Environmental Impact Assessment

PROPOSED CROSS CITY TUNNEL

Kings Cross to Darling Harbour

VOLUME 2

Department of
Urban Affairs and Planning

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Director-General's Report
Section 115C of the
Environmental Planning and
Assessment Act 1979

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APPENDIX A

Summary of Representations to the EIS

Department of Urban Affairs and Planning
September 2001

			• Upgrade streetscape at surface level for pedestrians and cyclists and public transport. • Council is concerned that investment in roads diverts much needed resources and investment away from public transport infrastructure.
0194 a)	The Honorable Richard Jones MLC Legislative Council		• Parliament has voted overwhelmingly to mandate particulate matter filtration on the M5East vent. • It will not be acceptable for the Darling Harbour vent to be built with out filtration.
0194 b)	The Honorable Richard Jones MLC Legislative Council	O	• The study does not adequately consider health effects • The EIS is inadequate as it does not consider impacts outside the CBD. • The construction and operation of the tunnel would be environmentally damaging.
0195	The Glebe Society		• Concerned about detrimental effects that this non-filtered, concentrated air pollution will have on Glebe. • Glebe is already exposed to 100,000 vehicle movements per day. The tunnel emission stack would compound Glebe's air pollution – especially with an easterly wind. • Decision not to filter would be offset by costs tot he wider community, including individual s and the health budget. • The capital cost of filtering would be partly offset by the savings from not building an exhaust stack. • The present proposal already embodies high operating costs due to the need to pump emissions from the eastern part of the tunnel to the exhaust stack at the western end. • It would be interesting to see the outcomes of a "whole of governmental approach".
0196	RAPI Royal Australian Planning Institute		• More study is needed on increased vehicular traffic, public transport alternatives, impacts on inner suburbs and real long term costs. • Potential for significant adverse impacts such as – increased traffic, noise and air pollution in localities east and western of the CBD. • There is a risk that congestion will simply be moved to other locations in nearby suburbs as drivers seek to botain access on to the arterial road system. • Benefit-Cost Analysis and traffic projections should consider long term trends, particularly in relation to incresing fuel costs and the need to meet greenhouse gas emission targets

NO.	SUBMISSION TYPE	SUPPORT/ OBJECT	SUMMARY OF POINTS
0001	Individual		• Current address of Woollahra Council is at Edgecliff
0002	Individual		• Objects to ventilation stack • Should incorporate ventilation system within an industrial/commercial construction project in area, of similar height
0003	Individual		• Request for extension of submission period • Few neighbours in Pyrmont are aware of, or understand, proposal • EIS period was inadequate • Most EIS volumes out of stock
0004	Individual	S	• Access to and from property will be difficult with bus lanes in Druitt Street • Partial closure of Druitt Street is likely to be ignored by general traffic • Policing impossible without delays/obstructions • No benefit in Druitt Street changes • There will continue to be considerable traffic from south that passes up into Park & Druitt Streets. Small decreases in traffic likely with CCT, so congestion at intersections of these streets will worsen
0005	Individual	S	• Project should be started ASAP
0006	Individual		• Resident of Pyrmont • Concerned at potential increase in air pollution in Darling Harbour, while improving regional air quality • Further air quality monitoring needed in Pyrmont, with results available publicly • Vehicle exhaust is potential carcinogen • Health impacts of air pollution • Low area surrounded by high buildings is least appropriate for emission stack • Why is air being blown from Kings Cross back to Darling Harbour for release

0007	SCEGGS Darlinghurst		• Concerned about several issues that could be disruptive during & after construction phase • Particularly concerned at impact of construction noise on boarding house • EIS noise modelling predicts high readings there • Excessive noise also impacts classes & examinations • To manage impacts, request notification of when this work will occur • Impact of road closures and disrupted bus services on children arriving & departing from school • Require further information about increase in Bourke Street traffic • Concerned about increase in level of prostitution in area immediately surrounding school
0008	Tonallia Pty Ltd		• Own hotel & vacant land on Sir John Young Crescent • Concerned at impact of construction vibration • Parameters should be set as to what vibration levels can be withstood by historic building • Monitor construction vibration at property boundary continuously • Independent geotechnical engineer should set parameters on water table movements & review and approve construction methods to maintain water table • Staging of construction needed to ensure pedestrian access to Sir John Young Crescent is maintained • Will construct vacant block, so construction access will be needed • Night construction work would have severe impact, and should not be permitted within 60 metres of hotel • Dilapidation reports are inadequate – stronger onus needs to be placed on contractor to protect surrounding buildings
0009	Individual		• Design exhaust stack as a monument • Invite design tenders, and run competition • Stack should be based on Olympic Torch • Goodwill would be created by design based on torch • Provide advertising space to help pay for construction • Make sure traffic is not distracted by it
0010	Individual		• Objects to unfiltered emission stack, based on air quality concerns & health of residents • Tunnel should not increase air pollution, given that there are viable options to improve it • One month of air monitoring does not provide conclusive results • RTA should use latest technology to maintain air quality • Vehicle exhaust is potential carcinogen • Low area surrounded by high buildings is ineffective in distributing emissions • More cost effective to have two filtered stacks at both ends of tunnel

