Appendix A

Current Climate, Climate Trends and Future Climate Conditions: Southern New Mexico and West Texas

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1 - Guidance

Analysis of climate change impacts to all USACE undertakings is governed by the following policy and guidance:

- USACE Climate Preparedness and Resilience Policy Statement (June 2014).
- Engineering and Construction Bulletin (ECB) 2018-14, *Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects*.

2 - Existing Conditions: Climate and Observed Trends

2.1 Introduction

The El Paso Rio Bosque wetlands are off-channel wetlands located on the U.S. side of the Rio Grande in south central El Paso, Texas. Water for the wetlands originates as groundwater pumped on site and as treated effluent from the Bustamante Wastewater Treatment Plan (WWTP). Effluent from the plant is primarily used for crop irrigation by El Paso County Water Improvement District #1 members downstream of the wetlands. Some portion of this effluent is diverted to the wetlands during the non-irrigation season, and a smaller portion may remain available during the irrigation system under emerging water agreements. The park also benefits from shallow groundwater seepage from the adjacent Riverside Canal, which carries diverted Rio Grande water during the irrigation season. The last will be adversely impacted by plans to line the Riverside Canal. Rainfall at El Paso provides stormwater runoff to the Rio Grande directly or via drains; stormwater is not currently captured for use within the city.

Water from the Bustamante WWTP originates primarily as City of El Paso municipal water supply. The City supply is comprised of Rio Grande surface water (obtained directly via surface water rights and by leasing water rights from agricultural water rights holders in El Paso County), and groundwater pumped from the Mesilla Bolson to the west and the Hueco Bolson to the east (El Paso Water Utilities 2007). Because a large share of the municipal water supply originates as Rio Grande surface water, this portion of the water supply is sensitive to changes in snowpack in the Upper Rio Grande in New Mexico and Colorado. Stormwater runoff, irrigation water demand and rates of groundwater withdrawal and recharge are sensitive to changes in local climate conditions. Consequently, climate change throughout the Rio Grande from West Texas north is relevant to the Rio Bosque wetlands.

Currently, storm water is not captured by the City of El Paso (El Paso Water Utilities and the City of El Paso 2009), but plans exist to construct a facility for this purpose.

2.1.1 Background

The Rio Grande Basin can be divided into two parts: the Upper Rio Grande Basin (above Elephant Butte Dam) and the Lower Rio Grande Basin (Elephant Butte Dam to the Gulf of

Mexico). Flows on the Upper Rio Grande are snowmelt dominated, with smaller, flashy late-summer storm flows; the Lower Rio Grande is operated for irrigation with spring runoff held at Elephant Butte Reservoir (and adjoining Caballo Reservoir) in southern New Mexico for irrigation season use by Texas. South of El Paso, at Presidio, Texas, flows in the Lower Rio Grande are supplemented by flows from the Rio Conchas, Mexico.

Generally, temperatures increase and precipitation decreases with southward movement along the Rio Grande. South of Albuquerque, mountain elevations become considerably lower and do not maintain a significant snowpack. Winter storms infrequently penetrate south of Albuquerque, so winters and springs become increasingly dry downstream of this location. The North American Monsoon becomes an increasing share of annual precipitation moving south from the Colorado border, but typically brings only localized, intense precipitation in contrast to slow, steady wide-area precipitation typical of winter storm systems.

