Appendix D: CLIMATE CHANGE PROJECTIONS

1. General Climate Trends

Climate change is likely to result in increases in temperature with associated changes in precipitation, more extreme storm events, including rainfall intensity and droughts, as well as increases in sea level and other consequences. Southern California is projected to have:

- Warmer winters, earlier warming in the spring, and increased summer temperatures.
- Some evidence for a slightly drier future climate relative to today.

Table 1 summarizes likely trends in temperature, precipitation, runoff, and fire risk as projected by downscaled Global Climate Models for the Goleta Slough area. The two emissions scenarios presented (A2 and B1) were developed for the IPCC Special Report on Emissions Scenarios (Nakicenovic et al 2000) and represent different plausible global trajectories as follows:

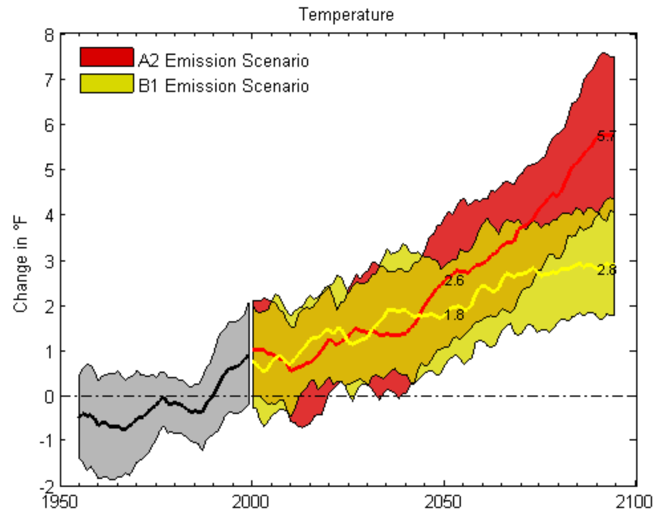
> HIGH EMISSIONS (Scenario A2). Medium-high emissions resulting from continuous population growth coupled with internationally uneven economic and technological growth. Under this scenario, emissions increase through the 21st century and by 2100 atmospheric carbon dioxide (CO2) levels are approximately three-times greater than pre-industrial levels.
>
> LOW EMISSIONS (Scenario B1). Lower emissions than A2 as a consequence of population peaking mid-century and declining thereafter, with improving economic conditions and technological advancements leading to more efficient utilization of resources. Under this scenario, emissions peak mid-century and then decline, leading to a net atmospheric CO2 concentration approximately double that of pre-industrial levels.

Temperatures are expected to rise for both scenarios, with a wide range of variability. The increase in temperature is projected to be fairly similar (+1.8 to 2.6°F) for both scenarios up to 2050, at which point the scenarios diverge, but both continue to increase. Precipitation is expected to increase until 2030 and then decrease, on average, but the change is relatively small and will likely be masked by the high variability of California rain events that already exists. Run-off, which is a derivative of precipitation, is projected to be highly variable, with an overall slight decrease. Fire risk is expected to decrease slightly over the next 100 years. Of the climate projections described in Table 1, temperature is the one best predicted by GCMs. The others are derivatives of temperature (or each other), which is partly why the uncertainty in precipitation and runoff is so great.

