Resolution Copper Project and Land Exchange
Environmental Impact Statement

USDA Forest Service
Tonto National Forest
Arizona

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Process Memorandum to File

Summary of Climate Change Trends in the Southwest

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Purpose of Process Memorandum

The purpose of this process memorandum is to identify the best sources of information related to climate change in the Southwest and provide a summary of this information for specialists working on the Resolution Copper Mine and Land Exchange Environmental Impact Statement. This process memorandum provides a summary of the best available scientific information from interagency and U.S. Department of Agriculture (USDA) Forest Service sources:

- Garfin, Gregg, et al. (Interagency). 2013. Assessment of Climate Change in the Southwest: A Report Prepared for the National Climate Assessment.
- Intergovernmental Panel on Climate Change (IPCC). 2014. *Climate Change 2014: Impacts, Adaptation, and Vulnerability.*
- U.S. Forest Service. 2008. *Forest Service Strategic Framework for Responding to Climate Change*. Version 1.0.
- U.S. Forest Service. 2012. Effects of Climatic Variability and Change on Forest Ecosystems: A Comprehensive Science Synthesis for the U.S. Forest Sector. Appendix 1: Regional Summaries. Southwest.
- U.S. Forest Service. 2012. *The U.S. Forest Service and Climate Change Fact Sheet*.
- U.S. Forest Service. 2015. *Climate Change Vulnerability Assessment: Tonto National Forest.* Albuquerque, New Mexico: U.S. Forest Service, Rocky Mountain Research Station. March.
- Western Regional Climate Center (WRCC). 2018. *Cooperative Climatological Data Summaries.* Available at: https://wrcc.dri.edu/Climate/west_coop_summaries.php. Accessed January 2018.
- U.S. Bureau of Reclamation. 2012. *Colorado River Basin Water Supply and Demand Study.* Available at: https://www.usbr.gov/lc/region/programs/crbstudy/finalreport/studyrpt.html.

Key Process Steps

Global Context

Global surface air temperatures have measurably risen since 1901 (IPCC 2014). Positive annual temperature trends are found over most land areas, particularly since 1981. Over the period 1981– 2012, relatively large trends have occurred over areas of Europe, the Sahara and Middle East, central and northern Asia, and northeastern North America (IPCC 2014). Averaged land and ocean surface temperature data shows a warming of 0.85 degrees Celsius (1.53 degrees Fahrenheit [°F]) between 1880 and 2012 (IPCC 2014). It is extremely likely that more than half of the increase in observed global surface temperature was caused by anthropogenic factors (such as greenhouse gas emissions) (IPCC 2014).

Hydrological systems are being altered by changing precipitation patterns and melting snow and ice, which affect water resources quality and quantity (IPCC 2014). Northern hemisphere mid to high latitudes show a likely increasing trend in precipitation. Overall, observed precipitation trends show a high degree of spatial and temporal variability, both negative and positive (IPCC 2014). It is likely that there are more land regions in which the number of heavy precipitation events has increased than decreased. Correlation between climate change and drought patterns has not been established (IPCC 2014).

North America (Canada, United States, Mexico)

Observed climate changes in North America include an increased occurrence in hot weather events, decrease in frost days, and increases in heavy precipitation, which has resulted in observed changes that include earlier peak snowmelt runoff and declines in the quantity of water stored in spring snowpack in areas of western U.S. and Canada (IPCC 2014).

Ecosystems of North America have been shown to be under increasing stress from rising temperatures, carbon dioxide (CO_2) concentrations, and sea levels, and are particularly vulnerable to climate extremes. Climate stresses occur alongside other anthropogenic influences on ecosystems, (including land use changes, human population growth, introduction and/or proliferation of non-native species, and pollution), the compounded results of which can be exacerbated by climate change. Evidence of climate change shows increased ecosystem vulnerability to multiple and interacting climate stresses in forest ecosystems through wildfire activity, regional drought, high temperatures, and infestations; and in coastal zones due to increasing temperatures, ocean acidification, coral reef bleaching, increased sediment load in runoff, sea level rise, storms, and storm surges (IPCC 2014).

