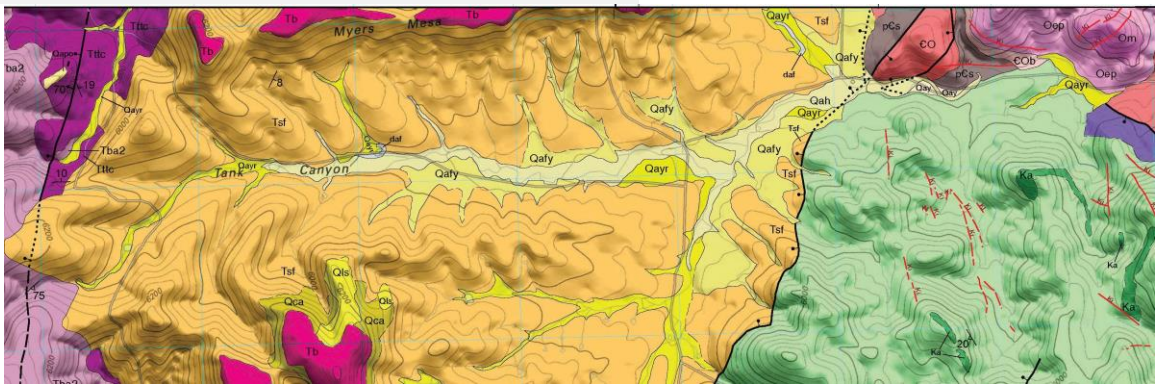

Figure 1 – Portion of Geologic Map Hillsboro 7.5-Minute Quadrangle, Sierra County, New Mexico (NMBGMR OGM 242).

Proximity Analysis

A limited proximity analysis of essential facilities was conducted utilizing the Community Anchor Site Assessment (CASA) database of essential facilities available on the New Mexico Resource Geographic Information System (RGIS) Clearinghouse (http://rgis.unm.edu/.) The CASA database consists of essential facilities such as schools and universities, hospitals, health centers, nursing homes, urgent care facilities, libraries, State Government buildings, Emergency Operations Centers, Fire Stations, Law Enforcement offices and other government and non-governmental facilities. 712 of the approximate 3,774 facilities in the CASA database are located in an area that has been identified as an alluvial fan. Table 2 shows the numbers by institution type. This proximity analysis reflects only a portion of the entire state of New Mexico, there are large parts of the state where the alluvial fans have either not been mapped or the maps are not yet available as digital data. As new geologic studies are released, a proximity analysis needs to be done for the essential facilities in those regions. Figure 2 shows the number of essential facilities on alluvial fans by HUC-8 watershed. Table 3 lists the essential facilities by county.

Table 2 – CASA Institutions on Alluvial Fans.

INSTITUTION	TOTAL
SCHOOLS K-12	207
LIBRARY	32
HOSPITAL	15
NURSING HOME	25
URGENT CARE	15
HEALTH CENTER	57
FIRE STATION	93
LAW ENFORCEMENT	42
EOC	12
UNIVERSITY	22
COMMUNITY COLLEGE	10
OTHER POST-SECONDARY	9
STATE GOVERNMENT	90
OTHER GOVERNMENT	63
NON-GOVERNMENT	20
TOTAL	712

