Appendix 1

Technical Responses to Questions Raised in Comments to 300 Airport Boulevard Project Draft EIR

TO: Michael Kay, Project Manager

FROM: Don Ballanti

DATE: May 2, 2012

Re: Technical Responses to Questions Raised in Comments to 300 Airport Boulevard Project DEIR

This responds to the following questions raised by comments submitted to the Draft Environmental Impact Report (DEIR) prepared for the 300 Airport Boulevard Project.

1. Does the DEIR Wind Study (DEIR Appendix I, herein "Wind Study") average its results, e.g., using early and late parts of typical day when wind speeds are low, to minimize wind impacts?

The wind speed ratios presented in the Wind Study do not have a relationship to time of day or season; they relate to the speed of the wind near the ground relative to the speed of the wind flowing high overhead, regardless of time of day.

Using wind tunnel testing, the Wind Study established wind-related impacts by determining relative change in R-values from the baseline to each land-use scenario analyzed in the DEIR. The "R-value" is the basic wind speed unit reported by the wind tunnel testing.[1] It is a ratio of the wind speed 10 scale feet above the test point at the model surface versus the speed of the constant "free-stream" or undisturbed wind at a height of 1,350 scale feet above the surface. The R-value is the fraction of wind speed remaining after slowing due to the roughness of the surface over which the wind passes; in general, the rougher the surface, the slower the wind, the lower the R-value. R-values are commonly used to determine comparative wind impacts.

Due to the methodology of the wind tunnel testing and the nature of flowing air, R-values would apply uniformly to any range of wind speed of concern at the site, from the lowest to the highest. Therefore, an R-value of 0.93 indicates a speed that is 93% of the "free-stream" speed, regardless of the "free-stream" speed – 30 mph, 10 mph or less. If the speed of the driving, free-stream wind were to vary, the speed at the test measurement point would vary in direct proportion.

Also, because the measurements for all scenarios and wind directions are normalized as R-values, they may be directly compared one-to-another to obtain valid measures of the relative effects of one scenario versus another.

For example, the 300 Airport Boulevard Project's R-value at any point on the study area grid may be compared to the R-value for the existing (baseline) scenario to determine the percentage change due to the Project relative to the existing condition. If the existing R-value were, for example, 0.76 and the Project R-value were 0.73, the project wind speed would be 96% (*i.e.*, 0.73/0.76) of the existing wind speed. Such comparisons hold true regardless of the speed of the wind.

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[1] The Atmospheric Boundary Layer Wind Tunnel ("ABL Wind Tunnel") at UC Davis was used to perform wind tunnel testing on for the Wind Study.

2. Is the study from Kungliga Tekniska högskolan correct that hot wire anemometers are ineffective at measuring wind speed at levels below 10 mph?

The KTH Royal Institute of Technology (Kungliga Tekniska högskolan) in Sweden has published many technical papers on hot wire anemometry. No specific paper is referenced, so the paper that formed the basis of this conclusion cannot be reviewed.

The language quoted from the KTH paper refers to "very low velocities (where natural convection becomes important)…". This is a well-known phenomenon, but is not significant here because the basic air velocities used in the wind tunnel test, which typically ranged from 1 m/s to 3 m/s (2 mph to 7 mph[2]), are orders of magnitude larger than the "very low velocities (where natural convection becomes important)…". These very low velocities are fractions of a mile per hour.

In addition, the heat sink effect referred to in the comment is also well-known, but again primarily affects wind speeds much less than used in the wind tunnel, and the heat sink effect was not an issue in measuring Project-related wind impacts.

3. Does the Wind Study focus on winds greater than 10 mph?

As discussed previously, the Wind Study's conclusions based on R-value comparisons, apply to the range of full-scale wind speeds, including speeds of less than 10 mph, except very low wind speeds of less than one mph that are not relevant to the Study.

4. Would the buildings constructed as part of the 300 Airport Boulevard Project prevent lighter winds from pushing around them?

