THE BAYLANDS

DRAFT
PUBLIC SPACE MASTER PLAN

Prepared for

THE CITY OF STARS
BRISBANE
CALIFORNIA

THE CITY OF BRISBANE

JUNE, 2009

Prepared by

The Dangermond Group
Creative Project Planning & Design

I. Executive Summary

The Dangermond Group (TDG) was retained by the City of Brisbane to develop a Draft Public Space Master Plan (Public Space Plan) for the Baylands. The Public Space Plan will be integrated into the community-based alternative plan for study in the forthcoming draft EIR. This report describes the Public Space Plan and includes a brief summary of the process utilized in its development.

The City's July 2008 Community Input on Alternativs report recognized the Baylands project should be a "connected" place, referring to a walking and bicycling orientation. What emerged over the course of the public space evaluations was that the Baylands had the potential for many other meaningful connections. This idea grew out of the recognition of necessary habitat connections, both on site as well as to the region. Opportunities also exist for connecting people with nature and with local and regional history. Portions of the site also provide Brisbane positive opportunities to interconnect with neighboring communities and the Bay Region. The Public Space Plan is based upon creating a "hallmark of sustainablity" as outlined in the Alternatives report as well as four additional primary principles:

1. Creating a connected place
2. Serving Brisbane, the Baylands, and the region
3. Creating a distinctive setting
4. Complementing future development

Based on the proposed concept, a total of 365 acres would be dedicated for Recreational Public Space and Open Space Use Areas, including approximately 113 acres in the Lagoon and 252 upland acres. An additional 135 acres would be Public/Private Use Areas. Five (5) specific types of public space uses are recommended for inclusion within the Baylands. These uses (and approximate acreages) are:

- Habitat Enhancement/Open Space (203 acres)
- Lagoon (113 acres)
- Recreational/Public Space Use Areas (49 acres)
- Trails (8 miles)
- Public/Private Use Areas (135 acres)

It is envisioned that the Baylands be viewed as a place of connections, with connected habitat areas, trail connections, and opportunities for people to connect with nature, with nature through art, and with history. The most noticeable unifying element recommended is the enveloping natural landscape portion of the site. A second unifying feature will be the trail system. The primary public use setting in the Baylands will be Visitacion Creek. It is planned to border the development for its entire length and will join all of the more significant public use features. Environmental art is also proposed as a unifying feature. Additional unifying elements would be the use of "Green Architecture" in all structures and other sustainability features, such as native plantings and solar roofs and other alternative energy development, including appropriately sited wind tur-

Figure 1. Undeveloped Baylands

bines. A final unifying element is the interface between the Baylands development and the public space area.

The creation or enhancement of approximately 203 acres of open space/ habitat is recommended. These lands have been planned to create a unifying natural landscape within which the recreational and public space use areas are located. Primary Habitat areas would include Visitacion Creek wetlands, the Lagoon shoreline, Ice House Hill, and Upland Habitats. The Lagoon itself is also recognized as an integral element in the Public Space Plan and is considered to be primarily a visual and wildlife resource. The objective for this area is to maintain and preserve existing conditions and habitat while improving viewing and trail access.

The Plan advocates siting four Recreational/Public Space Use Areas based on their ability to serve specifically identified groups and in response to the site's physical characteristics. These use areas are identified on the Public Space Plan map (see page 14) as the Charter High School / Community Area, the Group Area, the Interpretive Center, and the Regional Use Area east of the rail lines. In addition, the Plan recommends siting approximately seven (7) miles of Class I and one (1) mile of Class II trails throughout the Baylands area. In addition to providing regional and local connectivity, the recommended trail system would, where practical, consist of separated trails that accommodate both fast and slow traffic.

The Public / Private Use Areas are envisioned to focus on specific user groups. In addition, three Public / Private Use Areas will also actively promote the Brisbane community's vision of the Baylands. The Civic-Cultural Envelope will represent and preserve cultural histories and structures identified with the Baylands, Brisbane, and the region while the Green Development Center will capture the vision of the Baylands as a forward-looking center for sustainability and green development, and the Parkways and Plazas will offer connectivity throughout the development.

The proposed Public Space Plan has been designed so as to minimize operating cost support. This is proposed to be done by emphasizing natural landscapes, choosing revenue generating recreation facilities, creating settings to encourage private enterprise leases and forming non-profit entity support.

It is recommended that the City and UPC seek to reach consensus on how the public space areas should be governed and operated. The principles and objectives used to frame the issues of economics and governance include:

- Public space areas should remain in private or non-profit ownership, with the exception of the Charter High School, if that element moves forward. Open space easements should be granted to assure status in perpetuity.
- Habitat mitigation portions should either be endowed or have assured income streams from the development areas to properly maintain and operate.
- Public use portions should be operated in a manner so as to be as self supporting as possible through leasing to concessionaires, contracting out maintenance, creating revenue generating facilities and programming, and operation by volunteer non-profit groups.
- The development area should make up any additional funds required, to likely be assured through an assessment district arrangement.
- The City desires to operate the public park-like and interpretive features and provide active oversight over the remaining area
- If a non-profit entity is established to operate the entire public space areas, it should have representation from both the City and the development ownership group.

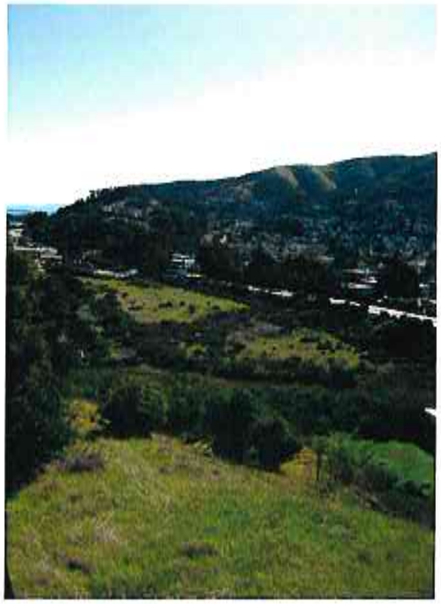

Figure 2. The Baylands and Brisbane from Ice House Hill

This Public Space Plan will be integrated into the City's ongoing process of developing a community-based alternative plan for study in the forthcoming draft EIR. It is anticipated that the EIR process will more specifically outline and define existing habitat, recommended roadways and transit locations, biological and toxics issues, and mitigation requirements that may impact recommendations made in this Public Space Plan. After the EIR is completed, this Plan may have to be reevaluated to take into account those conclusions.

Figure 8. City of Brisbane Baylands Public Space Plan

June 22, 2009 - The Dangermond Group

Use of Wind Tunnel Testing and Limitations on the Use of Computer Models for Analysis of Baylands Impacts on Windsurfing Resources

1.0 Introduction

Following the December 1, 2015 presentation of the Candlestick Preservation Association (CPA), the Commission expressed interest in getting more information regarding the accuracy of the wind modeling undertaken as part of the Brisbane Baylands EIR, as well as information on the use of computer modeling to evaluate impacts of proposed Baylands development on offshore windsurfing resources. To provide this information, the City retained the services of Charles Bennett, Dr. Bruce White, and Dr. C. P. van Dam, who were tasked with reviewing and commenting on CPA's December 1, 2015 presentation, including the presentation by EnviroComp Consulting, as well as EnviroComp Consulting's report, "*Some Comments on the Brisbane Baylands Program EIR Wind Study*."

Charles Bennett

Mr. Bennett has more than 45 years of experience in applied environmental studies. He has directed more than 275 CEQA/NEPA impact studies and 500 technical studies in air quality, wind effects, health and safety, noise, vibration, visual effects and electromagnetic hazard. Mr. Bennett has conducted over 150 wind studies in the San Francisco Bay Area and throughout the state, and served as technical advisor to the San Francisco Department of City Planning in the development of the City's ordinance to regulate the wind effects of high-rise buildings, and developed the wind data analysis and computer code used by all wind consultants in processing wind tunnel test data for San Francisco projects. Mr. Bennett directed wind studies to determine the better of two feasible orientations for the Giants downtown stadium, as well as studies to determine the wind conditions at seats in the stadium bowl and public spaces nearby. Additionally, Mr. Bennett's work has included wind studies at Candlestick Point, the Moscone Center expansion project, the Gap World Headquarters Building, UC San Francisco, and numerous other proposed developments.

Bruce White

Bruce White is Dean Emeritus and Professor Emeritus and is currently the Director of Engineering Translational Technology Center (ETTC) at the University of California, Davis. He is the author of more than 100 technical papers, review articles, and book chapters related to wind tunnel analysis. Dr. White has conducted well over 250 environmental wind-tunnel studies and 100 air quality studies for environmental impact assessment. He has been recognized by students for his teaching excellence and he has lectured internationally on his area of expertise in wind tunnel analysis.

Dr. C. P. "Case" van Dam

Dr. van Dam is a principal engineer at Senta Engineering, LLC. He is also the Warren and Leta Giedt Endowed Professor and Chair of Mechanical and Aerospace engineering at the University of California at Davis. Dr. van Dam previously served as a National Research Council (NRC) post-doctoral researcher at the NASA Langley Research Center. Van Dam's current research includes wind energy engineering, aerodynamic drag prediction and reduction, high-lift aerodynamics, and active control of aerodynamic loads. He has extensive experience in computational aerodynamics, wind-tunnel experimentation and flight testing. He teaches industry short courses on aircraft aerodynamic performance and wind energy; has consulted for aircraft, wind energy, and sailing yacht manufacturers; and has served on review committees for various government agencies and research organizations.

The conclusions of Mr. Bennett, Dr. White and Dr. van Dam are that:

1. The standard of care called for in the Baylands EIR Services contract – that the City's EIR consultant "use the standard of care in its profession to comply with all applicable federal, state, and location laws, codes, ordinances, and regulations" -- is "exactly what has been used in conducting the Brisbane Baylands wind study." Mr. Bennett noted that the methodologies and standard of care used in the Baylands EIR are the same as have been used in a large number of EIRs prepared to determine the physical effects of proposed development projects on the wind environment throughout the San Francisco Bay Area.
2. The scientific tool used to analyze wind-related impacts in the Baylands EIR was the well-established wind tunnel testing.

   The wind tunnel testing methodology used to evaluate impacts of proposed Baylands development "is a commonly used method, and is widely accepted in the scientific community." Error analysis for the results used in the analysis is provided by Dr. White's responses. The description and methodology of the experiments conducted for the wind tunnel tests are provided by Dr. White's responses.

   The "segmentation" of the wind tunnel model was determined by the scale of the model, and is in compliance with similarity criteria required for accurate wind tunnel testing. The wind tunnel testing conducted at University of California Davis thus yielded valid results. The use of "segmentation" is further described in Dr. White's report, below.

   The wind tunnel analysis conducted for the Baylands are validated by references provided in Dr. White's responses.
3. A review of available scientific literature regarding the efficacy of wind tunnel modeling, although not required for preparation of an EIR, validates the use of wind tunnel testing as was undertaken for the Baylands EIR.
4. The wind analysis undertaken for the Baylands, the significance threshold used to determine the significance of impacts, and the way "substantial degradation" of resources was analyzed in the EIR represent appropriate objective standards.
5. The principal conclusion of the EIR that "incremental changes in wind speed and turbulence in the launch and sailing areas are expected to be undetectable to most windsurfers" is supported by the scientific data collected from the wind tunnel tests, and specifically by analyzing changes in wind speed ratios and turbulence intensity.
6. The analysis area used in the EIR was based on Notice of Preparation comments provided by the San Francisco Boardsailing Association, which defined the most critical area for windsurfing.
7. Even with all the advancements in computer simulation of wind patterns over recent decades, accurate computer modelling and simulation of the effects of new development on

wind patterns remains a challenging task. To accurately analyze impacts of large-scale development such as Baylands development on windsurfing resources requires both large-scale modeling of atmospheric conditions and micro-scale modeling of the effects of proposed buildings. Both scales have their own specific tools, which are each ill-adapted for the other. To yield scientifically valid results requires "multi-scale simulations," which cannot be accomplished using currently available modelling packages. No generalized methodology for "multi-scale simulation," has been validated.

