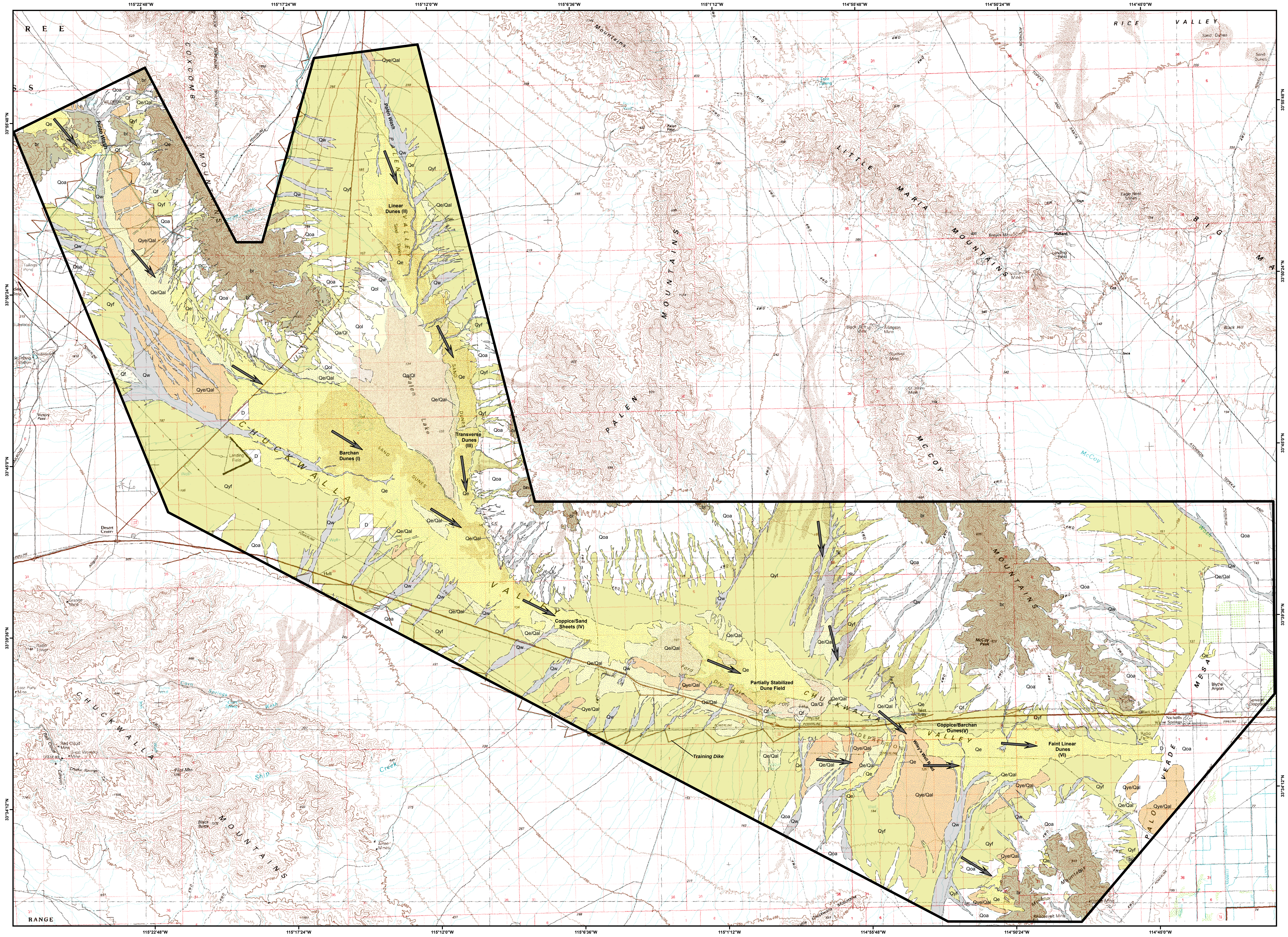

Projection: Universal Transverse Mercator, Zone 11 North, North American Datum of 1983

Topographic base from U. S. Geological Survey Eagle Mountains 30X60 Minute Quadrangle, 1986; Contour Interval 50 Meters. U. S. Geological Survey Blythe 30X60 Minute Quadrangle, 1986; Contour Interval 50 Meters.

