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November 22, 2007

To: Robert A. Hamilton
Consulting Biologist
7203 Stearns Street
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From: Norbert P. Psuty, Ph.D.
Consulting Coastal Geomorphologist

Re: Final Report, Coastal Dunes, Broad Beach, Malibu,
including Site Visit, October 30, 2007
and evaluation of other documents

Overview:

This report constitutes my professional opinion of the coastal geomorphological condition of the land parcel located at 30732 Pacific Coast Highway, Malibu CA, and the dunal components of the topography found thereon. It also includes my evaluation of the several reports prepared by Dr. Edith Read regarding the site.

I had the opportunity to visit the site on October 30, 2007 and to observe the geomorphological features that comprise the surface of that land parcel. I made observations of the character of the topography, the sediments, the landforms, aspects of the vegetation cover, and the spatial associations of these characteristics. I had paper copies of aerial photographs in the field with me and I noted some of the characteristics on these aerials. In addition, I took many digital photos of the site as a record of my observations. All ground photos in this report are from October 30, 2007.

I have copies of Dr. Read's reports of July 19, 1999; October 23, 2006; December 18, 2006; and July 30, 2007. I also have a copy of her updated map of May 30, 2007.

General Comments:

The site has a coastal foredune with dimensions that are similar to those seen on the property immediately to the east and on properties several parcels to the west. The general height, slope, vegetation cover, distance inland of the active beach were consistent with adjacent areas and thus appear to be in balance with the ambient processes. But, the foredune is not a coherent ridge. It is breached in several places, and

its form is altered in association with those breaches. Further, the locations of the breaches are sites where coastal dune forming processes have extended secondary aspects of the foredune a bit farther inland. That inland displacement of process and form is finite in dimension and comprises a subsequent modification of the initial foredune morphology. Together, these primary and secondary active foredune geomorphological features comprise the dunal forms on this property. In general, there were no dunes or significant dune remnants inland of the currently-active primary and secondary foredune system on this property.

Specifics:

Coastal Foredune – The foredune is a geomorphological feature that is in active exchange of sand with the beach. It is at the inland margin of the free sand beach and the seaward margin of pioneer vegetation (Martínez, et al., 2004). The pioneer vegetation serves as a sediment trap that causes a ride-shaped accumulation of sand parallel to the shoreline (Fig. 1). The coastal foredune shares the sediment budget of the beach system and tends to advance, retreat, or remain in place relative to the positive, negative, or equilibrium characteristic of the sediment budget of the general area.

Figure 1. Example of a coastal foredune located at the upper portion of the beach at the location of pioneer vegetation. It is an area of sediment accumulation caused by the sand-trapping characteristic of the vegetation.

Gaps in the Foredune and Features of Gaps:

The creation of blowouts or breaches in the primary foredune and the subsequent topographical forms created inland of the foredune ridge produce geomorphological features that are referred to as secondary coastal dunes (Psuty, 2004), that is, dune features that evolve from the previously-formed primary foredune ridge. Usually, the sand that is transported inland through the gap accumulates in small ridges along the sides of the gap to create a U-shape or parabola, or sand may extend and taper to a series of hummocks in a fan-shaped pattern inland of the foredune crestline. These hummocks represent the extent of the secondary and active component of the foredune evolution. These features are characteristics of secondary coastal dunes because they are a modification of the primary foredune form. They may be active secondary features if sand is being received and there is a potential for change in location as well as change in mass at the location. They would be inactive or stabilized if the form is completely static and completely covered with vegetation and beyond the zone of mobile sand transport. Under conditions of rapid eolian transport or inadequate vegetative stabilization, the opportunity for hummocks to develop is reduced and the resulting feature is a broad sand sheet extending inland from the location of the gap.

Figure 2. Example of a gap in the foredune crestline and subsequent eolian transport inland to form secondary ridges and hummocks.

Coastal Geomorphological Characteristics of the Site:

The site has a coastal foredune with dimensions that are similar to those seen on the property immediately to the east and on properties several parcels to the west. The general height, slope, vegetation cover, and distance inland of the active beach were consistent with adjacent areas and thus this location appears to be in balance with the ambient processes.

The foredune exists is four segments at this site (Fig. 3). There is a foredune segment at the eastern and at the western end of the land parcel. There are two more segments in the central portion of the parcel. There are three gaps in the foredune crest. At both the eastern and western segments there is a continuation of the general form and its dimensions of the foredune into the adjacent properties.

Figure 3. Distribution and association of foredune morphologies at the site.

The western foredune segment, F1, is a continuation of the foredune that extends westward to the boundary of the beach club. The foredune broadens a bit westward. Foredune segment F2 has an alongshore extent of about 40 ft, and has an inland projection of about 40 ft on its western margin. Foredune segment F3 has an alongshore

extent of about 35 ft and is a single ridge with inland projections at its margins. Foredune segment F4 has the greatest alongshore extent on the property (45+ ft) and also has the greatest topographical variety. It has a well-developed foredune ridge and there are secondary features immediately inland that are nearly as high with both vegetated and bare sand forms. Its total inland width is about 45 ft at this location. The topographical variety in F4 continues onto the adjacent property to the east.

Of the three gaps, the westernmost is about 25 ft wide and is a foot or so higher that the upper free sand beach. The central gap is the narrowest breach in the foredune, about 6 ft, and it is the highest, several feet above the upper free sand beach. The easternmost gap is similar in width to the western gap, about 15-20 ft. But, a part of the eastern gap is a bit higher and incorporates a more-defined ridge-like barrier to inland sand transport (Fig. 4). However, the ridge-like feature is unvegetated and is not accumulating sediment along its crest. For on the order of 70% of the alongshore distance at the site, the foredune is densely vegetated and it forms an effective barrier to inland sediment transport by wind.