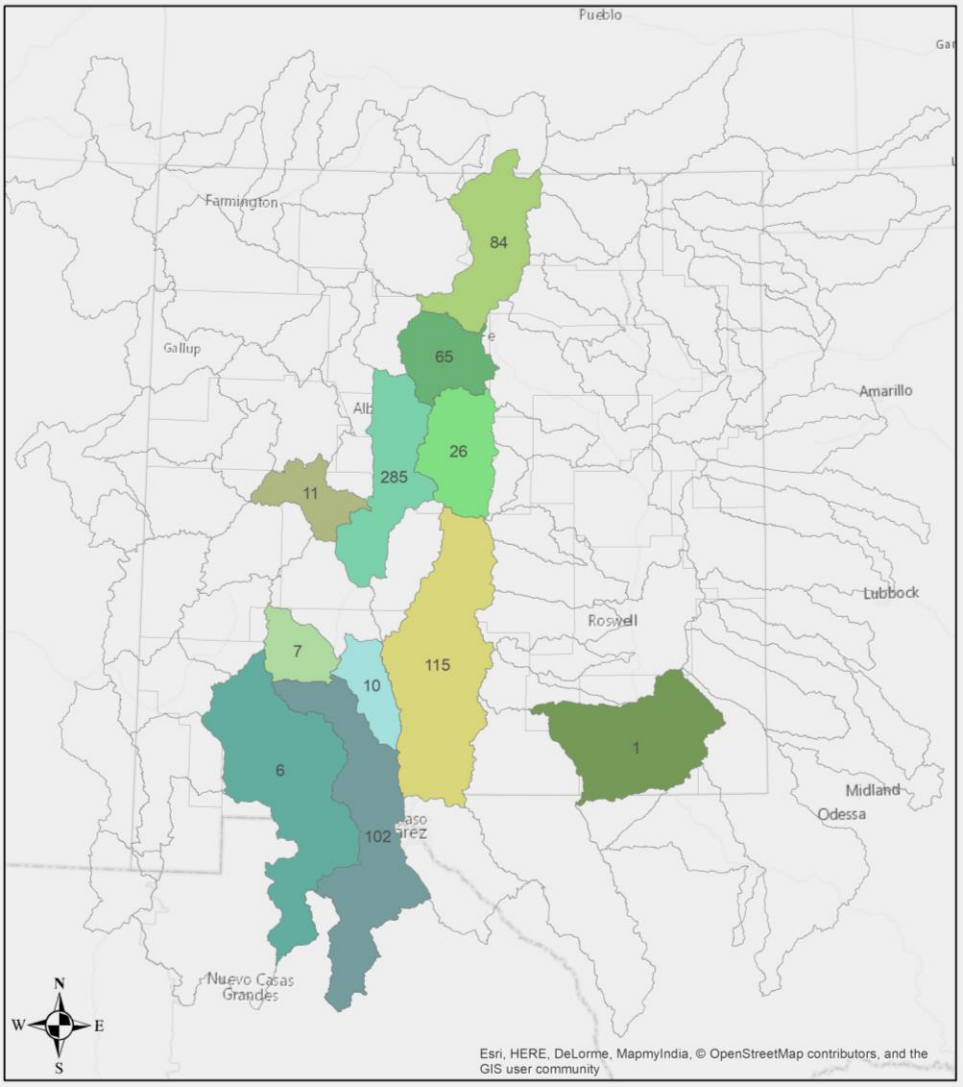

Figure 2 – Essential Facilities on Alluvial Fan by HUC-8 Watershed.

The CASA database defines the Non-Government institutions as non-profit entities and other non-governmental community resources such as Chambers of Commerce, non-profits and community centers. Health Centers include Clinics, School Based Health Centers (SBHC) and Federally Qualified Health Centers (FQHC). Government facilities comprise buildings or properties that are owned or leased by state, federal, and local governments. Figure 3 shows the distribution of the identified CASA facilities.

Table 3 – Essential Facilities on Alluvial Fans by County (note: not all counties had alluvial fan data).

INSTITUTION	BERNALILLO	DONA ANA	EDDY	LINCOLN	LUNA	OTERO	RIO ARRIBA	SANDOVAL	SANTA FE	SIERRA	SOCORRO	TAOS	TORRANCE	VALENCIA	TOTAL
SCHOOLS K-12	94	34		4	1	20	6	3	15		6	17	6	1	207
LIBRARY	9	5			1	3	2	4	3		1	2	1	1	32
HOSPITAL	8	2				2			1		1	1			15
NURSING HOME	15	3				2	1		2		1	1			25
URGENT CARE	9	2				2			2						15
HEALTH CENTER	31	7		1	1	2	1	3	4		2	5			57
FIRE STATION	15	17	1	2	1	16	5	2	15	3	2	10	3	1	93
LAW ENFORCEMENT	13	7		2	1	6	2		2	2	1	5	1		42
EOC	2	1		1		1	2	1	2			2			12
UNIVERSITY	9	4		1		2			2	2		1		1	22
COMMUNITY COLLEGE	4	4							2						10
OTHER POST-SECONDARY	7	1				1									9
STATE GOVERNMENT	34	19		1	1	10			10		2	7	5	1	90
OTHER GOVERNMENT	18	10		2		15	3	1	8		1	4	1		63
NON-GOVERNMENT	2	3		4		8	1				1	1			20
TOTAL	270	119	1	18	6	90	23	14	68	7	18	56	17	5	712

The geodatabase with the alluvial fan geology and the results of the proximity analysis will be available on both NM Flood and the RGIS Geospatial Data Clearinghouse websites. Local communities can utilize this geospatial data for Risk Assessment.