2.0 Response to the December 21 Presentations of the Candlestick Preservation Association and EnviroComp Consulting, by Charles Bennett

On December 1, 2015, CPA submitted a commentary and technical discussion, in which they claim that a significant portion of the Baylands EIR relating to analysis of project effects on the windsurfing resource is flawed and that the EIR should not be certified under CEQA. To support this claim, CPA relied on "Some Comments on the Brisbane Baylands Program EIR Wind Study," by EnviroComp Consulting.

EIR section 4.M deals with impacts on recreational resources. In providing comments on this section of the EIR, CPA uses the terms "research" and "experiment" to refer to the wind tunnel testing conducted for the EIR. However, wind tunnel testing is a commonly used, scientifically validated analysis tool in which a physical model of the project site in its existing condition, and a physical model of the proposed development in its cumulative (future) setting were tested to assess the changes in winds that pass over the Brisbane site that could be attributed to development of the Baylands, as required by CEQA.

Overall, CPA and their consultant have requested technical information beyond that required or normally provided for CEQA documents. The CPA request that that the Baylands EIR "be brought in-line with CEQA requirements prior to certification or that subsequent project-specific EIRs be required" due to alleged issues with the EIR's wind study is wrong because, as will be demonstrated, the Baylands EIR is, in fact in line with CEQA requirements and the technical analyses that follow demonstrate the validity of the Baylands wind study.

2.1 Use of Wind Tunnel Testing for Analysis of Impacts on Windsurfing Resources is Scientifically Valid, and Meets the Required Standard of Care for the EIR

CPA asserted that the analysis of windsurfing impacts did not meet the necessary professional standard of care, which refers to practices in accordance with what is widely accepted as legally required or accepted as proper by a responsible body of professionals skilled in the current state of a particular art. CPA noted that the professional service contract for the EIR specifically stated that the EIR consultant "shall use the standard of care in its profession to comply with all applicable federal, state and local laws, codes, ordinances, and regulations in connection with the performance of its services."

The required professional standard of care is exactly what was, in fact, used in conducting the Brisbane Baylands wind study, which reflects the standard of care and methodologies used in studies for a large number of EIRs which addressed the physical effects of proposed development on the wind environment. Over the last 25 years, the use of wind tunnel testing for CEQA analysis of wind effects of buildings over 100 feet in height has been common in areas north of the Baylands site in San Francisco. The City and County of San Francisco's concern has for the protection of the public from hazardous wind conditions, and the CEQA significance standard used for CEQA is one defined in the San Francisco *Planning Code*. Furthermore, as a result of the common use of wind tunnel testing over long period of time, San Francisco has determined it to be unnecessary for CEQA purposes that wind tunnel test studies include the types of technical background, qualification, and technical detail requested by EnviroComp. Furthermore, to our knowledge, other reviewing agencies in the Bay Area and the public have not requested such information for other wind studies, including studies prepared specifically to address impacts on windsurfing resources. This is in contrast to peer-reviewed research, where these types of information are typically needed to demonstrate that the new technique or approach achieves the desired result and compares well with established fact.

While it is reasonable for a member of the public to ask to review such technical background materials, as is provided here and in the reports of Drs. White and van Dam, the absence of such materials accompanying an EIR or a basic Technical Report of a wind consultant does not mean that such materials do not exist, nor that the wind study was not conducted using standard industry practices. Further, it also does not mean that the results are not reliable and trustworthy or that the results are not "scientific and factual." As is demonstrated below and in the reports of Drs. White and van Dam, the wind studies prepared for the Brisbane Baylands are scientific and factual, and present reliable information and valid conclusions. Furthermore, the computer modelling requested by CPA and EnviroComp would not be practical to undertake, and would not yield analyses that were superior to those undertaken for the Baylands EIR.

CPA discussed the validity of the approach by which the wind analysis for this project was carried out, and suggested that (1) one of several computer models should have been used to simulate wind flow, and (2) without computer modeling, the results are questionable and do not "comply with standard analysis practice."

CPA noted that professional engineering standards are required in all public works, and that these standards "are often published." CPA offered the example of the National Institute of Standards and Technology Technical Note (TN) 1655. However, while TN 1655 cautions about the potential for error in wind tunnel testing, it also includes footnote 1 on page 1 discussing computer modeling of wind flow, referred to as" Computational Fluid Dynamics," which states:

> [1] Computational Fluid Dynamics (CFD), or its application to wind engineering sometimes referred to as Computational Wind Engineering (CWE), is in principle an alternative means. However, although it can be useful for qualitative purposes, at present the information it provides on fluctuating pressures on bluff bodies is not sufficiently reliable to be accepted for structural design. As computational power increases, it is expected that CFD/CWE will become more useful for practical structural engineering applications, but when this will be the case is difficult to ascertain. Full-scale measurements in natural winds are another means of obtaining aerodynamic data; their usefulness is limited to calibration and validation applications. Finally, promising large-scale facilities of the type known as "Wall of Wind" are currently being developed, which allow in principle testing at considerably geometric and velocity scales than those typical of commercial wind tunnel tests (Huang et al., 2009).

While there are computer modeling programs that simulate turbulent flow near buildings, the complexity of the details in the type of simulation necessary for the Baylands is not typically found in available CFD models. The challenges associated with using CFD models for this type of simulation and analysis is explained in more detail in the responses provided by Dr. van Dam. These challenges include the duration of time necessary to run a CFD model that would include all necessary physical and mathematical parameters to accurately simulate turbulent wind flow over a large area. To resolve this issue, pragmatic CFD tools use assumptions and simplifications in modeling. As Dr. van Dam states, "There is not, therefore, a single CFD program or package (often referred to as codes, solvers, or models) that is universally applicable to all problems."

CPA's statement that by not using these models, the EIR does not follow standard analysis practice is simply untrue. CPA implies that CFD computer modelling is not constrained by size and scaling factors and can provide analytic detail over a test area that includes the wind's path across San Francisco and yet provide detail about wind conditions and effects within close to the surface of the Bay, within the defined wind test area. This implication is misleading, as discussed below in the responses provided by Dr. van Dam.

Wind tunnel simulation analyzing the effect of new development on wind flow is a commonly used method and is widely accepted in the CEQA profession. For example, as noted above, the use of wind tunnel testing for new development in San Francisco is common to assess impacts under CEQA and to determine compliance with wind requirements of the *Planning Code*. Wind tunnel testing as a part of the CEQA analysis of project impacts has been commonly used in Burlingame, San Francisco, Emeryville, Oakland, Sacramento, and many other communities.

CPA also states that by using wind tunnel modeling, the "buildings and the surrounding terrain cannot be adequately accounted" due to the limits of the wind tunnel's physical size. However, "similarity criteria" have been developed, studied, validated, and implemented in wind tunnel modeling that certify that a scaled model can accurately simulate the buildings and terrain needed. The model and wind tunnel used for the Baylands EIR follows these criteria. As described by Dr. White, the Baylands wind study derives the similarity parameters that must be met when performing wind tunnel experiments using conservation equations. Dr. White also describes how the UC Davis Wind Tunnel meets these similarity criteria.

Measurements of relative wind speed and turbulence intensity in the Baylands wind study were based on physical testing in the Atmospheric Boundary Layer Wind Tunnel at UC Davis. The UC Davis wind tunnel accurately models the surface layer of the atmosphere under stability categories of interest at the Candlestick Point State Recreational Area (CPSRA), which include conditions when winds are strong and not materially affected by solar heating.

The methods used to conduct the wind analysis for the Draft EIR are the same as those used by San Francisco in its EIR for the Executive Park project, which would also affect the windsurfing resource at CPSRA, including wind tunnel testing. The Executive Park project considered the location, magnitude, and extent of wind speed reduction and change in the range of turbulence intensity over a measurement grid as did the Baylands EIR.

See Final EIR Master Response 31 for and Dr. White's report that follows for further discussion of the use of wind tunnel testing for the Baylands.

CPA presented the shorthand empirical formula for wind wake extent of buildings as 10x to 30x the building height above downwind grade. When including the cumulative effects of the Baylands, proposed Recology expansion, and the Executive Park development, CPA concluded that "71% of the practical sailing area is impacted assuming a simplistic West-Northwest wind." While CPA disclaims wind tunnel test results, it also notes that the extent of impacts measured in the wind test is consistent with this formula[1].

2.2 Wind Tunnel Study Error Analysis

CPA claims that without an error analysis for systematic, as well as model error, the results from the Baylands wind study *could* be misleading, and should therefore not be accepted. Although an error analysis was, in fact prepared for the Baylands wind tunnel study, such analysis is not typically presented in an EIR. The error analysis for the wind tunnel test conducted by Dr. White is presented below as part of Dr. White's report. The error analysis describes the types of errors that are associated with the model being separated into overlapping sections for testing as well as errors associated with the measurement system (approximately 5%), and is widely accepted for use in CEQA. The error rate of the Baylands wind tunnel study is also comparable or superior to results that might be expected of any type of computer modelling.

2.3 Description of Wind Tunnel Study Methodology

The methodology used for the Baylands wind tunnel study is summarized in the Draft EIR and the Master Responses of the Final EIR. Similar to an error analysis, providing detailed methodology is typically unnecessary for CEQA purposes due to its widespread use in EIRs over long period of time.

In response to the comments of CPA and EnviroComp, further description of the wind tunnel facility, flow simulation and measurement systems are provided in Dr. White's report, below.

2.4 Wind Tunnel Testing Conducted for the Baylands Meet Applicable Criteria

CPA questioned the certification of the wind tunnel results and referred to ten as improperly run "experiments." The information provided by Dr. White below describes the similarity parameters required in running these wind tests, as well as how the UC Davis wind tunnel meets these criteria.

2.5 Literature Review; Study of the Effects of Past Developments

As mentioned in the discussion on error analysis and modeling criteria, a literature review for the Baylands wind study was not needed for the purposes of designing, conducting or analyzing the wind effects of the project in a CEQA analysis. Master Response 31 in the Baylands Final EIR cites the following references:

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[1] However, this analysis by CPA does not consider the existing conditions at the Baylands site, and therefore does not differentiate or show the potential impact of Baylands development itself.

Cermak, J.E., "Laboratory Simulation of the Atmospheric Boundary Layer," *AIAA Journal*, vol. 9, Sept., 1971, pp. 1746-54.

Cook, N.J., "A Boundary Layer Wind Tunnel For Building Aerodynamics," *Journal of Industrial Aerodynamics*, 1975, vol. 1, pp. 3-12.

Corrsin, S., Turbulence: Experimental Methods, Handbuch Der Physik, Encyclopedia of Physics, edited by S. Flugge/Freiburg, 1963, v. VIII/2, pp. 524-90.

Davenport, A.G. and N. Isyumov, "The Application of the Boundary Layer Wind Tunnel to the Prediction of Wind Loading," in *Proceedings of the International Research Seminar on Wind Effects on Buildings and Structures*, Ottawa, University of Toronto Press, Toronto, 1968, pp. 201-230.

J. C. R. Hunt an H. Fernholz, "Wind Tunnel Simulation of the Atmospheric Boundary layer: A Report on Euromech 50," *Journal of Fluid Mech.*, vol. 70, part 3 (Aug. 1975), pp. 543-559.

Dr. White's responses provide numerous additional references validating the use of wind tunnel testing. Dr. van Dam's responses also provide references on CFD computer modeling and their applications and limitations.