Figure 4. Irregular foredune crestline in the vicinity of the eastern gap between F3 and F4. Ridge forms are extending inland orthogonal to the shoreline, some hummocky features occur farther inland. There is a ridge of coarser debris (of cultural origin) within the gap, adjacent to F4.

The shore-parallel foredune ridge is regarded to be a primary foredune feature because it is in active exchange of sediment with the beach, through a combination of water and wind processes transporting sediment to accumulate in the zone of pioneer vegetation

(Fig. 5). The crestline is irregular in elevation and in plan view. In addition, there are gaps in the foredune ridge and there is some transport of sand through the gaps to cause accumulations inland of the general ridge crestline. These gaps are referred to as blowouts, indicating that wind processes have lowered the crestal elevation and are actively transporting sand inland through these breaks in the dune crestline. Both the central gap and the eastern gap include an artificial basal ridge that forms a barrier to inland transport (Fig. 4). Some of the sand that has blown through the gaps has accumulated in the foredune to the lee of the crestline, adding eolian topography to the inland side of the foredune (Figs. 2 and 4). Each of the four segments displays some topographical features that attest to this type of broadening of the foredune ridge. Together, the seawardmost portion of the foredune and the sand that has accumulated at its inland side combine to form the modern foredune ridge. Most coastal foredunes have a similar history and similar configuration. That is, the crest is crenulate in pattern and there are zones of inland transport of sand to occasionally broaden the foredune ridge.

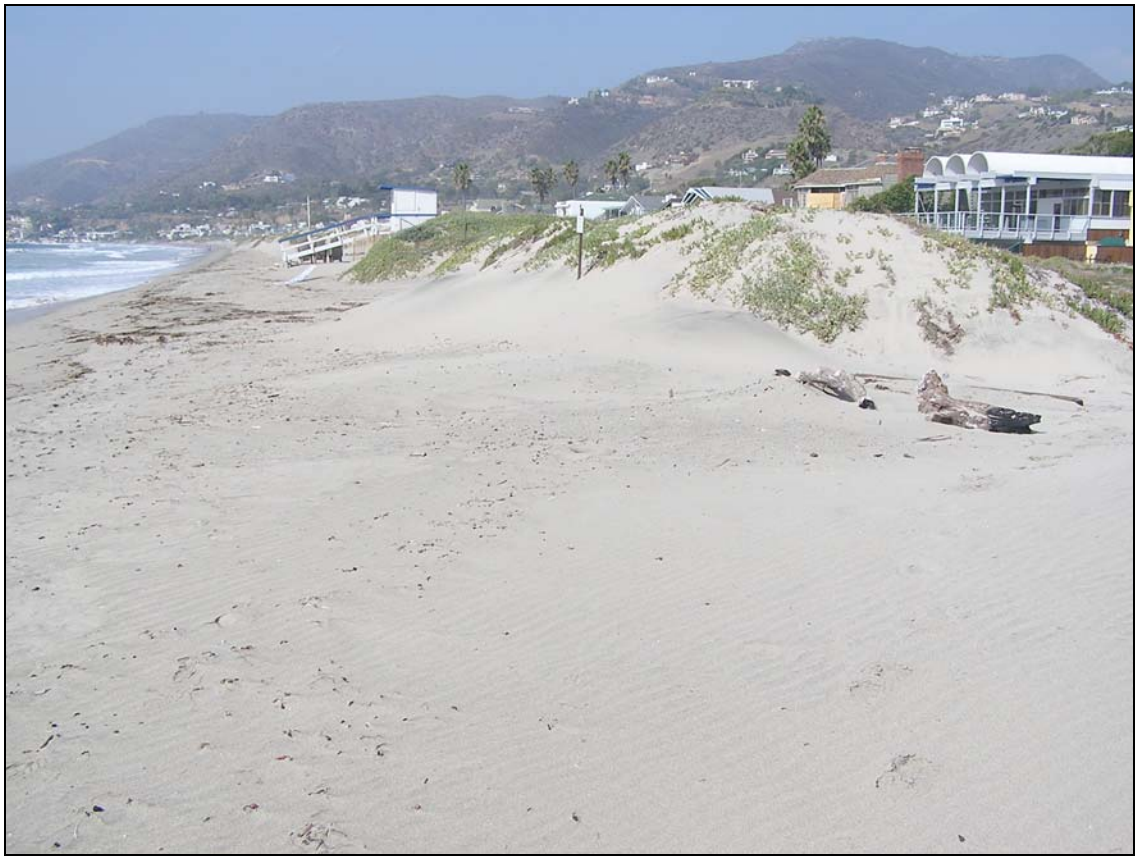

Figure 5. Foredune located at upper limit of beach and at position of pioneer vegetation. The recent spring tide swash line has approached the base of the foredune. Some debris is in the gap between foredune segments F3 and F4.

Mobile Sandy Hummocks:

As sand in transported through the gaps in the foredune, it spreads out as a fan-like deposit that blankets the area immediately inland of the foredune ridge. Some of the sand will be subsequently accumulated to create a secondary set of dunal forms inland of the

foredune. These are referred to as secondary dune hummocks or sand sheets, depending on the morphological character of the accumulations (Psuty, 2004). The broad sand sheet deposits that are worked and reworked by wind produce some mobile dune features and eventually show a concentration of larger and heavier particles on the surface. As the wind effectively removes the finer particles from a deposit, a lag surface composed of coarse particles begins to develop that is no longer mobilized by the ambient winds. And, although there may be fine sediments below the lag surface, the ambient winds are not able to reach below the surface and thus the source area for sediment supply becomes limited. Mobile sandy hummocks, 0.5-1.5 ft high, and lag surfaces were seen in the vicinity of the gaps in the foredunes, and extending inland (Fig. 3). The development of mobile sandy hummocks and lag surfaces is part of the secondary development or modification of the initial foredune topography and it is associated with the dissection of the linear foredune system and the creation of small bodies of sand migrating inland. In this instance, the mobile hummocks and the lag surface exist within the blowouts cutting through the foredune ridge and they extend a few tens of feet inland of the foredune ridge. In most of this site, the hummocky features are associated with small clumps of vegetation, sometime not (Fig. 6). The creation of the mobile sandy hummocks and the lag surface is a secondary component of the active foredune topography because it is a subsequent modification of the initial foredune ridge. It exists because of the creation of gaps in the foredune, because of funneling of sand inland through these gaps to create a sheet-like deposit, through the selective removal of finer surface sediment to create small mobile mounds, and the development of a lag surface composed of coarser sediment.