Additional Alluvial Fan Identification

In a separate Cooperating Technical Partners project, FY16-PM-MAS008 Mapping Activity Statement 006: Automated Landslide Hazard Detection, EDAC utilized Lidar data and Remote Sensing techniques to identify areas of landslide risk. Two areas in New Mexico were chosen for the study, the Santa Fe County and the Rio Hondo HUC08 Watershed study areas. In both cases, these areas have recently been covered by USGS Quality Level 2 (QL2) LiDAR data with nominal pulse spacing of 0.7- m which was used as the base data set from which the products were derived. While conducting the landslide analysis EDAC attempted to identify alluvial fans in the two study areas. This exercise involved unsupervised and object based classification techniques using slope and landscape related indices to attempt to generate alluvial fan classes. However, this technique but was not successful in identifying alluvial fans with

sufficient certainty for proper identification, it could serve as a method for initial identification of areas of potential alluvial fans that then would require further geologic investigation.

Future Work

As the NMBGMR continues to conduct geologic mapping the alluvial fan information will need to be added to this database. Periodically the proximity analysis will need to be repeated in newly mapped areas of the state.

Identification of alluvial fans as well as essential facilities that are located on an alluvial fan will allow local communities and institutions to better assess their risk and implement measures to reduce risk and potential losses. These measures could include flood hazard delineation (beyond that of the NFIP) and instituting local ordinances and regulations for alluvial fan development. At a state level, guidelines or regulations for new construction could be instituted; Appendix D of FEMA's Engineering Principles and Practices of Retrofitting Floodprone Residential Structures outlines many of these actions.

