HEGGIES

REPORT 10-6757-R2

Revision 1

Frasers Broadway Site Concept Plan

Wind Environment Study

Utilising Computational Fluid Dynamics

CONFIDENTIAL

PREPARED FOR

Frasers Broadway
C/- Incoll Management Pty Ltd
Level 1, 73 Miller Street
NORTH SYDNEY NSW 2060

9 MAY 2008

HEGGIES PTY LTD
ABN 29 001 584 612

Incorporating New Environment Graeme E. Harding & Associates Eric Taylor Acoustics

Frasers Broadway Site Concept Plan

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Utilising Computational Fluid Dynamics

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DOCUMENT CONTROL

Reference	Status	Date	Prepared	Checked	Authorised
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10-6757-R2	Revision 1	9 May 2008	Dr Neihad Al-Khalidy	Dr Peter Georgiou	Dr Neihad Al-Khalidy

EXECUTIVE SUMMARY

Heggie Pty Ltd (Heggies) has been commissioned by Incoll Management Pty Ltd on behalf of Frasers Broadway to prepare an Environmental Wind Study for the Frasers Broadway Site Concept Plan (Frasers Broadway).

This study is required to assist in the preparation, lodgement and approval of a Concept Plan for the Frasers Broadway site.

The current study of the Frasers Broadway Site winds has been undertaken using a quantitative Computational Fluid Dynamics (CFD) analysis approach. Using calibration techniques developed on previous projects, the CFD methodology used by Heggies is able to yield reasonably reliable estimates of wind speed magnitude. It is particularly useful in comparing one building massing scenario (eg the existing building configuration at the site) with another (eg the proposed Concept Plan Scheme).

On the basis of the current quantitative CFD analysis, Heggies has concluded the following regarding expected wind conditions for the proposed Concept Plan Scheme for the three prevailing wind directions of interest in the Sydney Wind Climate – namely northeast (summer), south (all-year-round) and west (winter) quadrant winds.

- Northeast winds occur primarily in summer months in Sydney and are generally mild in nature. In addition, the street alignment in the vicinity of the Frasers Broadway Site does not favour augmentation of wind intensities due to channelling effects, ie “canyon” winds.
- With the proposed Concept Plan Scheme development of the Frasers Broadway Site it is predicted that there will only be a marginal change to northeast wind conditions.
- Existing westerly wind conditions at various locations along Broadway already exceed the Sydney City Council (SCC) benchmark 16 m/sec walking comfort criterion. The highest winds occur when winds channeling along Broadway combine with the effects of downwash flow from taller developments along the roadway.
- With the proposed Concept Plan Scheme development of the Frasers Broadway Site it is predicted that the magnitudes of westerly winds may increase slightly compared to those currently experienced as a result of the influence of increased building massing along the southern side of Broadway.
- For winds approaching the site from the south there will be a general reduction in wind intensity along Broadway, in particular at locations in the vicinity of the UTS tower, following development of the proposed Fraser Concept Plan Scheme.
- High wind velocities are likely to be experienced on an intermittent basis at localized ground level sites distributed throughout internal passageways within the proposed site. Higher winds at these locations are the result of complex flow combinations of channeling and funneling between gaps, flows accelerating around building corners and previously described downwash effects.
- Windbreak treatments at locations exceeding the SCC 16 m/sec walking comfort criterion will be investigated during the detailed design phase of the project. Such amelioration treatments will be refined utilizing more precise environmental wind tunnel test studies to accurately identify wind hot spots and quantify the impact of wind mitigation options. These would include judicious placement of street trees and other landscaping, the use of building set-backs of Building 2 and building treatments such as footpath awnings.

TABLE OF CONTENTS

1 INTRODUCTION

Heggie Pty Ltd (Heggies) has been commissioned by Incoll Management Pty Ltd on behalf of Frasers Broadway to prepare an Environmental Wind Study for the Frasers Broadway Site Concept Plan (Frasers Broadway).

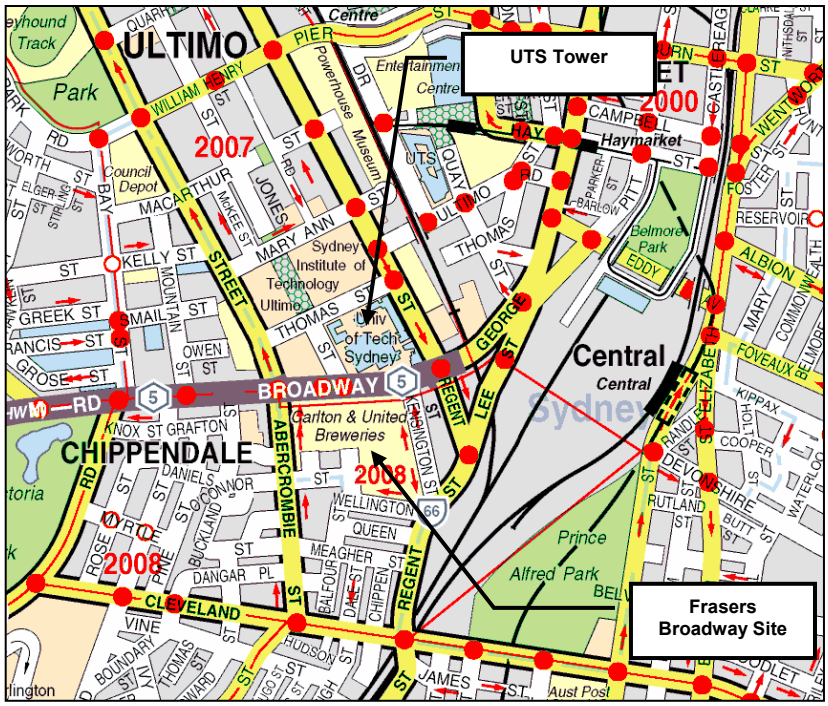
This study is required to assist in the preparation, lodgement and approval of a Concept Plan for the Frasers Broadway site.

Building details in the current application have not been resolved to the level normally required in a full Development Application. The purpose of the study is to verify the *overall viability* of the scheme in terms of Wind with more detailed assessment to follow at later planning stages.

1.1 Site Location

The site consists of several parcels of land fronting or adjacent to Broadway at Chippendale, NSW and covers an area indicated in **Figure 1**. From the northeast clockwise around to the northwest, the site is surrounded primarily by medium-rise, residential and commercial/retail buildings. To the north and northeast lies Sydney's CBD area. In the immediate vicinity is the 35-storey UTS high-rise tower located directly to the north of the taller tower proposed to be located within the northeast quadrant of the site.