Table 1: Climate Change Projections for Goleta Slough

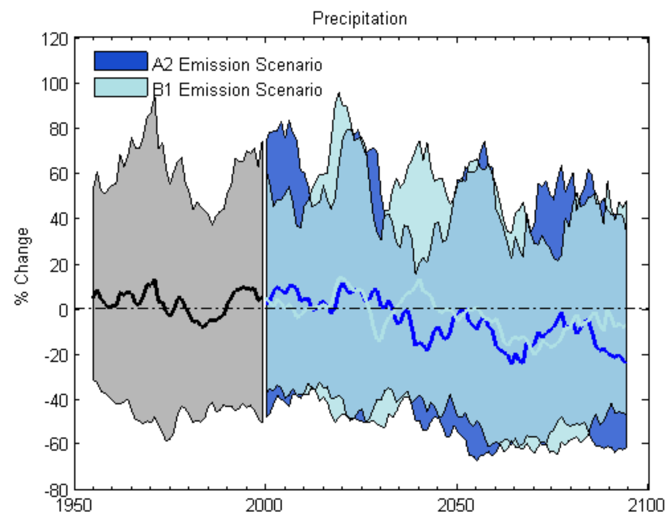
Temperature: Average temperature changes relative to the historic average from 1970-99. The heavy lines show average temperature change; the envelopes show the maximum and minimum projected change.

	2050	2100
B1	+1.8°F	+2.8°F
A2	+2.6°F	+5.7°F



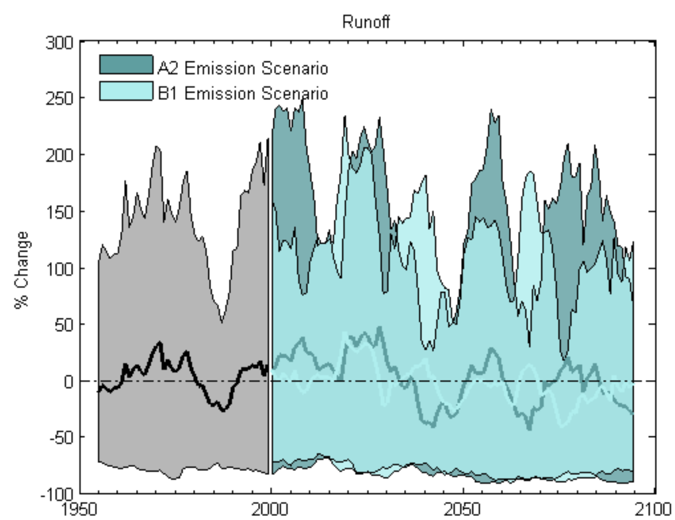
Precipitation: Average % change in precipitation relative to the historic average from 1970-99. The heavy lines show average precipitation changes the envelopes show the maximum and minimum projected change.

	2050	2100
B1	-5.2%	-7.4%
A2	-1.6%	-24.4%



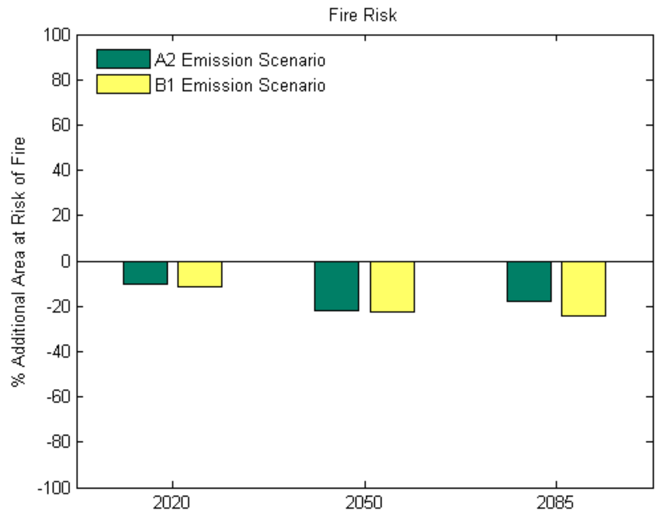
Runoff: Average % change in runoff relative to the historic average from 1970-99. The heavy lines show average precipitation changes the envelopes show the maximum and minimum projected change.

	2050	2100
B1	-16.1%	-1.8%
A2	-2.8%	-31.0%



Fire Risk: % change expected burned area, for 30 year averages ending in 2020, 2050, and 2085 compared to 2000.