0011	Individual		• Cumulative effect of unfiltered emission stack • Indifference shown to local people • No conclusive air quality data made available for Ultimo • Unfiltered emissions will be released at tunnel's lowest point • Area already suffers from heavy pollution • Filtration needed • Long term impact on RTA
0012	Individual		• Ultimo resident, very concerned at proposed unfiltered emission stack • Ultimo residents are to bear the full brunt of pollution • Two filtered stacks needed
0013	Individual		• Levy on leaded petrol, to provide funds to protect environment from effects of leaded petrol • CCT offers perfect opportunity for Govt to use this money • Filtration units needed • Dismayed that health of constituents has been disregarded • Evidence proves that fumed will be carcinogenic
0014	Individual		• Concerned at unfiltered emission stack • Why wasn't air quality monitoring undertaken in Pyrmont/Ultimo area • Health impact of fumes • State & Local Govt have stated plan to bring more people to live in city – will this be achieved with issue of health problems
0015	Individual		• Health impact of decreased air quality • Questions accuracy of results of tables in Chapter 6, EIS on stack emissions, as data was only gathered over a one to two month period • Original two stack proposal should be adopted • ESP filter adds minimal cost of $5-10 million in a $400 million project • Impact on air conditioning units • Currently, traffic congestion during morning peak on Allen Street Pyrmont & Pyrmont Bridge Road. This will worsen, as mentioned in EIS
0016	Individual		• Resident of Ultimo • Too much emphasis on private car use • Current awareness of global pollution • Light rail & monorail have no emissions

			• Stack proposal should be modernised • Health impact of fumes & carcinogens • Stack should be filtered • Drop in business & property values • Unfiltered stack will cause public outcry • Gov's duty of care
0017	Individual		• level walkway needed over Park Street, so that it is possible to walk length of Hyde Park
0018	Individual		• Inadequate submission period • To compound problem, six of the seven EIS volumes have been unavailable due to large demand • Project being unnecessarily rushed through during Olympic period • Request extension
0019	Leichhardt Council		• Inadequate submission period • Request for extension
0020	Transrid		• No right/.interest in land affecting proposal, son no comment/objection
0021	Individual		• Unwise to use money on CCT, which deals with only small part of Sydney's traffic problems • Patronage will not be high as motorists prefer an above ground route for short journeys
0022	New South Wales Crime Commission		• Located on corner of Kent & Druitt Street, with several authorised parking spaces for police cars etc in Druitt Street • Very important for public safety that vehicles can be parked as close as possible to building entrance • Concerned at proposal for an east-bound bus lane on Druitt Street, adjacent to parking area • How are authorised vehicles going to access parking area without crossing lanes carrying oncoming traffic
0023	Individual	S	• Change of address notification

0024	Asahi National Broadcasting		• Consider improvements to Cleveland Street as part of proposal. These could include: • Alternate routes for trucks • On street parking to increase distance between homes/pedestrians and cars • Encourage cars travelling east-west across city to use CCT, or Cleveland Street will be used for toll avoidance • Improve traffic conditions and residential amenity on Cleveland Street
0025	Individual		• Not enough consideration given to increased traffic on New South Head Road • Traffic noise in Rushcutters Bay Park • Low levels of traffic noise can compromise a park • Park should not exist as a "green barrier" to reduce traffic noise: should exist as a quiet haven itself • RTA should submit a formal plan for noise reduction on New South Head Road boundary of Rushcutters Bay Park, possibly in form of noise barrier disguised by plantings
0026	Individual		• Access for residents of Woolloomooloo, East Sydney and Darlinghurst to Western Distributor should not be made more difficult than it is now • Sick of changes to local area in order to boost patronage of privately operated roads • RTA should provide access for all, not just outer suburban residents and tourists
0027	A.I. Topper & Company Pty Ltd		• Property garage access is from Druitt Street • Require 24 hour access to garage, with heavy entry/exit during working hours • Concerned at impact of CCT on access and building, as this portion of Druitt Street seems to be a virtual bus terminal
0028	Individual		• Updated proposal for CCT is considerable improvement on original design • Concerned about single ventilation stack • Treatment of fumes needed
0029	Individual		• Diagram enclosed showing extraction of pollution from fumes using a water pump system
0030	The Great Synagogue, Sydney		• Objects to toll in both directions • Cumulative effect of tolls in CBD • Public amenities should be paid for from public funds • Upgrading of Boomerang Place-Yurong Parkway to a busy, noisy thoroughfare to &from Sir John Young Crescent. This is in direct contravention of the Lord Mayor's undertaking made when Cook & Phillip Park was constructed as a quiet parkway