Figure 1 Location Map of Frasers Broadway Site

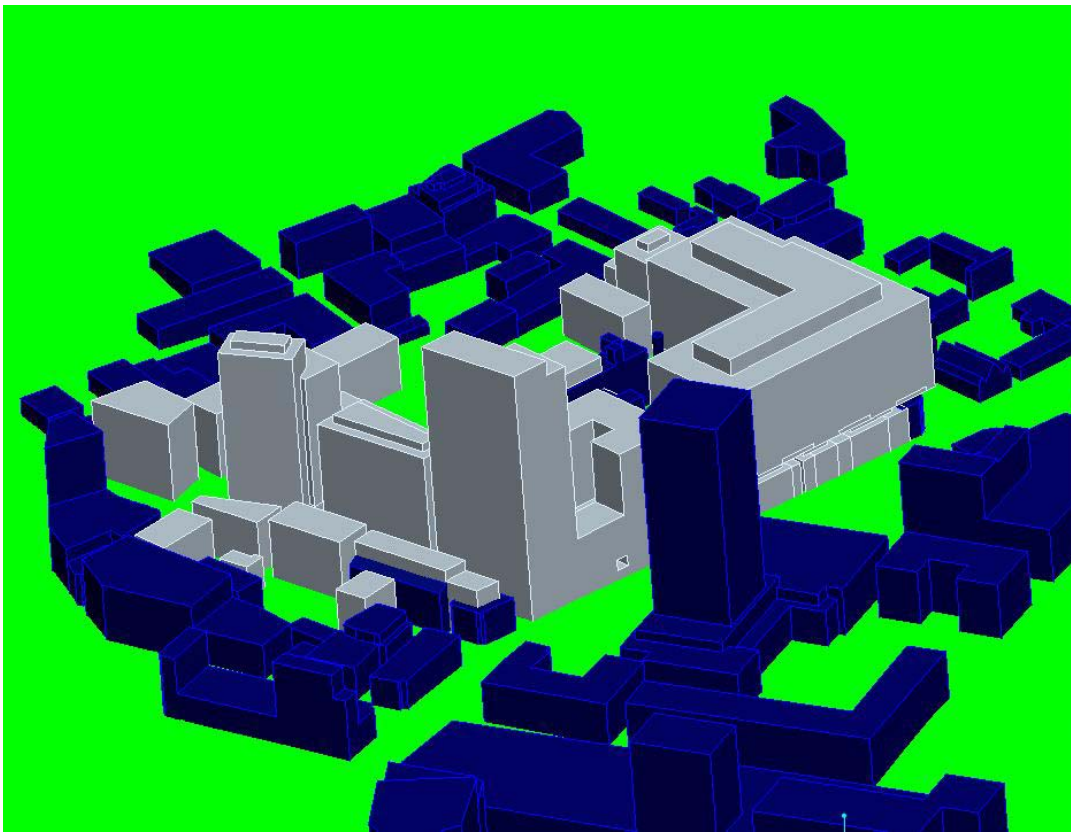


1.2 Concept Plan Scheme Layout

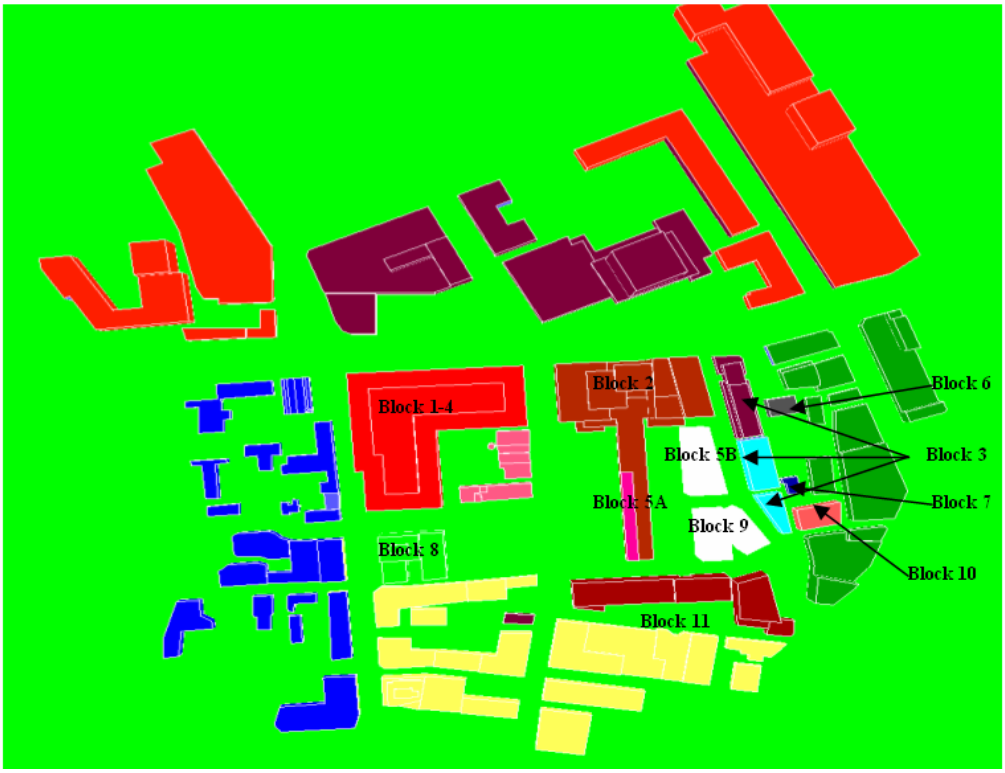
The current concept layout of the Frasers Broadway is shown in **Figure 2**. Of particular interest to this study are environmental conditions:

- Within the proposed park;
- Along all new and existing streets and lanes and publicly accessible open spaces;
- On all roof areas and setback roof terraces where recreational activities are likely.

Figure 2 Concept Plan Scheme



Proposed and Surrounding Buildings



Site Plan showing Proposed Buildings 1-11

1.3 Methodology Used in the Present Study

In the current study, the wind environment within and around the site has been assessed through the use of 3-D Computational Fluid Dynamics (CFD) model of the entire Frasers Broadway Site and surrounding streets and city blocks. The software package in the current CFD analysis is the commercially available code Fluent. The CFD model solves continuity, momentum and turbulence levels in the domain of interest (the computational domain) to predict the wind environment within and around the site.

1.4 Schedule of Commitments and Undertakings

Assessments prepared in the current report have not been resolved to the level normally required in a full Development Application. The following Schedule of Commitments and Undertakings summarises the studies required at later planning stages as design progresses.

Table 1 Frasers Site Statement of Commitments and Undertakings in relation to the Wind Environment

Planning Stage	Wind Studies
Stage1: Concept Plan	Broad Assessment of Environmental Wind Conditions throughout the site utilizing Numerical Simulation Techniques. Simplifying assumptions regarding turbulence levels needed for approximate comparison with existing building configuration.
Stage 2: Development Application	Detailed Assessment of Environmental Wind Conditions throughout the site using Wind Tunnel Tests. 6-8 weeks
Construction Certificate for individual sites	Cladding and Structural loads wind tunnel testing. 6-8 weeks
Tender and Contract documentation	Review as required
Construction Stage	Review as required
Post Construction/occupancy	Compliance reporting. Implementation of windbreak amelioration. Validation site measurements.

2 WIND ENVIRONMENT STUDY

2.1 Sydney's Wind Climate - Regional Wind Characteristics

In relation to the present study, the data of interest are mean hourly wind speeds, how these winds vary with azimuth, and their seasonal break-up into primary Sydney wind seasons. An analysis of mean hourly winds by direction and month reveals that Sydney is affected by two primary wind seasons, namely summer and winter/early spring.