	2020	2050	2100
B1	-12%	-23%	-24%
A2	-10.5%	-22%	-18%



All data for the plots shown above was processed using downscaled climate data downloaded through the Cal-Adapt web portal[1] on 10/18/2012. The climate grids were downscaled using the bias-correction spatial-disaggregation (BCSD) methodology—a two-step approach of (1) calibrating (bias-correcting) the historic model data to observed meteorological data, and (2) increasing the resolution of the climate grids (in this case from 1-degree to 1/8-degree or ~12km by 12km resolution) using local topographic gradients.

For a given emissions scenario, the range in results for the temperature, precipitation and runoff plots represent the range in General Circulation Models (GCMs). The lines shown for these plots represent a 10-year moving average for the downscaled data from four GCMs[2] that were available through Cal-Adapt. More information on this data is presented in Cayan *et al* 2009.

The fire risk plot represents an average of three GCMs[3] for three 30-year average time windows for A2 and B1 emissions. Additional detail on the fire risk data is provided in Westerling *et al* 2008.

2. Historic Trends in Sea Level

The Local rates of sea level rise are a result of two components – a global rate of sea level rise and a local component controlled by local or regional processes, such as tectonics, subsidence and changes to local wind fields. The combination of these two components leads to a rate of relative sea level rise which includes changes in the both the sea and land elevations. If sea level rises and the shoreline rises or subsides, the relative rise in sea level could be lesser or greater than the global sea level rise. Vertical land movement can occur due to tectonics (earthquakes, regional subsidence or uplift), sediment compaction, isostatic readjustment and groundwater depletion (USACE, 2011). As rates of global sea level continue to increase with climate change, at some point, the rate of vertical land movement will become less significant in determining the impact of sea level rise.

[1] www.cal-adapt.org
[2] NCAR CCSM3, NCAR PCM1, CNRM CM3, GFDL CM2.1
[3] Same GCMs with the exception of NCAR CCSM3

The Santa Barbara tide gage has a 30-year long period of record and a mean historic local sea level rise trend of 4.9 inches with a 95% confidence interval of ± 7.2 inches per century (Table 2, NOAA 2009). This large uncertainty in the historic record can be attributed to the discontinuous gage record resulting from several harbor construction projects. The most recent sea level rise report by the NRC estimates local mean sea level trends for a number of stations along the west coast. Santa Monica was the station nearest to Santa Barbara and is estimated to have a local historic mean sea level trend of 5.6 inches per century (Table 2**Error! Reference source not found.**, NRC 2012).

ESA PWA evaluated several studies and observations of vertical land motion more specific to the Goleta Slough area (Table 2). The values from these studies and observations were inconsistent in direction, and ranged from 5.9 inches/century of subsidence (NRC, 2012) to 8 inches/century of uplift (Gill, 2011). The NRC, 2012 estimate assumes a subsidence of 5.9 inches/century for all of California south of Cape Mendocino due to deep tectonic movements. This is a rough estimate that doesn't take into account localized variations in vertical land motion due to shallow subsidence and local tectonic movement. No studies of localized subsidence in the Goleta Slough vicinity were readily available.

Table 2: Historic Local Sea Level Trends and Vertical Land Movement

Source	Location	Period of Record	Mean Sea Level Trend (Local) inches/century	Est. Vertical Land Movement inches/century
IPCC, 2007	Global	1961 - 2003	7.1	N/A
NOAA, 2009	Santa Barbara	1973 - 2006	4.9 ± 7.2	8.0 ± 2.5*
NOAA, 2009	Rincon Island	1962 - 1990	13.1 ± 6.5	
NRC, 2012 Table	Santa Monica	1933 - 2008	5.6	
NRC, 2012 Table	Los Angeles			- 5.9 ± 5.1
Kirby and Burbank, 2003 Figure 1	Santa Ynez Mtns near Goleta Slough			~ 7.9

Positive values indicate uplift. The NRC values from each table are reported for the regions nearest to Goleta Slough.
* Gill, 2011, derived from Santa Barbara tide gage data.