No. The physical properties of the air and its motion in the atmosphere are similar over a range of speeds. There is no basis in fact to claim that "lighter winds" cannot push around structures in the same way that "heavier winds" can. The flows of the "lighter" and "heavier" winds would be the same, just as described in the wind test results. As discussed previously, if the speed of the driving, free-stream wind varies, the speed at the test measurement point would vary in direct proportion.

5. Is it accurate that turbulence of a structure is felt downwind for a distance of 20x the height of the structure?

The turbulence from a structure diminishes downwind from the structure. A rule-of-thumb is that it would disappear before a distance of 20x or less the height of the structure, however the phenomenon varies according to other factors, including primarily the shape of the structure.

6. Does the Wind Study fail to account for directional measurements?

No. The wind speed measurements that formulate the basis for the Wind Study's conclusions are sufficiently accurate to characterize the change in wind speed and wind direction that would occur over the vicinity due to the 300 Airport Boulevard Project.

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[2] The wind tunnel methodology used wind speeds in the range of 1 m/s to 3 m/s (2 mph to 7 mph) in the tunnel to establish the R-values applicable to the study area. These R-values, regardless of the wind speed used to establish them, are applicable across the range of the "free-stream" speeds.

The wind speed measurements in the ABL Wind Tunnel are made with a hot wire anemometer that has a single hot wire, stretched horizontally and oriented perpendicular to the axis of the wind tunnel in order to be most sensitive to horizontal flows of air. The single hot wire cannot directly resolve the three directional components of wind flow. However, the directional errors introduced into this series of test measurements are very small because the dominant flow direction for winds at every point on the test grid is parallel to the axis of the wind tunnel while the flow component perpendicular to the axis of the wind tunnel is very small and the vertical component of the flow near the test surface is negligible.

The variability in the air speed measured at points on the test grid is primarily due to the natural variability caused by wind passing over terrain roughness. However, directional or other errors in these measurements will also be manifested as added turbulence.

If the test measurement errors were large (i.e. if an appreciable fraction of the flow were circulating perpendicular to the axis of the wind tunnel) the turbulence measured at the test grid points would be high. However, the fact that turbulence levels at these grid points are as low as they are indicates that such errors in the measurements are small. Although we lack an accepted quantitative standard for determining the significance of changes in turbulence on wind-related recreational activity, the levels of turbulence intensity observed over the majority of the Study area are such that they would be perceptible only by sensitive devices such as the hot-wire anemometer, and likely not perceptible to humans.

7. Can Hot Wire Anemometry and the ABL Wind Tunnel Quantify Turbulence, or are other methodologies, e.g., a physical or hydrodynamic model, necessary?

Yes. A hot wire anemometer can quantify turbulence by accurately measuring the variability of a large number of velocity readings. The other factor in characterizing the winds in the study area under various existing and future conditions is the ability to correctly simulate the wind flows across the site under those different conditions. The ABL Wind Tunnel correctly simulates the flows of the wind across the site and the hot wire accurately measures wind speed and quantifies turbulence that would occur under existing, project, cumulative and alternative development conditions. The suitability of the ABL Wind Tunnel to simulate these winds is discussed further below.

The ABL Wind Tunnel was built to simulate the near-surface wind flow of the atmospheric boundary layer and specifically, to simulate the surface layer region of the ABL. The surface layer is the region of air from the earth's surface up to about 50 to 100 m in height where the mean turbulent velocity profile is two-dimensional and it is not substantially affected by the Coriolis motion due to the earth's rotation. Many researchers (Davenport and Isyumov, 1968; Cermak, 1971; Cook, 1975; Hunt and Fernholz, 1975; and others) have well documented that a properly designed and built ABL Wind Tunnel will accurately model the surface layer of the ABL under neutral atmospheric stability conditions. The UC Davis ABL Wind Tunnel accurately models that surface layer region of the atmospheric boundary layer.