Summer/Autumn: Summer/autumn winds occur mainly from the south and southeast, with a third prevailing (but generally weaker) direction from the northeast. The latter are typically mild and arise as offshore land-sea breezes. These offshore breezes do not penetrate far away from the coastline and have their most significant impact in the eastern parts of Sydney and the Harbour area.

Winter/Early Spring: These are dominated by winds from the westerly quadrants and provide the strongest winds throughout the year. Although not quite as strong, winds from the south are also common during this period.

These broad patterns are illustrated in the four wind roses shown in **Figure 3**, obtained from the Bureau of Meteorology's Sydney Airport Monitoring Station (continuous hourly monitoring). Wind roses at individual locations around Sydney would vary, primarily with distance from the coast. For example, areas located further away from the eastern seaboard and outer parts of Sydney Harbour would experience a lesser influence from prevailing northeast winds during summer.

The wind roses in **Figure 3** represent both the direction and velocity magnitude of winds at the site. Each 'petal' of the rose represents a wind direction segment corresponding to 22.5 degrees azimuth and the radial scale in bands of 3% represents the proportion of time wind will occur from that direction. For example, it can be seen winds of magnitude between 7.5 m/sec to 9.5 m/sec will occur from due west 2.0% of the time during spring. Integration around the ring equals 100% of the time.

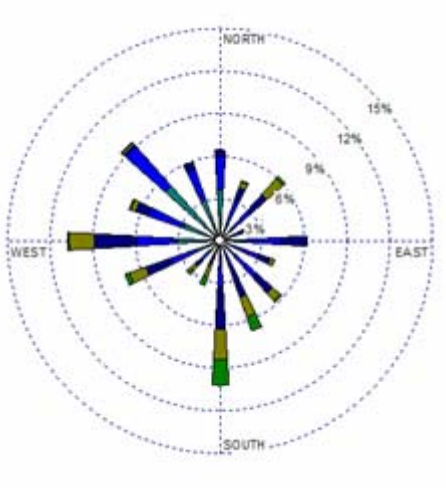
2.2 Influence of Local Surrounding Wind Environment on Wind Patterns at the Site

As previously noted, the Frasers Broadway Site is surrounded primarily by medium-rise residential and commercial/retail buildings from the northeast clockwise around to the northwest. To the north and northeast lies Sydney's CBD area which will provide considerable shielding for winds approaching the site from this direction. Accordingly, and in relation to Sydney's prevailing winds throughout the year:

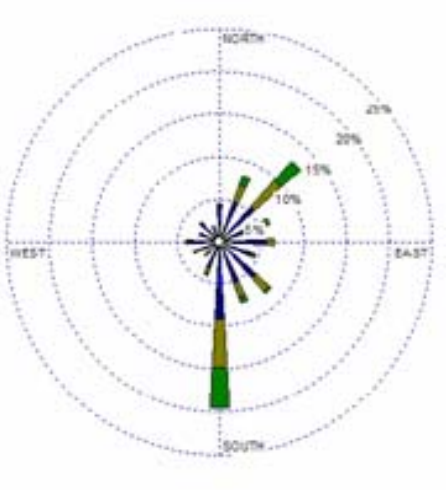
- Northeast winds (which are the prevailing winds in summer) will receive moderate sheltering from Sydney CBD buildings and areas of elevated terrain, as they approach the Frasers Broadway Site. These winds will normally provide a beneficial cooling effect to the site and are generally not expected to produce high velocity winds of most concern in the assessment of pedestrian comfort.
- Southeast (mainly summer) and particularly southerly (summer and winter) winds will receive minimal shielding as they approach the site and should be considered in the assessment of pedestrian level winds.
- Similarly, west quadrant winter winds (northwest around to the southwest) will receive minimal shielding as they approach the site and should be considered in the assessment of pedestrian level winds.

Figure 3 Representative Seasonal Wind Roses for Sydney (BOM Sydney Airport data)

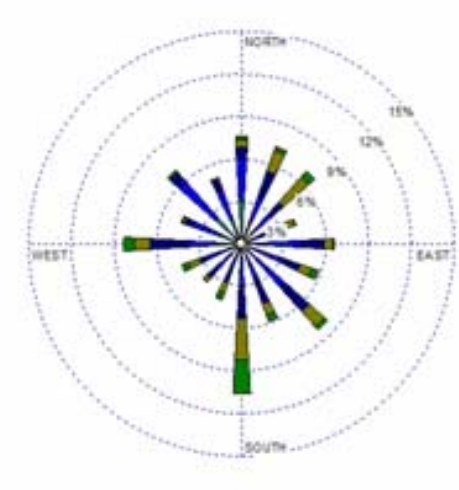
Spring



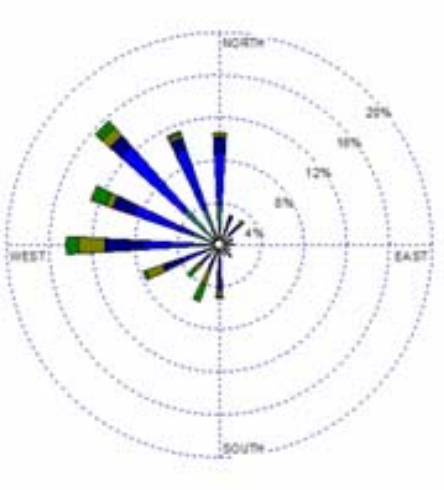
Summer

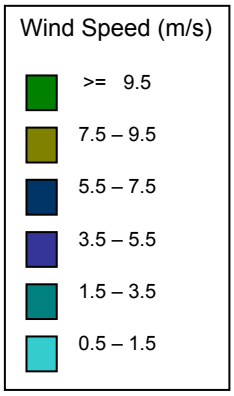


Autumn



Winter





2.3 Wind Amenity of the Concept Plan Scheme - Quantitative Summary

2.3.1 CFD Modelling of the Site and Surrounds

To assess the wind environment at the site in a quantitative manner, Heggies has carried out modeling of the site and surrounds using a Computational Fluid Dynamics (CFD) approach, specifically through the use of the FLUENT flow simulation software. 3-dimensional CFD models were constructed of the site appropriate for CFD analysis (refer **Figure 2**).

Also prepared for the current study is a CFD simulation of existing wind conditions at the site, ie as the site is configured September 2006.

The models take into account geometry of immediately surrounding developments with potential to significantly influence wind flows within the site. Further details of the CFD technique are contained in **Appendix A**.

CFD Modelling Simulations

The following CFD simulations have been carried out to assess the amenity of the site.

Existing Configuration:	Existing buildings at the site (April 2008)
Concept Plan Scheme:	Currently proposed Fraser building layout
Wind Direction 180:	Wind approaching the site from the south (180°)
Wind Direction 270:	Wind approaching the site from the west (270°)

2.3.2 Pedestrian Level Wind Acceptability Criteria

The choice of suitable criteria for evaluating the acceptability of particular ground level conditions has been the subject of research carried out in the past two decades. The acceptability criteria developed from this research and currently in use by Sydney City Council and other Councils within NSW have been summarised below in **Table 2**.