The major controls on inter-annual variation in temperature and precipitation in the Rio Grande basin are imperfectly understood but are heavily influenced by tropical east Pacific and Gulf of Mexico sea surface temperatures. Winter precipitation, in areas receiving any, is affected by sub-decadal scale variations in El Niño-Southern Oscillation, which refers to cyclical patterns of sea surface temperature and air pressure in the tropical Pacific that affect temperature and precipitation across North America. In warm (El Niño) years, warm sea temperatures encourage increased winter precipitation and the formation of large snowpacks in the southern Rocky Mountains and Southwest (Sheppard et al. 2002). In cool (La Niña) years, cool sea surface temperatures in the tropical eastern Pacific reduce the availability of atmospheric moisture to the Southwest, resulting in low winter precipitation and small snowpacks (Sheppard et al. 2002). Multidecadal changes in Pacific Ocean temperatures known as the Pacific Decadal Oscillation can enhance or suppress the effects of El Niño and La Niña, particularly in concert with changes in Atlantic sea surface temperatures (McCabe et al. 2004). Controls on the strength and intensity of North American Monsoon precipitation in the study area are imperfectly understood, but are related to the intensity of surface heating during the summer and summer sea surface temperatures in the Gulf of Mexico and the tropical eastern Pacific.

2.1.2 Current El Paso Climate

El Paso can be classified as arid, with average annual precipitation totaling 9.43 in. Daily high temperatures in January average 57.2°F (50-63.4°F), with minimum overnight temperatures averaging close to freezing (29.1-39°F). Average January precipitation is 0.45 in (0-1.34 inches). By contrast, daytime highs in July typically average 94.5°F (88.8-101.4°F) with overnight minimums averaging 72°F (68.7-76.5°F). Average July precipitation is 1.49 in (0.04-3.96 inches).

At 31.8° N latitude, El Paso lies south of the winter mid-latitude storm track, resulting in a pronounced dry season from November through May (Nielsen-Gammon 2011). From late June through early October, El Paso falls within the North American Monsoon region. The wet summer season is characterized by high daytime temperatures, advection of warm, humid air primarily from the Gulf of Mexico, and the formation of thunderstorms as this humid air rises over sun-baked land surfaces, nearby mountain ranges, and advancing fronts.

Monthly pan evaporation rates exceed precipitation by an order of magnitude. Annual pan evaporation at nearby Las Cruces, NM averages 92.91 in (Western Regional Climate Center n.d.). Pan evaporation rates are lowest in January at 3.0 inches and greatest in June at 12.91 inches and July at 12.05 inches. In El Paso in 1997, open pan evaporation totaled 98.11 inches, with January at 4.6 inches and July at 13.12 inches (Reclamation 2008).

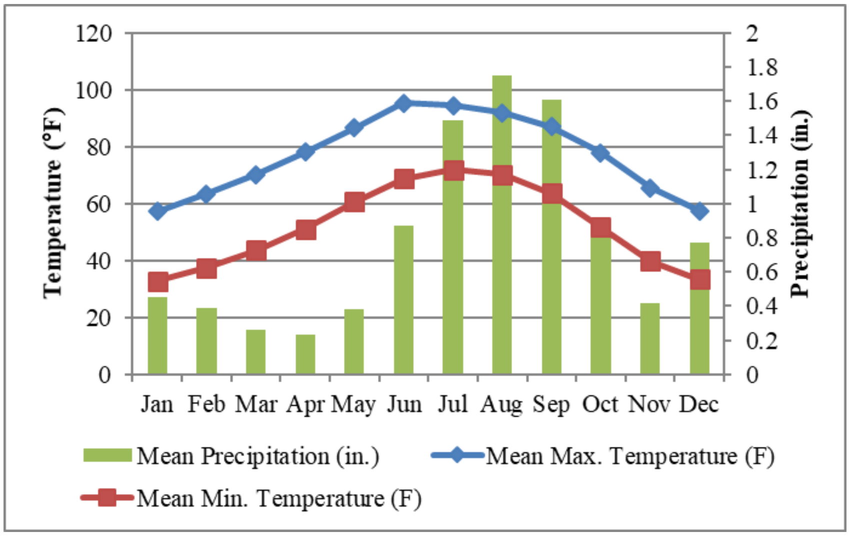

Figure 1 El Paso WSO Airport, Texas, NCDC 1971-2000 monthly climate normals.

