APPENDIX K

Objective-Based Alternative Analysis

(Revised February 2017)

APPENDIX K
OBJECTIVE-BASED ALTERNATIVE ANALYSIS

1.0 Introduction

Buena Vista Lagoon is located at the boundary between the Cities of Carlsbad and Oceanside in northern San Diego County. Historically, the lagoon was in a dynamic equilibrium between a tidal-influenced saltwater system during dry conditions and a river-influenced freshwater system during wet weather conditions. In 1940, however, the lagoon converted to a freshwater system as a result of installation of a weir (a type of barrier) across the lagoon outlet that precluded saltwater from entering the lagoon. In the decades since, the lagoon has been progressively degrading in terms of benefits and value to biological communities, habitats, and human uses. Encroachment of vegetation into the open water basins of the lagoon has been occurring, leading to water quality and vector issues as circulation decreases. The lagoon is currently identified as an impaired water body for indicator bacteria, nutrients, and sedimentation/ siltation on the State 303(d) list. Without enhancement, the lagoon is expected to become a vegetated freshwater marsh or riparian woodland-meadow within the next 30 to 50 years. This transition will reduce coastal habitat biodiversity; eliminate saltwater marsh coastal wetland functions and values; and result in increased concerns about vectors, water quality impairments, and changes to aesthetic resources, thereby further degrading the environment in the vicinity of the lagoon.

Numerous federal, state, and local agencies and organizations have been involved in lagoon enhancement efforts since the 1980s. In July 2012, San Diego Association of Governments (SANDAG) became the California Environmental Quality Act (CEQA) Lead Agency for the Buena Vista Lagoon Enhancement Project, and has combined data from previous studies along with public input from the Notice of Preparation Scoping meeting held on May 9, 2013, to guide development of feasible alternatives. The overall purpose of the Enhancement Project is to enhance the biological and hydrological functions of Buena Vista Lagoon. Seven objectives were identified to achieve the goal of the enhancement plan, with an additional cost minimization objective that is not addressed in this analysis. Four alternatives were established to meet this purpose; a freshwater system, a saltwater system, a hybrid system of freshwater and saltwater, and a no project alternative. To establish which of the alternatives will best achieve the stated purpose of the project, SANDAG has established a quantitative analysis comparing the alternatives' results. This supplemental analysis, which was completed in addition to standard alternative comparison under CEQA, is designed to determine how well each alternative will achieve the stated project objectives. The outcomes of this analysis, in addition to the conclusion of the Environmental Impact Report (EIR), public comments received on the EIR, and the engineer's cost estimates for construction and maintenance, will assist SANDAG staff in determining its recommended preferred alternative.

2.0 Evaluation Criteria and Metrics for Project Objectives

To determine each alternative's success in achieving project objectives, SANDAG first broke down those objectives into a number of more specific evaluation criteria and determined an appropriate metric for each criterion. Breaking down the objectives in this way allows for a more in-depth analysis of each facet of the project's broad and sometimes complex goals. Those objectives, criteria, and metrics are listed in Table 1, followed by a brief description of each method and the reasoning behind its inclusion in the evaluation. Once the analyses were performed and the metrics quantified for each alternative, quantifiable data existed to compare the magnitude of strengths and weaknesses of each alternative. The results of those analyses are included in Table 2.

2.1 Description of Metrics

Objective: Enhance and maintain sensitive habitats and native species, including rare and endangered species, to promote coastal biodiversity within the region.

2.1.1 Acreage of nesting habitat for threatened and endangered species

Approximately seven threatened and endangered species are known to occur or have a potential to occur within the lagoon based on current and historic observations, as noted in Table 2. To maintain/promote the existing populations of threatened and endangered species within the lagoon, it is important to understand the acreage of suitable habitat available for nesting for each of the threatened and endangered species within the lagoon. The acreage of habitat for each threatened and endangered species was calculated by summing the acreages of habitat types that could be utilized for nesting of each species, both for existing conditions and each alternative. Although not all of the habitats included are ideal for each species, they are usable and are included to provide a conservative estimate of available acreage. Some habitats can be used by multiple species (e.g., mid-marsh is used by light-footed Ridgway's rail and Belding's savannah sparrow). Calculation of available acreage accounts for this overlap, and each suitable habitat type is only included once in the total acreage calculations.

Table 1
Project Objectives and Evaluation Criteria

Project Objective	Evaluation Criteria	Metric
1. Enhance and maintain sensitive habitats and native species, including rare and endangered species, to promote coastal biodiversity within the region.	Maximize benefit to threatened and endangered species. Maximize habitat diversity. Minimize net impacts to sensitive habitat. Maximize benefit to native fish and bird species.	Acreage of nesting habitat for threatened and endangered species. Habitat diversity (Simpson's Diversity Index, existing and post-enhancement). Acreage of sensitive habitat retained. Acreage available to fish and bird guilds. Estimate of fish richness (# of species).
2. Promote a system of native wetland and terrestrial vegetation communities that can be sustained given the opportunities and constraints of the lagoon and anticipated sea level rise.	~~Transition areas.~~[1] Long-term habitat stability.	~~Water surface elevation during 100-year storm event (feet) in 2050/2100.~~[1] Predicted habitat diversity (Simpson's Diversity Index) in 2050 and 2100.
3. Create conditions that curtail the growth and expansion of cattails, bulrushes, and invasive species.	Minimize expansion of cattails, bulrushes, and invasive species.	Acreage subject to cattail and bulrush encroachment (acres of unvegetated wetland less than 4 feet deep and below predicted 25% soil salinity). Upland acreage subject to invasive species encroachment. Acreage subject to invasion by caulerpa.