Table 2 (Sydney City Council Based) Wind Acceptability Criteria

Type of Criteria	Limiting Gust Wind Speed Occurring Once Per Year	Activity Concerned	Common Experience Examples
Safety	24 m/s	Knockdown in Isolated Areas	People blown over by gusts
	23 m/s	Knockdown in Public Access Areas	Generally impedes progress, great difficulty with balance
Comfort	16 m/s	Comfortable Walking	Difficulty experienced walking for most people, umbrellas distorted by wind, wind noise on ears unpleasant
	13 m/s	Standing, Waiting, Window Shopping	Force of wind felt on body, hair disarranged
	10 m/s	Dining in Outdoor Restaurant	Raises dust and loose paper, clothing flaps

Councils' primary objectives relating to wind impact are generally aimed at:

a. Ensuring that new developments do not create wind *"hot spots"* with annual 3-second gust winds exceeding the 23 m/s "public safety" criterion and

b. Reducing instances, where feasible and practical, where either the 16 m/sec or 23 m/sec criteria are already currently being exceeded (existing windy conditions).

For ease of interpretation, the last column of **Table 2** lists the limiting activity associated with each colour contour in the results section with some common experience examples of wind effects at each wind intensity level.

The criteria provided in **Table 2** should not be viewed as *"hard"* numbers as the limiting values were generally derived from subjective assessments of wind acceptability. Such assessments have been found to vary with the height, strength, age, etc, of the pedestrian concerned. Some relaxation of the criteria given above may be acceptable for small (low usage) areas under investigation provided the general site and high usage areas satisfy the relevant criteria.

The limiting wind speed criteria in **Table 2** are based on the maximum wind occurring (on average) once per year. Winds at all other times would be less. In particular, a location with a maximum annual gust of 10 m/sec would experience winds throughout the year of a generally very mild nature, amenable to stationary activities (seating, dining, etc).

2.3.3 Application of CFD Modelling Results to SCC Acceptability Criteria

The criteria shown in **Table 2** are for 3-second gust wind speeds.

In the case of CFD analysis, wind is simulated as a steady, time-invariant flow, being more representative of the mean wind speeds through the site. For a normally distributed process (ie Gaussian distributed) it is reasonable to assume the 3-second maximum gust will be up to 3.5 standard deviations above the mean wind speed value. Accordingly, for the turbulence levels expected at the site a conservative estimate of the likely gust wind strengths at the site would be approximately twice the magnitude of mean wind speed.

This simplifying assumption allows the colour contour CFD results provided in this report to be roughly correlated to the wind acceptability criteria of **Table 2** for the various limiting pedestrian activities.

2.3.4 CFD Modelling Results – Existing Building Configuration

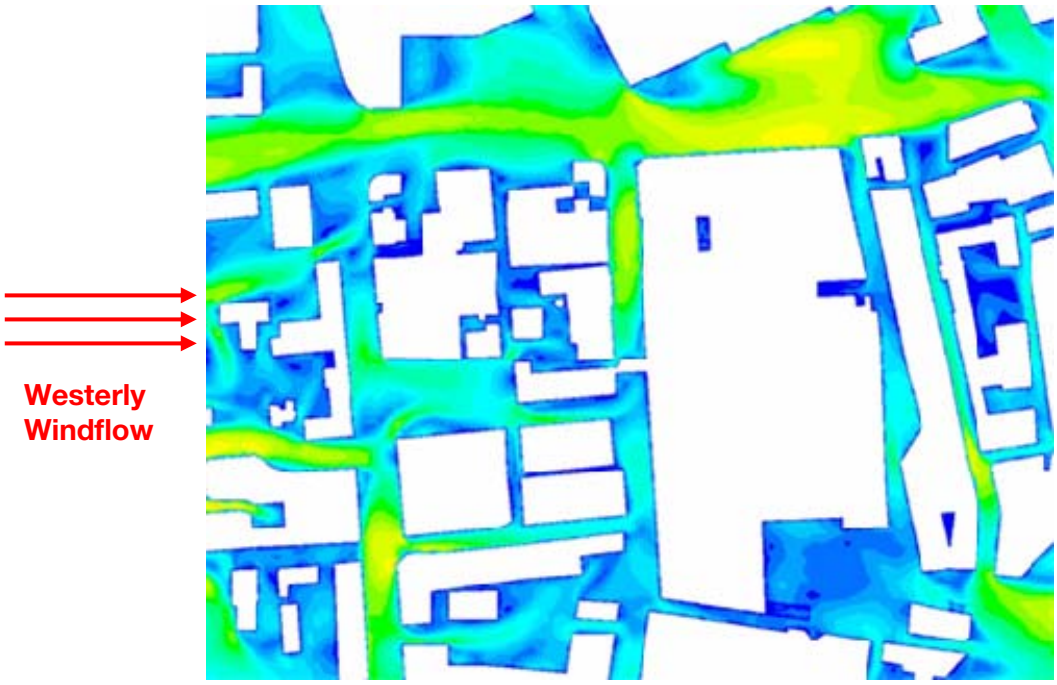
Wind velocities in the following scenarios contour diagrams can be compared approximately with the gust criteria of **Table 2** according to the colour of the streamline or contour. For example …

- green corresponds approximately to the benchmark **16 m/sec walking criterion** of **Table 2.**
- light blue corresponds approximately to the **13 m/sec stationary criterion** of **Table 2.**
- dark blue corresponds to **very still conditions** well below any criterion level of **Table 2.**

CFD Modelling Scenario: Existing Site – Westerly Winds

In order to evaluate the existing winds at the site, CFD simulations were performed for the existing site configuration. **Figure 4** shows a plan view of the Existing Site with results for winds approaching the site from the west for a 1-year return period. These results represent steady flow velocities shown in plan view through the existing site and immediately surrounding buildings close to ground level.

Figure 4 Existing Built Environment – Westerly Winds (plan view of site)