Furthermore, Dr. White's report provides references supporting the use of wind tunnels for this type of analysis, including the situation in Aruba mentioned by CPA. For the Aruba situation, a wind tunnel study was conducted to measure offshore wind conditions that would occur due to new development near the shore of a commonly used recreation area. That wind test was accompanied by an on-water, field validation, and the wind tunnel measurements were found to be in good agreement with the reported perceptions of experienced windsurfers in the area. Furthermore, in Aruba, the buildings were deemed to have "noticeable impact" for up to approximately 300 meters (10 typical building heights) downstream; "marginal impact' from 300 meters to 500 meters downstream; and, 'no impact beyond 500 meters. The accompanying series of full scale wind observations "suggested that the main impact to sailing was closer than 300 meters, and that the 'marginal impact" region was not of great consequence."

It is well documented in the scientific literature that a wind tunnel can correctly represent wind velocity, wind turbulence, and the power spectrum of the wind in the boundary layer of the atmosphere. Located at UC Davis, the wind tunnel used for the tests was built to simulate near-surface wind flow of the atmospheric boundary layer. Specifically, the surface layer region of the atmospheric boundary layer is well modeled in this wind tunnel. The surface layer is that region of air from the earth's surface up to about 50 to 100 meters in height and under neutral atmospheric stability conditions, where the mean turbulent velocity profile is two-dimensional and 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 documented that a properly designed and built atmospheric boundary layer wind tunnel will accurately model the surface layer of the atmosphere under neutral atmospheric stability conditions.

2.6 "Segmentation" of the Wind Tunnel Model

CPA criticized UC Davis wind tunnel modelling since it was conducted in segments. CPA claimed that any "segmentation" would introduce errors, which might be large and difficult to quantify.

However, as mentioned in this report and that of Dr. White, the scale of the wind tunnel model is determined by the implemented similarity criteria requirements (further described in Dr. White's report).

As discussed in Dr. White's report, the validity of segmentation of a model has previously been demonstrated. The segments contain measurement locations that overlap when shifted in the wind tunnel test section, allowing for direct comparisons. The results from measuring these overlapping points show a minimal 2% to 5% difference between the two segments in the model. As CPA quotes, 2% to 5% is not an appreciable error.

2.7 Criteria for Assessing Whether a significant Impact Would Result

CPA addressed the need for a scientific parameter to be established to properly assess the impact on wind due to proposed Baylands development. CEQA guidelines do not provide significance criteria for assessing impacts of proposed development on windsurfing, as explained in Section 4.M of the Draft EIR. Thus, included in the Draft EIR was development of an appropriate threshold of significance to evaluate impacts on windsurfing. The task of establishing significance criteria for windsurfing resources is not simple, since "windsurfing" covers a wide range of preferences and skill levels of individual windsurfers.

While CEQA encourages agencies to formally adopt and publish thresholds of significance (see CEQA Guidelines Section 15064.7(a)), they are not required to do so. Agencies have the authority to determine the significance of environmental impacts on a project-by-project basis. (*Oakland Heritage Alliance v. City of Oakland* [2011] 195 Cal.App.4th 884, 896.) The significance of an environmental effect may be determined by either a quantitative or qualitative standard, or a set of criteria.

The City as Lead Agency considered the thresholds of significance used in the known similar impact evaluations under CEQA – namely, wind impacts on CPSRA from the Executive Park project in San Francisco, and wind impacts on windsurfing at the Coyote Point Recreation Area caused by waterfront development in Burlingame. In these CEQA analyses, the threshold of significance, methodologies, and analyses were published in EIRs that were reviewed by the public and then certified by the Lead Agency. Due to the fact that the impact on windsurfing in CPSRA from development upwind of CPSRA is an impact that is common both to the Brisbane Baylands Project and to the approved Executive Park project, the Baylands EIR used the significance threshold used by San Francisco in its CEQA review of the Executive Park project's wind impacts on CPSRA[2].

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[2] City and County of San Francisco, *Draft Environmental Impact Report, Executive Park Amended Subarea Plan and the Yerby Company and Universal Paragon Corporation Development Projects* (San Francisco Case No. 2006.0422E, State Clearinghouse Number 2006102123), October 13, 2010.

Therefore, the Draft EIR (see page 4.M-10 of the Draft EIR) uses the following threshold of significance to evaluate impacts on recreational windsurfing by development of the Baylands:

> Baylands development would have a significant impact on recreational windsurfing resources if it would substantially degrade the windsurfing recreational resource by reducing wind speeds "to the point where the reductions would adversely affect windsurfing in prime windsurfing areas or substantially impair access to prime windsurfing areas from existing launch sites." (Draft EIR page 4.M-11)

To determine whether proposed Baylands development would substantially degrade the windsurfing recreational resource by reducing wind speeds to the point where the reductions would adversely affect windsurfing in prime windsurfing areas or substantially impair access to prime windsurfing areas from existing launch sites, thereby resulting in a significant impact under CEQA, the wind analysis for the Brisbane Baylands Draft EIR qualitatively evaluated two variables: relative wind speed and turbulence intensity. These two variables directly characterize the physical changes in wind conditions in the atmospheric boundary layer that would be caused by Project Site development. (See Master Response 33, Windsurfing: Alternative Analysis Methodology, for more discussion.)

In its comment letter on the Draft EIR, CPA proposes a different threshold of significance and an alternative method of evaluating the impacts of proposed Baylands development. As discussed in Master Responses 30 through 34, the threshold and alternative analysis methodology suggested in Comment Letter (CPA 2) has never been applied to the CPSRA windsurfing area in a publicly circulated CEQA document, in contrast to the threshold of significance used in the Draft EIR. Also, the ability of CPA's alternative analysis methodology to determine the impact of Baylands development on the CPSRA windsurfing resource is less compelling because it (1) incorporates weather events that are not affected by development of a project site, (2) uses data with an unknown quality or calibration, and (3) evaluates the data against subjective thresholds. (For additional discussion of CPA's proposed wind impact analysis thresholds and methodology, see Master Responses 30 and 31.)

2.8 Area Most Critical for Windsurfing

CPA stated that the area "most critical for windsurfing given safety concerns and wind flow patterns," including the area near the shore along the US 101 freeway, was not measured in the wind tunnel analysis.

As stated in Section 4.M of the Draft EIR, the area measured in the wind tunnel tests "covered approximately 280 acres of water surface that included the area identified by the San Francisco Boardsailing Association (SFBA) as the primary sailing area in this part of the Bay." The wind tunnel analysis conducted for the Baylands also considered data and analysis from the 2009 wind tunnel analysis undertaken for the Executive Park project to measure changes in wind conditions in the northern portion of the windsurfing area due to the Executive Park development, as can be seen in Appendix J of the Draft EIR.

As stated on Draft EIR page 4.M-5, "the SFBA provided accumulated GPS tracks that it considers to be representative of the primary sailing area in this area of the Bay." The information from the scoping comment letter was taken at face value and used to designate the area analyzed in the Draft EIR, and was considered to be the sailing area for use in EIR analyses.

CPA's desired analysis area, which is described in comments on the Draft EIR, includes a wider area that reaches to the shoreline on the west than the main sailing area identified by the SFBA and covered by the measurement grid. It also includes the "wind shadow" area between the grid of impact points and the shoreline that is known to have lower wind speeds than the more open waters to the east, because that area is closer to the shore, closer to the freeway, and closer to the land mass of Bayview Hill, the Project Site, and Candlestick Point.

Wind effects in adjacent areas of the Bay to the west and to the east (both in the "wind shadow" area nearer to the shore and to the east farther from the shoreline) can be estimated with reasonable accuracy using the extensive wind test data in the Draft EIR (See Draft EIR Appendix J) and an understanding of the wind phenomena.

The nine measured wind speed ratios described in Final EIR Master Response 32 provide substantial evidence of the relative wind speeds in the "wind shadow" area identified by CPA. Wind tunnel data indicate that wind speeds in the "wind shadow" area are reduced by approximately 3 percent, compared to winds in the larger grid area, and reduced by approximately 6 percent compared to winds 975 feet inland from the shoreline.

Because the "wind shadow" area is also closer to proposed Baylands development, it would also be expected that wind speed reductions and turbulence associated with Baylands development would be incrementally more than the values at points on the grid. However, the resulting speed reduction at any given location would be the largest for the west wind (given the shortest distance from the Project Site), and smaller for the other three wind directions. The Project's effect – its wind speed reduction – in the "wind shadow" area nearest the shore is estimated to be approximately 2 percent to 4 percent more than in the grid for the west wind, and would be less than that for other directions.

Wind tunnel test data from the 2009 wind analysis for the proposed Executive Park project was included for the Project only for portions of the grid that are not affected by Baylands Project Site development.

See Final EIR Master Response 32 for further discussion of the area measured in the Baylands wind tunnel test.

2.9 Installation of a Meteorological Station at the Baylands

CPA stated that full-scale meteorological data should have been used to determine what "favorable" conditions for windsurfing are. However, the definition of "favorable" conditions is subjective and dependent on the preferences and skill level of individual windsurfers, and has not been previously used in CEQA analyses for impacts of development on windsurfing resources in the San Francisco

Bay. A description of how this analysis determined degradation to windsurfing can be found in Draft EIR Section 4.M and EIR Master Response 30. Furthermore, the wind tunnel analyses accurately simulate "variations and wind and turbulence" as described in Dr. White's report that follows, which also provided references supporting agreement between wind tunnel simulation and "full-scale" data.

2.10 Comparison of Computer-Based Models for Analysis of Wind and Traffic Impacts

CPA compared the wind tunnel test to the protocol associated with an EIR transportation analysis and claimed none of the practices common for an EIR transportation analysis were adopted in the wind tunnel tests. However, the comparison of the Baylands transportation impact analysis to the wind analysis attempted by CPA and EnviroComp is misleading for the reasons:

- Modelling for traffic impact analysis is based on adding project-generated traffic to existing turning movements at intersections in order to evaluate impacts under "existing plus project" conditions. Traffic models do not produce existing conditions information, and collection of existing turning movement counts is therefore required. Also, because traffic patterns change during the life of a traffic model, continual re-calibration of the model is required. Long-tested criteria as to how and when traffic counts are to be taken and models are to be re-calibrated are commonly accepted throughout the transportation planning profession. No such criteria exist for wind analysis.

  Because weather and wind conditions are highly variable, information on existing wind conditions must be collected over a period of several years to be of practical value. Such information is available from sources such as the National Weather Service for the general vicinity. Site-specific conditions affecting wind flow and turbulence can be physically modelled to represent site-specific conditions, eliminating the need for multi-year wind monitoring at each specific location a wind analysis is to be conducted under CEQA.

- Software packages upon which modelling of impacts in the vicinity of the Baylands can be built are available for both for both traffic and wind. However, while the SF-CHAMP model has been constructed, calibrated, widely used, and is commonly accepted as the proper analysis tool for traffic impact analyses in San Francisco and adjacent portions of northern San Mateo County, no such analysis tool exists for wind impacts.

  While CPA and EnviroComp cite several software packages they assert could be used to analyze wind conditions and impacts at the Baylands, the software they cite is not ready to be used for wind analysis at the Baylands in the same way that the SF-CHAMP model was ready to be used for traffic analysis. Rather, a model of wind conditions under existing conditions and proposed Baylands development would need to be constructed. Dr. van Dam's report, provided below, cites the practical challenges constructing such a model would have, along with the resulting limitations on the accuracy of results.

- The SF-CHAMP traffic model and the software used to create that model have been validated over a many-year period, and have been successfully used for hundreds of traffic studies, thereby validating model results.

  As noted above and in Dr. White's report, below, methodologies have been developed for wind tunnel analyses, and have been validated through hundreds of wind studies. Dr. White's report demonstrates the calibration and validation of the wind tunnel model and analysis used for the Baylands.