0031	Individual	S	• Tunnels are unobtrusive, visually clean, important bypasses - more should be developed • Potential for a link from M4 Concord to Haberfield
0032	Individual		• No entrance/exit from CCT in vicinity of unit (Cnr Forbes & Cathedral Streets). To access tunnel, would need to drive to Rushcutters Bay & make U-turn • Link should be made from Bourke Street on ramp to eastern suburbs on to the CCT westbound. Perhaps via use of a U-turn style bay, and a similar exit utilising William Street exit
0033	East Sydney Neighbourhood Association (ESNA)		• Recognises need to improve east-west traffic flow through CBD & William Street • EIS identified several negative impacts on local area during construction. Traffic and consequential hazards & pollution in residential streets are additional impacts. Concern that these impacts will remain after construction • Serious negative impacts on amenity include: • Additional noise pollution on Crown & Darlinghurst Roads; • Additional east-west traffic to avoid toll or gain access to tunnel system (both CCT and ED); • Street prostitution driven off gentrified William Street into residential streets • ESNA strongly rejects notion that any negative impact can be justified on the basis that it only partly cancels out LAIP from ED construction. No gains from ED must be lost • ESNA will never support any scheme which would cause an increase in street prostitution/through traffic in East Sydney area • ESNA will support construction of CCT if Minister of DUAP makes his approval conditional on establishment of a LAIP for East Sydney, which would be designed to rectify concerns • CCT and upgrading of William Street is seen as an opportunity to remove street prostitution from neighbourhood • Concern that street prostitution is moving in a circuit, from SCEGGS Girls Grammar, down Bourke Street and across William Street to two brothels on Woolloomooloo side of Bourke street • Request traffic measures to stop the circuit. Measures to address this would also address rat run that has developed down Bourke Street to avoid ED toll • Single most effective measure would be to close Bourke Street on East Sydney side of William Street
0034	Australand	S	• More traffic travels between eastern suburbs and CBD than eastern suburbs and western suburbs, therefore project benefits would be improved if additional access and egress ramps were added to increase connectivity to eastern suburbs • Map enclosed

0035	AGL Gas Networks		• All works associated with natural gas mains are to managed and carried out by Agility/sub contractors appointed by Agility • RTA must pay all costs for relocating gas mains • Ongoing consultation required with RTA at all stages of project • All gas mains remain asset of AGL • RTA liable for any loss/damage to mains • No detailed costing/commercial proposal carried out as yet • Details of pipeline control, emergency response, design requirements, construction phase requirements and abandoned mains enclosed
0036	Individual		• Waste gas exit can create pollution • Suggest use of high-tension concentrated water to eliminate the waste gas exhausted • Diagram enclosed
0037	Individual		• Objects to unfiltered emission stack • Darling Harbour already suffers pollution, blocked from dispersal by high rise buildings • Why is there no filtered stack at other end of tunnel, or several along route? • Inadequate modelling • Cannot accurately predict movement & consequences of toxic plume • Wind tunnel modelling is not accurate for predicting performance of a non buoyant plume over Cockle Bay
0038	Individual		• Objects to single unfiltered emission stack at Darling Harbour • How can there be benefits in the city without corresponding diminution of Darling Harbour air quality • If good management of pollutants involves dispersal, how can this be managed with one stack • Do we already know existing pollution situation in the area • How often will cumulative effects of stack pose significant health risk to residents & workers • It should be highly desirable to monitor prevailing conditions before project completion • Impossible to replicate in laboratory the atmospheric conditions that prevail in Darling Harbour • Given recent criticism by CSIRO of RTA pollution projections for the M5 East, why is RTA persisting in using same, discredited methodology? • Duty of Govt to safeguard public health • Isn't Darling Harbour/Pyrmont/Ultimo area going to become most populous residential area in Australia? • CCT is only a good idea if it doesn't come at the expense of adversely affecting health of some 20,000 to 30,000 people