Stable Sandy Hummocks:

There are a number of small, vegetated sandy hummocks at distances 30-90 feet inland from the general trend of the foredune crestline (Fig. 7). They form a zone that is oriented from W to E, with an increasing inland distance toward the east. They are functionally related to the three gaps in the foredune and to the secondary transfer of sand inland. They are the topographical features, less than 1.0 ft high and in the range of 5-8 ft across, formed near the margin of the eolian-transported accumulation in contact with stabilizing vegetation. Many of the inter-hummock areas are characterized by coarser sediments, indicative of eolian transport that has mobilized the available sand and has left the coarser fragments as a stable veneer on the surface. This is a common condition in areas that have winds blowing over sediments of variable transport origin (by water as well as by wind), or sediments previously transported by much higher energy levels (such as storm conditions). Some of the inter-hummocky area has a mixture of silt in the surface and in the sediments immediately below the surface (I poked to 4-6 cm). Silt is not usually transported by wind in this coastal environment, but could be transported by storm waves or it could be sediment left in place deposited by flood waters at an earlier time, or it could have been introduced by cultural practices. Whichever the origin, the silt and the coarser sediment combine to form a basal surface on which the sand hummocks occur or are adjacent to. This stable lag surface also limits the amount of local sand available to contribute to the enhancement of the hummocks. This zone is transitional between the actively-moving sand and the disturbed area located farther inland.

Figure 6. Numerous mobile sandy hummocks occur both within and to the margins of the lag surface, with varying degrees of associated vegetation. The darker areas from left to right in the middle of this photo are lag surfaces extending inland from the gap between F3 and F4.

Although I do not have wind data to confirm the analysis, there is geomorphological evidence for a WSW to ENE vector that is further modifying the form and distribution of the hummocks associated with the gaps in the foredune on this property. Some of the evidence is the substantial accumulation of sand at the fence line and vegetation at the boundary of the beach club to the west of the parcel. The area seaward of the beach club building is without a foredune and is generally bare sand. The effective transport direction is to the east and there is the equivalent of a foredune created at the fence line where sand has been accumulating in the line of vegetation (similar to the foredune setting). Further, the zone directly to the east of the fence line is replete with small dunal forms created by sand that has moved beyond the fence line. Nearly all of it is well vegetated and relatively stable at this time. There are some minor residual remains of hummocks that are no longer active extending onto the property from this source, they are inland of the active foredune and gap geomorphology on the parcel visited at this time. They are not part of the normal foredune topography.

Another indication of the WSW-ENE vector is the orientation of the inner belt of sand hummocks related to the gaps in the foredune. It appears that the field of hummocks is being elongated toward the east-northeast (Fig. 3), both moving in that direction and having greater mass of sand at the eastern and northeastern margin of the property. There

is also less lag surface visible at the eastern margin of the property, indicative of less eolian deflation and more accumulation.

Figure 7. Sequence of foredune topography: the foredune ridge is at the far right, the mobile sand hummocks are inland of the ridge, and the stable hummocks are at the left of the photo. Silt and coarse debris create a darker color to the surface around the stable hummocks, view is to the east-northeast. The sequence is a gradation rather than absolute boundaries. The three units comprise the broad foredune system.

Disturbed Area:

All of the site is disturbed, but the inner half of the site is especially modified from its natural condition. The aerial photo from 1972 (Read, 10/23/06; Image #7234087 in the California Coastal Records Project, http://californiacoastline.org/) shows the topographical characteristics at a former time. On this photograph, only the inner 25% of the site has a vegetation cover over a field of modest hummocks. A small building exists near the northeast corner of the parcel. The remainder of the site is largely destabilized because of the removal/destruction of vegetation cover. The seaward portion of the site has a few small, dissected remnants of a foredune that have little continuity across the upper margin of the beach. A subsequent aerial photo from 1979 shows a more extensive disruption and removal of the dunal topography in the disturbed area (Read, 10/23/06; Image #7948040 in the California Coastal Records Project, http://californiacoastline.org/). At this time, the inland half of the site has been leveled and nearly all of the formerly-vegetated hummocks have been obliterated. A second

building appears in the northeastern corner of the parcel. The disturbed area has two large patches of bare sand in this photo as well as a number of catamarans both inland as well as on the upper beach adjacent to some of the foredune remnants. There is a wide path at the western side, about 15-20 ft in width, leading from near the PCH to the beach. There is another path leading from the buildings to the beach at the eastern side. In the post-1979 era, there has been some recovery of foredune features, but the portion of Figure 3 labeled 'Disturbed' continues to remain devoid of dunal features. It retains an almost planar surface, a condition that is strongly suggestive of excavation or leveling and removal of the pre-existing topography. The disturbed area has not recovered much topography from that time to the current period.

There is also evidence of disturbance in the foredune location (1979). Several paths continue from the inland location through the foredune zone. Only a few small mounds of vegetated topography appear at the upper beach location (far less than is seen to the east and west of the site on aerial photos from the comparable time). However, there does appear to be a more well-defined series of vegetated hummocks in the position of the foredune in the 1979 aerial photo than in the 1972 aerial photo.