Water resources are already stressed in many parts of North America due to non-climate change anthropogenic forces, and are expected to become further stressed due to climate change (IPCC 2014). Decreases in snowpack due to rising surface temperatures are already influencing seasonal streamflow, and though indicative of future conditions, recent floods, droughts, and changes in mean flow conditions cannot yet be directly attributed to climate change. However, the 21st century is projected to witness decreases in water quality and increases in urban drainage flooding throughout most of North America as a result of climate change. In addition, there will be projected decreases in water supplies for urban areas and irrigation in North America (except in general for southern tropical Mexico, northwest coastal United States, and west coastal Canada). Many adaptation options currently available can address water supply deficits (such as reducing leaks from water systems, increasing conservation efforts, installing water meters, and developing interagency agreements and regulations for water supply management); adaptation responses to flooding and water quality concerns are more limited (such as using green infrastructure to capture rainwater, elevating equipment and infrastructure over flood heights, moving infrastructure to less vulnerable areas, and designing infrastructure to be adaptable to changing conditions) (IPCC 2014).

Observed impacts on livelihoods, economic activities, infrastructure, and access to services in North American urban and rural settlements have been attributed to sea level rise, changes in temperature and precipitation, and occurrences of such extreme events as heat waves, droughts, and storms (IPCC 2014). Among the most vulnerable are indigenous peoples due to their complex relationship with their ancestral lands and higher reliance on subsistence economies (due to geographic isolation and poor conditions of rural infrastructure that can compromise hazard response capacity, raise costs of living, and limit the diversity of imported food, fuel, and other supplies), and those urban centers where high concentrations of populations and economic activities in risk-prone areas combine with several socioeconomic and environmental sources of vulnerability. Much of North American infrastructure is currently vulnerable to extreme weather events and, unless investments are made to strengthen them, would be more vulnerable to climate change (IPCC 2014). Water resources and transportation infrastructure are in many cases deteriorating, and are thus more vulnerable to extremes than strengthened ones. Extreme events have caused significant damage to infrastructure in many parts of North America (IPCC 2014).

The Southwest (includes Arizona, California, Colorado, Nevada, New Mexico, Utah, and adjacent U.S.–Mexico border areas)

Average daily temperatures in the Southwest between 2001 and 2010 were the highest for all decades between 1901 and 2010 (average annual temperature increased 1.6 degrees F [± 0.5 degrees F], between 2001 and 2010), and fewer cold waves and more heat waves occurred in the region between 2001 and 2010 than in previous decades. Over the last 600 years, the period since 1950 has been warmer than any other period of comparable length. Droughts between 2001 and 2010 over the areal extent of the Southwest were the second largest during 1901–2010; however, these droughts were less severe than those that occurred in the preceding 2,000 years. Streamflow totals in the four major drainage basins of the Southwest (Sacramento-San Joaquin Rivers, Upper Colorado, Rio Grande, and Great Basin) have been lower (by 5%–37%) than their twentieth century averages, and flows of snowmelt-fed streams have experienced earlier arrival times in the late twentieth century than in the early 2 twentieth century (Garfin et al. 2013).

Future projections indicate that warming will continue, with more warming in the summer and fall than winter and spring, and winter cold snaps less frequent. Precipitation will decrease in the southern portions of the Southwest and increase or remain consistent in the northern portions, and precipitation extremes in winter will become more frequent and intense (summer has not been adequately studied). As a result of temperature increases, late winter-spring snowpack will decrease. As a result of these changes in the water cycle, stream flow and soil moisture will continue to decline and drought is projected to be more frequent, intense, and prolonged across most of the Southwest, which would result in water deficits that would be in excess of those experienced in the last 110 years. The scarcity of water, higher rates of evaporation, and higher rates of runoff due to increased precipitation, wildfire, and flooding would result in decreases in surface water quality. Ecosystem function and species will be affected, resulting in changes in distribution and timing of seasonal events in the life cycle of species. Additionally, substantial changes in land cover are projected as a result of changing fire regimes, outbreaks of forest pests, and other ecosystem disturbances (Garfin et al. 2013). Overall, the high degree of variation in elevation, landform, and ecosystems in the Southwest increases the degree to which the region would be affected by climate change.