Mean velocity profiles, turbulence intensity profiles and even the turbulent kinetic energy power spectra all are well simulated in the ABL Wind Tunnel. Matching each of these three quantities in the ABL Wind Tunnel represents increasing levels of truer simulation of the atmospheric boundary layer. The mean velocity profile is the easiest to simulate, while the turbulence intensity profiles are more difficult to model, and the power spectra profiles are the most difficult to simulate. However, proper simulation of the power spectra in the surface layer ensures that all scalable motions (or eddy sizes and their distributions) of turbulence in the ABL surface layer are being accurately modeled. The only non-scalable motions in the ABL surface layer are the smallest eddies (typically less than 10 centimeters in size in the atmosphere). Fortunately, these small eddies have negligible or no influence on the motion of air that are responsible for the movement of air and transport of momentum and energy in the surface layer of the atmospheric boundary layer.

The UC Davis ABL Wind Tunnel models all three of these quantities (mean velocity profile, turbulence intensity profile, and power spectra profile) quite well. Plots of the full-scale theoretical curves versus ABL Wind show good agreement between the theory and the tunnel results. Of particular importance is the agreement of the simulated power spectra with the classical Von Karman full-scale power spectra. Reasonable agreement between the well-known Von Karman equation and wind-tunnel data assures that adequate simulation of the turbulent energy cascading process is occurring in the inertial subrange and the energy dissipation range (large wave numbers) of the ABL. This is the demonstration that adequate simulation of the ABL surface layer is occurring in the UC Davis ABL Wind Tunnel under the most stringent criterion, i.e., simulation of the power spectrum.

Further, the U.S. EPA's Guideline for Fluid Modeling of Atmospheric Diffusion (EPA Publication 600/8-81-009, Environmental Science Research Laboratory) confirms that the spectrum of turbulence in a simulated atmospheric boundary layer, i.e., in a wind tunnel, compares accurately with that in the real atmospheric boundary layer:

> "For a given class of turbulent flow, a decrease of the Reynolds number decreases the range of the high-frequency end of the spectrum, whereas the size of the energy-containing eddies changes only very slowly with Reynolds number.
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> "To be somewhat more quantitative, it is useful to examine the trends observed experimentally and theoretically in grid-generated turbulence. A good measure of the width of a turbulent energy spectrum is the ratio of the integral scale, I, to the Kolmogoroff microscale, η. It may be shown through arguments presented by Corrsin (1963), that this ratio is related to the Reynolds number to the exponential power 3/4.
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> "Where the Reynolds number is the grid Reynolds number (based upon upstream velocity, U, and mesh size, M). Ideally, both I and η would be reduced in the same proportion in a model (i.e., the geometrical scale ratio), so that the width (number of "decades") of the spectra would be identical in model and prototype. It is clear, however, that this would require identical Reynolds numbers in model and prototype. This relationship may be used to estimate the comparative widths of model (m) and prototype (p) spectra.
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> "Assuming that the ratio of flow speed to viscosity is roughly the same in model and prototype. (L is a characteristic length in the flow, for example, the mesh size or the height of a building.) Hence, at a scale ratio of 1:1000, a seven-decade-wide atmospheric spectrum is "modeled" by a four and one half-decade-wide laboratory spectrum. This appears to be a drastic reduction in spectral width, but observations of grid-generated flows show that only the high-frequency end of the spectrum is cut out, so that this reduction in spectral width has insignificant effects. It is found empirically that I/M at a fixed distance x/M downstream from a grid is nearly independent of Reynolds number (Corrsin, 1963). Similarly, it may be expected in other flow geometries that I/L at corresponding geometrical locations will be roughly independent of Reynolds number, i.e.,
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> $$I_p/L_p = I_m/L_m.$$