Map Scale: 1:100,000

5 2.5 0 5 Miles

10 5 0 10 Kilometers

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EOLIAN SYSTEM MAP OF THE EAST RIVERSIDE AREA

A Project for the California Department of Fish and Wildlife
By the California Geological Survey

By: Jeremy T. Lancaster CEG

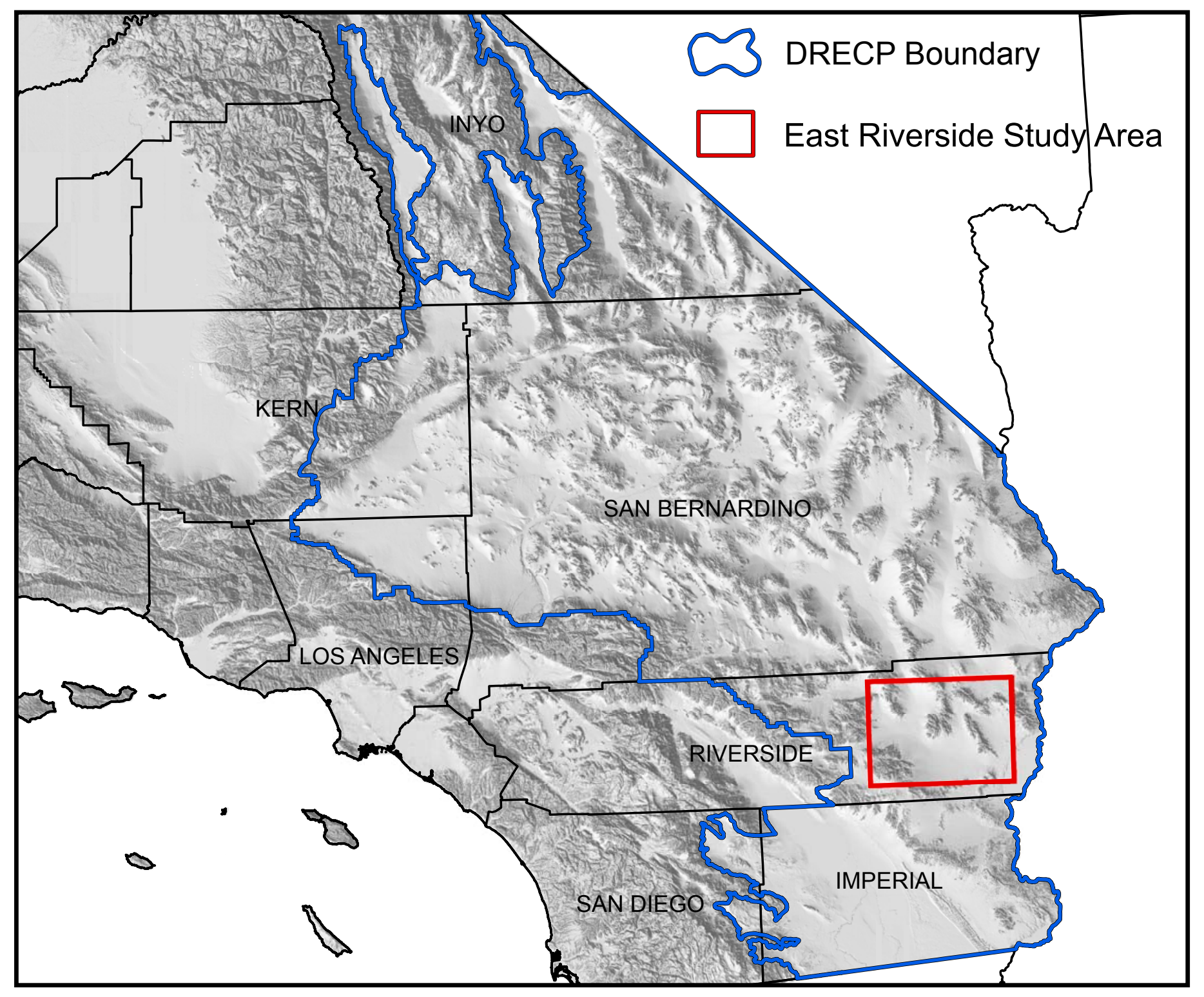

PLATE 2

PROJECT OVERVIEW

Eolian deposits are recognized as areas of higher biological value because they support specific natural communities and wildlife habitats. In response to potential increased land use from renewable energy projects in California where eolian deposits and processes are present, the California Department of Fish and Wildlife (CDFW) and the State and Federal Renewable Energy Action Team have designated sand dunes and their associated processes as areas of higher biological value for inclusion into a Habitat Conservation Plan / Natural Community Conservation Plan. This plan is known as the Desert Renewable Energy Conservation Plan (DRECP, http://www.drecp.org/). The Department of Conservation's California Geological Survey (CGS) provided CDFW with technical assistance on Eolian System Mapping under the Cooperative Endangered Species Conservation Fund (Section 6) Grant Program (Agreement Number P1382002). This project addresses the need for map-based information that identifies the presence of active eolian deposits and their source areas. The East Riverside area is one of several priority areas that are part of the DRECP, identified as Development Focus Areas.

This map of the East Riverside area was developed by CGS to assist in identifying components of the eolian system, including active areas of deposition, source areas, and zones of sand transport. This 100,000 scale map is based on compilation of existing sources and new mapping by CGS of Quaternary age surficial deposits that form the interpretive source in the identification of eolian deposits, sources, and zones of transport for the East Riverside study area. Depending on the geomorphic setting, eolian processes range from primary to secondary (Blair and McPherson, 1994). Within the regional zone of transport, eolian sand accumulates as dunes, sand sheets, and sand ramps. Eolian processes are primary where thick deposits accumulate, develop dune forms, and influence the geomorphology of the landscape. Where these eolian sand accumulations attain sufficient thickness (> 1.5 m) they are typically portrayed as eolian deposits on geologic maps. However, complex interactions occur locally on the