In the last 150 years, the Southwest has experienced rapid population increases and urban expansion. Between the years of 1973 and 2000, the extent of urban land development, mining, fire, and other natural disturbances increased across the Southwest (Garfin et al. 2013). The footprint of urban areas is expected to double from approximately 4 million acres to 8–9 million acres by 2050, with low-density housing contributing an additional 10–11 million acres. The region will likely grow by an additional 19 million people (largely in urban areas), which will result in an increase in demand and reliance on natural resources (such as water) (Garfin et al. 2013). Management of these resources is challenged by a complex pattern of land ownership. The increase in low-density development is expected to result in a significant increase in number of miles traveled by vehicles.

The Colorado River Basin

The Colorado River Basin occupies an area of approximately 250,000 square miles, covering portions of seven western states. The majority of land within the Basin receives less than 10 inches of precipitation per year, though the mountainous higher-elevation areas may receive more than 40 inches per year. The natural flow in the Basin is highly variable year to year as a result of the variability in climatic conditions. Most of the annual flow consists of natural runoff from mountain snowmelt, which is historically highest in late spring and early summer though may temporarily increase in late summer and early autumn as a result of precipitation events (U.S. Bureau of Reclamation [BOR] 2012). While this summer precipitation does not contribute a significant portion of annual flow, it is locally important in Basin areas of Arizona, Nevada, and California (BOR 2012).

The Colorado River is approximately 1,400 miles long, originating along the Continental Divide in Colorado, and terminating in Mexico. Between 1906 and 2010, the annual natural flow at the Lees Ferry gaging station has ranged from 5.5 million acre-feet (maf) to 25.5 maf, averaging 15.0 maf. The Colorado River Compact of 1922 apportioned 15.0 maf per year to seven states (Lower Division States include Arizona, Colorado, and Nevada [7.5 maf]; Upper Division States include Colorado, New Mexico, Utah, and Wyoming [7.5 maf]), and the 1944 Treaty with Mexico allocated 1.5 maf to Mexico, totaling an annual apportioned flow of 16.5 maf. Between 1998 and 2007, overall consumptive uses and loss from Upper and Lower Division states, and including Mexico's allocation, averaged approximately 15.4 maf per year. Upper Division States have not fully developed their apportioned amount, using an approximate average of 4.3 maf of the apportioned 7.5 maf per year (BOR 2011).

In the portions of Arizona within the Lower Colorado River Basin, annual consumptive use of Colorado River water in 1971 was approximately 1.3 maf, and grew 115% to 2.8 maf in 2003 (the highest use year). Between the time periods of 1971 to 1980 and 2001 to 2010, proportion of water use for agriculture dropped from 95% to 52.5%, and the proportion of municipal and industrial use increased from 1.6% to 22.8% (Central Arizona Project [CAP] deliveries began in 1985 and contributed to this increase). Water use for mining was negligible between 1971 and 1980, and between 2001 and 2010 it averaged 63 thousand acre-feet (kaf) annually, or 1.9% of total water consumption (BOR 2012, Appendix X).