> Indeed, the integral scale is found to be roughly half the size of the characteristic length and is independent of Reynolds number in a wide variety of classes of flows.
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> "In summary, integral scales reduce with the first power of the geometrical scale ratio (as desired), whereas Kolmogoroff microscales reduce with only the one-fourth power of the geometrical scale ratio. As we have seen in our previous discussion, the largest eddies contribute to the spread of a plume (eddy movement) and the ones small than the plume width have little dispersive effect; hence, the mismatch of Reynolds number between the model and the prototype is insignificant.
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> "A practical example here will make the point clear. The Kolmogoroff microscale in the atmosphere is about one millimeter between 1 and 100m above ground (Lumley and Panofsky, 1964). As indicated by the concepts above, at a scale ratio of 1:500, the spectral width in a model would be approximately two orders of magnitude smaller than desired. The Kolmogoroff microscale in the model would be about 100 times larger than required by rigorous similarity. This would correspond to a Kolmogoroff microscale of 10 cm in the atmosphere. It is difficult to image a practical atmospheric diffusion problem where eddies as small than 10 centimeters would contribute significantly to the spread of a contaminant."

Thus the ABL Wind Tunnel is well-situated to correctly simulate the flow of surface winds and enable the direct measurements necessary to determining changes in wind speed and to quantify turbulence.

To quantify turbulence, which was done for the Wind Study, the hot-wire anemometer provides approximately 30,000 individual voltage samples that are averaged and the root mean square calculated for each test location. These data, when converted to velocity using calibration curves, provide the mean velocity and turbulence values used in the calculation of the equivalent wind speed. This type of analysis produces results in the form of *turbulence intensity*, which is further discussed below.

Turbulence Intensity (TI)

Turbulence is the fluctuating velocity component of air flow. In the atmosphere, the wind near ground level is highly turbulent. Its velocity vector V at any time t can be decomposed into three components u, v, and w, respectively, in the longitudinal (horizontal), vertical, and lateral directions. Each of the three components can further be decomposed into a mean (temporal average), u_m, and a fluctuating component, u'.

Note that turbulence is always three-dimensional even if the mean velocity of flow is one-dimensional or two-dimensional. For instance, although the wind over a large flat area is essentially horizontal ($u = V$, $v = 0$, and $w = 0$), all the three components of turbulence, u', v' and w' exist. Because u' (the longitudinal component) is the strongest turbulence component and the most relevant to the evaluation of the 300 Airport Boulevard Project, this is the value that was measured in the wind tunnel and the discussion of turbulence intensity will deal with this component only.

A measure of the intensity of turbulence is the root-mean-square (rms) value of u', namely,

$$u_1 \text{ (turbulence intensity)} = (\ (u')^2\ )^{1/2}$$

where (u')2 represents the square of the temporal mean. The value of turbulence intensity divided by the mean velocity U is called the relative intensity of turbulence or the turbulence level.

In reporting the results of the wind tunnel tests performed for the 300 Airport Boulevard Project, the value reported as TI is the relative turbulence intensity, expressed as a percentage of the mean velocity,

$$TI\ = \text{(turbulence intensity)} / U$$

8. Does the Wind Study fail to account for wind gusts or gustiness caused by the 300 Airport Boulevard Project?

No. References to the terms *gusts* or *gustiness* confuse the technical concept of *gust* with small-scale *variations in wind speed* more accurately referred to, and measured as, turbulence related to the Project. The primary distinction between these terms is their magnitude and the time-scale over which they occur.

Gusts are larger wind fluctuations meeting the technical definition of *gust*,[3] which are more accurately categorized as weather changes, and which are independent of the effect of the 300 Airport Boulevard Project. Wind gusts and lulls occur for many reasons and are predominately naturally occurring effects, not generated by wind passing by objects on the ground. This can include the typical build-up and decrease of wind speed over the course of a typical spring and summer afternoon and evening.

As opposed to gusts as technically defined, fluctuations in the speed (or direction) of wind at the ground level resulting from wind interaction with the 300 Airport Boulevard Project are accurately measured (as velocity and turbulence) in the ABL Wind Tunnel, as previously discussed.