Project Objective	Evaluation Criteria	Metric
4. Protect, improve, and maintain water quality (e.g., reduce eutrophication) to meet water quality standards and address the 303(d) listed water quality impairments.	Improve general water quality. Reduce levels of bacteria that can cause illness. Decrease nuisance algae and nutrients. Maintain dissolved oxygen (DO) at levels appropriate for target biota.	Residence time – dry weather (days). Percent of days in a year bacteria levels exceed thresholds established in the San Diego Basin Plan. Percent of days algal biomass exceed thresholds established in the San Diego Basin Plan. Percent of time below DO objectives established in the San Diego Basin Plan.
5. Reduce vector concerns (e.g., potential for mosquito-borne disease) by minimizing potential mosquito breeding habitat.	Reduce area for mosquito-borne vectors.	Acreage of potential mosquito breeding habitat.
6. Maintain or reduce current flood risk to existing infrastructure and adjacent development.	Minimize flood inundation at infrastructure and adjacent development. Maintain or improve flood risk relative to the FEMA FIRM. Minimize future flood risks under sea level rise conditions.[1]	Elevation during 100-year storm event (feet). Area within modeled 100-year storm event floodplain (acres). Water surface elevation during 100-year storm event (feet) in 2050/2100.
7. Maintain and enhance public access to the lagoon and recreation opportunities that are consistent with resource protection.	Maximize recreational access. Maximize recreation for a variety of users.	Number and length of new trails. New opportunities available for fishing. Number of new access points (for trails, fishing, etc.).

Note: FEMA FIRM references Federal Emergency Management Agency Flood Insurance Rate Map.

[1] This metric was moved to Objective 6, as it is more closely aligned with the objective.

Table 2
Alternatives Metrics Comparison

Objective #	Project Objective	Metric	Existing Conditions	Alternative			
				Freshwater	Saltwater	Hybrid	
						A	B
1	Enhance and maintain sensitive habitats and native species, including rare and endangered species, to promote coastal biodiversity within the region.	Acreage of nesting habitat for threatened and endangered species	**100.9**	**63.9**	**126.9**	**98.7**	**99.2**
		Light-footed Ridgway's rail (total)	**96.2**	**57.6**	**68.6**	**67.3**	**67.8**
		Coastal and valley freshwater marsh	96.2	24.7	0	10.2	10.2
		Proposed cattail maintenance area	0.0	32.9	0	30.5	30.5
		Southern coastal salt marsh low	0	0	33.2	6.3	6.5
		Southern coastal salt marsh mid	0	0	35.4	20.3	20.6
		Western snowy plover (total)	**0.6**	**1.3**	**0.8**	**0.8**	**0.8**
		Beach	0.6	1.3	0.8	0.8	0.8
		California least tern (total)	**0.6**	**1.3**	**0.8**	**0.8**	**0.8**
		Beach	0.6	1.3	0.8	0.8	0.8
		Least Bell's vireo and southwestern willow flycatcher (total)	**2.2**	**2.2**	**0**	**0**	**0**
		Southern willow scrub	2.2	2.2	0	0	0
		Belding's savannah sparrow (total)	**0**	**0**	**90.4**	**46.8**	**47.1**
		Southern coastal salt marsh high	0	0	55.0	26.5	26.5
		Southern coastal salt marsh mid	0	0	35.4	20.3	20.6
		Coastal California gnatcatcher	**1.9**	**2.8**	**2.6**	**4.1**	**4.1**
		Coastal scrub	0.6	0.6	0.5	0.7	0.7
		Diegan coastal sage scrub	<0.01	0.6	0.8	2.1	2.1
		Diegan coastal sage scrub: *Baccharis*-dominated	1.3	1.6	1.3	1.3	1.3
		Habitat diversity (Simpson's Diversity Index, existing and post-enhancement)	0.63	0.65	0.84	0.87	0.87
		Acreage of sensitive habitat retained	229.8	62.9	52.8	63.0	63.0
		Acreage available to fish (total)	106.7	137.9	55.9	99.2	103.4
		Deep open water (8–12 feet deep)	0	4.5	4.0	5.0	5.0
		Open water non-tidal	106.7	133.4	0	32.1	32.1
		Open water tidal	0	0	51.9	62.1	66.3
		Estimated fish richness	12	12	75	87	87
		Acreage available to specific bird guilds					
		Waterfowl	217.8	220.5	221.8	220.7	220.7
		Shorebirds	111.6	82.9	167.6	117.2	117.9
		Wading birds	218.3	216	217.8	215.7	215.7
		Raptors	228.7	231	211.7	226	225.8
		Aerial fish foragers	106.8	171.8	55	134.8	134.1
		Gulls	129.7	161.4	105	134.4	133.9
		Upland species	18.7	15.9	15.2	16.3	16.3
		Riparian species	14.4	13.1	12.6	13.5	13.5