The annual mean and minimum temperature in the Lower Basin have increased 1.8–3.6 degrees F for the time period 1900–2002, and data suggest that spring minimum temperatures for the same time period have increased 3.6–7.2 degrees F (BOR 2011). Winter temperatures have increased up to 7.2 degrees F, and summer temperatures 1.6 degrees F. Increasing temperature has been correlated with decreasing snowpack and earlier runoff in the Basin, with runoff increasing between November and February and decreasing between April and July (April to July is traditionally recognized as the peak runoff season in the Basin) (BOR 2011). While future projected temperature increases are anticipated to change mean annual precipitation to a small degree, the majority of changes to annual flow in the Basin are related to changes in runoff timing. Increased temperatures are expected to diminish the accumulation of snow and the availability of snowmelt, with the most substantial decreases in accumulation occurring in lower-elevation portions of the Basin where cool-season temperatures are most sensitive to warming (BOR 2011). These changes will drive changes in the availability of natural water supplies, as changes in runoff timing could disrupt traditional timing of inflows, flood control, and storage capture strategies.

Future demands are anticipated to change as a result of increased air temperatures, increased greenhouse gas concentrations, and changes in patterns of precipitation, humidity, and atmospheric aerosol and ozone levels, as well as increased population levels and development. Future water demand for agricultural irrigation in the Lower Basin is anticipated to decrease as a result of an overall reduction in irrigated acreage from increasing urbanization (BOR 2012). Demand for municipal and industrial water uses is anticipated in increase (the degree to which is influenced by local factors that may include climate, demographics, amount of industrial demand, and number of visitors), primarily as a result of population increase, though it will be tempered by an expected decrease in per capita use as technology advances and conservation measures are adopted (BOR 2012). Increased in demand related to energy in the Lower Basin is expected to be small, representing 1% of the total increase in Arizona, as nearly all growth in energy-related demand occurs in California (BOR 2012). Water demand for mineral production in Arizona is anticipated to increase from 0.7% (in 2015) to between 0.9% and 1.3% of demand in 2060, though can fluctuate based on market prices for any given product (BOR 2012). Demand for fish, wildlife, and recreation is anticipated to remain constant over time in Arizona (BOR 2012). Current tribal quantified Colorado River water rights (diversion) in Arizona total approximately 1.4 maf, with additional unquantified tribal rights. Existing tribal demand is currently equal to the quantified right, and is anticipated to increase and eventually exceed the quantified right in the future. The same is expected of unquantified tribal rights (BOR 2012).

USDA Forest Service Lands

Climate change is expected to change forest ecosystems, with the most rapid and obvious changes being caused by altered disturbance regimes (such as fire or pest outbreaks). Currently observed changes include earlier spring melt of snowpack, fires are becoming larger, bark beetles are moving higher in elevation and attacking tree species previously climatically protected, bark beetle and other insect outbreak have become larger and more frequent (very cold winters generally reduce extent and population), and drought has killed trees that occur in the drier regions of the species' ranges. Overall trends in temperature and precipitation show that the U.S. has warmed over the last 100 years, but these trends differ by region (the southeastern U.S. has cooled by <0.7 degrees Celsius and receives more precipitation than 100 years ago, while the Southwest has warmed and now receives less precipitation than 100 years ago). Invasive species are expected to become more widespread, particularly in areas subject to disturbance and in arid forests. Flooding and resulting sediment movement is also expected to become more widespread as a result of higher rain:snow ratios in the West, but is anticipated to be variable both in terms of chronology and geographical occurrence. Finally, increased drought will exacerbate existing stresses. Overall, southwestern forests are expected to experience lower carbon storage than in the past, and may become carbon contributors (due to increased wildfire and tree die-offs from drought and/or insect outbreaks) while southeastern forests will experience an increase in foliage growth and become carbon sinks to a greater degree than currently observed.

Temperature projections indicate that when compared to 1971 through 2000, average annual air temperature across the continental United States will likely increase from 0.8 to 1.9 degrees C by 2050, from 1.4 to 3.1 degrees C by 2070, and from 2.5 to 5.3 C degrees by 2099.