9. Review and comment on the alternate wind analysis presented by commenters.

The commenter presents a sample of output of the complex Computational Fluid Dynamics (CFD) computer code, ANSYS Fluent, pointing out the regions where the wind speed would be less than 90% of the initial wind speed.

As the commenter states, CFD is commonly used in external applications such as automobile and aircraft design, as well as other external applications. However, it is not usual for this code to be used to simulate highly turbulent external flows around large-scale 3-D structures and surface roughness elements. The commenter does not discuss the accuracy of the model in representing the physical situation or the choice of the initial and boundary conditions in the calculation. The comment also makes no representation

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[3] "A sudden brief increase in the speed of the wind. It is of a more transient character than a squall and is followed by a lull or slackening in the wind speed…According to United States weather observing practice, gusts are reported when the peak wind speed reaches at least 16 knots (18.4 miles per hour) and the variation in wind speed between the peaks and lulls is at least 9 knots (10.4 miles per hour). The duration of a gust is usually less than 20 seconds." *Glossary of Meteorology.*

about the appropriateness of the application of this model to this task, or about the accuracy of the result.

The comment leaves a number of issues important to the result unresolved, including:

> a. Inputs. The comment does not discuss its choices for initial and boundary conditions in the calculation. Also, the alternative does not discuss its inputs for physical phenomena such as turbulence which can affect the model's conclusions.
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> b. Building Shapes. The building shapes in the model appear to be rectangles, differing from the rounded corners and curved sides of the proposed buildings. The size and shape of the mechanical penthouses cannot be determined from the image provided.
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> c. Existing Conditions. It is not clear that the existing conditions were considered in order to correctly assess the area within which the existing wind speed would be reduced by at 10% or more. Among the existing conditions that would affect the result are the basic mass of the peninsula and the wind shadow that is known to exist near the levee in the WNW wind condition.

As a result, without knowing how and whether the numerical model addressed the above-listed factors, it is impossible to assess the accuracy of the model's results

10. Should the wind study have used a local wind sensor, such as the one attached to the Boardsports rental shop?

While a local wind sensor may be convenient, there is no assurance that the local sensor provides accurate wind speed and direction information about the “free-stream” winds that pass overhead. The SFO station, only a couple of miles WNW of the site, provides a reliable (quality-assured) long-term record of wind speed and direction of these important winds. The accepted standard for determining wind speed and direction is to take measurements at a height of 10 meters above ground or above nearby obstacles, so that the wind direction is not distorted and the wind speed is neither accelerated nor slowed by local buildings or structures. With such a station as a standard, it is easy to make comparisons with local sensors that may be subject to substantial localized distortions in the speed or direction of the wind, but which nonetheless may provide useful localized wind information (as suggested by the iWindsurf.com website’s discussion of the SFO station).

Considering the wind tunnel testing that was performed for the 300 Airport Boulevard Project, the SFO station provides the correct direction, speed and frequency of occurrence for the winds. For each local wind direction or speed distortion caused by buildings on-site or in the vicinity, that distortion will be replicated in the model since it includes those buildings. The SFO station is more likely to match winds in the more open areas of the Bay (as noted on the iWindsurf.com website) and overall provides an accurate baseline against which to measure potential Project impacts to wind.

11. How was the Study area for the Wind Study identified?

As stated in the Wind Study, the Study Area was identified by considering the relationship of the Project site to the uses of the Bay and the Coyote Point Recreation Area. Using the beach launch areas identified in the Coyote Point Recreation Area Master Plan as a guide, the Study area encompasses the waters bayward of these launch points out to a the northern edge of the Project area, and east to just before the western limit of the swimming area. This covers the entire near-shore area accessed by these launch sites as well as transit routes used to access sailing areas further out in the Bay. This study area encloses all of the near-shore area of the Bay within which the Project's wind impacts could occur.

REFERENCES

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