- The "industry standards" for the wind tunnel analysis and standards for software and measurement calibration were in fact used in the wind tunnel tests. These standards are described in Dr. White's report, which describes the methodology and validation of wind tunnel testing.
- Whereas communities throughout California and the nation have adopted level of service standards for analysis of traffic impacts, no such standards are known to have been formally adopted for analysis of impacts on windsurfing. Thus, "applying industry standard thresholds for determining the degradation of service that would be experienced through the development" is possible for traffic impact analysis, it is impossible to accomplish for wind studies since there is simply no industry standard threshold in existence. As discussed in the Baylands Draft EIR and Final EIR Master Responses, the wind analysis used for the Baylands used the same methods and significance criteria to conduct the wind analysis as those used by San Francisco in its EIR for the Executive Park project, which would also affect the windsurfing resource at CPSRA.

2.11 Conclusions

The comments presented by the CPA rely on an "audit" prepared by EnviroComp Consulting. This audit makes four main points in regards to the wind study conducted for the Brisbane Baylands EIR. These points are the following:

1. Not using Computational Fluid Dynamics (CFD) computer modeling for the Baylands study "does not comply with standard analysis practice;"
2. The wind tunnel experiments were "poorly described," and therefore the validity of the results are questionable,
3. No literature review was conducted to "review and study past effects of urban developments;" and
4. There was no effort to establish "objective, scientific parameters" for assessing the impact of the project on windsurfers.

With regard to the first point made by the EnviroComp audit, CFD modelling is not a common or standard source for analysis in the type of wind study prepared for the Baylands. The use of wind tunnel test in this type of study is, however, common, and is used often to study impacts under CEQA in other projects. The information provided by Dr. White and Dr. van Dam both support use of the wind tunnel analysis prepared for the Baylands.

EnviroComp's second point that the wind tunnel experiments were not well described and therefore the results are questionable is an invalid statement. It is not common practice to describe the background in methodology of wind tunnel modeling, measurement system, or error analysis in an EIR. All of this information is, however, available in the response provided by Dr. White, below.

EnviroComp's third point that a literature review should have been a part of this analysis is also not a practiced standard in CEQA wind analysis. Some of the literature offered in the EnviroComp "audit" is not relevant to the Baylands wind study (e.g., discussion of agricultural wind breaks, wind flow around building exhaust stacks, and wind flow around wind turbines). Furthermore, the literature referenced by EnviroComp that is relevant to the Baylands, in fact, supports the methodology used to analyze Baylands wind impacts: the wind test on the development in Aruba cited by EnviroComp used a wind tunnel to perform the analysis. The responses from both Dr. White and Dr. van Dam contain, below, provide numerous relevant references to support the use of a wind tunnel modeling and the limitations in using CFD computer modeling.

The last point made by EnviroComp's claims that there was no scientific means used in the Baylands wind study to establish the parameters to assess the impact Baylands development would have on windsurfers. This claim is untrue. Wind tunnel testing is frequently used in analyzing wind impacts of new development under CEQA. Wind tunnel modeling is a scientifically accepted use for this type of analysis, as supported by the responses from Dr. White and Dr. van Dam, below. In addition to the validity of the wind tunnel tests as a scientific standard to analyze these wind effects, Master Response 30 of the Final EIR, as well as Section 4-M of the Draft EIR both describe the methodology behind using the wind tunnel results to assess the impact of the project.

Furthermore, many of the comments made by CPA in addition to their summary of the EnviroComp audit are addressed in the EIR Master Responses 30 through 34.

This Response provides the information that is necessary to respond to all other comments from the CPA. The conclusions put forth by CPA wrong. CPA started with an unsupported assumption, namely they assumed that the EIR is not in-line with CEQA requirements. This Response provides technical materials that are sufficient evidence of the validity of the Baylands wind study, and also adds commentary about the opinions and claims made by CPA and EnviroComp.

3.0 Wind Tunnel Testing Undertaken for the Brisbane Baylands, by Bruce White, Ph.D.

3.1 Potential for Uncertainty and/or Error of the Wind Tunnel and Testing Procedures

The subject tests for the Brisbane Baylands project were conducted in a manner to reduce the overall uncertainty and to allow for extremely repeatable relative results. There are two types of uncertainty: systematic and random. Random errors can be reduced through the use of accurate calibration and data collection methods with high quality instrumentation. For the test at hand, systematic errors can be largely eliminated by using relative metrics, i.e. R ratios, between settings. For each model location and wind direction, the only variable between tests is the building layout within the model. The same data acquisition system and other equipment is used, which means that most of the systematic errors present are correlated and therefore do not add to the uncertainty of the measurements. The same is true when a model is too large to fit into the wind tunnel in one piece, as was the case for this project. Each 'strip' acts as a single system, with its own systematic errors, but the relative comparisons between settings benefit from most of these errors being correlated. In previous testing which required that the model be subdivided into multiple pieces, overlap points have been taken at the same model location on the multiple pieces, and these results have shown agreement within 5%, with lower relative error of approximately 2% commonly observed.

In most experimental procedures the results are calculated based upon a set of measured parameters, with each measurement having a level of uncertainty associated with it. For this analysis, the uncertainty will be taken to be the range of values in which the true value will fall 95% of the time. This uncertainty can be estimated using the technique described by Kline and McClintock [1]. Where, w_R is the uncertainty of the result, R is the function used to obtain the calculated result, $x_1 \ldots x_n$ are the independent variables, and $w_1 \ldots w_n$ are the uncertainties in the independent variables. The resulting uncertainty can be obtained by Equation 1:

$$w_R = \left[\left(\frac{\partial R}{\partial x_1}w_1\right)^2 + \left(\frac{\partial R}{\partial x_2}w_2\right)^2 + \cdots + \left(\frac{\partial R}{\partial x_n}w_n\right)^2\right]^{1/2} \qquad (1)$$

This uncertainty can be expressed as a percentage of readings obtained. For hot-wire data in turbulent flow, uncertainty analysis is made for time averaging techniques. The results of the uncertainty analysis are summarized in Table 1.

	Elements, x_i	Typ. Value	dx_i	V(x+dx)	$(dV/dx_i)dx_i$	$1/V(dV/dx_i)dx_i$
	Mean Velocity V, m/s	3.000				
Calibration	Volts at Zero Vel. (Eo)	4.706	0.01	3.032	0.033	1.10%
	E-Eo, Volts	1.9565	0.005	3.016	0.016	0.55%
	ΔP, in Water	0.0440	0.1	3.024	0.024	0.81%
Measurement	Eo, Volts	4.612	0.03	3.099	0.099	3.31%
	Reference Velocity, Uf	3.15	0.05	3.050	0.050	1.68%
	Others					3%
TOTAL						**5.38%**

3.2 Discussion of Measurement Methodology

3.2.1 Atmospheric Boundary Layer at University of California Davis

In the Brisbane Baylands project investigation, the Atmospheric Boundary Layer Wind Tunnel (ABLWT) located at University of California, Davis was used (Figure A-1). Built in 1979 the wind tunnel was originally designed to simulate turbulent boundary layers comparable to wind flow near the surface of the earth. In order to achieve this effect, the tunnel requires a long flow-development section such that a mature boundary-layer flow is produced at the test section. The wind tunnel is an open-return type with an overall length of 21.3 m and is composed of five sections: the entrance, the flow-development section, the test section, the diffuser section, and the fan and motor.

The entrance section is elliptical in shape with a smooth contraction area that minimizes the free-stream turbulence of the incoming flow. Following the contraction area is a commercially available air filter that reduces large-scale pressure fluctuations of the flow and filters larger-size particles out of the incoming flow. Behind the filter, a honeycomb flow straightener is used to reduce large-scale turbulence.

The flow development section is 12.2 m long with an adjustable ceiling for longitudinal pressure-gradient control. For the present study, the ceiling was diverged ceiling so that a zero-pressure-gradient condition is formed in the stream wise direction. At the leading edge of the section immediately following the honeycomb flow straightener, four triangularly shaped spires are stationed on the wind-tunnel floor to provide favorable turbulent characteristics in the boundary-layer flow. Roughness elements are then placed all over the floor of this section to artificially thicken the boundary layer. For a free-stream wind speed of 4.0 m/s, the wind-tunnel boundary layer grows to a height of one meter at the test section. With a thick boundary layer, larger models could be tested and thus measurements could be made at higher resolution.

Dimensions of the test section are 2.44 m in stream wise length, 1.66 m high, and 1.18 m wide. Similar to the flow-development section, the test section ceiling can also be adjusted to obtain the desired stream wise pressure gradient. Experiments can be observed from both sides of the test section through framed Plexiglas windows. One of the windows is also a sliding door that allows access into the test section. When closed twelve clamps distributed over the top and lower edges are used to seal the door. Inside the test section, a three-dimensional probe-positioning system is installed at the ceiling to provide fast and accurate sensor placement. The traversing system scissor-type extensions, which provide vertical probe motion, are also made of aerodynamically shaped struts to minimize flow disturbances.

The diffuser section is 2.37 m long and has an expansion area that provides a continuous transition from the rectangular cross-section of the test section to the circular cross-sectional area of the fan. To eliminate upstream swirl effects from the fan and avoid flow separation in the diffuser section, fiberboard and honeycomb flow straighteners are placed between the fan and diffuser sections.

The fan consists of eight constant-pitch blades 1.83 m in diameter and is powered by a 56 kW (75 hp) variable-speed DC motor. A dual belt and pulley drive system is used to couple the motor and the fan.

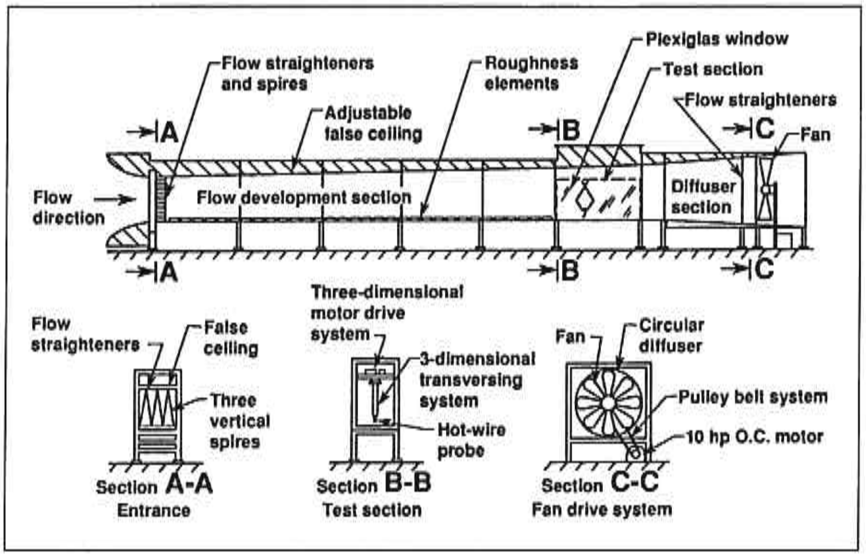

Figure A-1: Schematic diagram of the UC Davis Atmospheric Boundary Layer Wind Tunnel.

3.2.2 *Instrumentation and Measurement System*

In testing the Brisbane Baylands project, wind tunnel measurements of the mean velocity and turbulence characteristics were performed using hot-wire anemometry. A standard Thermo Systems Inc. (TSI) single hot-wire sensor model 1210-60 was used to measure the wind quantities. The sensor was installed at the end of a TSI model 1150 50-cm probe support, which was secured onto the support plate of the three-dimensional sensor positioning system in the U.C. Davis Atmospheric Boundary Layer Wind Tunnel (ABLWT) test section. A 10-m shielded tri-axial cable was then used to connect the probe support and sensor arrangement to a TSI model IFA 100 constant temperature thermal-anemometry unit with signal conditioner.