0039	Individual	O	• Resident of Pyrmont, health and lifestyle will be grossly affected by proposed unfiltered emission stack • Impact on children • Honest & suitable alternative must be found
0040	Individual		• Strongly object to unfiltered emission stack in proposed location • Potential damaging impact on population health in Darling Harbour, Pyrmont & Ultimo • Potential increment of air pollution localised in these areas • Potential for driving tourists away
0041	Individual		• Resident of Pyrmont, deeply concerned about local air pollution • Inadequate air quality monitoring, so accurate emission predictions are impossible • Darling Harbour is a hollow surrounded by tall buildings. Must be better solution so that fumes can be dispersed • Request extension of submission period
0042	Individual		• Objects to unfiltered emission stack • Darling Harbour already suffers pollution, blocked from dispersal by high rise buildings • Large groups of children frequent the area • Duty of care • Why is there no filtered stack at other end of tunnel, or several along route? • Electrostatic inhibiting equipment could be used to remove particles from exhaust gas. This equipment should be included in estimates
0043	Individual		• Residents of Ultimo/Darling Harbour will be enveloped in a concentrated, toxic fallout from proposed stack • Car fumes do kill you • In past, seamen died from asbestos, are you going to give cancer to our children without measuring cost of filtration • Shipping companies were heavily penalised for small accidental pollution, can Govt afford to pay enormous cost of deliberate pollution
0044	St Vincent's Clinic	S	• CCT will alleviate transfer of traffic from east-north-south to the west and vice versa • There should be adequate space for existing traffic exiting tunnel where it is held up at traffic lights. Particularly for traffic exiting tunnel to Harbour Bridge, the south, Chinatown or western side of Sydney via Harbour/Bathurst Street • Existing tunnel should be continued as a main tunnel right up to Victoria Street beyond White Bay. However, current entrance/exit points should remain. This would add to cost, but would attract high volumes of usage • Electronic tolls needed

0045	Individual		• Process of EIS and community consultation is flawed • Vehemently opposed to unfiltered emission stack • Will RTA guarantee that indoor of home will not be compromised as result of stack? • Once built, if pollution levels exceed predicted goals, what will happen? Will tunnel close until pollution levels fall? • Will RTA guarantee that property value will not drop – otherwise who will? • Will RTA guarantee that noise from fans used in stack, combined with tunnel noise, will not exceed EPA levels in bedroom? If not who will • If health deteriorates as result of cumulative effects of particulate & gas emissions as a result of stack, will RTA pay the bill? • In light of CSIRO report on M5 East, can results be trusted
0046	Individual	S	• Should rethink proposed one lane each way on Park Street, as flow from multi-laned William Street will jam at start of Park Street
0047	Individual		• Proposed narrowing of Park Street across Hyde Park is serious flaw • Drives this road every day, already suffers heavy traffic • Strongly suggest proposed footpath widening along this block be abandoned, exiting lanes should be maintained for traffic
0048	Individual		• Objects to unfiltered emission stack • Aim of improving regional air quality is misleading because construction will concentrate pollution in Darling Harbour • As a Pyrmont resident, concerned about aggregation of existing pollution because stack is located in low lying area, and fumes from motor vehicles are potential carcinogens • Why is it necessary to blow pollution all the way to Kings Cross and then back to Darling Harbour? • Why are there no plans for in-tunnel filtration/ alternate cleaning options? • Population health study should be conducted in area prior to construction
0049	Individual	S	• CCT will benefit city in many ways & improve journey times for motor vehicles • Difficult to obtain information from meetings and EIS without index • Traffic flow onto Anzac bridge already exceeds capacity at peak times , a situation which can only worsen with CCT • EIS discussed closing access to Ultimo/Pyrmont via Allen & William Henry Streets from western distributor, however no map was included to clarify this • At community meeting, it seemed that it was extension of King street viaduct that would prevent access from city to Harris Street, but details were not clear • Any restriction of entry to Ultimo/Pyrmont throws more strain upon one access point from western distributor, ie at

			fish markets, or the area pinpointed in EIS as having greatest increase in traffic • No mention of City West Development in EIS, which will be felt along length of Harris Street • Unfiltered stack makes nonsense of claim for reducing air pollution in Sydney overall • Pollution is massive and concentrated at one point • Site selected for stack is lowest out of any option s • Background levels of pollution in Ultimo/Pyrmont were not monitored • Consultation period should be extended • Concentrated, unfiltered emissions from several kilometres of intensively used road tunnels cannot be simply dismissed as posing no health hazard to people in immediate vicinity • Monitoring is very least RTA owes those affected. Air quality should be assessed at key times during the day & reports made public • Traffic flow in Ultimo/Pyrmont projections is acknowledged to be "skeletal". Report shows no awareness that traffic within the area will increase exponentially as City West Development is completed
0050	Individual		• Concerned at unfiltered emission stack • Resident of Pyrmont, concerned about air quality • Why is there only one stack proposed, and not a second stack at Kings Cross? • Has a toll fee been considered to help offset cost of filtered stack? • More practical to locate any stack/s in elevated area to allow better dispersion of fumes • Compensation from ill health attributed to vehicle exhaust?
0051	Individual		• Pollution filtering needed for CCT and other Sydney road tunnels • Proposed CCT design may not be suitable for latest within tunnel filtering technology. EIS mentions provision for chamber construction at a later stage, however design should be rectified so that filtering can occur immediately • Moving pollution does not solve pollution – filtering needed • Rationale that "car exhaust is improving" is weak - filtering needed • Proposed travel times are dubious – more roads create more traffic • Is RTA conducting assessment of its own proposal? Lack of opportunity for scrutiny, balance and change • Changes needed now are: • Status quo not to filter tunnels • Readiness to utilise best-practice technology • Funds should be directed to adequate cross regional public transport for Sydney & land use planning to reduce need for cars • Proposed tunnel would add too much complexity to roads on western side of CBD