Objective #	Project Objective	Metric		Existing Conditions	Alternative			
					Freshwater	Saltwater	Hybrid	
							A	B
2	Promote a system of native wetland and terrestrial vegetation communities that can be sustained given the opportunities and constraints of the lagoon and anticipated sea level rise.[1]	~~Water surface elevation during 100-year storm event (feet) in 2050/2100~~[2]		~~(Note: for this metric, the Existing Conditions column represents the No Project condition)~~				
			~~Weir Basin~~	~~12.7/13.1~~	~~9.6/10~~	~~7.5/9.5~~	~~6.4/8.8~~	~~6.4/8.8~~
			~~Railroad Basin~~	~~12.8/13.2~~	~~9.7/10.2~~	~~7.9/9.8~~	~~7.1/9.3~~	~~7.1/9.3~~
			~~Coast Highway Basin~~	~~12.8/13.3~~	~~10.4/10.6~~	~~8.3/10.4~~	~~7.5/9.6~~	~~7.5/9.6~~
			~~I-5 Basin~~	~~16.9/17~~	~~15.4/15.4~~	~~8.8/10.8~~	~~16/16~~	~~16/16~~
		Predicted habitat diversity (Simpson's Diversity Index) in 2050		0.63	0.65[3]	0.80	0.86	0.86
		Predicted habitat diversity (Simpson's Diversity Index) in 2100		0.63	0.38	0.55	0.63	0.63
3	Create conditions that curtail the growth and expansion of cattails, bulrushes, and invasive species.	Acreage subject to cattail and bulrush encroachment (acres of unvegetated wetland less than 4 feet deep and below predicted 25% soil salinity)		106.8	1.0	0	0.9	0.9
		Acreage subject to invasion by *Caulerpa taxifolia*		N/A	0	55.0	70.3	69.5
4	Protect, improve, and maintain water quality (e.g., reduce eutrophication) to meet water quality standards and address the 303(d) listed water quality impairments.	Residence Time – dry weather (days)						
			Weir Basin	82	118	1	2	1
			Railroad Basin	75	116	1	1	1
			Coast Highway Basin	36	82	3	18	17
			I-5 Basin	8	33	3	23	22
		Percent of days in a year bacteria levels exceed thresholds established in the San Diego Basin Plan (west to east)						
			Weir Basin	13%	13%	0%	0%	0%
			Railroad Basin	13%	13%	0%	1%	1%
			Coast Highway Basin	11%	11%	1%	5%	5%
			I-5 Basin	5%	5%	1%	11%	11%
		Percent of days algal biomass exceeds thresholds established in the San Diego Basin Plan (west to east)[4]						
			Weir Basin	40%	1%	0%	0%	0%
			Railroad Basin	42%	4%	0%	0%	0%
			Coast Highway Basin	35%	0%	0%	0%	0%
			I-5 Basin	11%	14%	0%	0%	0%
		Percent of time below DO objectives established in the San Diego Basin Plan (west to east).						
			Weir Basin	12%	4%	0%	0%	0%
			Railroad Basin	20%	16%	0%	0%	0%
			Coast Highway Basin	7%	18%	0%	2%	2%
			I-5 Basin	0%	4%	0%	6%	6%

Objective #	Project Objective	Metric		Existing Conditions	Alternative			
					Freshwater	Saltwater	Hybrid	
							A	B
5	Reduce vector concerns (e.g., potential for mosquito-borne disease) by minimizing potential mosquito breeding habitat.	Acreage of potential mosquito breeding habitat		96.2	32.9	0	30.5	30.5
6	Maintain or reduce current flood risk to existing infrastructure and adjacent development.	Elevation during 100-year storm event (feet)						
			Weir Basin	12.0	9.6	7.0	6.0	6.0
			Railroad Basin	12.1	9.7	7.3	6.7	6.7
			Coast Highway Basin	12.1	10.4	7.7	7.0	7.0
			I-5 Basin	15.8	15.4	8.2	16.0	16.0
		Area within modeled 100-year storm event floodplain (acres)		318	303	263	285	285
		Elevation during 100-year storm event (2050/2100) (feet)						
			Weir Basin	12.7/13.1	9.6/10	7.5/9.5	6.4/8.8	6.4/8.8
			Railroad Basin	12.8/13.2	9.7/10.2	7.9/9.8	7.1/9.3	7.1/9.3
			Coast Highway Basin	12.8/13.3	10.4/10.6	8.3/10.4	7.5/9.6	7.5/9.6
			I-5 Basin	16.9/17	15.4/15.4	8.8/10.8	16/16	16/16
7	Maintain or enhance public access to the lagoon and recreation opportunities that are consistent with resource protection.	Number and length of new trails		– No formal trails within lagoon – Hosp Grove Trail – 5.5 miles, some located along lagoon's south edge. – Jefferson Street sidewalks and bike lanes – Carlsbad Boulevard bike/ pedestrian access via Class 2 bike lanes, a sidewalk, and Coastal Rail Trail Reach 1	New Boardwalk New trail to fishing area in northern Railroad Basin	New Boardwalk New trail to fishing area in northern Railroad Basin	New Boardwalk New trail to fishing area in northern Railroad Basin	New Boardwalk New trail to fishing area in northern Railroad Basin
		New opportunities available for fishing		Informal fishing opportunities at road and lagoon edges	4.5 acres of deep open water fish habitat, including trail access Fishing access from Boardwalk	4 acres of deep open water fish habitat, including trail access Fishing access from Boardwalk	5 acres of deep open water fish habitat, including trail access Fishing access from Boardwalk	5 acres of deep open water fish habitat, including trail access Fishing access from Boardwalk
		Number of new access points (e.g., trails, fishing, etc.)			New Boardwalk access – 3 sets of stairs to Carlsbad Blvd, access at Maxton Brown and Nature Center. New trail to fishing area in northern Railroad Basin	New Boardwalk access – 3 sets of stairs to Carlsbad Blvd, access at Maxton Brown and Nature Center Replace Carlsbad Blvd access along new bridge – two bike lanes, sidewalk, and separated pathway New trail to fishing area in northern Railroad Basin	New Boardwalk access – 3 sets of stairs to Carlsbad Blvd, access at Maxton Brown and Nature Center Replace Carlsbad Blvd access along new bridge – two bike lanes, sidewalk, and separated pathway New trail to fishing area in northern Railroad Basin	New Boardwalk access – 3 sets of stairs to Carlsbad Blvd, access at Maxton Brown and Nature Center Replace Carlsbad Blvd access along new bridge – two bike lanes, sidewalk, and separated pathway