Conclusions:

There is a modern foredune and associated foredune topography on this site at this time. It has three gaps or breaches in the crestline and there is an associated dunal topography created by eolian transport inland through the gaps. This associated topography is a secondary formation that consists of a broad sand sheet, often characterized by a concentration of coarse material on the surface (a lag surface), and a zone of small sand hummocks on and at the inland margin of the lag surface. This sequence of active dunal topography is limited to the seaward portion of the site. There is an absence of active dunal topography in the disturbed area at the inland portion of the site. There is evidence of disturbance throughout the site, extending from the position of the present foredune to the inland boundary of the parcel. However, there has been recovery of the foredune geomorphology in the post-1979 time period that includes the primary foredune, and the secondary mobile hummocks and stable sandy hummocks. Continual recovery of the coastal foredune and its primary and secondary features is related to the integrity of the foredune ridge. A more coherent foredune ridge will concentrate geomorphological development in the zone of pioneer vegetation inland from the upper beach. A less coherent foredune ridge will support more transport through the gaps, creation of a lag surface, and the enhancement of sandy hummocks on and at the margin of the lag surface (as shown on Fig. 3).

Comments on Reports by Dr. Read:

I have read the reports prepared by Dr. Edith Read dated July 19, 1999; October 23, 2006; December 18, 2006; and July 30, 2007. I have also seen the updated dune delineation map by Read, updated May 30, 2007. Overall, I think that Dr. Read has made a very good assessment of the conditions at this site. She has established and defended a

definition of coastal foredunes that is generally consistent with the geomorphological literature. She has made a number of comments, interpretations, and observations that I am going to comment on:

1. In Read (7/30/07), she indicates that these dunes are being affected by the reduction of sediment supply arriving from Trancas Creek and thus will not be re-created into their former dimensions and extent. I want to emphasize that point. All foredune systems are continually evolving and that evolution is dependent on the supply of sediment reaching their location. I agree with Dr. Read that the conditions of reduced sediment supply to the coastal foredune at this location will affect their subsequent development negatively, and will likely result in diminished extent of the foredune system. However, there is some sediment currently available and a foredune system could be supported, albeit at a scale less than what existed prior to cultural development in the past century.
2. In Read (7/30/07), there is discussion about backdune or plain, and sandsheet/washover areas. She provides an interpretation about the use of these terms and their meaning from an ecological and a geomorphological perspective. She specifically applies my geomorphological classification of foredune terminology (Psuty, 2004) to that offered by Barbour and Johnson (1988). Unfortunately, this comparison is not appropriate. I use the concept of sandsheet/washover areas to apply to loci of abundant sand that constitutes an accumulation that may be reworked into subsequent morphologies. Barbour and Johnson (1988) appear to apply their term to a negative or erosional situation that results in topographical depressions. They are not the same; one is driven by the presence of additional sediment, the other by the absence of sediment input.
3. The updated dune delineation map by Read (5/30/07) appears to be based on the presence of vegetation species that inhabit dune or sandy areas and are present on this site. My interpretation of foredune conditions is based on geomorphology and has a different net distribution, but in some ways has considerable similarity. Dr. Read has mapped the presence of vegetation types. I have mapped the presence of dunal topographies. Dune topographies indicate that the active zone of eolian features related to the present foredune is narrowest at the western margin of the site and widest at the eastern margin (see Fig. 3 in this report). Both portrayals show the presence of the foredune and aspects of the inland extension of the dunal system. A major difference in the two maps is the width of the dunal area at the western margin. I used the formation of the existing foredune as the starting point and then expanded the dunal system as it relates to the eolian transport through the gaps into a landward position. I mapped that extent as the limits to my active coastal foredune system. However, in my description of dunal features in the general vicinity of the site, I commented on the location of the beach club to the west where there was no foredune at the shoreline. I described a “foredune-like” ridge at the fence that is perpendicular to the shoreline, and inland of the general trend of the foredune crestline. That ridge is the site of very dense vegetation trapping a lot of sand moving across the bare sand surface of the beach club. Some of that sand extends into the adjacent property to the east, and it appears that there are some old, minor (stabilized) sand

hummocks extending farther to the east and entering the margin of this parcel of land (30732 PCH). Related to form and function, these stabilized hummocks are not part of the normal foredune system and they were created by an unusual and presumably temporary condition from offsite. I incorporated them in the area of disturbance of former habitat and distant from the current locus of beach/foredune interaction.

FORECAST:

There is a sand beach along this portion of the coast and there will be some foredune development consistent with the supply of sand available to maintain the beach and be transported into the adjacent pioneer vegetation. Under normal conditions, the foredune will attain dimensions similar to those in the environment at present (location, height, width, topography). If the foredune ridge is unbroken, the eolian transport will be largely restricted to the 50 ft or so comprising the broad foredune similar to that at the eastern boundary of the land parcel. If the foredune ridge has gaps, there will be an opportunity for inland transport of wind-blown sand to accumulate in the form of a sand sheet or small migrating sand hummocks. The larger and more persistent the gaps, the greater the opportunity for inland transport and creation of sandy hummocks at greater distances from the foredune ridge. There is not a lot of sand in this coastal system and thus the dune features will never attain great dimensions. Indeed, because of a decreasing sediment supply being delivered to the coast due to flood-control measures, the pace of dune development will be slower in the future than in the past.

If the only wind direction were onshore, the sand transported inland would accumulate and dunes would increase in size as a function of the sand availability. However, there is a significant offshore wind system in the area (Santa Ana winds) that could easily dislodge any sand that came through the gaps and was not fixed by ambient vegetation. The recent Santa Ana event left some indication of its effects in the form of small streams of sand pointing offshore adjacent to vegetation clumps in the sandy hummock zone, and small tongues of sand on the seaward sides of the gaps in the foredune (see details in Fig. 6). The Santa Ana winds are a factor in the net sand transport and they substantially reduce the rate of hummock formation by returning sand to the position of the foredune and to the beach.