Hot-wire sensor calibrations were conducted in the ABLWT test section over the range of common velocities measured in the wind-tunnel boundary layer. Signal-conditioned voltage readings of the hot-wire sensor were then matched against the velocity measurements from a Pitot-static tube connected to a Meriam model 34FB2 oil micro-manometer, which had a resolution of 25.4 μm of oil level. The specific gravity of the oil was 0.934. The Pitot-static tube was secured to an aerodynamically shaped stand and was positioned so that its flow-sensing tip is normal to the flow and situated near the volumetric center of the test section. Normal to the flow, the end of the hot-wire sensor was then traversed to a position 10 cm next to the tip of the Pitot-static tube.

Raw voltage data sets of hot-wire velocity measurements were digitally collected using a LabVIEW data acquisition system, which was installed in a desktop computer. Hot wire voltages were obtained from the signal conditioner output of the IFA 100 anemometer connected to a multi-channel terminal board linked to a United Electronics Inc. (UEI) analog-to-digital (A/D) data acquisition board, which is installed in one of the ISA motherboard slots of the PC. LabVIEW software was used to develop virtual instruments (VI) that would initiate and configure the A/D board, then collect the voltage data given by the measurement equipment, display appropriately converted results on the computer screen, and finally save the voltage data into a designated filename.

For the hot-wire data acquisition, data is acquired as 30,000 samples collected at a sampling rate of 1000 Hz. This acquisition setting greatly satisfies the Nyquist sampling theorem as the average tunnel turbulence signal was 300 Hz. These voltage readings from the anemometer transducer were individually converted to instantaneous wind speeds by applying a calibration curve, which was acquired prior to the testing. The converted velocity data and its histogram is displayed along with the mean voltages, mean velocity, root-mean-square velocity, and turbulence intensity. The resulting mean speeds and turbulent intensities represent one-hour of full-scale measurements of time averaged wind speeds and fluctuations. The raw voltages and reduced data are saved in the computer hard drive.

3.3 Discussion of Modeling in an ABLWT

3.3.1 *Physical Model*

For the current testing, a scale of 1:600 was used for the scaling of the building and terrain. Geometric similarity existed between the scaled model and full-scale case. This is the same scale that has been used for 25 years of pedestrian-level wind testing for ordinance compliance purposes in the city of San Francisco, and for CEQA impact analysis in San Francisco and other California cities. This scale represents an approximate width and length of area equal to 2400 feet width normal to the flow direction and a fetch of 7200 feet in the direction of the wind flow. Additionally, at this scale, the height of the scaled boundary layer in the tunnel equates to a height approximately equal to the full-scale boundary-layer height, i.e., 1000 feet to 1500 feet, which provides for proper scaling of the large-scale eddies in the turbulent atmospheric boundary layers.

3.3.2 Wind-Tunnel Atmospheric Flow Similarity Parameters

Wind-tunnel models of a particular test site are typically several orders of magnitude smaller than the full-scale size. In order to appropriately simulate atmospheric winds in the UC Davis Atmospheric Boundary Layer Wind Tunnel (ABLWT), certain flow parameters must be satisfied between a model and its corresponding full-scale equivalent. Similitude parameters can be obtained by non-dimensionalizing the equations of motion, which build the starting point for the similarity analysis. Fluid motion can be described by the following time-averaged equations.

Conservation of mass:

$$\frac{\partial \overline{U}_i}{\partial t_i} = 0 \text{ and } \frac{\partial \rho}{\partial t} + \frac{\partial (\rho \overline{U}_i)}{\partial x_i} = 0$$

Conservation of momentum:

$$\frac{\partial \overline{U}_i}{\partial t} + \overline{u}\ \frac{\partial \overline{U}_i}{\partial x_j} + 2\varepsilon_{ijk}\Omega_j \overline{U}_k = -\frac{1}{\rho_0}\frac{\partial \overline{\delta P}}{\partial x_i} - \frac{\overline{\delta T}}{T_0} g\delta_{i3} + \nu_0 \frac{\partial^2 \overline{U}_i}{\partial x_j} + \frac{\partial (\overline{-u_j u_i})}{\partial x_j}$$

Conservation of energy:

$$\frac{\partial \overline{\delta T}}{\partial t} + \overline{U}_i \frac{\partial \overline{\delta T}}{\partial x_i} = \left[\frac{\kappa_0}{\rho_0 c_{p_0}}\right] \frac{\partial^2 \overline{\delta T}}{\partial x_k \partial x_k} + \frac{\partial (-\overline{\theta u_i})}{\partial x_i} + \frac{\overline{\phi}}{\rho_0 c_{p_0}}$$

Here, the mean quantities are represented by capital letters while the fluctuating values by small letters. δP is the deviation of pressure in a neutral atmosphere. ρ_0 and T_0 are the density and temperature of a neutral atmosphere and ν_0 is the kinematic viscosity. In the equation for the conservation of energy, ϕ is the dissipation function, $\overline{\delta T}$ is the deviation of temperature from the temperature of a neutral atmosphere, κ_0 is the thermal diffusivity, and c_{p_0} is the heat capacity.

Applying the Boussinesq density approximation, application of the equations is then restricted to fluid flows where $\overline{\delta T} << T_0$. Defining the following non-dimensional quantities and then substituting into the above equations.

$$\overline{U}_i' = \overline{U}_i' / U_0 \; ; \; u_i' = u_i / U_0 \; ; \; x_i' = x_i / L_0 \; ; \; t' = tU_0 / L_0 \; ; \; \Omega_j' = \Omega_j / \Omega_0 \; ; \; \overline{\delta P}' = \overline{\delta P} / \rho_0 U_0^2 \; ;$$

$$\overline{\delta T}' = \overline{\delta T} / \delta T_0 \; ; \; g' = g / g_0 \; ; \; \overline{\varphi}' = \overline{\varphi} / \varphi_0$$

The equations of motion can be presented in the following dimensionless forms.

Continuity Equation:

$$\frac{\partial u_i'}{\partial k_i'} = 0 \text{ and } \frac{\partial \rho'}{\partial t'} + \frac{\partial(\rho' u_i')}{\partial x_i'} = 0$$

Momentum Equation:

$$\frac{\partial \overline{U}_i'}{\partial t'} + \overline{U}_j' \frac{\partial \overline{U}_i'}{\partial x_j'} + \frac{2}{Ro} \varepsilon_{ijk} \overline{U}_k' \Omega_j' = -\frac{\partial \overline{\delta P}'}{\partial x_i'} + \frac{1}{Fr^2} \overline{\delta T}' \delta_{3i} + \frac{1}{Re} \frac{\partial^2 \overline{U}_i'}{\partial x_j' \partial x_j'} + \frac{\partial(-\overline{u_j' u_i'})}{\partial x_j'}$$

Turbulent Energy Equation:

$$\frac{\partial \overline{\delta T}'}{\partial t'} + \overline{U}_i' \frac{\partial \overline{\delta T}'}{\partial x_i'} = Pr \cdot \frac{1}{Re} \frac{\partial^2 \overline{\delta T}'}{\partial x_k' \partial x_k'} + \frac{\partial(-\overline{\theta' u_i'})}{\partial x_i'} + \frac{1}{Re} \cdot Ec \cdot \overline{\varphi}'$$

Although the continuity equation gives no similarity parameters, coefficients from both other equations do provide the following desired similarity parameters.

1. Rossby number: $R_0 \equiv U_0 / L_0 \Omega_0$
2. Densimetric Froude number: $Fr \equiv U_0 / (g L_0 \delta T_0 / T_0)^{1/2}$
3. Prandtl number: $Pr \equiv \rho_0 c_{p_0} \nu_0 / \kappa_0$
4. Eckert number: $Ec \equiv U_0^2 / c_{p_0} \delta T_0$
5. Reynolds number: $Re \equiv U_0 L_0 / \nu_0$

In the dimensionless momentum equation, the Rossby number is extracted from the denominator of the third term on the left hand side. The Rossby number represents the ratio of advective acceleration to Coriolis acceleration due to the rotation of the earth. If the Rossby number is large, Coriolis accelerations are small. Since UC Davis ABLWT is not rotating, the Rossby number is infinite allowing the corresponding term in the dimensionless momentum equation to approach zero. In nature, however, the rotation of the earth influences the upper layers of the atmosphere; thus, the Rossby number is small and becomes important to match, and the corresponding term in the momentum equation is sustained.

Most modelers have assumed the Rossby number to be large, thus, neglecting the respective term in the equations of motion and ignoring the Rossby number as a criterion for modeling. Snyder (1981) showed that the characteristic length scale, L_0, must be smaller than 5 km in order to simulate diffusion under neutral or stable conditions in relatively flat terrain. Other researchers discovered similar findings. Since UC Davis ABLWT produces a boundary layer with a height of about one meter, the surface layer vertically extends 10 to 15 cm above the ground. In this region the velocity spectrum would be accurately modeled. The Rossby number can then be ignored in this region. Since testing is limited to the lower 10% to 15% of the boundary layer, the length in longitudinal direction, which can be modeled, has to be no more than a few kilometers.

Derived from the denominator of the second term on the right hand side of the dimensionless momentum equation, the square of the Froude number represents the ratio of inertial forces to buoyancy forces. High values of the Froude number infer that the inertial forces are dominant. For values equal or less than unity, thermal effects become important. Since the conditions inside the UC Davis ABLWT are inherently isothermal, the wind tunnel generates a neutrally stable boundary layer; hence, the Froude number is infinitely large allowing the respective term in the momentum equation to approach zero.

The third parameter is the Prandtl number, which is automatically matched between the wind-tunnel flow and full-scale winds if the same fluid is been used. The Eckert number criterion is important only in compressible flow, which is not of interest for a low-speed wind tunnel.

Reynolds number represents the ratio of inertial to viscous forces. The reduced scale of a wind tunnel model results in a Reynolds number several orders of magnitude smaller than in full scale. Thus, viscous forces are more dominant in the model than in nature. No atmospheric flow could be modeled, if strict adherence to the Reynolds number criterion was required. However, several arguments have been made to justify the use of a smaller Reynolds number in a model. These arguments include laminar flow analogy, Reynolds number independence, and dissipation scaling. With the absence of thermal and Coriolis effects, several test results have shown that the scaled model flow will be dynamically similar to the full-scale case if a critical Reynolds number is larger than a minimum independence value, which is the case in all testing performed for the Brisbane Baylands project. The gross structure of turbulence is similar over a wide range of Reynolds numbers; all modelers use this approach today.

3.3.3 *Wind-Tunnel Atmospheric Boundary Layer Similarity*

Wind-tunnel simulation of the atmospheric boundary layer under neutrally stable conditions must also meet non-dimensional boundary-layer similarity parameters between the scaled-model flow and its full-scale counterpart. The most important conditions are:

1. The normalized mean velocity, turbulence intensity, and turbulent energy profiles.
2. The roughness Reynolds number, $\mathrm{Re}_z = z_0 u_* / \nu$.
3. Jensen's length-scale criterion of z_0/H.
4. The ratio of H/δ for H greater than $H/\delta > 0.2$.

In the turbulent core of a neutrally stable atmospheric boundary layer, the relationship between the local flow velocity, U, versus its corresponding height, z, may be represented by the following velocity-profile equation.

$$\frac{U}{U_\infty} = \left(\frac{z}{\delta}\right)^{\alpha}$$

Here, U_∞ is the mean velocity of the inviscid flow above the boundary layer, ■s the height of the boundary layer, and ✓is the power-law exponent, which represents the upwind surface conditions. Wind-tunnel flow can be shaped such that the exponent ✓will closely match its corresponding full-scale value, which can be determined from field measurements of the local winds. The required power-law exponent, α, can then be obtained by choosing the appropriate type and distribution of roughness elements over the wind tunnel flow-development section.

Full-scale wind data suggest that the atmospheric wind profile at the site yields a nominal value of ✓ = 0.2. This condition was closely matched in the UC Davis Atmospheric Boundary Layer Wind Tunnel by systematically arranging a pattern of 2" x 4" wooden blocks of 12" in length along the entire surface of the flow-development section. The pattern generally consisted of alternating sets of four and five blocks in one row. A typical velocity profile is presented in Figure 3-2, where the simulated power-law exponent is ✓= 0.33.