Data available online at: http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?tx2797

2.1.3 Temperatures: Current Trends and Modeled Future Values

2.1.3.1 Literature Review

In the Rio Grande Basin below El Paso, TX, December-February average temperatures have increased approximately 4°F since 1960, particularly since about 1980 (Nielsen-Gammon 2011). A longer term trend is evident in Far West Texas (El Paso area), with larger negative temperature departures from the mean (comparatively more cool) early in the century and larger positive departures from the mean (comparatively more warm) towards century's end. Spring (March-April) and fall (October-November) average temperatures have shown no particular trend, indicating no significant change in the length of the growing season in this region (Nielsen-Gammon 2011). As in winter, temperatures in Far West Texas have a tendency to show a more definite trend than elsewhere in Texas, being relatively cooler early in the twentieth century and warmer towards the end. Summer (May-September) temperature trends are comparable to those of winter, with a definite warming trend evident beginning after 1970 (Nielsen-Gammon 2011). At a century-scale, Far West Texas is warming faster than any other region of Texas with temperatures increasing at 1.1 to 2.2°F per century (Nielsen-Gammon 2011; Vose et al. 2017).

As summarized by Gutzler (2013:4):

> *Temperature across the southwestern U.S. has increased so much and so steadily relative to interannual variability – especially in the warm season – that temperatures from the first half of the 30-year averaging period* [1981-2010] *are considerably colder than temperatures in more recent years, or expected temperatures in future years. Thus the seasonal outlooks almost always indicate enhanced probability of "above normal" temperature in the middle Rio Grande.*

2.1.3.2 Model Projections of Temperature under a Changing Climate

Model projections indicate that surface temperatures in the Southwest will warm substantially over the 21st Century (highly likely), and warming is likely to be higher in summer and fall than in winter and spring (Cayan et al. 2013). For the Southwest as a whole, compared to the period 1976-2005, models used in the most recent national climate assessment project (Vose et al. 2017):

- For the 2036-2065 period, the increase in average annual temperature is projected to range from 2-4°F (lower scenario) to 4-6°F (higher scenario).
- For the period 2070-2099, the increase in average annual temperature is projected to range from 4-6°F (lower scenario) to 6-8°F (higher scenario).
- Both cold and hot extremes are anticipated to be 5-11°F warmer than currently by the end of the 21st Century. By mid-century, the number of days above 90°F per year are projected to increase by 40-50 days in West Texas.

2.1.4 Precipitation: Current Trends and Modeled Future Values

Recent studies indicate an increase in regional precipitation for the period 1986-2015 compared to the average for 1901-1960 period of greater than 15% in winter, summer and fall, and decline in spring precipitation of a similar magnitude (Easterling et al. 2017). In the broader Rio Grande basin, the pattern is more varied, with decrease in winter, spring, and summer precipitation of 5 to >15% in the hydrologically important headwaters region (northern NM and southwestern CO), offset by increases in fall precipitation in the same area (Easterling et al. 2017). Declines in winter and spring precipitation are particularly concerning because these changes reduce streamflows in the Rio Grande, the primary surface water source for El Paso.

2.1.4.1 Hydrologic Trends

An attempt was made to investigate hydrologic trends in the project area via the USACE Climate Preparedness and Resilience Program Climate Hydrology Assessment Tool and Nonstationarity Tool. However, Rio Grande mainstem flows in this region are controlled primarily by irrigation demand, with water stored in Elephant Butte and Caballo Lakes upstream of the study area and released based on downstream demand. Neither tool contained usable gage records due to this regulation, a general paucity of available gages in west Texas and Southern NM, and the limited temporal range of available gage records (including gages downstream of the project area).