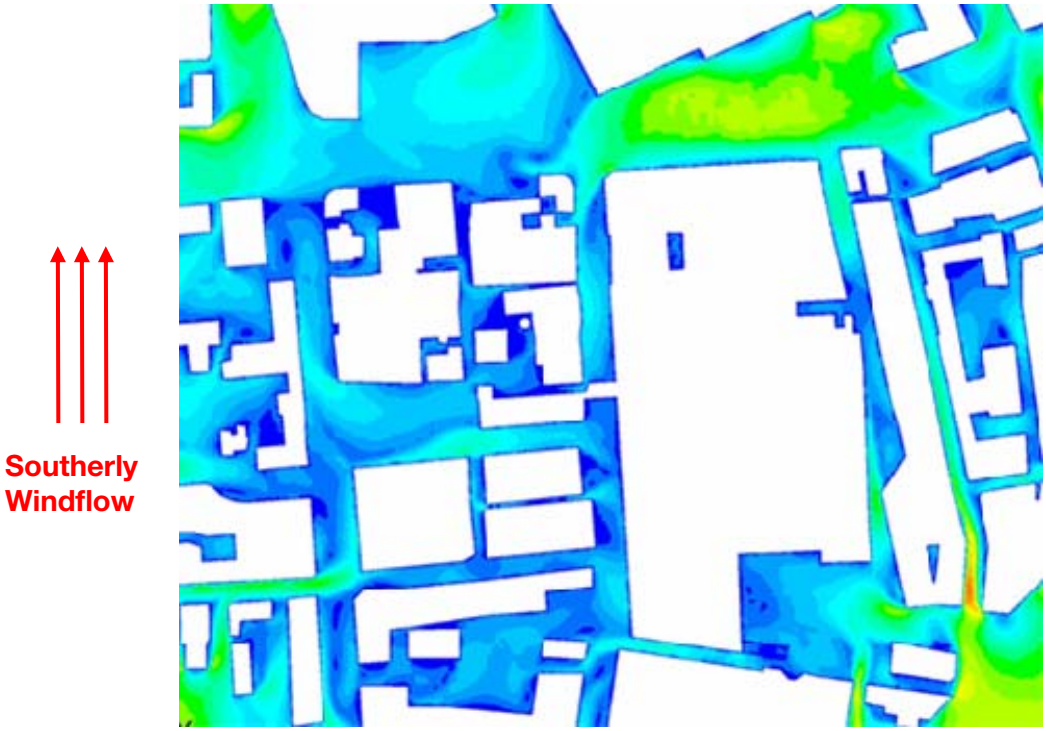
The following can be seen in relation to the existing site under westerly winds:

- Wind flow channels along Broadway aided by the massing of building developments either side of the roadway and the local topography rising towards the University of Technology Sydney (UTS) tower. In the vicinity of UTS tower horizontal channeling winds combine with vertical downwash flow captured by the UTS tower massing (located opposite the Frasers Broadway Site). This downwash effect is caused by stagnated wind flow against upper levels of the tower being drawn towards ground level and which continue to accelerate around the building.
- The CFD simulation indicates that it is likely that localized areas along Broadway in the vicinity of the UTS tower are exceeding the 16 m/sec criterion for westerly winds in the existing condition (yellow contours).
- Higher wind velocities are also present at several other localized areas throughout the existing site, including localized sections along Abercrombie Street. These winds are caused by flow funneling between gaps and around building corners.

CFD Modelling Scenario: Existing Site – Southerly Winds

Figure 5 shows results for winds approaching the site from the south for a 1-year return period. Again the results present steady flow velocities through the existing site and immediate surrounds close to ground level.

Figure 5 Existing Built Environment – Southerly Winds (plan view of site)



The following can be seen in relation to the existing Frasers Broadway Site under southerly winds:

- High wind velocities are also experienced on Broadway in the vicinity of the UTS tower in the current site configuration. These winds are caused by vertical downwash flows off the large windward southern facades of the UTS building.
- Southerly winds flow through the site from the south before reaching UTS building. These winds accelerate through Frasers Broadway Site buildings and are observed to exceed the 16m/s walking criterion in localized areas.
- Relatively low wind velocities for the southerly wind case are observed across the rest of the site.

2.3.5 CFD Modeling Results - Proposed Concept Plan Scheme

CFD Modelling Scenario: Proposed Concept Plan Scheme - Westerly Winds

Figure 6 shows the results of the CFD simulation for the currently proposed building layout for winds approaching the site from the west for a 1-year return period.

Figure 6 Frasers Concept Plan Scheme – Westerly Winds (plan view)

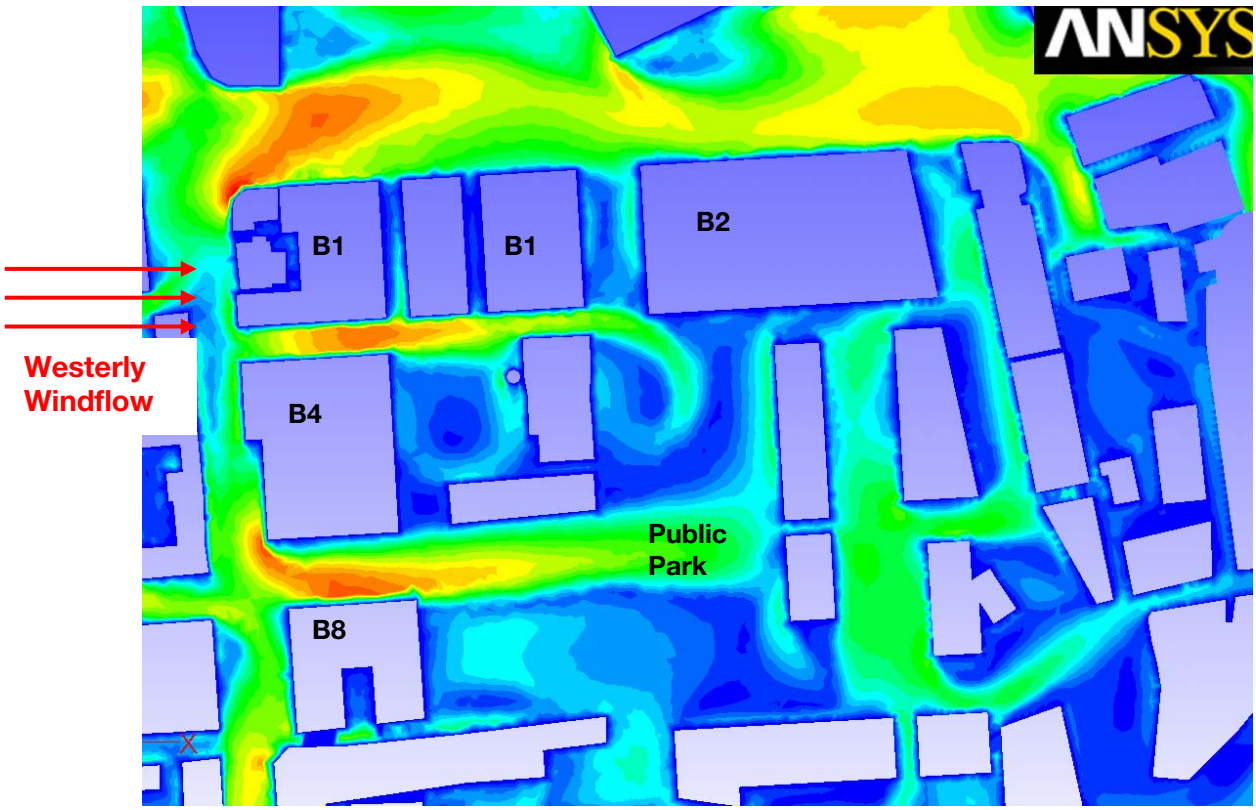
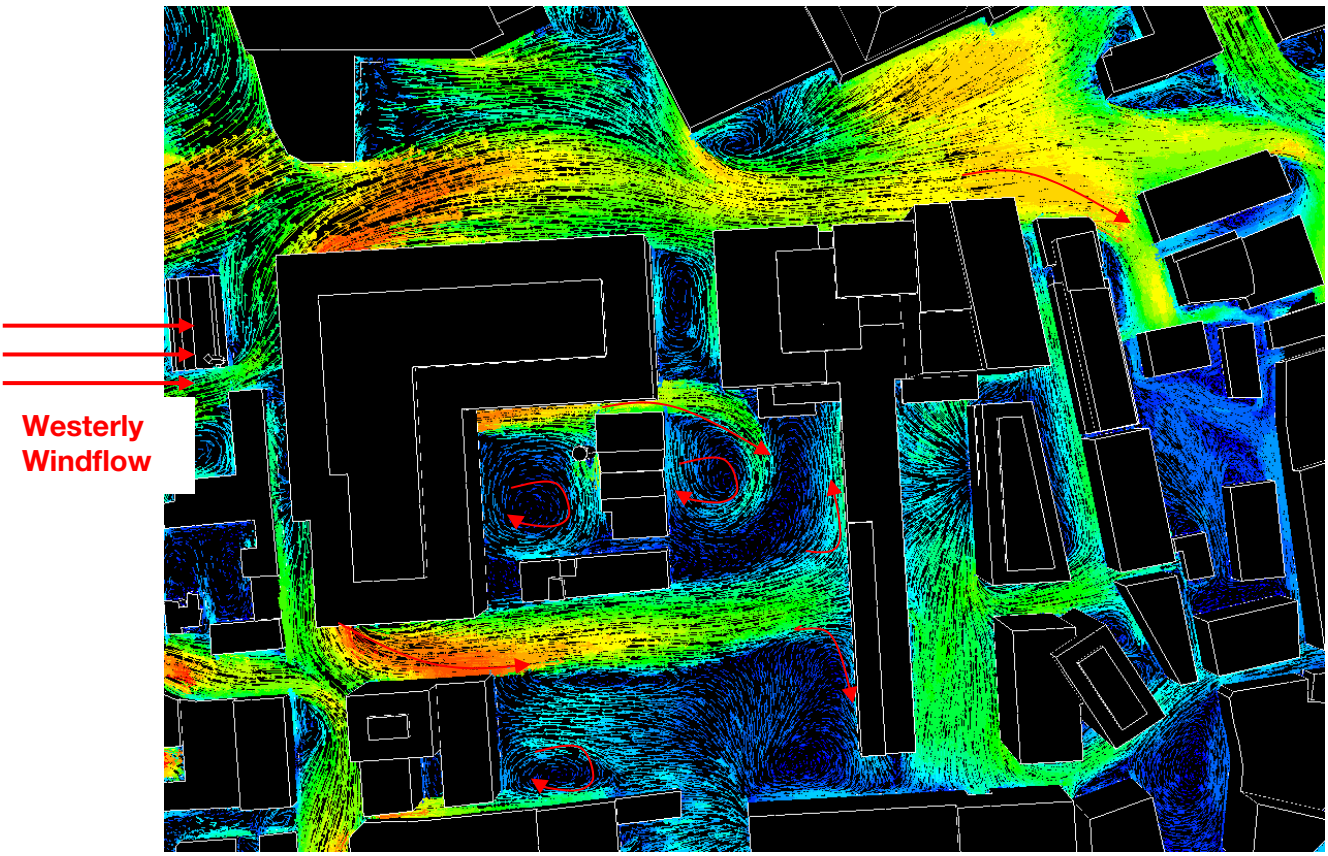