It is likely that the present small sandy hummocks immediately inland of the modern foredune are several decades in age, and are related to the presence of the gaps in the foredune ridge. If the foredune were coherent, it is likely that any hummocks present to their lee would be centuries in age (many centuries) because of the competing wind transfer directions. The condition of future dunal topography is contingent on the integrity of the coastal foredune. The greater the coherence and integrity of the foredune, the lower the rate of inland transfer of sand and the slower the rate of inland dunal development. It is likely that the natural evolution of the coastal foredune and the associated dunal topography at inland positions are occurring at the centurial time scale. Human interference with the integrity of the coastal foredune will accelerate the process

of inland dunal topographical development. Human regulation of the foredune-creating processes and resulting landforms should be directed to restoration and maintenance of the sediment availability and the continuity of the pioneer vegetation on the foredune ridge. With adequate protection of the processes of sedimentation inland of the upper beach, the foredune system will be preserved and the focus of conservation can be directed toward the seaward portion of the parcel. With an absence of enhancement and maintenance of the foredune system, the inland extent of eolian sediment transfer will increase and wider buffer zones will be required to preserve coastal dune morphologies.

Literature Cited

Barbour, M. G., and A. F. Johnson, 1988. Beach and Dune. In: M. G. Barbour and J. Major (eds.), Terrestrial Vegetation of California. California Native Plant Society Special Publication Number 9, pp. 223-261.

Martínez, M. L., N. P. Psuty and R. A. Lubke, 2004. A Perspective on Coastal Dunes. In: M. L. Martínez and N. P. Psuty (Eds.), Coastal Dunes: Ecology and Conservation. Springer-Verlag (Berlin), pp 1-10.

Psuty, N. P., 2004. The Coastal Foredune: A Morphological Basis for Regional Coastal Dune Development. In: M. L. Martínez and N. P. Psuty (Eds.), Coastal Dunes: Ecology and Conservation. Springer-Verlag (Berlin), pp. 11-27.

Read, E., July 19, 1999. Vegetation and Sensitive Resource Evaluation, Tentative Parcel Map No. 24070, Trancas Canyon/Broad Beach Property, Malibu Bay Company, 3 p.

Read, E., October 23, 2006. Assessment of Historic and Current Biological Resources, 30732 Pacific Coast Highway (Broad Beach), 16 p.

Read, E. December 18, 2006. Rincon Consultant's Biological Constraints Discussion of MBC Property at 30732 Pacific Coast Highway, 3 p.

Read, E., May 30, 2007. Updated Dune Delineation Map, 1 p.

Read, E., July 30, 2007. Assessment of the Extent of Coastal Foredunes at 30732 Pacific Coast Highway (Broad Beach): A Review of the Science, 9 p.

Glossary of Terms – as applied in a coastal environment

Blowouts – These are gaps or depressions in the foredunes where wind may be funneled and erode the sediment on the margins of the blowouts. Sediment transported through blowouts may contribute to dunal development on the landward margins of the foredune ridge.

Eolian Processes – the mechanical processes associated with moving air, or wind; wind processes may erode, transport, as well as deposit sediment.

Foredune –A linear sand ridge located at the upper margin of the bare sand beach. It is at the site of pioneer vegetation that can survive in this harsh environment and trap sediment to create the topographical ridge.

Lag Surface – A coarse veneer that develops as the wind removes fine sediments and leaves the larger particles behind. The materials eventually create a surface that shields the underlying sediments from further eolian transport.

Pioneer Vegetation – The vegetation types that can grow in the very strenuous zone at the seaward margin of the foredune, extending into the upper beach. This is the vegetation that is the most seaward in the dune topography.

Primary Dune – The seawardmost dune ridge in the coastal environment (the foredune)

Sandy Hummocks – Small mounds of wind-blown sand, either vegetated or bare.

Secondary Dune – Dunal features usually extending inland from the foredune, and frequently derived from the erosion and destruction of the foredune. Secondary dunes are modifications of the primary dune.

Sediment Supply – The availability of sediment to be moved and accumulated to create landforms.

Sediment Budget – A measure of whether more sand is entering a system, leaving a system, or whether a system is balanced in some time duration. A negative sediment budget results in erosion; a positive sediment budget results in accumulation, a balanced sediment budget results in no change over some period of time.

Survey of Globose Dune Beetles at 30732 Pacific Coast Highway Malibu, CA, comparing distribution in dunes with or without houses

Prepared for Malibu Bay Company
Malibu, CA

Prepared by:
Cristina Sandoval, PhD

May 5, 2008

INTRODUCTION

Malibu Bay Company owns a property that covers approximately 2.08 acres located at 30743 Pacific Coast Highway, hereafter the "project site" or "site," on a stretch of the Malibu coast known as Broad Beach (Figures 1, 2).

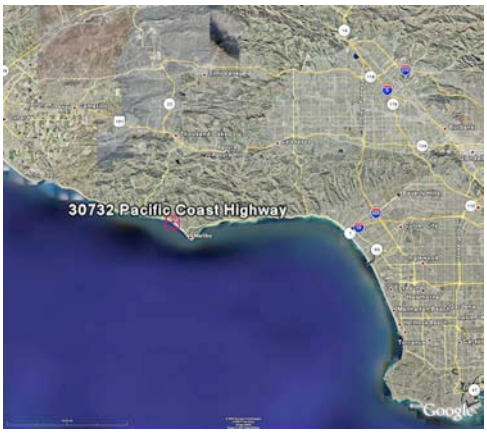

Figure 1, Regional Location (left). The project site is located in the northwestern part of Malibu, approximately three miles up the coast from Pt. Dume.

Figure 2, Project Vicinity (right). The site is located near the southern end of Broad Beach, roughly 200 feet northwest of the mouth of Trancas Creek. The stringline is shown in green. Sampling transects were conducted in dunes on the site, on the three properties immediately southeast of the site, and on the property immediately northwest of the site.