2.1.4.2 Model Projections of Precipitation under a Changing Climate

Model projections summarized in the most recent National Climate Assessment (Easterling et al. 2017) indicate drying in west Texas and southern NM in all seasons. Summer monsoon (convective) precipitation increases slightly (<10%) in nearby areas, but not in the immediate El Paso area. Winter precipitation may increase slightly (<10%) in the Rio Grande headwaters, but spring precipitation (which exerts a significant influence on spring runoff flows for Rio Grande (Chavarria and Gutzler 2018)) are projected to decline by up to 20% in the Rio Grande headwaters regions.

These findings are consistent with earlier studies that projected long-term drying in West Texas generally (NOAA (2013a), Gutzler 2013).

2.1.5 Projected Changes to Water Supply in the Upper Rio Grande Basin

A large share of the flows through the Bustamante WWTP into the El Paso Rio Bosque Wetlands originates as spring snowmelt runoff in the Upper Rio Grande basin. The Rio Grande has its headwaters in the San Juan Mountains of Colorado and flows generally south across the New Mexico and Texas borders to El Paso. Elephant Butte Dam, and Caballo Reservoir together mark the southern boundary of areas subject to spring runoff pulse; flows downstream of these two reservoirs consist of primarily of irrigation return flows (Reclamation 2011a). New Mexico contributes a total of 0.4 million acre-feet per year to Texas (Ward 2011). Groundwater withdrawals are the primary water source in the Texas portion of the Rio Grande. Other than some irrigation use and El Paso municipal use, Far West Texas relies on groundwater for most of its water supply, with an average of 395,458 acre-feet per year withdrawn mainly from the Edwards-Trinity outcrop and the Hueco-Mesilla Bolsons (Texas Water Development Board 2008).

Flows in the Upper Rio Grande are sustained by mountain snowpacks in Colorado and northern New Mexico, with large volume spring runoff peaks in May and early June, and smaller, flashier peaks during the monsoon season (July, August, and September). Snow rarely falls south of Socorro New Mexico in areas directly contributing flow to the Rio Grande. From Elephant Butte downstream to the Rio Conchos confluence, irrigation return dominates river flows. The Rio Conchos originates squarely within the North American Monsoon region, producing runoff peaks in late summer and early fall that are reduced by water resources development for agricultural use in the basin.

(a) Projected Changes to Upper Rio Grande Basin Snowpack, Snowmelt and Runoff

- Reductions in snowpack, declines in snow water equivalence, and advances in snowmelt are all projected to contribute to substantial declines in flows in the Southwest's rivers (Cayan et al. 2013). The future flows in the Rio Grande are likely to decrease by approximately one third by 2100, resulting in large decreases in water storage at Elephant Butte (Reclamation, USACE, and Sandia 2013; Reclamation 2011b). Decreased river flows are likely to reduce the ability of the Rio Grande to transport sediment, leading to net reductions in the rate of sediment accumulation at regional dams (Pinson et al. 2012, Huang and Makar 2013).

Spring runoff flooding on the Rio Grande only directly affects the basin above Elephant Butte because all runoff is captured at Elephant Butte and Caballo Reservoirs for hydropower and downstream irrigation use. These captured flows are released over the irrigation season in response to demand. Nowhere in the Rio Grande Basin in Texas is there any significant use of uncontrolled, run-of-the-river flow as water supply (Ward 2011). The impact of climate change on the Lower Rio Grande is likely to be primarily felt as a reduction in available flows for irrigation rather than significant changes to the timing of that availability.

2.1.6 Potential Impacts to Ecosystem Restoration Projects

Climate change may affect ecosystem restoration in the El Paso Rio Bosque Wetlands project area through:

- Decreases in water availability due to overall reductions in surface water available in the Rio Grande system and due to increased water demand across all sectors that could compete with ecosystem needs.
- Increased surface evaporation may concentrate pollutants in surface water bodies.
- Increased surface evaporation and warmer surface waters may result in decreased dissolved oxygen levels in surface waters.
- Higher temperatures may drive up evapotranspiration rates across the growing season, and increase surface water evaporation rates.
- Increases in groundwater use may occur to compensate for decreases in surface water. This may affect water table heights both regionally and locally, affecting groundwater availability at the wetlands.
- Ecological systems that already operate near thresholds for water availability may cross those thresholds, and undergo fundamental changes in the type of vegetation and wildlife they support.