landscape between source and deposition areas. Eolian sand is transported across playa lakes, playa fringe, alluvial fans, alluvial washes, and along bedrock divides. In these geomorphic settings, the primary processes acting on the landscape are gravity-driven flow of water and gravity-induced slope movements (e.g. translational failures and rockfalls). Along playa margins and piedmont landforms, transported eolian sediment interacts with vegetation and topographic irregularities that act as baffles, causing eolian sediment to deposit as thin sand sheets superimposed on these geomorphic surfaces. In the presence of vegetation, sand sheets are typically thin, relatively planar, and lack dune form (Cooke et al., 1993).

To address this complexity, CGS used a hybridized mapping nomenclature that identifies both the primary geomorphic process and the secondary processes superimposed on those features that are specific to eolian systems. Using an original surficial geologic nomenclature of Bedrossian et al. (2012), CGS developed a hybrid geologic nomenclature to identify the presence of eolian veneers. For example, a Holocene to late Pleistocene age alluvial fan (Qyf) within an active eolian transport corridor, may be overlain by a veneer eolian sand. In order to represent the superimposition of this secondary process on the landscape, the map unit is termed Qe/Qal. Conversely, the designation Qe is used singularly when the map unit attained an estimated thickness of > 1.5 m.

In addition to the hybridized mapping nomenclature, CGS used aerial photographic interpretation and field observations of deposit thickness, texture, and soil development in order to attribute map units with their relative state of activity. The relative state of activity is identified by interpretation of aerial photography and by observing the relative degree of soil development, including consolidation and pedogenic horizon development. Where eolian deposits have formed during past episodes of activity (late Quaternary), but have been stabilized by soil development, the land surface may have relatively lower reflectance, or albedo. Active eolian surfaces typically present features that suggest fresh scour of existing soil and vegetation, or deposition of eolian sand over pre-existing land cover. These surfaces have a relatively high albedo. Where observations suggested a period of stability, eolian deposits are designated as Qye (Inactive). Where observations suggest relatively recent activity, eolian deposits are designated as Qe.