Recent biological investigations of the project site revealed the presence of the Globose Dune Beetle *(Coelus globosus*) on the site's broken foredune ridge and among

mobile and stable hummocks that are also part of the site's broad foredune system[1,2]. Little is known about this beetle's biology and conservation needs. Its range is restricted to a narrow fringe of foredunes immediately above high tide from Bodega Head in Sonoma County south to Ensenada in northwestern Baja California, including the Channel Islands except San Clemente, and populations north and south of Point Conception represent distinct geographical variants (Doyen 1976). The Globose Dune Beetle was classified by the U.S. Fish and Wildlife Service as a "Category 2" candidate for federal listing before Category 2 was eliminated in 1996. It remains a California Special Animal, meaning that its population status is tracked by the California Natural Diversity Database. Considering that the Globose Dune Beetle's required habitat is of very limited distribution and vulnerable to a variety of disturbances, preserving and restoring the integrity of foredune ecosystems occupied by this species seems to be paramount for its conservation.

The goal of this study is to determine the extent to which the presence of residences—or certain human activities that may be associated with beachside residential development, such as the planting and irrigation of dune-stabilizing plants—affect the local distribution of Globose Dune Beetles in dunes situated close to those residences. This determination is critical to evaluating the possible conservation value of the area south of the stringline to conserving Globose Dune Beetles. The survey results may also help to predict the outcome of certain habitat restoration or management methods, such as provision of irrigation, on Globose Dune Beetles.

METHODS

On April 16th of 2008, I sampled Globose Dune Beetles (GDBs) at 30732 Pacific Coast Highway and at four adjoining parcels—one to the northwest and three to the southeast—that have existing residences (see Figure 4 on the following page). Ideally, this study would have included more replicates of vacant parcels, but this was not possible since the rest of Broad Beach is fully developed and Zuma Beach to the southeast is a groomed public beach that lacks dunes. On April 16th, 2008, I sampled the dunes for beetles along transects using a standardized scoop of sand and a square sieve 23 cm on a side and 8 cm deep. I conducted a total of 14 transects: 5 at the project site and 9 at the other nearby lots. Each transect included six sampling points, starting at the beach/foredune interface and ending near the stringline:

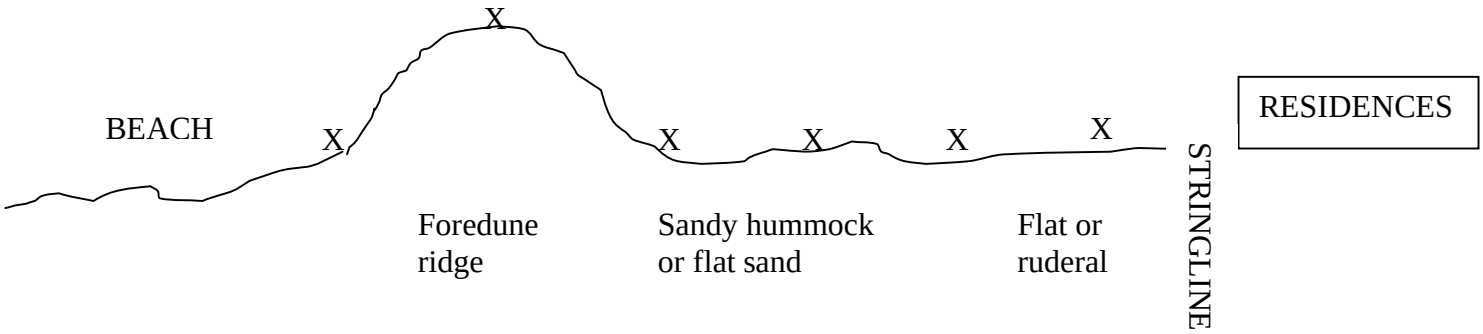

Figure 3. Schematic cross-section of the six sampling points ("X") along each transect from the front of the foredune ridge inland to the stringline formed by existing residences.

The exception was transect 14 (outside of picture), where a fence prevented me from sampling at the northerly 2 points. For each sample point, I noted geomorphology (front of foredune ridge, top of foredune ridge, back of foredune ridge, flat sand, or secondary dunes), vegetation, soil type, and whether the survey area was irrigated. The points were