Objective #	Project Objective	Metric	Existing Conditions	Alternative			
				Freshwater	Saltwater	Hybrid	
						A	B
							New trail to fishing area in northern Railroad Basin

[1] Given the continued influence of sea level rise and changes to salinity from increased freshwater inputs to the lagoon, habitat distribution within the lagoon will shift over time. This predicted distribution is relatively speculative, however, as it accounts for only sea level rise, which is one of many anticipated components of climate change. Other trends, such as changes in salinity due to altered conditions within the watershed, or changes in rainfall and weather patterns, are extremely difficult to predict and are not accounted for in this prediction.

[2] This metric was moved to Objective 6, as it is more closely aligned with the objective.

[2] ~~The acreage available to adjust to sea level rise is 0 under the Freshwater Alternative because the height of the weir will remain fixed at +5.6 feet.~~

[3] Simpson's Diversity Index for Freshwater Alternative is assumed to be relatively constant into the future; with adaptive management strategies in place habitat distribution is predicted to remain relatively stable as sea level occurs under this alternative. Sea water intrusion into the lagoon as sea levels rise above the weir elevation would result in more saline conditions that would eventually lead to habitat conversion to a more saltwater wetland system, but it is speculative to estimate when that would occur.

[4] Nitrogen and phosphorus are two factors that go into algal biomass calculations; therefore they are not included as separate metrics in this comparison. More specific information on individual nutrients is available in the Buena Vista Lagoon Enhancement Project Bacteria and Nutrient Modeling Report (Everest 2015).

2.1.2 Habitat diversity (Simpson's Diversity Index, existing and post-enhancement)

Maximizing habitat diversity is a major objective of the Enhancement Project. The Simpson's Diversity Index (1-λ') is a metric that reflects habitat diversity by presenting the probability that two points randomly selected from the site map will belong to different habitats. The index is calculated using the following formula:

$$\mathbf{1} - \boldsymbol{\lambda}' = 1 - \frac{\sum_{i=1}^{h} ni(ni-1)}{N\,(N-1)}$$

where: *λ'* = Simpson's Diversity Index, *h* = number of different habitats, *n* = the total number of acres of a particular habitat, and *N* = the total number of acres of all habitats.

The value of this index ranges between 0 and 1; the greater the value, the greater the site diversity. By using the Simpson's Diversity Index, the numerical variability of acre-by-habitat distribution in the area of the project under each alternative can be quantified.

2.1.3 Acreage of sensitive habitat retained

Post-implementation, it is important to understand what sensitive habitats are retained within the project area, outside of the work area, to understand what is available to promote biodiversity and contribute to enhanced sensitive habitats within the work area. These areas would contribute to the function of enhanced habitats within the work area to promote biological diversity and maintain native species diversity within the lagoon. The acreage of sensitive habitat retained includes all sensitive habitat that occurs outside of the limits of grading/dredging (and outside of the areas that would be temporarily impacted) within the project area, after implementation of the Enhancement Project. These acreages were calculated for each alternative.

2.1.4 Acreage available to fish

Buena Vista currently provides a recreational fishery for freshwater fish species. Under each of the alternatives, maintaining area for fish to spawn and grow is an important component of the project, and in the event a saltwater alternative is selected, it is important to provide area for development of a native marine fishery. Total acreage that would remain available to fish was calculated by summing the acreage of each habitat type that could support fish; namely, open water, deep open water, and open water tidal.