This map, along with others developed as part of this study to address eolian system processes, is regional in nature and should not be used as a substitute for detailed studies in any specific area. It is intended for regional planning efforts and may be used as the framework to identify regional eolian processes and to guide future studies. For additional discussion regarding the East Riverside area and other mapped areas, please refer to the project report (Lancaster and Bedrossian, 2014).

East Riverside Area

The East Riverside area is located entirely within the Mojave Desert geomorphic province in Riverside County. The Mojave Desert is a broad interior region of isolated mountain ranges separated by expanses of desert plains that form sharp angles between the Garlock Fault to the northwest and the San Andreas Fault to the southwest (Norris and Webb, 1990). The area is characterized by isolated mountain ranges separated by desert plains averaging 750 m in elevation, with extreme variations in relief from 180 to 2,440 m (Bedrossian et al., 2012). The climate is arid, hot, and dry with average annual temperatures reported for Blythe ranging between 15.4° and 30.5°C (59.7° and 87.7° F) (DRI, 2014). According to the Desert Research Institute (DRI), January mean temperatures range from 5.4° to 19.4°C (41.7° to 66.9°F) and July mean temperatures range from 27.3 to 42.4°C (81.1° and 108.4°F). The average annual rainfall is 90.2 mm/yr (DRI, 2014).

The east to west trending Chuckwalla Valley is a prominent feature in the map area. This internally draining valley extends roughly 88 km (55 mi) from Chiriaco Summit to a few miles west of Blythe. The northwest portion of the valley contains Pinto Wash, the primary drainage entering Chuckwalla Valley from the Pinto Basin. This wash enters the Chuckwalla Valley between the Eagle Mountains to the west and the Coxcomb Mountains in the east. The Pinto Wash and the unnamed wash that drains tributary drainages southwest to Chiriaco Summit combine northeast of Desert Center terminating in Palen Dry Lake. The lowest point of this playa lake lies at an elevation of 130 m. To the northeast, a series of alluvial washes drain the Palen Valley toward the northern margin of Palen Dry Lake from between the Palen Mountains in the west and the McCoy Mountains in the east. From Palen Dry Lake to Ford Dry Lake in the east (playa elevation of 106 m) drainages are relatively confined by the gently sloping bajada extending from the Chuckwalla Mountains in the south, and the steeper bajada extending from the McCoy Mountains in the north. The valley broadens in the area of Ford Dry Lake. The playa lake serves as the terminus of surface flow from drainages in the western Chuckwalla Valley.

During the Quaternary Period, the Chuckwalla Valley has functioned as an alluvial basin, receiving water-borne sediment from the numerous mountain ranges that bound the valley. Alluvial deposits of Pleistocene age are found bordering these mountain ranges and are typically tilted, folded, and dissected. During wetter glacial periods the Ford Dry Lake may have intermittently filled and desiccated (Kenney, 2010a). Today the region is dominated by broad alluvial basins that continue to receive deposits from adjacent uplands. Holocene age alluvial fans and alluvial washes mimic the Pleistocene flow regime and locally cover, or are inset into, Pleistocene deposits. Holocene alluvial fan and alluvial wash deposits are comprised of poorly consolidated sand and gravel with subordinate amounts of silt and clay. These deposits merge onto the valley floor from north and south, locally aggrading on the distal piedmont plain and the basin floor.

The Chuckwalla Valley area is considered to be part of a regional sand transport corridor, extending from Dale Lake (east of Twentynine Palms), through the eastern Pinto Basin and into the Chuckwalla Valley (Zimbleman et al., 1995; Muhs, 2003). According to Lancaster and Tchakerian (2003), prevailing winds in the Mojave Desert are from the west and south, but structurally controlled topography exerts significant influence on regional wind patterns so that winds tend to blow parallel to the various valley axes. Throughout the central and eastern Mojave Desert, topographic control of winds and sand transport results in well-defined eolian sediment transport corridors that are characterized by areas of active and inactive dunes and sand sheets, together with sand ramps, i.e., topographically controlled accumulations of eolian, fluvial and slope deposits (Zimbleman et al., 1995). Transport of eolian sediment occurs as sand moves east to southeast due to resultant annual wind directions from the northwest dominantly controlled by Pacific winter storms with perhaps some influence of spring and summer winds from the southwest (Muhs, 2003). The sources of eolian sediment along this regional transport corridor include playa lakes, alluvial fans, alluvial washes, and to a lesser degree, Pleistocene and Holocene eolian deposits, that lie within or are near to the transport corridor.