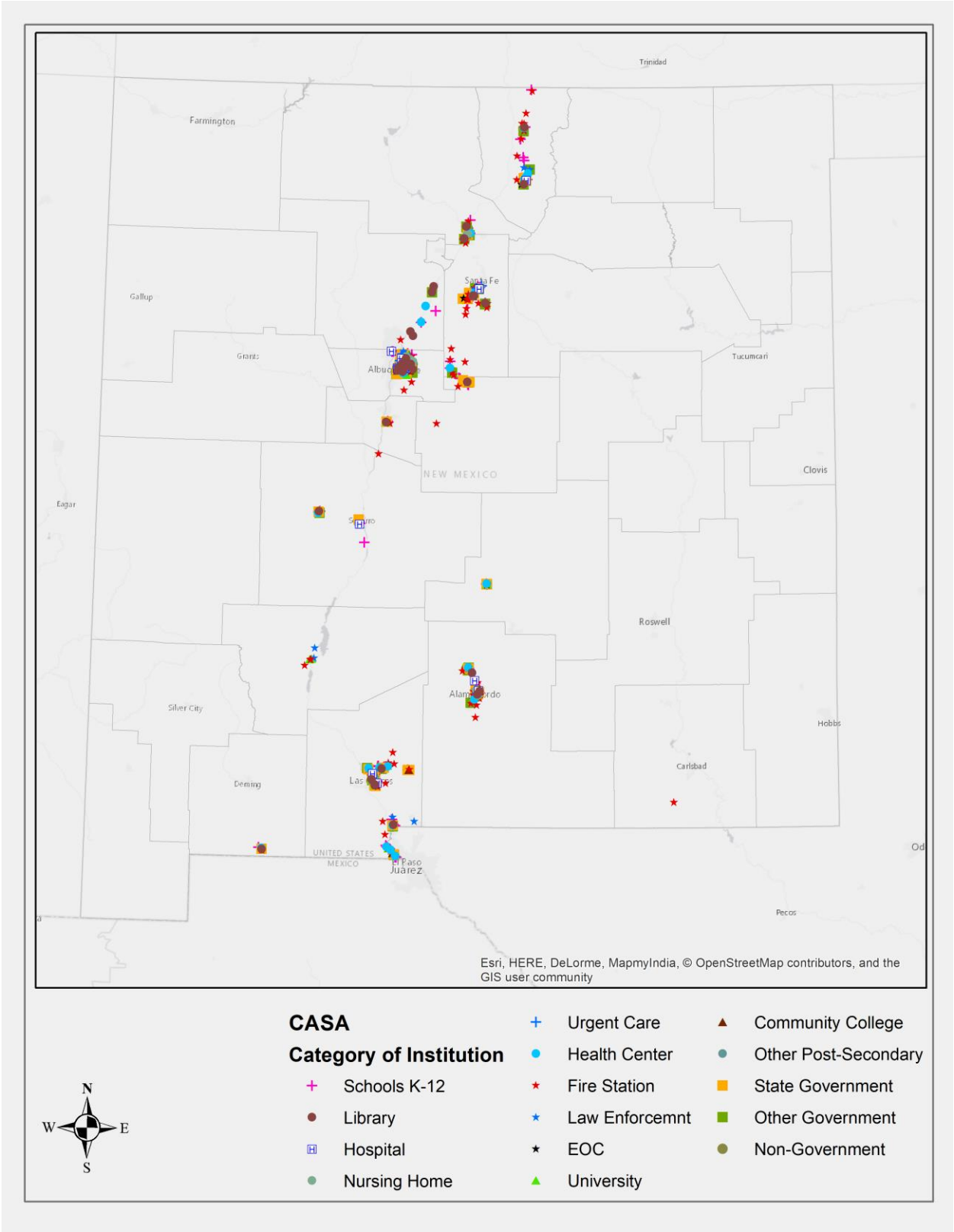

Figure 3 – CASA Facilities.

Resources

NM Flood
www.nmflood.org

NM Flood is a one stop resource for flood risk information in the State of New Mexico. Any and all FEMA Risk map deliverables will be posted here, as well as relevant articles and links.

RGIS
http://rgis.unm.edu/

The New Mexico Resource Geographic Information System (RGIS) Program and Clearinghouse is the digital geospatial data clearinghouse for the state of New Mexico.

NMBGMR
https://geoinfo.nmt.edu/index.html

The New Mexico Bureau of Geology & Mineral Resources is a research and service division of the New Mexico Institute of Mining and Technology (NM Tech). It is a non-regulatory agency that serves as the geological survey for the State of New Mexico

References

Cardinali, Mauro, Guzzetti, Fausto, and Brabb, Earl E., *Preliminary maps showing landslide deposits and related features in New Mexico*, 1990. USGS Publications Warehouse. Open-File Report 90-293. http://pubs.er.usgs.gov/publication/ofr90293

Federal Emergency Management Agency (FEMA). 1989. *Alluvial Fans: Hazards and Management*. FEMA 165. http://www.fema.gov/library/viewRecord.do?fromSearch=fromsearch&id=1633.

FEMA P-259, *Engineering Principles and Practices of Retrofitting Floodprone Residential Structures, Appendix D Alluvial Fan Flooding* , Third Edition (2012). https://www.fema.gov/media-library/assets/documents/3001

Jochems, Andrew P., Shari A. Kelley, William R. Seager, Colin T. Cikoski, and Daniel J. Koning, 2014, *Geologic Map of the Hillsboro Quadrangle*, *Sierra County, New Mexico*, OFGM 242

New Mexico State Hazard Mitigation Plan, September 2013, http://www.nmdhsem.org/uploads/files/NM%20HMP%20Final%209-30-13.pdf