2.1.5 Estimated fish richness

The number of fish species the lagoon can support reflects the potential health of the fishery that can exist in Buena Vista under enhanced conditions. This number is calculated as fish richness, which was predicted for each alternative. Information for existing conditions, the Freshwater Alternative, and the freshwater portion of the Hybrid

Alternative was based on the current fish count in Buena Vista, as reported in the Buena Vista Lagoon Enhancement Project Biological Resources Technical Report (AECOM 2014). Conversion of the lagoon to a marine environment, such as that proposed under the Saltwater Alternative and west portion of the Hybrid Alternative, would allow for saltwater fish species to utilize the lagoon as well. Numerous saltwater species could use the lagoon; in order to predict the species richness that could exist under enhanced marine conditions, data from the restoration of Batiquitos Lagoon were used. Batiquitos Lagoon is a nearby system that was converted from a freshwater to a saltwater system, and resulted in conditions likely similar to those at Buena Vista Lagoon (Merkel 2009). Species richness for the Hybrid Alternative assumes existing freshwater species would continue to exist in the east portion of Buena Vista Lagoon, while the west portion (the marine area) would be populated by the saltwater species anticipated under the Saltwater Alternative.

2.1.6 Acreage available to bird guilds

In addition to fish species, Buena Vista Lagoon supports a number of bird species, not only those threatened and endangered species listed in Table 2. These birds can be broken into guilds, which each have similarities in the habitats they use, forage or prey base, or other characteristics. Providing habitat for various bird guilds under enhanced conditions is important for the Enhancement Project to ensure a diversity of birds is supported within the lagoon. Bird guilds utilize a range of habitats for nesting and foraging/hunting, some of which are more ideal that others. Total area available for use by different bird guilds was calculated under existing conditions and each enhancement alternative. Calculations are conservative and include those areas that may not be ideal for use by the birds, but could be anticipated to be used to some degree. Totals were calculated by summing the acreage of each habitat type that would support a given bird guild. A description of those guilds, and of common uses for each habitat, is included in Table 3 below.

Table 3
Bird Guilds and Suitable Habitat Types

Guild	Typical Species	Suitable Habitat	General Use of Habitat
Waterfowl	• Diving ducks • Dabbling ducks • Loons • Grebes	• Freshwater Habitat Transition Zone • Coastal and Valley Freshwater Marsh • Deep Open Water • Mudflat • Open Water • Proposed Cattail Maintenance Area • Southern Coastal Salt Marsh (Nontidal) • Southern Coastal Salt Marsh High • Southern Coastal Salt Marsh Low • Southern Coastal Salt Marsh Mid	Waterfowl typically use open water areas and adjacent vegetation for foraging and roosting. This vegetation can include both freshwater and saltwater marsh habitats, as well as deep and shallow open water and channels.
Shorebirds	• Western snowy plover • Western/least sandpiper • Long-billed/short-billed Dowitcher • Willet	• Freshwater Habitat Transition Zone • Beach • Coastal and Valley Freshwater Marsh • Mudflat • Proposed Cattail Maintenance Area • Southern Coastal Salt Marsh (Nontidal) • Southern Coastal Salt Marsh High • Southern Coastal Salt Marsh Low • Southern Coastal Salt Marsh Mid • Transitional	Shorebirds primarily utilize muddy, sandy, and rocky shoreline and beach areas in both freshwater and saltwater resources. Within coastal lagoons, they will use these habitats along with shallow water areas for foraging. Some shorebirds may also nest along these shorelines in sandy/shell beach habitats as well as areas with marsh vegetation.
Wading Birds	• Heron • Egret • Black-necked stilt • American avocet • Light-footed Ridgway's rail	• Freshwater Habitat Transition Zone • Coastal and Valley Freshwater Marsh • Eucalyptus Woodland • Mudflat • Open Water • Proposed Cattail Maintenance Area • Southern Coastal Salt Marsh (Nontidal) • Southern Coastal Salt Marsh High • Southern Coastal Salt Marsh Low • Southern Coastal Salt Marsh Mid	Wading birds are similar to shorebirds and are commonly found along shorelines, including coastal lagoons and other freshwater resources. They also forage within shallow waters and mudflats, and some forage in upland habitats. Nesting requirements for wading birds vary, and include low to high marsh vegetation, as well as taller riparian areas and trees.
Raptors	• Ospreys • Falcons • Peregrine falcon	• Freshwater Habitat Transition Zone • Beach • Coastal and Valley Freshwater Marsh • Coastal Scrub • Open Water	Raptors are birds of prey, and hunt and feed on other animals. Their prey items can consist of small mammals, birds, fish, and insects. Areas that support these types of animals, including developed areas, as well as riparian,