Figure 7 Frasers Concept Plan Scheme – Westerly Winds (wind velocity vectors)



Flow vectors throughout the proposed Frasers Broadway Site, including the proposed park, are illustrated in the CFD results of Figure 7 for a 1-year return period westerly wind. These results represent steady flow velocities through the site but can again be compared approximately with the gust criteria of **Table 2** according to the colour of the vector. Additional red arrows have been superimposed to aid interpretation of dominant flow patterns.

The following can be seen in relation to wind conditions expected with the proposed Concept Plan Scheme under westerly winds:

- Relatively high wind speeds are experienced along the north perimeter of the site due to channeling of westerly wind flow along Broadway. The magnitudes of these winds are slightly higher than winds experienced for the existing condition with localized wind flow patterns and the distribution of higher velocity regions changing probably as a result of the influence of increased building massing along the north Frasers Broadway Site perimeter (southern side of Broadway).
- Westerly winds also channel and accelerate along east/west aligned internal roadways, in particular those running parallel to Broadway, eg the open areas between Buildings 1 and 4 and Buildings 4 and 8 as indicated by the yellow and red contours. Confinement of the wind flow between building gaps causes winds to further accelerate through these passageway as shown in **Figure 6,** with localized winds in this region approaching and/or potentially exceeding the 16 m/sec walking criterion.

- Conditions within the proposed park remain relatively calm under westerly winds. Meandering blue streamlines in the lee of the park west perimeter building illustrate wake flow of significantly reduced velocity. Winds throughout much of the park remain below the 13 m/sec comfort criterion at ground level. Wind speeds further downstream from the proposed park regain some intensity as they flow between building gaps.

Southerly Winds

Figure 8 shows the results of the CFD simulation for the Concept Plan Scheme and winds approaching the site from the south with a 1-year return period.

Figure 8 Frasers Concept Plan Scheme – Southerly Winds (plan view)