			• High air pollution in Sydney and global warming • Not good enough to push through road tunnel projects whilst ignoring generated air pollution
0052	Individual	S	• Bondi residents have long suffered difficulties travelling west across city • CCT best news in years • Get on with it
0053	Individual	S	• Project should be completed ASAP • Confident modern science & engineering can be used to resolve environmental issues • RTA should be complimented on Eastern Distributor, which has transformed north-south access to the Eastern Suburbs • CCT should transform traffic movement from east to west
0054	Individual		• Protests against installation of unfiltered emission stack • Family history of asthma, increased air pollution will affect health • Potential carcinogens in vehicle exhaust • One month of air quality monitoring was inadequate, with no readings for Ultimo/Pyrmont, who will be affected by stack • Air quality should be monitored for at least a year in all affected areas, with results made publicly available • Low lying area surrounded by buildings is least appropriate for distributing emissions • Filtered stacks should be built at both ends of Darling Harbour & Kings Cross • Concerned that annual air quality results are being averaged throughout Sydney, not reflecting situation that air quality goals are exceeded around stack area • RTA has not made it clear if there will be continuos air monitoring at stack site, with results publicly available
0055	Telstra		• Main impacts on Telstra OnAir's facilities will be: • Requirement to relocate existing base station facilities at Darling Harbour • Requirement to provide mobile communication services within the tunnel, both during construction & once tunnel is operational • Plans showing antenna location enclosed • Offer of additional support to RTA on issues relating to voice/data communications

0056	Individual	S	• Project will increase traffic capacity of Anzac Bridge, City West Link & Victoria Road • Noise abatement measures needed • Small precinct south of Victoria Road between Quirk and Maney Streets, Rozelle, now suffers extreme noise from Anzac Bridge, which will only worsen • Should be considered as part of environmental impact
0057	City East Enhancement & Creation of Sydney Boulevard Residents Group	S	• Tunnel is critical to maintaining efficient traffic flow across east-west axis of CBD • Excellent opportunity to revitalise William Street area in regard to leisure, pedestrian, tourist & commercial activities • However, current design does very little to encourage "people" activities • Tremendous opportunity is missed to create a grand pedestrian boulevard. Scheme simply builds up another underground traffic artery. Existing surface traffic not sufficiently reduced for pedestrian activities to dominate • Traffic reductions should be at least 50% if 4 lanes of tunnel are being provided • Purpose of design should be to encourage people functions on surface, rather than maximise vehicular traffic • Design has inadequate potential to create these people functions in vicinity of William Street • Express buses should be put underground • Stronger city access should be created for Eastern suburbs traffic • Inadequate visual focus created atop William Street • Existing ugly black tunnel portal should be scrapped, ugly western hole should be filled with terrace gardens or grand fountain • Commercial space should be provided in front of buildings • Project should be driven by aesthetic & urban design considerations, not just traffic engineering concerns
0058	Uniting Church in Australia		• Church is undergoing renewal of community involvement, having previously been ethnic based church with members from outside the area • Current users are mostly local • This provides evidence that there is substantial population growth in area, along with increasing local community interest • Therefore this is not the time to allow increased pollution in area • Filtering is essential to enable revitalised community to lead normal life
0059	Bright & Duggan		• Strata manager for property in Pyrmont • Deeply concerned over unfiltered emission stack • Attention should be drawn to recent CSIRO report, where modelling used by RTA on M5's unfiltered emission stack was seen to be so unreliable it caused public outcry • Concerned at social equity rationale behind proposal to remove pollutants from CBD, only to release them at