Guild	Typical Species	Suitable Habitat	General Use of Habitat
		• Proposed Cattail Maintenance Area • Riparian Enhancement • Southern Coastal Salt Marsh (Nontidal) • Southern Coastal Salt Marsh High • Southern Coastal Salt Marsh Low • Southern Coastal Salt Marsh Mid • Southern Willow Scrub • Urban/Developed • Eucalyptus Woodland	scrub, marsh, and open water areas, are therefore an important component of raptor habitat. Raptors typically roost in tall vegetation or trees, with the exception of a few species that nest/roost on the ground.
Aerial Fish Foragers	• Terns • Pelicans	• Deep Open Water • Open Water • Proposed Cattail Maintenance Area	Aerial fish foragers prey on fish in the water, and typically are visual hunters that need open water or channels for effective hunting.
Gulls	• California gull • Western gull	• Beach • Deep Open Water • Disturbed Habitat • Mudflat • Open Water • Southern Coastal Salt Marsh (Nontidal)	Gulls are birds that occur in a variety of habitats, but prefer open water, coastlines, mudflats, beaches, and disturbed/developed habitats.
Upland Species	• Bushtit • Thrasher • Grosbeaks • Kingbirds • Wrens	• Coastal Scrub • Diegan Coastal Sage Scrub • Diegan Coastal Sage Scrub: Baccharis-Dominated • Eucalyptus Woodland • Nonnative Grassland • Nonnative Riparian • Riparian Enhancement • Southern Willow Scrub • Urban/Developed	Upland bird species include species that primarily feed on insects and invertebrates. These species both forage and nest in areas with scrub or riparian vegetation, and will venture into adjacent developed areas as well.
Riparian Species	• White-tailed kite • Red-shouldered hawk • Cooper's hawk • Red-tailed hawk • Flycatchers • Vireos • Song sparrow • Herons • Wrens	• Nonnative Riparian • Eucalyptus Woodland • Riparian Enhancement • Southern Willow Scrub • Urban/Developed	Riparian bird species utilize the area between wetland/river and upland. Bird species that utilize riparian areas in coastal lagoon environments include both birds of prey and insect foragers, who can extend out into woodland and upland scrub, as well as developed areas, for foraging purposes.

Objective: Promote a system of native wetland and terrestrial vegetation communities that can be sustained given the opportunities and constraints of the lagoon and anticipated sea level rise.

~~**2.1.7 Acreage available to adjust to sea level rise (2050/ 2100)**~~

~~As noted above, the Enhancement Project is being designed to enhance the lagoon in its current condition, but is also trying to design resiliency into the project to accommodate potential future sea level rise. As sea level rise occurs, the availability of transitional upland areas available to convert to wetland habitats is a critical component of such resiliency. By 2050, a predicted sea level rise of up to 2 feet could occur, and areas within that 2-foot elevational rise could transition to wetland habitats, while intertidal habitats (inundated only part of the time) transition to subtidal areas (inundated all of the time). By 2100, a predicted sea level rise of 5.5 feet could occur, and the habitat conversion described above could continue. Future habitat distribution has been predicted through hydrologic modeling for the project in year 2050, which includes this 2-foot elevational rise in sea level. Total wetland acreage under existing conditions was subtracted from the total wetland acreage for 2050 and 2100 to determine the area available to transition over that period. Providing transitional habitats to accommodate sea level rise to the extent practicable, given the current constraints surrounding the lagoon, is a goal of the Enhancement Project. Predicted habitat distributions are relatively speculative, however, as the modeling accounts for only sea level rise, which is one of many anticipated components of climate change. Other trends, such as changes in salinity or runoff volumes due to altered conditions within the watershed, or changes in rainfall and weather patterns, are extremely difficult to predict and are not accounted for in this prediction. The proposed habitat distributions under each of the Enhancement Project alternatives also differ in their shorter-term post-enhancement wetland subtotals. For example, many areas that are currently riparian and/or upland would be converted as part of the Enhancement Project to wetland areas under the Saltwater and Hybrid alternatives. These same areas would not become wetland habitats under the Freshwater Alternative, but would become a freshwater habitat transition zone that would be expected to convert to wetland through sea level rise.~~

~~**2.1.8/2.1.9**~~ **2.1.7/2.1.8 Predicted habitat diversity (Simpson's Diversity Index) in 2050 and 2100**

The Enhancement Project is designed to enhance current conditions at Buena Vista Lagoon but also strives to create a system that is resilient into the future given anticipated sea level rise. Resiliency does not necessarily require that habitat distribution remains constant, but maintaining habitat diversity as sea level rises, as much as is practicable, is an objective of the Enhancement Project. Establishing a predicted diversity index, similar to that calculated for existing and post-enhancement conditions, can provide insight to the comparative resiliency of the different enhancement alternatives into the future. Future habitat distributions in 2050 and 2100 were predicted through hydrologic modeling, and these predicted distributions were used to calculate future diversity indices. It is important to note that the predicted habitat

distributions are relatively speculative, however, since sea level rise is one of many anticipated components of climate change. Other trends, such as changes in salinity or runoff volumes due to altered conditions within the watershed, or changes in rainfall and weather patterns, are extremely difficult to predict. Future conditions in portions of the lagoon that would be maintained in the short term as freshwater (e.g., with a weir) are particularly complex to predict. Both water level and salinity are anticipated to influence future habitat types. Given the uncertainty of future freshwater inputs from the developing watershed, as well as the variability in wave conditions that influence the amount of saline water entering the lagoon, assumptions have been made based on modeling but remain speculative. This added complexity and uncertainty exist under the Freshwater Alternative, the eastern portion of the Hybrid Alternative (e.g., I-5 Basin), and the No Project Alternative.