USDA Forest Service Climate Change Strategy/ Forest Service and Climate Change Fact Sheet

Generally speaking, the Forest Service strategy for responding to climate change includes helping forests adapt to climate change by implementing forest thinning projects, controlling invasive species, restoring wetlands and streams, assisting species migration, and managing human uses. Overall Forest Service strategy for increases in carbon sequestration capability include rapid reforestation of forests damaged by natural events, providing technical assistance to regional and state climate action groups to support carbon sequestration, and demonstration projects. There are also attempts to reduce the use of fossil fuel energy by fostering the substitution of wood-based building projects for aluminum and concrete, more use of excess and waste wood as renewable sources of heat and power, and development of cost-competitive wood-based biofuels to replace fossil fuels. Finally, the Forest Service's Global Change Research Program continues to build on existing expertise and contribute to long-term data sets (Forest Service 2012).

As the impacts of climate change on most terrestrial ecosystems are expected to occur at a rate that will outpace the ability for many individual plant and animal species and entire communities to migrate and adapt, the Forest Service has developed a strategic framework for responding to climate change (Forest Service 2008). This framework outlines goals and recommendations for sustaining forests and grasslands and the ecosystem services they provide into the future.

- Goal 1: Science. Advance understanding of environmental, economic, and social implications of climate change and related adaptation and mitigation activities on forests and grasslands.
- Goal 2: Adaptation. Enhance the capacity of forests and grasslands to adapt to the environmental stresses of climate change and maintain ecosystem services.
- Goal 3: Mitigation. Promote the management of forests and grasslands to reduce the buildup of greenhouse gasses, while sustaining the multiple benefits and services of these ecosystems.
- Goal 4: Policy. Integrate climate change into all Forest Service policies, program guidance, and communications and put in place effective mechanisms to coordinate across and within Deputy Areas.
- Goal 5: Sustainable Operations. Reduce the environmental footprint of Forest Service operations and be a leading example of a green organization.
- Goal 6: Education. Advance awareness and understanding regarding principles and methods for sustaining forests and grasslands, and sustainable resource consumption, in a changing climate.
- Goal 7: Alliances. Establish, enhance, and retain strong alliances and partnerships with Federal agencies, State and local governments, Tribes, private landowners, non-governmental

> organizations, and international partners to provide sustainable forests and grasslands for present and future generations.

There are no specific objectives for managing for climate change on Tonto National Forest for several reasons. The state of knowledge needed to address climate change at a forest scale is still evolving and research needs have not been fully realized; most global climate models have not yet been refined to apply to land management at a forest scale; and, more specifically to Tonto National Forest, the current forest plan is under revision and directives related to climate change under the 2012 planning rule have not yet been applied.

Local Conditions

In the town of Superior, Arizona (station 028348), climate summaries for 1981–2010 describe an annual average maximum temperature of 79.3 degrees F, with the highest temperatures occurring in July (97.4 degrees F), and annual average minimum temperature of 59.3 degrees F, with the lowest temperatures occurring in January (44.0 degrees F). Annual precipitation levels for that time period is 19.51 inches (WRCC 2018). Climate summaries for the same time period in Globe (station 023500) describe an annual average maximum temperature of 78.8 degrees F, with the highest temperatures occurring in July (97.5 degrees F), and annual average minimum temperature of 50.9 degrees F, with the lowest temperatures occurring in December (33.9 degrees F). Annual precipitation levels for that time period is 12.68 inches (WRCC 2018). Climate summaries for the same time period in Miami (station 025512) describe an annual average maximum temperature of 78.1 degrees F, with the highest temperatures occurring in July (97.1 degrees F), and annual average minimum temperature of 51.8 degrees F, with the lowest temperatures occurring in January (34.9 degrees F). Annual precipitation levels for that time period is 18.38 inches (WRCC 2018).