3. Future Projections and Guidance on Sea Level Rise

3.1. Background and Previous Studies

In March 2011, the OPC published a resolution recommending that state agencies incorporate the risks posed by sea level rise into project and program plans (OPC, 2011). The resolution was targeted towards state agencies and non-state entities implementing projects or programs funded by the state or on state property (OPC, 2011). The OPC (2011) provides the following guidance on which SLR projections to use:

- Assess vulnerabilities over a range of SLR projections, including analysis of the highest SLR values presented in the state guidance document;
- Avoid making decisions based on SLR projections that would result in high risk; and
- Coordinate and use the same SLR projections when working on the same project or program.

Table 3: OPC 2011 Global Sea Level Rise Projections Relative to Year 2000

Year		Average of Models	Range of Models
2030		7 in (18 cm)	5 – 8 in (13 to 21 cm)
2050		14 in (36 cm)	10 – 17 in (26 to 43 cm)
2100	Low	40 in (101 cm)	31 – 50 in (78 to 128 cm)
	Medium	47 in (121 cm)	37 – 60 in (95 to 152 cm)
	High	55 in (140 cm)	43 – 69 in (110 to 176 cm)

The State of California provided interim guidance via the OPC on SLR projections (see Table 3 and OPC 2011) and requested that the National Research Council (NRC) establish a committee to assess sea-level rise to inform the state efforts. The states of Washington and Oregon, the U.S. Army Corps of Engineers, the National Oceanic and Atmospheric Administration, and the U.S. Geological Survey subsequently joined California in sponsoring the NRC study to evaluate sea-level rise in the global oceans and along the coasts of California, Oregon, and Washington for 2030, 2050, and 2100 (NRC, 2012).

The National Research Council recently released their study results (NRC 2012). Figure 1 shows a comparison between the range in NRC global and regional sea level rise estimates. NRC's projected values for CA are somewhat lower than the Vermeer and Rahmstorf (2009) projections, which were used in developing the OPC 2011 interim guidance. For Los Angeles (the regional estimate nearest to Goleta), NRC 2012 predicts a regional sea level rise (which includes an allowance for vertical land motion) of 5 to 24 inches by 2050 and 17.4 to 65.5 inches by 2100 (Table 4)

Table 4: NRC 2012 Relative Regional Sea Level Rise Projections Relative to Year 2000

Year	Projection (A1B scenario)	Range (B1 and A1F1 scenario)
2030	5.8 in (14.7 cm)	1.7 to 11.8 in (4.6 to 30.0 cm)
2050	11.2 in (28.4 cm)	5 to 23.9 in (12.7 to 60.8 cm)
2100	36.7 in (93.1 cm)	17.4 to 65.5 in (44.2 to 166.5 cm)

Note: Projections are for Los Angeles and include a vertical subsidence of 1.5 ± 1.3 mm/year.

The US Army Corps of Engineers (USACE) issued circular EC 1165-2-212 in October 2011 which provides guidance for the incorporation of direct and indirect physical effects of projected future sea level rise (USACE, 2011). According to this guidance, planning studies and engineering designs should evaluate alternatives against a range of local sea level rise projections which are defined by "low", "intermediate" and "high" rates of local sea level rise.

As sea level rises, the likelihood that a particular land elevation will be exceeded will increase. The first impacts that will affect infrastructure will be from extreme events as shown in Figure 2. The figure shows that as mean sea level rises so will the elevation of events of a fixed recurrence. This means that for a fixed elevation the frequency of being inundated will increase over time. For infrastructure this will mean that operations will be affected more frequently well before the site is permanently inundated by mean sea level.

The aforementioned studies do not provide consensus on whether the severity of storms will change as a result of climate change. Therefore, for the Goleta Slough Ecosystem Management Plan, ESA PWA assumes that increases in sea level rise can be added to flood event statistics derived from historic storm conditions.