Objective: Create conditions that curtail the growth and expansion of cattails, bulrushes, and invasive species.

~~2.1.10~~ 2.1.9 Acreage subject to cattail and bulrush encroachment

Buena Vista Lagoon currently has large, dense stands of cattails that continue to encroach into the open water areas of the lagoon. The encroachment of cattails can lead to a number of biological, water quality, and vector issues through decreasing habitat diversity, water circulation, and vector control effectiveness. Cattails can grow in open water areas that are typically less than 4 feet deep and have a soil salinity of less than 25 percent. The Enhancement Project goals include curtailing the continued expansion of cattails to prevent the continued degradation of the lagoon. Areas subject to expansion of cattails after enhancement are represented by open water habitat less than 4 feet deep that would remain freshwater after enhancement. Saltwater areas would require some time to transition from cattails to salt marsh habitats, but existing cattails not actively removed by enhancement would die off and further encroachment would not occur.

~~2.1.11~~ 2.1.10 Acreage subject to invasion by caulerpa

The encroachment of invasive species after enhancement is complete is a concern within the lagoon. Potential aquatic invasive species include caulerpa, a saltwater plant species that could colonize in enhanced saltwater open water areas. The area of open water habitats subject to invasion by aquatic invasive species has been calculated.

Objective: Protect, improve, and maintain water quality (e.g., reduce eutrophication) to meet water quality standards and address the 303(d) listed water quality impairments.

~~2.1.12~~ 2.1.11 Residence time – dry weather (days)

Residence time reflects the amount of time a particle of water remains in a specific location within the lagoon and reflects circulation within the system. Lack of this

circulation can influence water quality in the system, with higher residence time often resulting in lower water quality and lower residence time often resulting in improved water quality. Residence time analysis was conducted using the Environmental Fluid Dynamic Code (EFDC) developed by the U. S. Environmental Protection Agency, described in detail in the Buena Vista Lagoon Enhancement Project Bacteria and Nutrient Modeling Final Report (Everest 2015). EFDC was used to simulate tidal exchange between the ocean and lagoon and the freshwater inflow from Buena Vista Creek under dry weather (3 cubic feet per second [cfs]) and wet weather (50 cfs) conditions. Residence times within the lagoon were determined based on the simulated transport and dilution of an initial amount of conservative dye placed uniformly throughout the lagoon over a 30- to 60-day period.

~~2.1.13~~ 2.1.12 Percent of days in a year bacteria levels exceed thresholds established in the San Diego Basin Plan

This metric reflects the percentage of days over a simulated year that the amount of total coliform bacteria in each basin exceeds the water quality objectives established in the San Diego Basin Plan, as described in the Buena Vista Lagoon Enhancement Project Bacteria and Nutrient Modeling Final Report (Everest 2015). Coliform bacteria levels reflect the lagoon's 303(d) listing for indicator bacteria, and reducing levels of these bacteria is critical to achieving the project objective of improved water quality. Daily average bacteria concentrations were determined for each basin using the EFDC hydrodynamic model. The percent exceedance was determined as the number of exceedance days divided by the number of days in a year.

~~2.1.14~~ 2.1.13 Percent of days algal biomass exceeds thresholds established in the San Diego Basin Plan

This metric is based on objectives for algal biomass established by the San Diego Regional Water Quality Control Board in the San Diego Basin Plan, as described in the Buena Vista Lagoon Enhancement Project Bacteria and Nutrient Modeling Final Report (Everest 2015). Excessive algae are a sign of poor circulation and potentially compromised water quality, and its presence can reduce dissolved oxygen (DO) levels in the surrounding water. The reduced DO levels in the water column can lead to unhealthy conditions for aquatic organisms. For all basins except the I-5 basin, nuisance biomass is primarily composed of macroalgae, and a numeric target of 90 grams per cubic meter (g m^{-3}) dry weight algae was used. In the I-5 basin, biomass is dominated by phytoplankton, and a numeric target of 25 milligrams per cubic meter (mg m^{-3}) was used. The percent exceedance was calculated by dividing the number of days of exceedance in the modeled year by the total number of days. Because nitrogen and phosphorous concentrations are factors in algal biomass calculations, they are reflected in this metric rather than considered separately in order to avoid redundancy. More specific information on individual nutrients is available in the Buena Vista Lagoon Enhancement Project Bacteria and Nutrient Modeling Report (Everest 2015).

~~2.1.15~~ 2.1.14 Percent of time below DO objectives established in the San Diego Basin Plan

As described above, low DO levels in the water column can harm aquatic life and produce unpleasant odors. When DO values fall to a certain level, the abundance and diversity of benthic organisms can decrease and localized fish kills can occur. The numeric target for DO, 5 milligrams per liter (mg L^{-1}), is based on the San Diego Basin Plan target value, as described in the Buena Vista Lagoon Enhancement Project Bacteria and Nutrient Modeling Final Report (Everest 2015). A daily value was calculated for each day of the model year using the hydrodynamic model described above. The percent exceedance was calculated by dividing the number of days of exceedance in the modeled year by the total number of days.

Objective: Reduce vector concerns (e.g., potential for mosquito-borne disease) by minimizing potential mosquito breeding habitat.