Monthly climate normals for the periods of 1961 to 1990, 1971 to 2000, and 1981 to 2010 were compared for the Superior and Miami, Arizona weather stations described above (not enough data were available to compare normals for the Globe station). In Superior, annual mean temperature increased 0.4 degrees F between the periods of 1961–1990 and 1971–2000, and 1.3 degrees F between the periods of 1961–1990 and 1981–2010. Annual precipitation totals increased 0.9 inches and decreased 0.6 inches for the same time periods. In Miami, annual mean temperature increased 0.8 degrees F between the periods of 1961–1990 and 1971–2000, and 3.4 degrees F between the periods of 1961–1990 and 1981–2010. Annual precipitation totals decreased 0.2 inches and 2.0 inches for the same time periods.

A climate change vulnerability assessment was developed for Tonto National Forest lands, and scored Ecological Response Units (ERUs) based on the probability or risk of significant change under future climate change. ERUs within 10 miles of the West Plant Site include Mojave-Sonoran Desert Scrub (112,463 acres), Interior Chaparral (52,954 acres), Semi-Desert Grassland (38,049 acres), Juniper Grass (18,890 acres), Pinyon-Juniper Evergreen Shrub (7,854 acres), riparian communities (3,258 acres), and Madrean Encinal Woodland (39 acres). Land classified as "sparsely vegetated" (which includes both disturbed lands and naturally occurring barren areas) includes 3,360 acres in addition to the ERUs listed above (Forest Service 2015). Vulnerability analyses are not available for desert scrub ERUs because the Tonto National Forest represents the northern extent of these communities, and as a result the vulnerability scores may be overstated; however, these communities are generally well adapted to weather extremes and variability across temporal scales. Vulnerability scores are also not available for riparian communities, though vulnerability can be inferred from the 6th-level watershed composite scores in Table 1 below (Forest Service 2015).

Of the Interior Chaparral ERU, 9% of the total area analyzed scored as low vulnerability, 65% scored as moderate, 23% scored as high, and 3% scored as very high. Of the Semi-Desert Grassland ERU, 10% scored as low, 51% as moderate, 30% scored as high, and 9% scored as very high. Of the Juniper Grass ERU, 67% scored as moderate, 9% scored as high, and 25% scored as very high. Of the PJ Evergreen Shrub ERU, 5% scored as low, 44% scored as moderate, 34% scored as high, and 17% scored as very high. Finally, of the Madrean Encinal Woodland ERU, 8% scored as low, 37% scored as moderate, 36% scored as high, and 18% scored as very high. Table 1 provides the composite score of vulnerability for 6th-level watersheds (for which it is available) within 10 miles of the West Plant Site. Of the twenty-three 6th-level watersheds, 13 are scored as moderate, nine are scored as high, and one (Whitlow Canyon) is scored as very high (Forest Service 2015).

Table 1. Sixth-Level Watershed Composite Vulnerability Scores

Name	HUC12 #	Vulnerability
Lyons Fork	150501000204	Moderate
Devils Canyon	150501000205	Moderate
Upper Mineral Creek	150501000206	Moderate
Lower Mineral Creek	150501000207	High
Walnut Canyon	150501000302	Moderate
Box Canyon – Gila River	150501000309	Moderate
Arnett Creek	150501000401	Moderate
Silver King Wash- Queen Creek	150501000402	Moderate
Potts Canyon	150501000403	High
Hewitt Canyon	150501000404	High
Alamo Canyon- Queen Creek	150501000405	Moderate
Cottonwood Canyon	150501000703	Moderate
Whitlow Canyon	150501000801	Very High
Middle Queen Creek (local drainage)	150501000809	Moderate
Superior Tank	150501000901	Moderate
Bloody Tanks Wash	150601030602	Moderate
Haunted Canyon	150601030701	High
West Fork Pinto Creek	150601030702	High
Upper Pinto Creek	150601030703	Moderate
Middle Pinto Creek	150601030704	High
Campaign Creek	150601030705	High
Pine Creek	150601060101	High
Fish Creek	150601060105	High