			Darling Harbour, which has high population and visitation • Pollutants should be dispersed at other points along proposed route , rather than being concentrated in geographic depression where so many people live & work • Doubt expressed by Executive Committee that temperature inversion conditions, such as extreme rises in air-borne pollutants in & around Darling Harbour area, can be simulated and properly measured in a laboratory wind tunnel
0060	Individual		• Protests against installation of unfiltered emission stack • Family history of asthma, increased air pollution will affect health • Potential carcinogens in vehicle exhaust • One month of air quality monitoring was inadequate, with no readings for Ultimo/Pyrmont, who will be affected by stack • Air quality should be monitored for at least a year in all affected areas, with results made publicly available • Low lying area surrounded by buildings is least appropriate for distributing emissions • Filtered stacks should be built at both ends of Darling Harbour & Kings Cross • Concerned that annual air quality results are being averaged throughout Sydney, not reflecting situation that air quality goals are exceeded around stack area • RTA has not made it clear if there will be continuos air monitoring at stack site, with results publicly available
0061	Individual		• Toll is poor value in terms of distance and time savings • Tunnel should not be so long - single operator will have a long term stranglehold over city traffic in all directions • Govt should disclose any requirements of agreement with tunnel company that affect use of existing main roads • Govt should provide assurance that road users whose journeys do not use tunnel are not disadvantaged by plan • Govt should conduct proper research into effect on public transport users, & improve these services • ICAC should conduct public review of contract, whether it is in public interest
0071	McCormacks Strata Management	O	• Vehemently oppose construction of unfiltered emission stack at Darling Harbour • Own nearest apartment block to stack • Potential carcinogens will in long term cause asthma in children and possible cancer in adults • Reserve right to claim unlimited damages when health suffers • Building of stack in one of most densely populated areas of Sydney, adjacent to Tumbalong Park, is illogical • Owners should not have to bear expense of additional cleaning of facade due to emissions • Many Pyrmont residents do not drive cars, CCT is therefore an unfair non-user pay system • Stack must have latest filters to protect against carcinogens

0072	Travellers Auto Barn		• Travellers Auto Barn will suffer the greatest impact of the CCT • Two of five main construction activities occur on their doorstep, namely cut & cover tunnel and William Street modifications • Access of vehicles to showroom will be severely restricted during construction • Require either guaranteed access or detailed prior knowledge of restricted access & limits restriction periods, and/or financial compensation • A specific liaison officer should be appointed to deal with concerns of community & business that directly front cut & cover construction zone • Preliminary noise, vibration & dust testing should occur in every business likely to be affected by cut & cover construction phase • Monitoring should continue through construction • Must be able to maintain a conversation in showroom at all times, or financial compensation is required • Request easy, unobstructed pedestrian access to business • Appropriate signage should be provided by RTA during construction phase • Closure of Bourke Street is to be included in consideration of economic impact of construction on business • Cumulative impact of recent construction activity should be considered • EIS coverage of business disruption is only three lines thick. More testing required to set a reliable economic value on these impacts • Detailed economic assessment in accordance with DUAP's draft EIS manual guideline is required • Where direct monetary valuation of impacts is impossible, comparison with quantified costs and benefits is needed • EIS is deficient to the point of negligence in consideration of economic impact of construction activities • During operation, southern side of William Street should not be planted with trees. Trees could cause problems with awnings, obscure traffic and increase the risk of accidents for vehicles accessing showroom • Widened footpaths must incorporate the driveways that currently exist • Parking is to be restored to William Street to return vitality to commercial premises • In the absence of satisfactory measures in response to these issues, will commence legal proceedings in defence of position
0073	Individual		• Low lying area will make dissipation of fumes difficult • Stack should be filtered • Sydney air quality is seen negatively by people overseas • Unchecked air pollution will affect life expectancy and tourist industry

0074	Individual		• Main concern is impact of noise on tenants • Noise levels of intolerable nature will occur at William Street property • Request recognition of situation, and money for soundproofing if EPA limits are exceeded • Community consultation with regard to noise reduction should be highest priority
0075	Individual		• CCT will cause increase in Harris Street, Allen Street and Pyrmont Bridge Road traffic, particularly during morning peak • Air quality data in chapter 6 of EIS only based on one/two months of monitoring near stack site. Accuracy is therefore doubtful • Regular air pollution monitoring in the area needed, with results available to public • E.S.P filter would only create $5-10 million additional cost. These filters break down particulate matter in pollution and should be considered
0076	State Rail Authority		• Reservation of Metro West Rail corridors is a priority • RTA should ensure ongoing consultation with SRA & RAC regarding this issue • Alternative public transport options considered in EIS did not receive robust formulation, selection or analysis, which could be targeted as a weakness in EIS process • Proposed T2 lane in William Street may not provide sufficient transit priority • This lane is separated from curb by cycle lane which may pose operational constraints on pick-up/drop-off of bus passengers along William Street
0077	Individual		• Concerned at environmental impact of releasing unfiltered air through single ventilating stack • Lowest point in Darling Harbour is worst site possible for stack • Cumulative impact of small sized particles • Multiple stacks could reduce individual health impacts • In-tunnel filtering of air needed • High speed jets should be used to propel emissions higher into atmosphere
0078	Individual		• Is there an exit for traffic to Kings Cross / Potts Point at Darlinghurst Road / Victoria Street • Seems all traffic is committed to tunnel • Tunnel should relieve traffic and reduce fumes for city pedestrians • Increased safety for pedestrians
0079	Individual	S	• Looks forward to tunnel being completed ASAP