Geology Map References

Title	Reference	Link
Geologic Map of the Southern Espanola Basin	Daniel J. Koning and Adam S. Read, 2010, Geologic map of the southern Espanola Basin, OFR 531	https://geoinfo.nmt.edu/publications/openfile/details.cfml?volume=531
Surficial Geology (The Map of Surficial Geologic Materials of New Mexico)	James Barker, Maureen Wilks, Glen Jones, Adam Read, Karl Frisch, Judy Vaiza, Lynne Hemenway, Terry Gonzales, Donn Schwatzenberg, Larry Kehow, Jami Bailey, Natalie Runyon, John W Hawley, David J. Mccraw, David W. Love, Sean D. Connell, Map of Surficial Geologic Materials of New Mexico, Larger Work: Construction Aggregate on State Trust Lands NMBGMR Open Fire Report 462 a, b, c. 2006	https://geoinfo.nmt.edu/publications/openfile/details.cfml?volume=462
Ambrosia Lake	Charles Ferguson and Dave McCraw, 2010, Geologic map of the Ambrosia Lake quadrangle, McKinley County, New Mexico, OFGM 203	https://geoinfo.nmt.edu/publications/openfile/details.cfml?volume=203
Angus, Fort Stanton, Ruidoso, Ruidoso Downs	Geoffrey C. Rawling, 2008, Geology of the Ruidoso Area, Lincoln and Otero counties, New Mexico, OFR 538	http://geoinfo.nmt.edu/publications/openfile/details.cfml?Volume=507
Arroyo Hondo	Keith Kelson and Paul Bauer, 2006, Geologic map of the Arroyo Hondo quadrangle, Taos County, New Mexico, OFGM 116	https://geoinfo.nmt.edu/publications/maps/geologic/ofgm/details.cfml?volume=116
Arroyo Seco	Keith Kelson and Paul Bauer, 2010, Geologic map of the Arroyo Seco Quadrangle, Taos County, New Mexico, OFGM 170	https://geoinfo.nmt.edu/publications/maps/geologic/ofgm/details.cfml?volume=170
Bay Buck Peaks	Robert Osburn and Charles A. Ferguson, 2007, Geologic Map of the Bay Buck Peaks, Socorro County, New Mexico, OFGM 147	https://geoinfo.nmt.edu/publications/maps/geologic/ofgm/details.cfml?volume=147
Bland	Fraser Goff, Steven L. Reneau, Scott Lynch, Cathy J. Goff, Jamie N. Gardner, Paul Drakos, and Danny Katzman, 2007, Preliminary Geologic Map of the Bland Quadrangle,, Los Alamos and Sandoval Counties, New Mexico, OFGM 112	https://geoinfo.nmt.edu/publications/maps/geologic/ofgm/details.cfml?volume=112

Capitan Nogal Map	Geoffrey C. Rawling, 2011, Geology of the Capitan and Nogal quadrangles, Lincoln County, New Mexico, OFGM 538	https://geoinfo.nmt.edu/publications/openfile/details.cfml?volume=538
Cerro Montoso	Bruce D. Allen, J. Michael Timmons, Amy L. Luther, Phil L. Miller, David W. Love, 2014, Geologic Map of the Cerro Montoso Quadrangle,Socorro County, New Mexico, OFGM 238	http://geoinfo.nmt.edu/publications/maps/geologic/ofgm/details.cfml?Volume=238
Cubero	Colin T. Cikoski, Paul G. Drakos, and Jim Riesterer, 2016, Geologic Map of the Cubero Quadrangle,Cibola County, New Mexico, OFGM 256	https://geoinfo.nmt.edu/publications/maps/geologic/ofgm/details.cfml?volume=256
Guadalupe Mtn	Keith I. Kelson, Paul W. Bauer, and Ren Thompson, 2008, Geologic Map of the Guadalupe Mountain Quadrangle, Taos County, New Mexico, OFGM 169	https://geoinfo.nmt.edu/publications/maps/geologic/ofgm/details.cfml?volume=168
Guaje Mnt	K. A. Kempter, S. Kelley, J. Gardner, S. Reneau, D. Broxton, F. Goff, A. Levine, and C. Lewis, 1998, Geologic Map of the Guaje Mountain quadrangle, Los Alamos and Sandoval counties, New Mexico, OFGM 55	https://geoinfo.nmt.edu/publications/maps/geologic/ofgm/details.cfml?volume=55
Hillsboro	Andrew P. Jochems, Shari A. Kelley, William R. Seager, Colin T. Cikoski, and Daniel J. Koning, 2014, Geologic Map of the Hillsboro Quadrangle, Sierra County, New Mexico, OFGM 242	https://geoinfo.nmt.edu/publications/maps/geologic/ofgm/details.cfml?volume=242
Jemez Springs	Shari Kelley, Kirt A. Kempter, Fraser Goff, Mike Rampey, Bob Osburn, and Charles A. Ferguson, 2003, Geologic Map of the Jemez Springs Quadrangle, Sandoval County, New Mexico, OFGM 73	https://geoinfo.nmt.edu/publications/maps/geologic/ofgm/details.cfml?volume=73
Las Vegas NW	Alvis L. Lisenbee, 2003, Geologic Map of the Las Vegas NW Quadrangle, San Miguel County, New Mexico, OFGM 78	https://geoinfo.nmt.edu/publications/maps/geologic/ofgm/details.cfml?volume=78
Latir	Lipman, P.W., and Reed, J.C., Jr., 1989, Geologic map of the Latir volcanic field and adjacent areas, northern New Mexico: U.S. Geological Survey Miscellaneous Investigations Series I–1907, 1 sheet, scale 1:48,000. Digital edition by Brandt, T.R, 2011.	https://pubs.usgs.gov/imap/i-1907/
Lobo Springs	Fraser Goff, Shari A. Kelley, Kate Zeigler, Paul Drakos, and Cathy Goff, 2008, Geologic Map of the Lobo Springs Quadrangle, Cibola County, New Mexico, OFGM 181	https://geoinfo.nmt.edu/publications/maps/geologic/ofgm/details.cfml?volume=181
Los Cordovas	Keith Kelson and Paul Bauer, 2003, Geologic Map of the Los Cordovas quadrangle, Taos County, New Mexico, OFGM 63	https://geoinfo.nmt.edu/publications/maps/geologic/ofgm/details.cfml?volume=63