~~2.1.16~~ 2.1.15 Acreage of potential mosquito breeding habitat

While some freshwater marsh remaining after enhancement can indicate potential breeding area for mosquitos, additional measures are being incorporated into the Enhancement Project to reduce the potential for those areas to support breeding. Specified cattail management areas have been determined for stands of cattails that extend more than 150 feet from an open water area. In these areas, cattails would be managed to reduce the suitability of the habitat for vectors, while minimizing impacts to other species that may use these habitats, such as light-footed Ridgway's rail. Management would involve mowing or dredging channels within dense cattail stands to allow for swaths of open water throughout the vegetated area, resulting in increased circulation, access for aquatic predators, and aerial treatment effectiveness. These areas would be adaptively managed to adjust as more effective management strategies are developed. The metric of remaining cattail stands in the lagoon remains a helpful measure for alternatives comparison, however, since less potential vector breeding area requires less maintenance activity and less continued monitoring to ensure effectiveness of that maintenance.

Objective: Maintain or reduce current flood risk to existing infrastructure and adjacent development.

~~2.1.17~~ 2.1.16 Elevation during 100-year storm event (feet)

Development surrounds Buena Vista Lagoon and includes infrastructure as well as private residences. Flooding within these developed areas is an existing concern and it is a project objective to ensure that flood risk is not increased due to enhancement options. Comparison of predicted flood elevations (using a two-dimensional numerical hydrodynamic model [TUFLOW]), described in the Buena Vista Lagoon Enhancement Project Fluvial and Tidal Hydraulics Analyses, during storm events allows a comparison of how each enhancement alternative would change conditions from existing elevations

(Everest 2014). These elevations represent the anticipated flood risk to existing infrastructure and adjacent development.

~~2.1.18~~ 2.1.17 Area within modeled 100 year storm event floodplain (acres)

A large percentage of the lagoon and some adjacent areas, particularly to the west of the weir basin, and north, south, and east of the I-5 basin, are located within the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) 100-year flood zone, which represents the area potentially flooded during a 100-year storm event. The change in area predicted for inundation during that storm event represents the ability of the project to maintain or reduce current flood risk. The hydrodynamic model used for the project calculated the projected area of the 100-year storm event floodplain for each alternative, compared to the current area.

2.1.18 Sea level rise (2050/2100)

The Enhancement Project is being designed to enhance the lagoon in its current condition, but is also trying to design resiliency into the project to accommodate potential future sea level rise. By 2050, a predicted sea level rise of up to 2 feet could occur, increasing water elevations during storm events. By 2100, a predicted sea level rise of 5.5 feet could occur. These increased elevations increase the risk of flooding of adjacent infrastructure and/or roadways, as well as the potential for exposure of people or property to flooding hazards. Predicted flood elevations (as generated by TUFLOW, described above) represent the flooding risk for each alternative under sea level rise conditions.

Objective: Maintain and enhance public access to the lagoon and recreation opportunities that are consistent with resource protection.

2.1.19 Number and length of new trails

Although there are no formal trails traversing the lagoon, many informal pathways are used to access the lagoon perimeter and the Coastal Rail Trail has recently been constructed along Carlsbad Boulevard across the lagoon by the City of Carlsbad. The Audubon Nature Center and Maxton Brown Park also provide access to the lagoon perimeter, and maintaining or enhancing public access is an important objective of the Enhancement Project. Trails and other designated pathways are vital in ensuring that public access to the lagoon is available in a way that is consistent with resource protection. The inclusion of new trails and paths can enhance public access to the lagoon, both physically and visually.

2.1.20 New opportunities available for fishing

Recreational freshwater fishing within the lagoon is allowed and is a popular pastime. Various fish populations are found in the lagoon, and maintaining biologically healthy fisheries is an important part of ensuring this recreation opportunity remains after

enhancement of the lagoon. The creation of new fishing areas would enhance fish habitat and contribute to maintaining/increasing the quality of recreational fishing opportunities. Deep water areas suitable for supporting both freshwater and/or saltwater fish species for recreational fishing represent additional potential for fishing amenities in the lagoon. The creation of the Boardwalk under all alternatives would also offer a greater variety of fishing opportunities.

2.~~2~~1.21 Number of new access points (for trails, fishing, etc.)

The lagoon currently has a limited number of physical access points in terms of trails and designated fishing areas, as well as visual access points. The inclusion of new access points, including stairs connecting the Boardwalk to Carlsbad Boulevard and the trail to the fishing area in the Railroad Basin, supports and enhances passive and active recreational opportunities at the lagoon.

2.2 Conclusion

The performance of each alternative in regard to the metrics described above reflects the extent to which the alternatives fulfill the project objectives, as described in the Notice of Preparation. Quantitative metrics such as these allow for a direct comparison between alternatives, which takes into account each of the Enhancement Project goals. By doing so, this metrics-based comparison—in addition to the CEQA process and public comments received—will assist SANDAG in determining its preferred alternative going forward on the Enhancement Project. Ultimately, the comparison will help ensure the project achieves its goals of enhancing the biological and hydrological functions of Buena Vista Lagoon.

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