0080	Rail Access Corporation		• Existing rail tunnels and Town Hall Station should be protected from risk to rail safety & damage due to subsidence and vibration from construction machinery through: • "Rail safety plan" for approval by RAC and SRA • Dilapidation report & subsequent continuous monitoring of all tunnels and Town Hall Station prior, during and post construction • Limiting construction in "zone of influence" to hours when train services are not operating • Should be no encroachment by CCT into corridor of planned Metrowest rail link under Sussex & Kent Streets and the station box to be located under Bathurst Street, as shown in plans to be provided by RAC • Existing 33kV power supply used by City underground rail system should not be adversely affected by CCT • Development approval conditions covering each issue are essential
0081	Stockland Trust Group	O	• CCT will cause considerable traffic problems at Kings Cross during construction period • However main objection is to proposed reduction of traffic lanes in William Street • Widening of William Street footpath unnecessary • Reducing lanes will worsen current congestion • Proposal will result in further decline in desirability to maintain offices & employment in the CBD • Traffic delays only add to costs of all businesses & to air pollution
0082	Royal Australian Institute of Architects	S	• Integrated inner metropolitan public transport system should be urgently considered as part of these works • Money spent on CCT should be matched by money spent on public transport to & from eastern & western suburbs • Layout of William Street should include parking lanes, to allow for safer pedestrian & retail environment • Median proposed for William Street should be removed to provide space • Two open design competitions should be developed for major urban spaces at Kings Cross and Darling Harbour ends of the project • Commercial aspects that will impact on urban environment should be clearly spelt out in conditions of approval
0083	Individual	S	• Project should proceed ASAP
0084	Individual		• Deceived by RTA solicitors statement that property would not be affected by roadworks • Excavation & tunnelling in the immediate vicinity, and the presence of emission stacks makes whole project unacceptable

0085	Royal Botanic Gardens Sydney		• Concerned that EIS devotes one paragraph to impacts on The Domain • Response represents gross oversimplification of issues. Other relevant issues raised in previous letter include: • Reinstatement of sandstone to halt erosion & impacts on edge of The Domain • Site plan is unrealistic, as trees are dotted on for visual effect, although thin layer of soil over sandstone would not support trees. Misleading plan should not be publicly exhibited • Retention of heritage stairway and gate piers is essential • Integrity of Domain will only be retained by continuing established planting pattern • Path system on plan does not relate to desire lines or landscape • Balustrade fencing appropriate for entire length of tunnel aperture as far as gate piers & should use organic materials
0086	Individual	O	• Strong objection due to proposal for unfiltered emission stack at Darling Harbour • Unfiltered emission stacks are considered obsolete in light of newer technology • Statements in EIS summary are misleading; • Project may have "no significant impact" relative to current impact on biological diversity, however to consider current impacts as acceptable is tantamount to RTA displacing responsibility for vehicle emissions • RTA should consult with Sydneysiders Against Polluting Stacks
0087	Individual		• Noise reduction due to Eastern Distributor construction • Concerned that noise does not return because of traffic emerging from tunnel in Sir John Young Crescent • Exit in Sir John Young Crescent will reduce ground level traffic crossing Crown Street intersection • Less noise impact on Crown Street residents if proposed exit was moved further north, as far as possible towards traffic lights at Palmer Street and Sir John Young Crescent • Alternatively, transparent noise barrier could cover vehicles until they reach Palmer Street traffic lights
0088	Individual	S	• Tunnel should have been completed years ago • CCT should be coordinated with Anzac Bridge
0089	Individual		• Disappointed that improved air quality was not considered important project objective on flyer • Improved amenity in CBD is commendable, but reduction in exhaust due to traffic not having to accelerate away from 18 sets of stop lights should have been highlighted