In the lower 20% of the boundary layer height, the flow is then governed by a rough-wall or "law-of-the-wall" logarithmic velocity profile.

$$\frac{U}{u_*} = \frac{1}{\kappa} \ln\left(\frac{z}{z_o}\right)$$

Here, u_* is the surface friction velocity, ✱is von Karman's constant, and z_o is the roughness height. This region of the atmospheric boundary layer is relatively unaffected by the Coriolis force, the only region that can be modeled accurately by the wind tunnel (i.e., the lowest 100 m of the atmospheric boundary layer under neutral stability conditions). Thus, it is desirable to have the scaled-model buildings and its surroundings contained within this layer.

The geometric scale of the model should be determined by the size of the wind tunnel, the roughness height, z_o, and the power-law index, α. With a boundary-layer height of 1 m in the test section, the surface layer would be 0.2 m deep for the UC Davis ABLWT. For the current study, this boundary layer corresponds to a full-scale height of the order of 800 m. Since the highest elevation of the topography modeled in the vicinity of the Brisbane Baylands project site is about 90 m full-scale, the entire model is contained in this region of full-scale similarity.

Due to scaling effects, full-scale agreement of simulated boundary-layer profiles can only be attained in wind tunnels with long flow-development sections. For full-scale matching of the normalized mean velocity profile, an upwind fetch of approximately 10 to 25 boundary-layer heights can be easily constructed. To fully simulate the normalized turbulence intensity and energy spectra profiles, the flow-development section needs to be extended to about 50 and 100 to 500 times the boundary-layer height, respectively. These profiles must at least meet full-scale similarities in the surface layer region. However, with the addition of spires and other flow tripping devices, the flow development length can be reduced to less than 20 boundary layer heights for most engineering applications. A representative energy spectra for the wind tunnel is shown in Figure 3-3.

In the U.C. Davis Atmospheric Boundary Layer Wind Tunnel, the maximum values of turbulence intensity near the surface range from 35% to 40%, similar to that in full scale. Thus, the turbulent intensity profile, u'/u versus z, should agree reasonably with the full-scale, particularly in the region where testing is performed. Figure 3-4 displays a typical turbulence intensity profile of the boundary layer in the ABLWT test section.

The second boundary-layer condition involves the roughness Reynolds number, Re_z. According to the criterion given by Sutton (1949), Reynolds number independence is attained when the roughness Reynolds number is defined as follows.

$$Re_z = \frac{u_* z_0}{\nu} \geq 2.5$$

Here, u_* is the friction speed, z_0 is the surface roughness length and ν is the kinematic viscosity. Re_z larger than 2.5 ensures that the flow is aerodynamically rough. Therefore, wind tunnels with a high enough roughness Reynolds numbers simulate full-scale aerodynamically rough flows exactly. To generate a rough surface in the wind tunnel, roughness elements are placed on the wind tunnel floor. The height of the elements must be larger than the height of the viscous sub-layer in order to trip the flow. The UC Davis ABLWT satisfies this condition, since the roughness Reynolds number is about 40, when the wind tunnel free stream velocity, U_∞, is equal 3.8 m/s, the friction speed, u_*, is 0.24 m/s, and the roughness height, z_o, is 0.0025 m. Thus, the flow setting satisfies the Re number independence criterion and dynamically simulates the flow.

To simulate the pressure distribution on objects in the atmospheric wind, Jensen (1958) found that the surface roughness to object-height ratio in the wind tunnel must be equal to that of the atmospheric boundary layer, i.e., z_o/H in the wind tunnel must match the full-scale value. Thus, the geometric scaling should be accurately modeled.

The last condition for the boundary layer is the characteristic scale height to boundary layer ratio, H/δ. There are two possibilities for the value of the ratio. If $H/\delta \geq 0.2$, then the ratios must be matched. If $(H/\delta)_{F.S.} < 0.2$, then only the general inequality of $(H/\delta)_{W.T.} < 0.2$ must be met (F.S. stands for full-scale and W.T. stands for wind tunnel). Using the law-of-the-wall logarithmic profile equation, instead of the power-law velocity profile, this principle would constrain the physical model to the 10% to 15% of the wind tunnel boundary layer height.

Along with these conditions, two other constraints have to be met. First, the mean stream wise pressure gradient in the wind tunnel must be zero. Even if high- and low-pressure systems drive atmospheric boundary layer flows, the magnitude of the pressure gradient in the flow direction is negligible compared to the dynamic pressure variation caused by the boundary layer. The other constraint is that the model should not take up more than 5% to 15% of the cross-sectional area at any down-wind location. This assures that local flow acceleration affecting the stream wise pressure gradient will not distort the simulation flow.

Simulations in the U.C. Davis ABLWT were not capable of producing stable or unstable boundary layer flows. In fact, proper simulation of unstable boundary layer flows could be a disadvantage in any wind tunnel due to the artificial secondary flows generated by the heating that dominate and distort the longitudinal mean-flow properties, thus, invalidating the similitude criteria. However, this is not considered as a major constraint, since the winds that produce annual average dispersion are sufficiently strong, such that for flow over a complex terrain, the primary source of turbulence is due to mechanical shear and not due to diurnal or heating and cooling effects in the atmosphere.

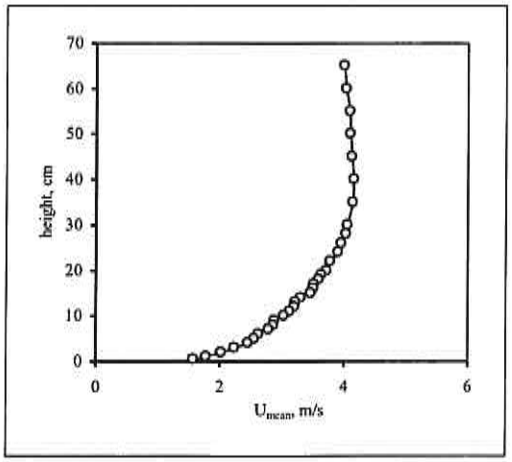

Figure 3-2: Mean velocity profile for a typical wind direction in the wind tunnel. The power law exponent α is 0.33. The reference velocity at 65 cm height is 3.55 m/s.

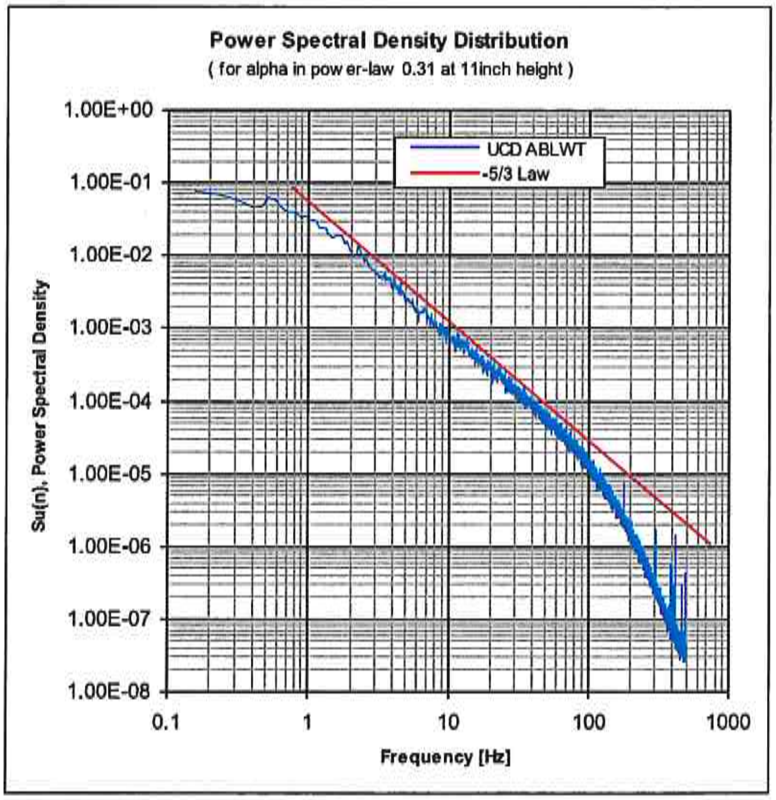

Figure 3-3: Power Spectral Density Distribution in Boundary Layer of UC Davis ABLWT.

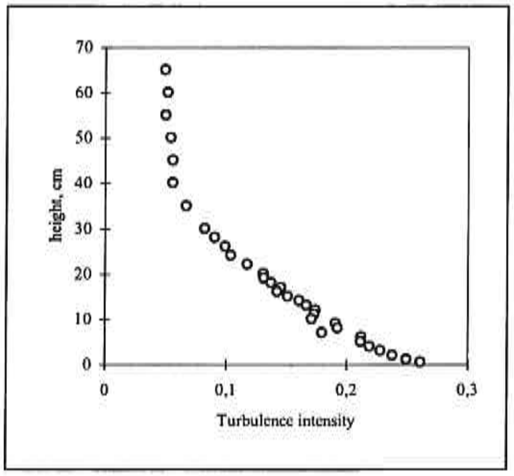

Figure 3-4: Turbulence intensity profile for a typical wind direction in the wind tunnel.

3.4 Discussion of Wind Tunnel Validation, Specifically for Building Modeling in the ABL

Studying the effects pedestrian level winds (PLW) around buildings using atmospheric boundary layer wind-tunnels (ABLWT) and hot-wire anemometry is well documented within the literature (e.g. [2-13]) and is widely accepted as a preferred method of study [14]. When compared with full-scale measurements, the accuracy of hot-wire anemometry within an ABLWT has been shown to be within 10% for relatively windy areas, which are the areas of interest for windsurfers [14]. The American Society of Civil Engineers (ASCE) acknowledges the usefulness of ABLWTs for the study of wind interactions with buildings and has published advice on the best practices in the ASCE Manuals and Reports on Engineering Practice No. 67: Wind Tunnel Studies of Buildings and Structures [15], with which the techniques used in the present study are consistent.

Furthermore, it is relevant to note that an ABLWT was used for a detailed investigation of the effects of beachside development on the sailing conditions for windsurfers at the island of Aruba. The wind tunnel measurements, made with pressure probes, were found to be in good agreement with the reported perceptions of experienced windsurfers in the area. There, in Aruba, the buildings were deemed to have 'noticeable impact' up to approximately 300 meters – 10 typical building heights – downstream; 'marginal impact' from 300 meters to 500 meters downstream; and, 'no impact' beyond 500 meters. The accompanying series of full scale wind observations "suggested that the main impact to sailing was closer than 300 meters, and that the 'marginal impact' region was not of great consequence." [16].

In summary, the wind tunnel can provide accurate flow around building/s and detail of mean wind speeds and turbulence levels to a scale of 10s of centimeters at full size, e.g., much less than the height of a wind surfer (17).

Quoting from the ASHRAE FUNDAMENTALS HANDBOOK (18) "The wind tunnel is the main tool used to assess and understand the airflow around buildings. ... Models of buildings, complexes and the local surrounding topography are constructed and tested in a simulated turbulent atmospheric boundary layer. The airflow and wind pressures, snow loads, structural response or pollutant concentration can then be measured by properly scaling the wind and exhaust flow characteristics." This was the method used for the Brisbane Baylands project wind tunnel testing.

"Weil et al. (19), Petersen (20), and Dagaliesh (21) all found good agreement between the results of wind tunnel simulations and corresponding full-scale data" (18). Further stating: "Physical modeling is the most appropriate for applications involving small-scale atmospheric motions, such as ... wind speeds arounds building clusters ... and airflow over hills".

The United States Environmental Protection Agency (22) provides strict wind tunnel testing guidelines for simulation of air flow around clusters of buildings, and these criteria were exactly matched or met for the Brisbane Baylands project wind tunnel testing.