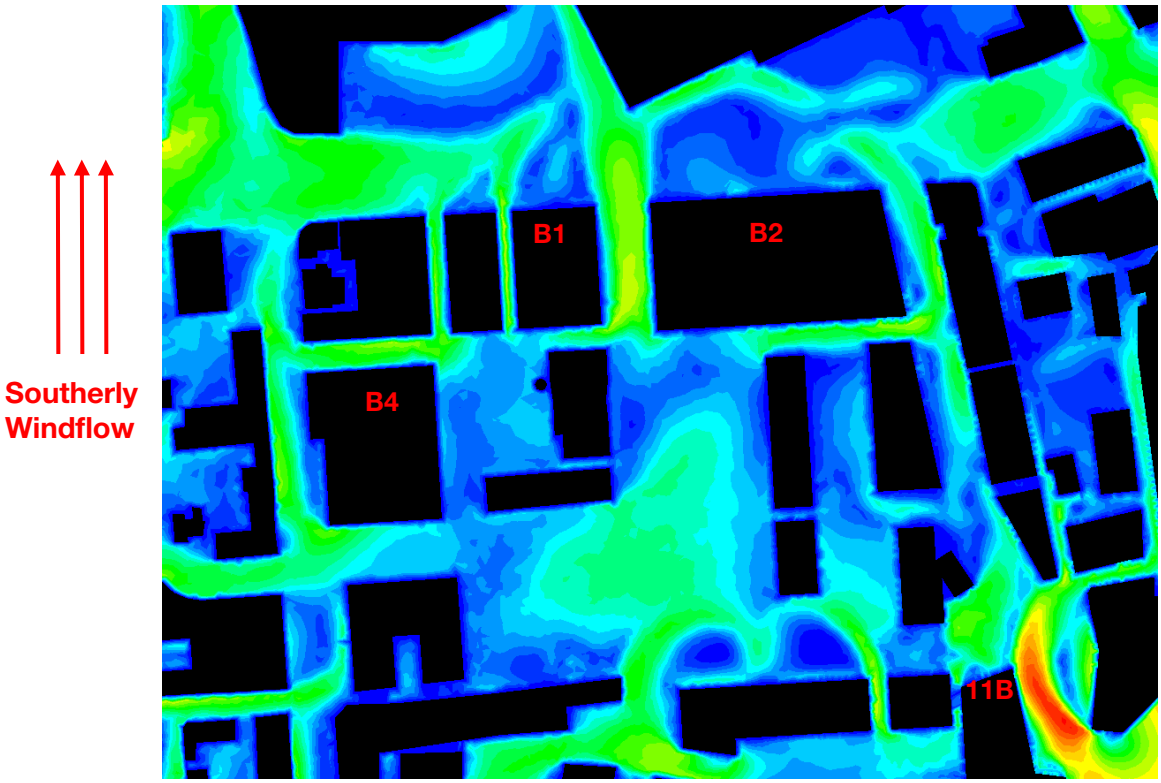
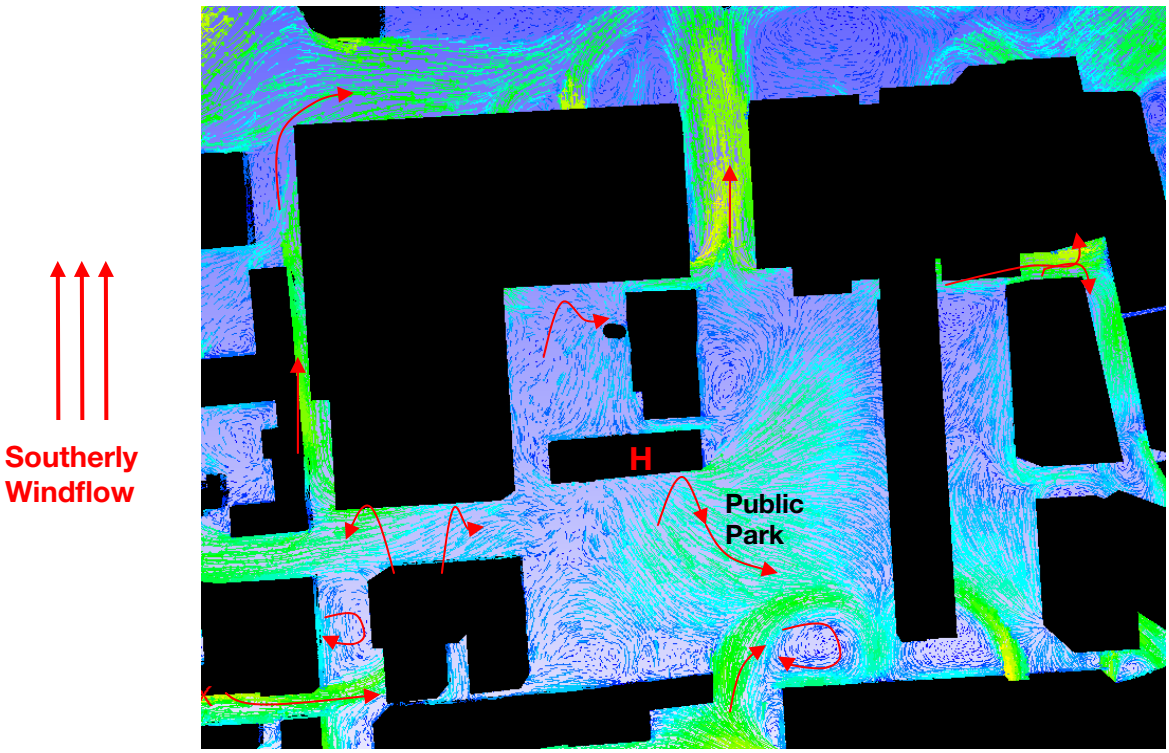


Figure 9 shows flow vectors throughout most internal area of the proposed Frasers Broadway Site, including the proposed park for a 1-year return period westerly wind. Again these results represent steady flow velocities and red arrows have been added to aid interpretation of dominant flow patterns.

Figure 9 Frasers Concept Plan Scheme – Southerly Wind (wind velocity vectors)



The following can be seen in relation to site winds for the Concept Plan Scheme under southerly wind flow:

- It is observed that the general increase in building massing across the site in fact provides some sheltering to existing high southerly wind velocities on Broadway. The general high-rise nature of tower B2 positioned directly upstream of the UTS tower provides significant shielding to southerly winds. The CFD results suggest this shielding effect significantly reduces winds contributing to the downwash flow off the UTS tower, in turn enhancing wind amenity at locations on Broadway as compared to existing conditions.
- High southerly wind velocities may also be experienced at localized ground level locations intermittently distributed throughout internal passageways across the site. Higher winds at these locations are the result of complex flow combinations of channeling and funneling between gaps, flows accelerating around building corners and previously described downwash effects.
- Southerly winds accelerate between building 11B and the existing building to the east of building 11 B (see Figure 8) and observed to exceed the walking criteria in that localised area. Street planting at the edges of the buildings is recommended to provide an acceptable wind environment in that localised area.
- The above results demonstrate high velocities in the passageway adjacent to the south perimeter of building B1. High winds at these locations occur as wind flow over the site is brought to ground level off the broad south facades of buildings B1 and B4 causing high wind velocities at ground level area in the passage.

- Similarly, southerly wind flow impacting the broad facades of the heritage building (Building H in **Figure 9**), turns toward ground and spills out into the park area. From **Figure 8** it can be seen that the wind penetrates to the public park through the passageways between the existing buildings on the south side of the proposed Fraser Broadway Site. Winds throughout the majority of the site's park remain below the 13 m/s comfort criterion.

2.3.6 CFD Modeling Results - Approved Concept Plan Scheme

It is worth mentioning that Heggies conducted a wind study on the Approved Concept Plan Scheme refer to Heggies report 10-4650 dated 24/10/2006. Results of that study are shown in Figure 10 and Figure 11 for westerly and southerly wind conditions respectively.

Figure 10 Approved Concept Plan Scheme (Plan View): West Winds – Velocity Contours