Interpretation and Description of Map Units

CGS focused preliminary mapping efforts on the identification of late Pleistocene to Holocene age eolian deposits. Mapping included the identification of features related to primary geomorphic processes (e.g. alluvial fan), followed by interpretation of those deposits related to secondary processes (e.g. eolian sand sheets superimposed on alluvium). CGS made field observations and collected data in April 2014. These observations included identification of soil texture and pedogenic development, as well as descriptions of surface cover, including the presence of gravel lag, desert pavement, or the accumulation of freshly deposited eolian sands. Based on field observations, Quaternary alluvial deposits exhibiting soil development and/or having a gravel lag, were not retained as map units. These are Pleistocene to mid-Holocene age deposits that have been isolated from deposition for thousands of years. Eolian transport may occur across these surfaces, but thick, laterally continuous deposition of eolian sand is of low potential.

The collection of site-specific wind data was not a part of the project scope, however, CGS used recent studies by Muhs et al. (2003) and Kenney (2010a, 2010b) as the primary references for analyzing potential sand sources and sand transport directions in the East Riverside study area. In order to identify regional transport pathways Muhs (2003) examined wind regimes in Blythe, finding that drift potential is about due east, resulting from primarily northwest and southeast winds. To assist the identification of sand transport path ways for several renewable energy projects, Kenney (2010a and 2010b) evaluated sand transport corridors in the Chuckwalla and adjacent valleys. This evaluation benefitted from surficial geologic mapping, identification of wind vectors from dune crest orientations and ventifacts, as well as analysis of mineralogic provenance. This study presents the Chuckwalla Valley as a complex eolian system, with sand transport entering the valley from: (1) Dale Lake – Clarks Pass to Palen Dry Lake corridor; culminating at the Palen Dry Lake dune field (2) Palen Valley corridor entering the Palen Dry Lake – Chuckwalla Valley Axis sand corridor, south of Palen Mountains; (3) an area of sand transport and wind erosion within the partially stabilized dunes at Ford Dry Lake; and, (4) Palen-McCoy sand corridor entering the Chuckwalla Valley axis on the east side of the valley that drains the Palen Pass area. In addition to identifying transport path ways in the area, Kenney (2010a) also ranked discrete zones of transport activity south of Palen Dry Lake. Given the scale and regional nature of this CGS assessment, relative ranking of discrete transport zones was neither adopted from (Kenney, 2010a) nor conducted independently. However, CGS reviewed aerial photography and made observations of dune crest orientations, as well as field observations of leeward dune orientations on coppice. These data indicate overall sand transport azimuth directions of: (I) 125° in the barchan dune field south of Palen Dry Lake (II) 140° in the linear dunes located in the upper Palen Valley; (III) 175° in transverse dunes located on the western piedmont slope of the Palen Mountains; (IV) 135° in lee dune orientations developed in coppice dunes west of Ford Dry Lake; (V) 150° in lee dune orientations developed in coppice and barchan dunes, southwest of Wiley's Well Road and Highway 10; and, (VI) 90° in linear dune crests east of Wiley's Well Road and north of the transmission power line access road (numerals related to locations on map). These observations are fairly consistent with those identified by Kenney (2010a, 2010b). Along the zones of sand transport, active dunes and sand sheets (map unit Qe) are punctuated by eolian sand accumulations that have been stabilized by vegetation. These stabilized areas suggest a period of inactivity. However, given these areas are relatively small and intermixed, falling below the minimum map unit of 40 acres, they are not differentiated from the active sand accumulations on this map. In and along the margins of the active zone of sand transport, strong interactions occur between alluvial fan and alluvial wash systems with active sand sheet distribution. These areas of active distributary flow appear to form the most prominent sources of eolian sand. As observed in the field, sand sheets and coppice dunes form in direct response to alluvial deposition. Most alluvial fans (Qf/Qyf) and washes (Qw) on the distal piedmont, and near the zone of active sand accumulation, are bordered by sand sheets and coppice dunes. The following description of map units summarizes CGS observations.