Despite these contributing factors to projected changes in climate risk to ecosystem restoration projects, the USACE Watershed Vulnerability Assessment Tool shows that compared to other watersheds in the region and nationally, the future risk is not significantly greater (Figure 2). The greatest source of risk is impacts to at-risk freshwater plants, which this project seeks to mitigate.

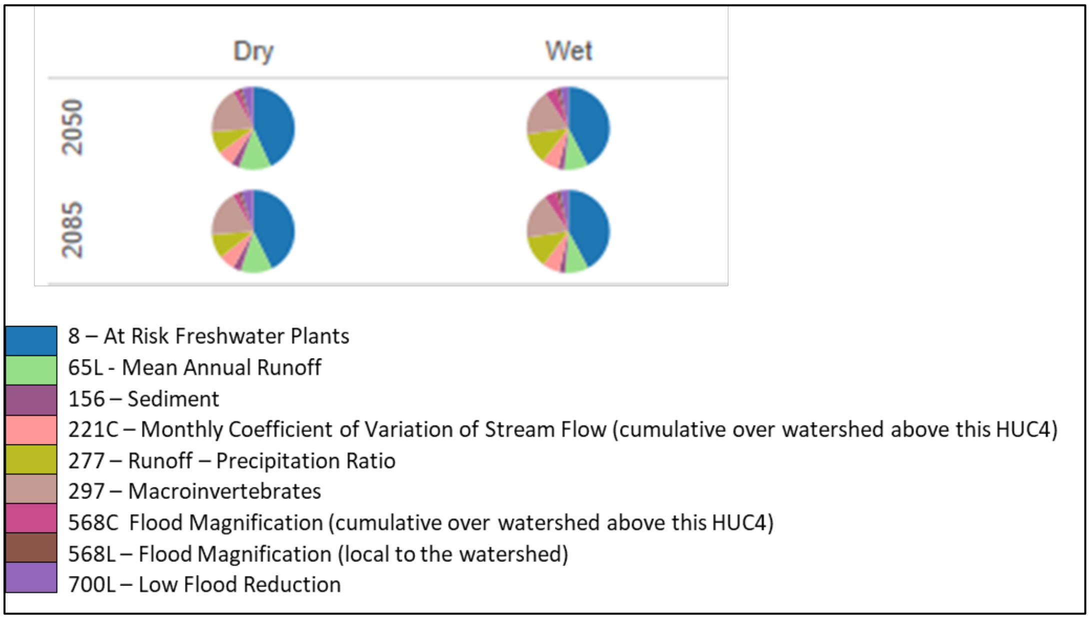

Figure 2 Watershed vulnerability assessment for ecosystem restoration, HUC 1304, Rio Grande – Amistad.

3 - Summary

Climate change is anticipated to impact the study area primarily through temperature increases, which are projected to rise by 4- 8.0°F by 2100, with extreme temperatures as much as 11°F higher. Temperature increases are likely to drive evaporation increases. Precipitation is anticipated to decline by up to 10% in all seasons.

The impacts to the study area of these changes are likely to be changes in water availability due significant reductions in storage at Elephant Butte resulting in reduced water availability in El Paso; lower water tables as groundwater is increasingly used to replace lost surface water supplies; and increased water demand due to evaporative losses in wetland areas. Many western municipalities are currently exploring options for storm water runoff capture. Implementation of such reforms may affect water supply quantity and quality in the El Paso area. Broader scale impacts to plant community composition (drought and thermal tolerance), migratory bird species composition (changes in migration routes, species drought and heat tolerances, food availability, and migration routes), insects and other species are likely but not quantifiable at present.

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