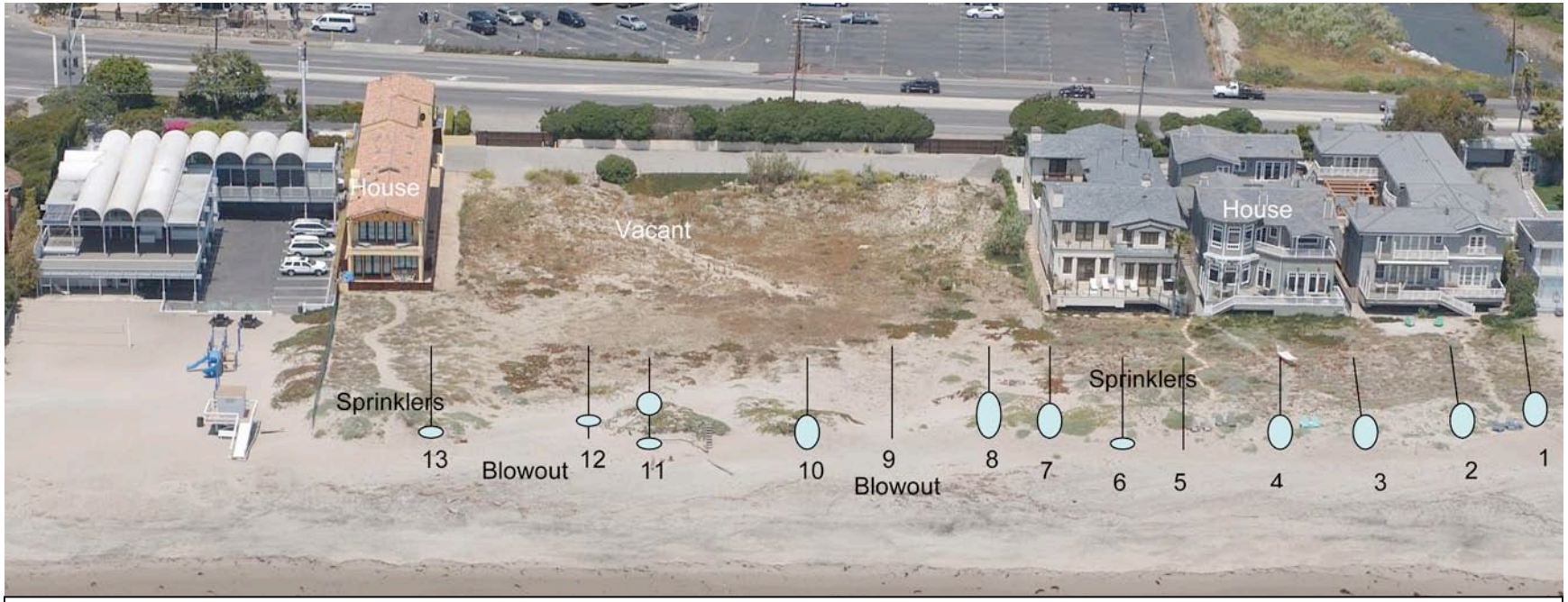

Figure 4. Location of transects on Broad beach. The blue bubbles represent locations where Globose Dune Beetles were found.

not equally spaced along each transect because I maximized the chances of finding the beetles by sampling at the most suitable habitats within each portion of the dune system.

Adult beetles caught in the sieve were identified *in situ* using a magnifying scope and then immediately released. It was important to carefully distinguish between Globose and Ciliate Dune Beetles (*Coelus ciliatus*), both of which occur on Broad Beach. *Coelus ciliatus* has a wider range and less restricted habitat requirements than does *Coelus globosus* and is not regarded as biologically sensitive. Adults can be identified under magnification by a row of hair in the head (Doyen 1976). Larvae are indistinguishable, so I counted the total number of larvae in each sample. I present only results for *C. globosus* (adults). I used General Linear Models (JMP software) to analyze the effect of several variables on the distribution of the GDB.

Figure 5. The author sorting beetles collected in sieve for identification.

RESULTS

The GDB were found to be most abundant on the front and top of the foredune ridge (average of GDB 3.3 per sample). The densities of GDB varied among transects and several factors were correlated with this variation, as described below.

Distance from ocean:

The density of dune beetles varied along the vertical profile of the beach (ANOVA, P = 0.0035). Abundances were high in the first two points (3.3 GDB/sample), intermediate in the second two points (0.23 GDB/sample, 0.31 GDB/sample) and absent in the two points farthest from the ocean. Because dune beetles were always absent from these upper sites, these samples were excluded from further analysis.

Presence/absence of houses inland from the foredune.

A specific question related to development is the extent to which a buffer zone might be needed to protect beetle habitat. To examine this specific hypothesis, I considered whether the presence of a house might truncate the distribution of beetles. Habitat effects were controlled for by expressing the density of beetles at a point as a proportion of the total number of beetles found in a transect. Comparing the distribution of beetles in front of houses and in front of the undeveloped lot (Figure 6) along the transects, indicates a distinct correlation between the presence of houses and a truncated distribution of GDB (note that using transects as replicates decreased the power of the analysis, resulting in lower P-values and this should not be confused with a reduction in biological significance). A T-test of the median position of the distributions indicated a significant

effect of house (P = 0.02). Where houses were present, the peak in the beetle distribution was lower on the beach (mean transect point = 1.23) than it was in front of the open lot (mean transect point = 2.05). Because irrigation is associated with houses and was found to have an important effect in the analysis of beetle density, I did a separate analysis including (along with the presence of a house) whether irrigation occurred along the transect. Areas that were irrigated had a lower (mean transect point = 1.1) distribution than non-irrigated transects (mean transect point = 1.8) (P = 0.048). However, there remained a residual (marginally significant) effect of house independent of irrigation (P = 0.09), which is statistically significant under the one-tailed expectation of a negative effect. By comparing the raw means of the three groups, the distribution of beetles was lowest in front of houses with irrigation (mean transect point = 0.9), followed by houses without irrigation (mean transect point = 1.5) and highest at the undeveloped lot (mean transect point = 2.0). This appeared to result, in part, from an absence of beetles at points 3 and 4 in front of any houses compared with their presence at these locations in the undeveloped lot (figure 6). Despite the change in distribution of GDB where houses were present, there was no difference in the mean number of GDB per sample between the built lots and the project site.

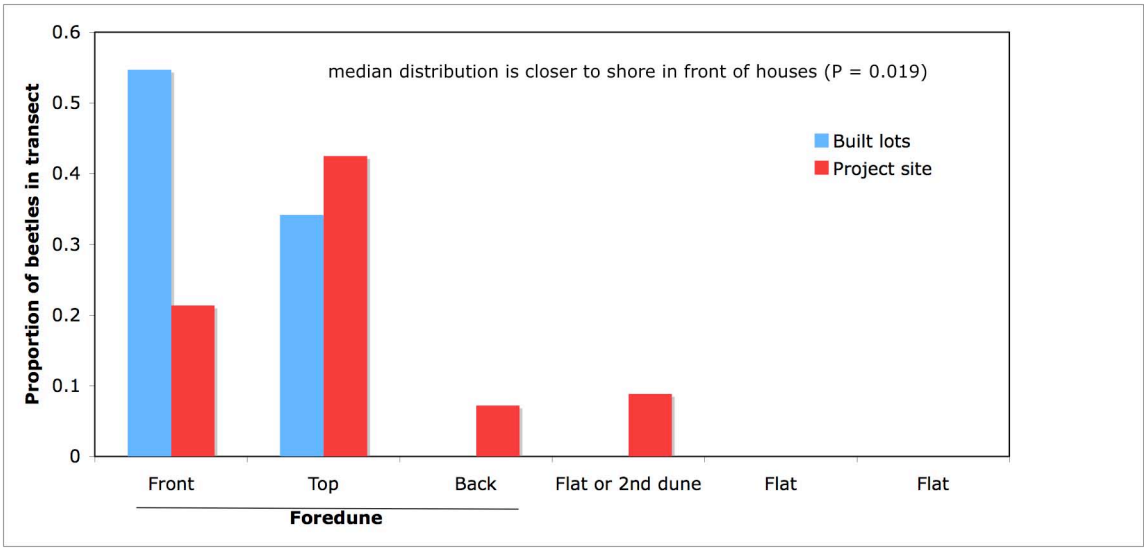

Figure 6. Distribution of Globose Dune Beetles along transects at the project site and at nearby lots with existing residences