Active Eolian Deposits	
Qe/Qal	Active windblown deposits consisting primarily of sand sheets and coppice dunes superimposed on alluvial deposits typically < 1.5 m in thickness. Sand is predominantly fine- to medium- grained. Dry color is typically very pale brown 10YR 7/4.
Qe	Active windblown deposits consisting of dunes and sand sheets typically greater than > 1.5 m in thickness. Sand is predominantly fine- to medium- grained. Dry soil color is typically very pale brown 10YR 7/3 to 7/4. Dunes include transverse, crescentric, parabolic, and barchan forms, as well as coppice dunes and amorphous sand hummocks.
Active Eolian Sources	
Qw	Alluvial wash deposits consisting of unconsolidated fine - to coarse-grained sand and sandy gravel with subordinate fine sand and silt; bar and swale morphology.
Qf	Alluvial fan deposits of latest Holocene age. Unconsolidated to slightly consolidated sand and gravel, poorly to moderately sorted, fine - to coarse-grained; gravel includes pebbles, cobbles, and boulders. Surfaces exhibit bar and swale morphology, locally obscured by eolian deposition, and are traversed by active alluvial washes (Qw).
Qyf	Alluvial fan deposits of latest Pleistocene and Holocene age. Unconsolidated to slightly consolidated sand and gravel, poorly to moderately sorted, fine - to coarse-grained; gravel includes pebbles, cobbles, and boulders. As mapped, this unit is broadly distributed throughout the Chuckwalla Valley, locally containing active alluvial fans and washes that serve as sources of eolian sediment. Modification of surface drainage by the construction of training dikes for the control of storm water runoff creates downstream shadow effects, rendering parts of these alluvial fans abandoned.
Qa/Ql	Alluvial valley and lacustrine deposits of late Holocene age. Poorly consolidated silt, sand, and clay. Dry soil color is light yellowish brown 10YR 6/4. In the map area, these deposits comprise Palen Dry Lake. As apparent from field observations and aerial photographic review, lakebed deposits are interlayered with alluvial deposition by ephemeral sheet flow.
Potential Eolian Sources	
Qye/Qal	Stabilized windblown deposits consisting primarily of sand sheets and a small percentage of stabilized dunes superimposed on alluvial deposits. Sand is predominantly fine- to medium- grained. Dry soil color is light yellowish brown 10YR 6/4 to pink 7.5YR 7/4. These deposits may exhibit pedogenic soil development consisting of a reddened cambic soil horizon, or carbonate filaments and coatings on pebble clasts, with carbonate morphology of Stage I to I+.
Qol	Lacustrine deposits of late Pleistocene age. Moderately consolidated silt, very fine sand and clay. Dry soil color is brownish yellow 10YR 6/6. In the map area, these deposits are present on the west side of Palen Dry Lake and are locally dissected and abraded by alluvial channels and wind action.
Other Map Units	
Qoa	Alluvial deposits of Pleistocene age (undifferentiated). This map unit is comprised of alluvial fan, alluvial valley, and alluvial terrace deposits. In general, these deposits are capped by a gravel lag or desert pavement with moderately to strongly developed desert varnish.
br	Bedrock (undifferentiated). This map unit is comprised of a variety of Paleozoic sedimentary, Mesozoic granitic, and Tertiary volcanic and sedimentary rocks.
D	Areas within active sand transport/deposition resulting from anthropogenic modification of the land surface. In the map area, these include farms and other land uses larger than 10 acres
— — — — -	Contact between map units, approximately located. May be gradational where local variations in map unit thickness exist.
➞	Predominant transport direction. Inferred from geomorphic interpretation of dune crest migration, sand sheets and streaks, and ventifacts. Active sand transport occurs between mapped source and active eolian deposits.

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