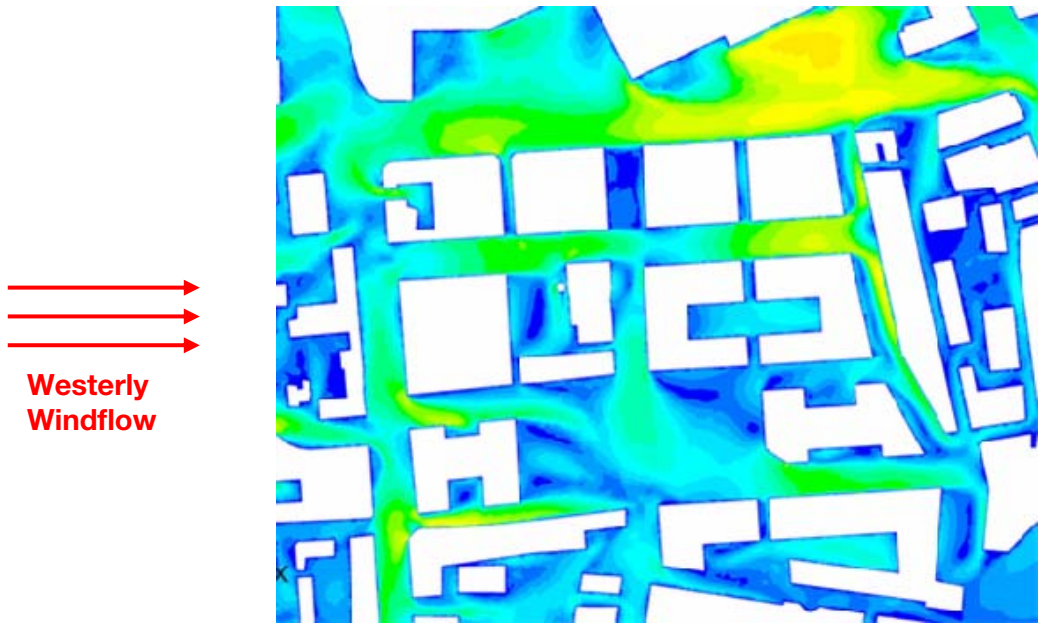
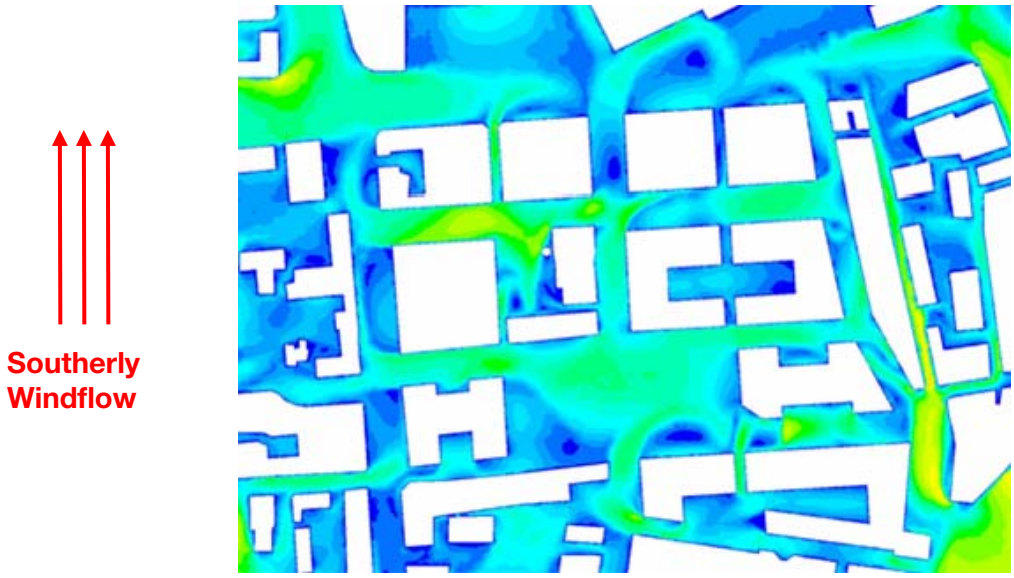


Figure 11 Approved Concept Plan Scheme - South Winds (Plan view)



In comparison to the proposed Concept Plan Scheme development of the Frasers Broadway Site (section 2.3.5) the following can be summarised:

- The magnitudes of westerly winds are slightly lower along Broadway and at the gaps along east/west aligned internal roadways.
- The magnitudes of southerly winds are slightly lower between building 11B and the existing building to the east of building 11 B. In general winds throughout much of the site remain below the 13 m/s for both options.

Wind break treatments and landscape should significantly improve the wind environments within the site. Wind break treatments can be investigated and refined using the developed CFD model for the site or during the detailed design phase using environmental wind tunnel test studies.

2.4 Summary of Wind Environment Analysis

On the basis of the current quantitative CFD analysis of CUB precinct winds, Heggies has concluded the following regarding expected prevailing wind conditions for the Proposed Concept Plan Scheme.

- Existing westerly wind conditions at various locations along Broadway already exceed the Sydney City Council (SCC) benchmark 16 m/sec walking comfort criterion. The highest winds occur as channeling of westerly winds along Broadway combines with the effects of downwash flow from taller developments along the roadway.
- With the proposed Concept Plan Scheme development of the Frasers Broadway Site it is predicted that the magnitude of westerly winds will increase slightly compared to those experienced for the existing condition as a result of the influence of increased building massing along the(southern side of Broadway.
- For winds approaching the site from the south there will be a general reduction in wind intensity along Broadway, in particular at locations in the vicinity of the UTS tower, following development of the proposed Fraser Concept Plan Scheme.

- High wind velocities are likely to be experienced on an intermittent basis at localized ground level sites distributed throughout internal passageways within the proposed site. Higher winds at these locations are the result of complex flow combinations of channeling and funneling between gaps, flows accelerating around building corners and previously described downwash effects.
- Windbreak treatments at locations exceeding the SCC 16 m/sec walking comfort criterion will be investigated during the detailed design phase of the project. Such amelioration treatments will be refined utilizing more precise environmental wind tunnel test studies to accurately identify wind hot spots and quantify the impact of wind mitigation options. These would include judicious placement of street trees and other landscaping, the use of building set-backs of Building 2 and building treatments such as footpath awnings.

NUMERICAL MODELLING ASSUMPTIONS

The CFD model used for this study was prepared using GAMBIT software and processed using FLUENT finite volume software. The package was used to solve the Navier-Stokes conservation equations for continuity and momentum in the computational domain, to predict air velocity magnitude across various areas of the development. An iterative procedure was used to solve the governing equations in the computational domain.

Geometry and Mesh

A geometrically representative 3-dimensional model of the proposed Fraser Broadway Precinct and immediate surrounds was constructed.

The geometry was created using the 3- Dimensional modelling package 'Pro-Engineer'. 3D geometry was then imported into the CFD pre-processor Gambit for geometry clean up and mesh generation. The computational domain was covered by a mesh of approximately 7 million hexahedral and tetrahedral elements and 2 million nodes with six degrees of freedom (p,u,v,w,k,ε,).

Boundary Conditions

This study is restricted to the investigation of pressure driven flows along the laneway, ie flow induced along the lane on windy occasions.

An estimate of average wind velocity was determined for the prevailing westerly wind direction using based upon Bureau of Meteorology data for Sydney Airport and guidance from the Australian Wind Code AS1170.9 (1989). A profiled velocity inlet was modelled upstream surrounding the site. At the downstream end of the model a pressure outlet boundary condition was applied.

The following additional boundary conditions were used

- Turbulence specification k-ε model (kinetic energy and dissipation rate) were calculated from empirical relationships.
- A wall function data group was used to avoid using a very fine mesh near the wall and improve turbulent flow simulation.

Validity of the Numerical Solution

Typical convergence residuals histories demonstrating valid numerical solution are shown in Figure 10.

All simulations were performed on a Windows 64 Bit Platform using multi-processors computer with 8 Gb of operational memory (RAM).

Figure 10 Residuals (Southerly Wind Conditions)