Distance from creek (transect number): GDB declined in abundance as one moved away from Trancas creek (GLM, P = 0.053).

Vegetation: Density of GDB varied with respect to the presence of native vegetation (ANOVA, P = 0.044). The density where native vegetation was present was 2.36 GDB/sample compared to 0.5 GDB/sample where vegetation was absent. There were 2.7 GDB/sample in areas without Highway Iceplant (*Carpobrotus edulis*) compared to 0.9 GDB/sample in areas with Highway Iceplant (ANOVA, P = 0.036).

Irrigation: GDB were less abundant at sites that were irrigated (0.2 vs 2.2 GDB/sample, ANOVA, P = 0.05).

CONCLUSIONS

This study attempted to investigate the effect of houses north of the stringline on the abundance and distribution of GDB. During the study, variables related to the

management of the landscape in sites with houses were found to be correlated with the presence of houses. There were no sites with houses that had a similar condition as the project site where the dunes had not been modified for landscaping. Therefore I examined the effect of these variables, rather than the presence of houses alone.

Exotic vegetation, particularly Highway Iceplant, covered much of the dune area, and GDB was less abundant under these conditions, both at the project site and at the lots with existing residences. Even more striking was the decrease in GDB abundance in irrigated dunes versus non-irrigated dunes. Beetles were also absent from non-vegetated sand as occurred in the blowouts.

The presence of houses inland from the foredunes did not affect the density of GDB when compared to the project site without a house. However, GDB were found farther inland at the project site than at parcels with residences. This result appears to reflect a broader distribution of Highway Iceplant (negative correlation) and artificial irrigation (negative correlation) in lots with houses, and the presence of sandy hummocks (positive correlation) within the project site but not in lots with houses.

It appears that, west of Trancas Creek, the most important action to protect the GDB is an appropriate management of the dunes south of the stringline. The proposal for a conservation area that protects the secondary dunes, and is managed to be restored with native plants and without irrigation might benefit the GDB. Given the absence of GDB beyond point 4 in the transects, it seems that the proposed conservation area (buffer) south of the stringline is sufficient to protect these beetles from development north of the stringline, as long as the appropriate management is in place. However, it is important to note the area north of the stringline line contained imported soil which is unsuitable for

the GDB. I did not study whether GDB could occur north of the stringline, if natural sandy conditions existed, because these conditions are only present east of the Trancas Creek, where there is a confounding variable of the whole beach being groomed.

Beyond the scope of this project, I suggest the following recommendations to improve the GDB population on Broad Beach. Lots with residences could be encouraged to remove Highway Iceplant from the dunes, planting native species, and stop artificial irrigation. Also, because GDB were most abundant in dunes near Trancas Creek (also observed in other beaches with creeks), a part of the recreational beach east of the creek could be left ungroomed to re-establish a suitable habitat for the beetles. This management would also favor the Sandy Tiger beetle (*Cicindela hirticollis gravida*), a species that has not yet been surveyed for at Broad Beach, without causing significant impact to recreational opportunities.

Sandy Tiger Beetle, mating pair

Globose Dune Beetle

REFERENCES

Doyen, J. T. 1976. Biology and Systematics of the genus *Coelus* (Coleoptera: Tentyriidae). Journal of The Kansas Entomological Society. 49:595-624.

Federal Register, 1994. Endangered and Threatened Wildlife and Plants; Animal Candidate Review for Listing as Endangered or Threatened Species.. Federal Register: November 15, 1994. http://www.epa.gov/EPASPECIES/1994/November/Day-15/pr-42.html

Hamilton, R. A., Cooper, D. S., Ferren, W. R., and Sandoval, C. P. 2008. Biological Resources Assessment, 30732 Pacific Coast Highway, Malibu, California. Report dated 6 March 2008 prepared for the Malibu Bay Company.

Psuty, N. 22 November 2007. Report on site visit, October 30, 2007; Broad Beach, Malibu, Coastal Dunes; review of other materials.

Sandoval, C. P. 1997. Survey of Dune Beetles at Haskell's and adjacent beaches. Report to Tynan Group Inc.

Statistical notes

Habitat and point were highly correlated and these were not used together in models. Iceplant and native were also highly correlated and these were not used together in models to avoid colinearity. Stepwise linear regression was used to determine the combination of the above factors (and their interactions) which explained the most variation in the simplest model (using AIC criteria) and eliminating non-significant interactions.

The model found that plant type did not have a significant independent effect and that point was a slightly better predictor than habitat (though both point and habitat gave similar results). This model explained 47% of the variance in the abundance of globose dune beetles. The density of globose dune beetles increased toward the creek ($P = 0.027$), decreased in areas of irrigation (0.5 vs 2.1 beetles, $P = 0.046$) and was higher at mid elevations than at low elevations (and absent at high elevations) ($P < 0.0001$). There was also a significant interaction between elevation and distance from the creek ($P = 0.004$)

indicating that the effect of the creek was only apparent at mid elevations (i.e. distance from the creek did not affect the distribution of beetles at low elevations). Adding house to this model did not explain any significant variation in beetle density.