Mt Taylor	G. R. Osburn, S. A. Kelley, F. Goff, P. G. Drakos, and C. A. Ferguson, 2009, Geologic Map of the Mount Taylor quadrangle, Cibola County, New Mexico, OFGM 186	https://geoinfo.nmt.edu/publications/maps/geologic/ofgm/details.cfml?volume=186
Ranchos de Taos	Paul. Bauer, Keith. Kelson, Scott Aby, J. Lyman, M.R. Heynekamp, and Dave McCraw, 2000, Geologic Map of the Ranchos de Taos Quadrangle, Taos County, New Mexico, OFGM 33	https://geoinfo.nmt.edu/publications/maps/geologic/ofgm/details.cfml?volume=33
Redondo Peak	Fraser Goff, Jamie N. Gardner, Steven L. Reneau, and Cathy J. Goff, 2005, Geologic Map of the Redondo Peak Quadrangle, Sandoval County, New Mexico, OFGM 111	https://geoinfo.nmt.edu/publications/maps/geologic/ofgm/details.cfml?volume=111
Seton Village	Adam S. Read, John B. Rogers, Steven Ralser, Brad R. Ilg, and Shari Kelley, 2003, Geologic Map of the Seton Village Quadrangle, Santa Fe County, New Mexico, OFGM 23	https://geoinfo.nmt.edu/publications/maps/geologic/ofgm/details.cfml?volume=23
Taos	Keith I. Kelson and Paul W. Bauer, 2015, Geologic Map of the Taos quadrangle, Taos County, New Mexico, OFGM 23	https://geoinfo.nmt.edu/publications/maps/geologic/ofgm/details.cfml?volume=43
Valle San Antonio	Fraser Goff, Steven L. Reneau, Cathy J. Goff, Jamie N. Gardner, Paul G. Drakos, and Danny Katzman, 2006, Geologic Map of the Valle San Antonio quadrangle, Sandoval County, New Mexico, OFGM 132	https://geoinfo.nmt.edu/publications/maps/geologic/ofgm/details.cfml?volume=132
Vermejo Peak	Fridrich, C.J., Shroba, R.R., Pillmore, C.L., and Hudson, A.M., 2009, Preliminary geologic map of the Vermejo Peak area, Colfax and Taos Counties, New Mexico, and Las Animas and Costilla Counties, Colorado: U.S. Geological Survey Open-File Report 2009–1189, 1 sheet, scale 1:50,000.	https://pubs.usgs.gov/of/2009/1189/
Wiliamsburg	Jochems, Andrew P. and Koning, Daniel J., 2015, Geologic Map of the Williamsburg Quadrangle, Sierra County, New Mexico, OFGM 132	https://geoinfo.nmt.edu/publications/maps/geologic/ofgm/details.cfml?volume=250