Consequently, the above discussion of best analysis techniques of structures/buildings/smoke stacks on the earth's surface within the boundary layer and their impacts clearly shows that using an ABLWT is the best and superior method for determining impacts of future buildings and smoke stacks[3].

3.5 Summary

In prior sections of this response, are presented the details of the wind tunnel testing that demonstrate that the test conditions meet all the stated requirements of ASHRAE standard testing requirements and the generally accepted testing standards within the wind tunnel testing community.

Thus, it is safe to conclude that the Brisbane Baylands wind tunnel assessment of future wind impacts in the vicinity of the project was the most generally accepted analysis technique to use for the CEQA review, because wind tunnel testing is widely accepted by the scientific community, as well as by governmental agencies.

3.6 References

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[3] Note, although this project does not contain proposed smoke stacks and their impact, it is worth noting that these are arguably more difficult to determine their impact than simple assessment of proposed building impacts, and yet this is still the preferred method, even by government agencies issuing permits, as they have adopted the ASHRAE method as an acceptable assessment method.

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4.0 Limitations of Computational Fluid Dynamics in the Modeling of Flows in Urban Environments, by C.P. van Dam, PhD.

4.1 Introduction

Only fifty years ago, the study of flows was done almost exclusively with physical models in wind and water tunnels/tanks. In the 1960's, the convergence of discoveries in mathematical formulations describing flow and the advent of powerful computers (prior to that, "computers" referred to people doing calculations by hand!) led to the emergence of a powerful new tool, the modeling of flow with computers, commonly referred to as computational fluid dynamics (CFD). Since its inception, there has been great anticipation that CFD would wholly replace wind tunnel testing with physical models. But while there have been incredible advances in both the formulation of flow physics and computing capabilities, this is unlikely to occur for many decades, if ever.

NASA periodically surveys CFD and wind tunnel capabilities to support the long-term planning of their research tools[4,5]. While their focus is on aeronautics, their conclusions apply broadly to any flow study:

> ...wind tunnels are and are expected to continue to be an important part of the design process. The essential reason for this is twofold: the lack of computational capacity... and the lack of adequate modeling for the exceedingly complex... flows. Based on Moore's Law, conventional computer improvements will require more than 20 years to provide adequate computational capability...[2]

The conclusion to draw from such statements is not that CFD (or, for that matter, wind tunnel testing) is inadequate. Instead, the crux is that even with all the advances of the past half-century, modeling of flow remains a very difficult problem.

4.2 Computational Modelling Challenges

Perhaps the most conceptually obvious approach to CFD is *direct numerical simulation*, DNS. For DNS, all the governing physical equations (for fluids, these are the Navier-Stokes equations) would be discretely solved over the subject(s) of interest and its surrounding space, across the time period of interest. The subject(s), space, and time must be discretized at sufficiently fine resolution to properly capture the flow physics. The volume of space, often referred to as the *domain*, must be sufficiently large to encompass all the flow affecting and affected by the subject(s); this is usually much larger than the subject itself, at least one order of magnitude. The duration of time modelled must be sufficiently long to allow the flow to fully develop and to capture any transient flow phenomena. Unfortunately, DNS is infeasible in all but the simplest cases. As explained by Malik and Bushnell[2]:

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[4] J. Slotnick, A. Khodadoust, J. Alonso, D. Darmofal, W. Gropp, E. Lurie, and D. Mavriplis, "CFD Vision 2030 Study: A Path to Revolutionary Computational Aerosciences," Mar. 2014.

[5] M. R. Malik and D. M. Bushnell, "Role of Computational Fluid Dynamics and Wind Tunnels in Aeronautics R and D," Sep. 2012.

> Direct numerical simulation (DNS) of the Navier-Stokes equations captures all of the spatial and temporal scales in the flow and, thus, is independent of the modeling assumptions, but the computational cost scales as Re^3; therefore, its use will continue to be limited to simplistic geometries with an objective to obtain physical insight into transitional and turbulent flows. The proper role of DNS in turbulent-flow simulations must be that of a research tool and not a brute force engineering tool for the characterization of aerodynamic flows, even if advancements in quantum computing routinely would allow such computations.

Instead of DNS, pragmatic CFD tools employ an array of assumptions and simplifications, making practically unsolvable problems tractable. These simplifications -- such as the use of less mathematically intensive submodels to characterize certain flow phenomena -- are carefully selected and designed for the type of flow and application being studied. There is not, therefore, a single CFD program or package (often referred to as codes, solvers, or models) that is universally applicable to all problems. This point is particularly pertinent to the problem at hand, as it involves two different scales -- the mesoscale and what is sometimes called the microscale. This is discussed herein as we survey the CFD packages that were proposed to model the prospective building complex and nearby recreational use area. Note that while we mention specific CFD packages below, our discussions encompass the broader categories which comprise these packages.

4.3 Mesoscale Solvers for Atmospheric Flows

MM5 and WRF are mesoscale CFD models, commonly used for applications such as regional weather forecasting and air quality modeling. *Mesoscale* implicitly refers to mesoscale meteorology and denotes the scale of the flow phenomena being modeled (from ones to hundreds of kilometers over minutes to many days), with domain sizes commonly on the order of hundreds of kilometers or more. MM5 is the precursor to WRF. Development of MM5 stopped in in 2006 and WRF is generally accepted as its replacement. The remaining discussion therefore is focused on WRF, but broadly applies to MM5 and other mesoscale codes. WRF, the Weather Research and Forecasting model[6,7], is one of, if not the, most widely used mesoscale models in the world.

WRF couples the relatively simple[8] Euler equations with a number of submodels to incorporate the effects of key meteorological drivers. For example, microphysics submodels account for the effects of water vapor and precipitation. These submodels have largely been developed for mesoscale modeling and have proven effective in this application.

WRF has limited built-in abilities to model flow details at smaller scales. CFD models represent bodies and space as *grids* or *meshes* of discrete points. WRF's gridding system uses a simple terrain-following

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[6] http://wrf-model.org

[7] Skamarock, W. C., J. B. Klemp, J. Dudhia, D. O. Gill, D. M. Barker, M. G Duda, X.-Y. Huang, W. Wang, and J. G. Powers, 2008: A Description of the Advanced Research WRF Version 3. NCAR Tech. Note NCAR/TN-475+STR, 113 pp., doi:10.5065/D68S4MVH.

[8] This is not to imply that WRF is simple; indeed, it is remarkably sophisticated. The Euler equations are simple only relative to the full and less-reduced forms of the Navier-Stokes equations.

scheme that cannot accurately resolve the geometries of buildings or other such structures. Even if a building was coarsely gridded in, WRF lacks an appropriate viscous model for the turbulent and separated flows on and around such structures. Note that WRF does have large eddy simulation (LES, discussed further in the next section, *General Microscale CFD Solvers*) capability, but it has not been tested for such an application and, as discussed below, shares the drawbacks common to any LES modelling.

Instead of directly modeling the geometry of buildings and solving for the flow around them, WRF has urban parameterization models[9] that use a small number of parameters to describe an urban area and its aggregated effects on the surrounding flow. This is a simplified modeling approach that is appropriate for studying mesoscale flow, but is not intended to capture smaller scale details at the building level.

4.4 General Microscale CFD Solvers

Whereas WRF is specifically designed for mesoscale meteorological modeling, Fluent and OpenFOAM are more general CFD packages. They are fundamentally different, incorporating Reynolds-averaged Navier-Stokes (RANS), Unsteady Reynolds-averaged Navier-Stokes (URANS), and Large Eddy Simulation (LES) solvers for to model turbulent flows. RANS (from hereon out, the use of the term RANS implicitly includes URANS) solvers simplify the full Navier-Stokes equations by replacing a key nonlinear term with more readily solved turbulence models. RANS is currently the de facto method for "production" CFD. LES is a sort of hybrid between DNS and RANS, directly simulating the more important large scale flow features and using simpler models for smaller ones. It (or a hybrid RANS-LES) is largely regarded as the next step in CFD and has been an active area of research. It is not, however, commonly used for "production" CFD analyses, as it requires very fine grid resolutions and is therefore computationally very expensive, and requires careful tuning to produce good results.

RANS solvers can model flow in the so-called microscale, such as on the level of one or a small number of buildings. However, greatly expanding the modelling domain while retaining detail of terrain and structures would result in an impractically large grid that could not be feasibly solved.

4.5 Coupling Mesoscale and Microscale Solvers

The fundamental challenge to the modelling problem at hand is that it occurs simultaneously on two scales -- the mesoscale (weather, terrain, and upstream urban structures) and the microscale (the prospective development and its immediate surroundings). Each scale has its own specific tools, which are ill-adapted for the other. As illustrated in the figure below, one approach to resolve this is to perform multi-scale simulations, coupling, for example, a RANS solver such as OpenFOAM for the prospective development and its immediate vicinity, with a mesoscale solver such as WRF for the

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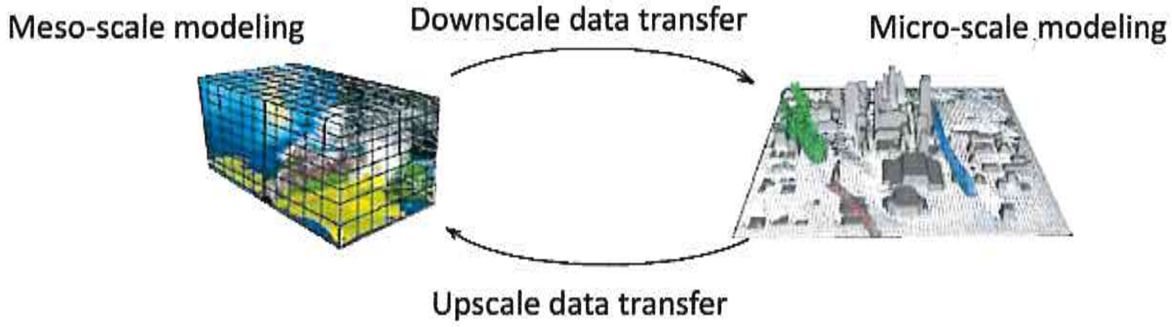
[9] F. Chen, H. Kusaka, R. Bornstein, et al., "The integrated WRF/urban modelling system: development, evaluation, and applications to urban environmental problems," International Journal of Climatology, vol. 31, no. 2, pp. 273–288, Feb. 2011.

broader region extending further beyond.



Adapted from Chen et al., Int. J. Climatol., 2011.

This has, in fact, been done in several efforts over the last few years. Critically, these have all been research efforts, performed largely in isolation of one another, for different applications, with different code configurations, and with limited validation. They have not produced a generalized methodology or code which can be readily used for routine analysis. Results have been promising and have advanced the state-of-the-art, and it appears that with additional research and development over the coming years, coupled multi-scale solvers will emerge as a mature, robust, practical technology. In their work with these solvers, Zajaczkowski et al[10], Wyszogrodzki et al[11], and Nakayama et al[12] discussed the pros and cons of such an approach. They and other studies found that much work remains to be done. As stated by Zajaczkowski et al., "These efforts are the subjects of on-going research. With further development the techniques investigated here could be useful in various contexts."

It is important to differentiate between methods that are well vetted and widely practiced, and methods that are still under research and development. In the prior sections, accepted "off-the-shelf" uses for two types of CFD codes are presented. The multi-scale approach discussed here is still being actively researched and developed. Codes and procedures have not yet been well defined and limitations and uncertainties have not yet been quantified. At this time, using such an approach would require intensive effort and time to design and implement, extensive computing resources beyond the norm to

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[10] Zajaczkowski FJ, Haupt SE, Schmehl KJ (2011) A preliminary study of assimilating numerical weather prediction data into computational fluid dynamics models for wind prediction. J Wind Eng Ind Aerodyn, 99:320–329.

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[12] Nakayama H, Takemi T, Nagai H (2012) Large-eddy simulation of urban boundary-layer flows by generating turbulent inflows from mesoscale meteorological simulations. Atmos Sci Lett, 13:180–186.

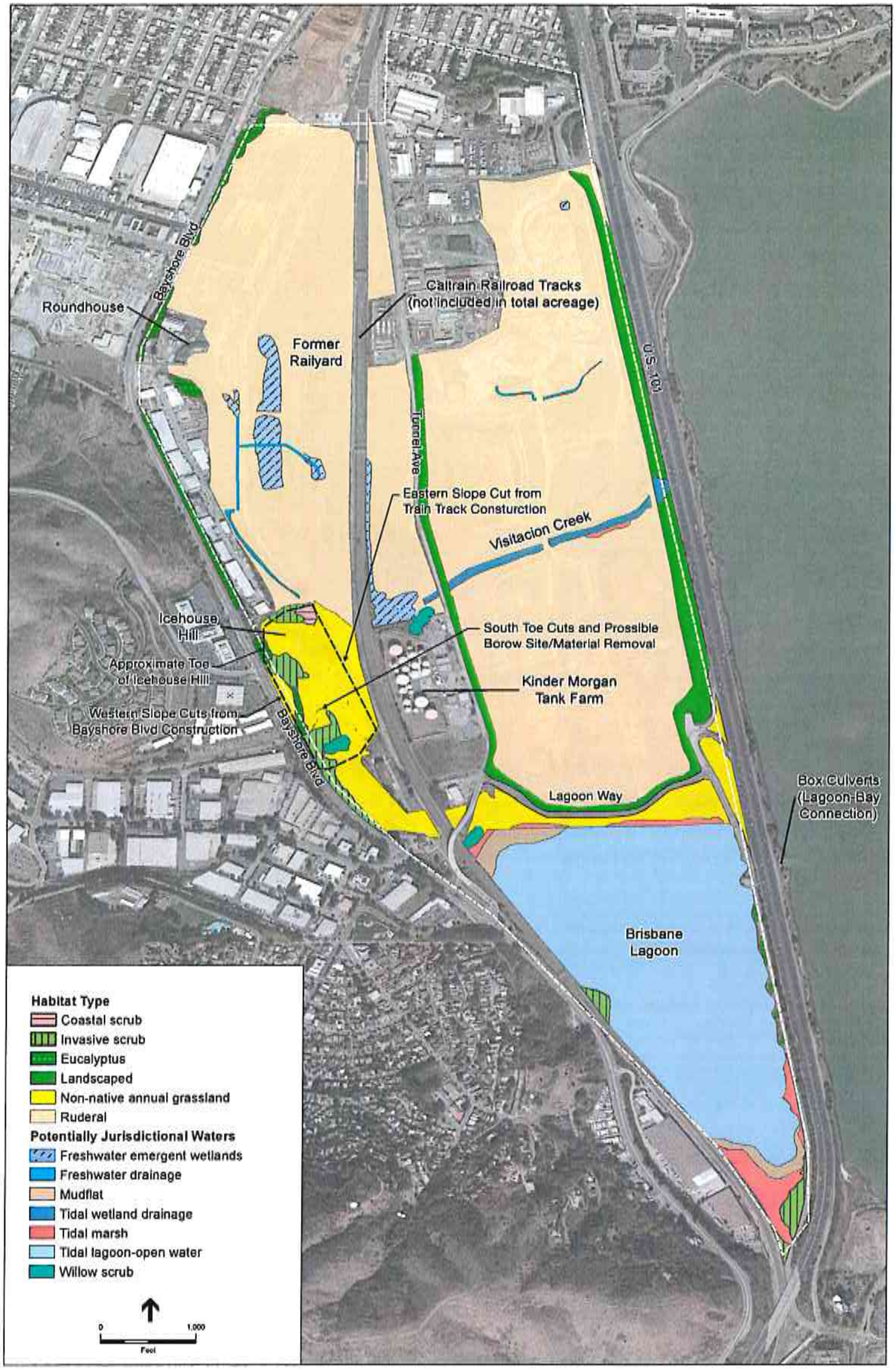
calibrate and run it, and verification of its results with another CFD code, wind tunnel testing, and/or full-scale testing.

4.6 Conclusions

Even with all the advances in computing over recent decades, accurate modelling and simulation remains a challenging task. CFD is a powerful tool, but it must be used judiciously to generate meaningful results. The experienced CFD practitioner knows that a code can always be coaxed to yield an answer. However, it is only for a narrow range of problems that those answers are likely to be correct.

While mesoscale codes like WRF and RANS solvers like OpenFOAM are well vetted for many use cases, the coupling of them together is not trivial and remains an area of ongoing research and development. Much work remains to make coupled multi-scale methods ready for routine use: the development of robust codes and procedures; study and validation across a range of cases including verification with other CFD codes, wind tunnel testing, and/or full-scale testing; and quantification of uncertainties. Without this foundational work, employing such a method would be premature and would not reduce uncertainty; it would add to it.

Engineering analysis is very much an exercise of using "the right tool for the right job." The proportion of CFD to wind tunnel testing has steadily increased over the decades, but physical testing in the wind tunnel and at full-scale will always be important analysis and validation tools. Today, the wind tunnel remains the preferred tool in many cases: studies across ranges of flow/wind angles; specific, well-vetted applications; and areas where gaps remain in CFD capability.



SOURCE: ESA, 2013

Brisbane Baylands . 206069

Figure 4.C-1
Vegetation and Habitat Types

"Dry" Wetland Conditions
1/13/2012

"Average" Wetland Conditions
2/18/2007

"Wet" Wetland Conditions
3/8/2010

Three Month Precipitation Total
(Total includes month that aerial was dated and two preceding months)

Wetland Map	Date of Google Earth Aerial	3 Month Precipitation Total	Months of Precipitation
"Dry"	1/13/2012	3.84 inches	November 2011 to January 2012
"Average"	2/18/2007	8.16 inches	December 2006 to February 2007
"Wet"	3/8/2010	11.45 inches	January 2009 to March 2010

Monthly Rain Fall Totals

Month	Monthly Rainfall 2006-2007	Monthly Rainfall 2009-2010	Monthly Rainfall 2011-2012
October	0.33"	2.96"	1.18"
November	1.64"	0.20"	1.55"
December	3.37"	3.07"	0.13"
January	0.65"	5.97"	2.16" "Dry" Wetland Map*
February	4.14" "Average" Wetland Map*	2.70"	0.66"
March	0.27"	2.78" "Wet" Wetland Map*	4.76"
April	1.14"	2.75"	2.79"

*Shading indicates month in which wetland aerial was dated from Google Earth satellite imagery.

SOURCE: Metis Environmental Group

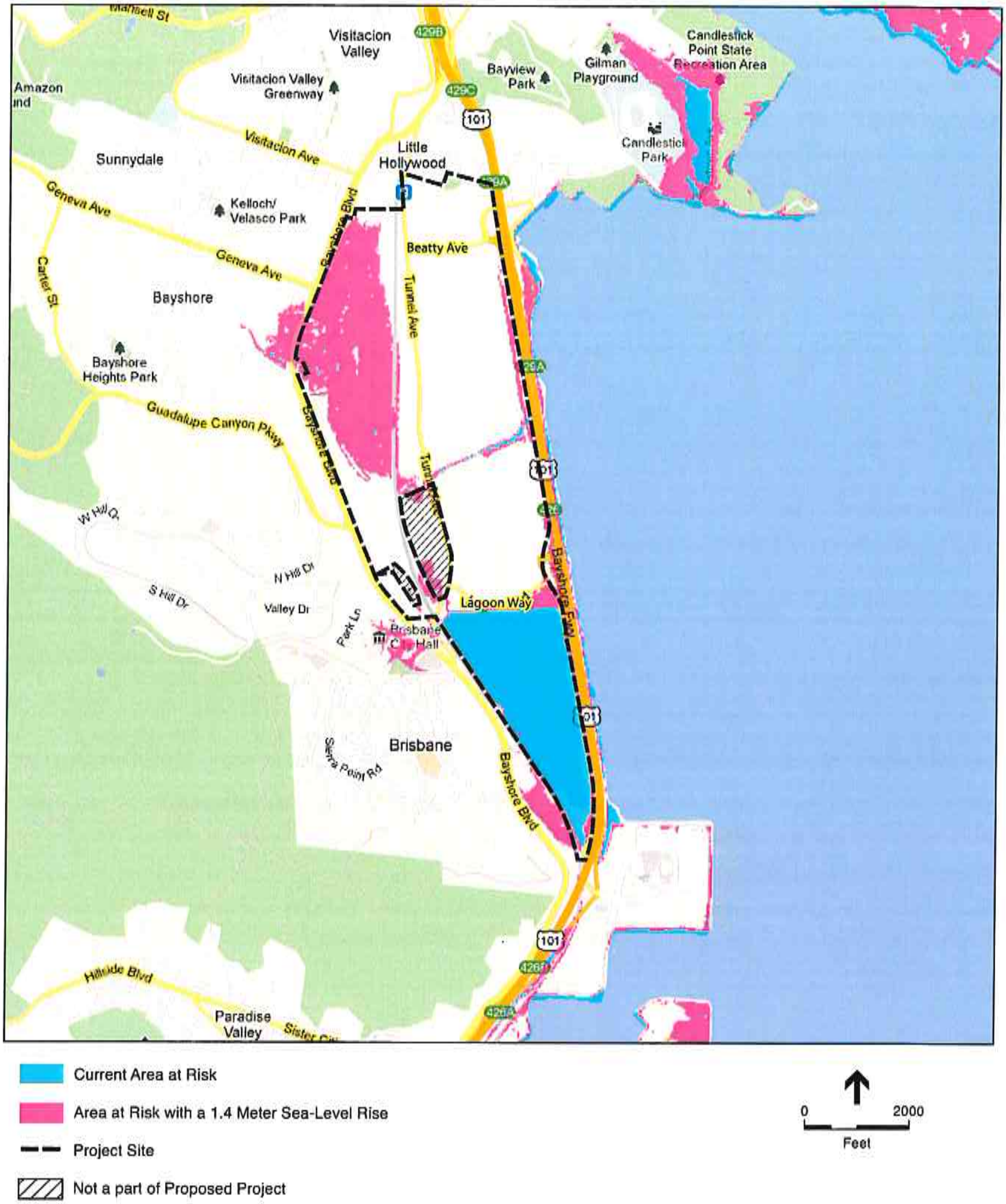
Figure 2.4-1
20-Year Wetlands Analysis

SOURCE: ESA, 2012; FEMA, 2012

Brisbane Baylands . 206069

Figure 4.H-3

100-Year Flood Zones



SOURCE: Pacific Institute, 2012

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Figure 4.H-4
Projected Sea Level Rise

(Version 3/16/17) Council Baylands Hearing Schedule

September 29, 2016: Project Overview, EIR Summary, Overview of Planning Commission Recommendation

November 17, 2016: Site Remediation, Title 27 Landfill Closure, and related policy issues

December 15, 2016: Site Remediation, Title 27 Landfill Closure, and related policy issues (continued from November 17, 2016)

January 24, 2017: Traffic, Noise, Air Quality, Greenhouse Gas (GHG) emissions, and related policy issues

February 16, 2017: Noise, Air Quality, Greenhouse Gas (GHG) emissions, and related policy issues

February 28, 2017: Water Supply, Public Services and Facilities, and related policy issues

March 16, 2017: Other Environmental Issues: Biological Resources; Cultural Resources; Geology/Soils/Seismicity; Hydrology; Recreation; Energy; and related policy issues
April 6, 2017: Economics, Development Feasibility, Municipal Cost/Revenue, and related policy issues
May 4, 2017: Land Use, Planning, Aesthetics, Housing and Population, and related policy issues
May 23, 2017: Applicant and Community Group Presentations

June-July 2017 TBD : Council deliberations