0090	Individual		• Three surface streets, Bourke, Palmer & Riley pass through Woolloomooloo, and therefore provide possibility of avoiding toll • Road users will not pay toll if it is avoidable • Expense of single lane diversion to Sir John Young Crescent would be small percentage of overall project cost, and should therefore be covered by toll on CCT only • Supports toll on CCT, but not for Sir John Young Crescent exit, as avoidance will cause traffic delays in the Eastern Suburbs
0091	Individual		• Will not visit Darling Harbour again once CCT built • Flyer gives no indication that worlds best practice will be utilised in the "not very high stack", or that there is adequate breeze to disperse fumes • Stack is to be located in a depression, hidden from prevailing breezes by city • Harbour Tunnel exhaust located where there is a very open fetch • Anywhere with an open fetch to ensure dispersal would be more appropriate • Little air flow on ground level compared with on roof of building • Darling Harbour already affected by emissions from existing flyovers, will become a swirling grey toxin soup • Air quality for children is everybody's concern • Best solution should be achieved, not cheapest • Success of Daring Harbour could be compromised • Stack will not pass public opinion • Viable alternative should be presented to ensure success of overall scheme
0092	Individual		• Significant contributor to state through taxes and public transport use • Riding bicycle as a transport solution provides a valuable perspective on the RTA • RTA has failed in its mission & is incapable of resolving transport & mobility issues in NSW • To state that light rail into city & pedestrian improvements cannot happen until tunnel is completed makes no sense • Not necessary to preserve ease of access to CBD by motor vehicles, extra lanes for private car use will is not the solution. Lanes should be provided for light rail • Eastern Distributor has resulted in greater danger for cyclists • Tunnel is manifestation of problems
0093	Individual		• Public transport bonuses should be maximised • Bus transit lanes should be continuous in both directions from end of Victoria Road to city as part of project • Western Distributor traffic should be stopped crossing transit lane at Black Wattle Bay • Increase tolls by 20% and use extra funds to construct Eastern Suburbs Light Rail

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0094	Sydney Ports Corporation	S	• SPC has facilitating role to ensure road access for heavy vehicles carrying cargo to & from port precincts • Limited possibility of port trucks using tunnel should not be excluded • Access at western end of tunnel should be suitable for use by rigid & articulated trucks (semi trailers) in a northerly direction • B-Double access also an issue for transport operators, the stevedores & the SPC • Possibility of trucks carrying hazardous cargo through tunnel should also be examined, or suitable alternatives must be designated
0095	B		• Request extension of submission period • Seek guarantee that construction site will not be located adjacent & in front of hotel • Site base should be further away from Day Street landscaping in front of hotel • Impact on business • All "noisy" work causing building vibration and external noise should not commence until 9:00am and stop after 5:00pm/6:00pm, seven days per week • Seek advice on how to prevent disruption from noise & vibration, and what compensation would be offered • Request written assurance that any structural damage to hotel be compensated • Expect to determine health impact from exhaust stack by proposed extended time frame • Strongly recommend that modification of Bathurst Street to a two-way system commence at same time as Day Street closure • Prior to any changes to Day Street, hotel should be consulted. Important issues include: • Accessibility of coaches • Taxi Rank • Landscaping • Structural integrity • Request meeting to discuss feasibility of creating second level of car parking during tunnel construction • Further issues to be discussed up to 30/10/00
0095	*PARKROYAL at Darling Harbour*	O	• Owner has made inquiry to Darling Harbour Authority regarding sale or possible leasing of land. • Requests that when land adjacent to hotel levelled, there be provided appropriate landscaping • Need to erect sound barrier between roadway & land, preventing any increased noise level • Any noisy works to be conducted after 9.00 am

			• Need for minimum of 1 month's notice to be provided to Hotel Management, notifying of any scheduled sheet piling work, including dates & times • Requests RTA's assurance that current exterior noise levels in hotel guests' rooms not be exceeded at completion of tunnel project • Requests that appropriate signage be displayed showing direction to hotel from Liverpool St. • Requests that detailed plan of timing be advised to hotel • To be notified in advance of any street closure that may affect arrival or departure of hotel guests • Formally requests that if any further air quality tests take place that hotel rep. be present to verify readings
0096	Barak Pty Ltd		• Own heritage building on William Street • Concerned that CCT will generate noise & vibration • Impact on tenants • Economic impact on company due to loss of tenants • RTA & CCT have responsibility to address these issues prior to construction • Request meeting • Tree planting on southern side of William Street not consistent with existing awnings, trees should be planted in centre of street as road dividers. Poplar tree would be suitable • Viability of ground floor activities severely compromised by loss of kerb side parking • Critical to restore parking
0097	South Sydney City Council		• Closing date for submissions deferred • Council will lodge supplementary submission on William street upgrading issues
0098	Individual		• Increase in traffic, noise and air pollution on Lang Road due to Eastern Distributor • A total of five lanes of traffic is being directed onto Lang Road • Lang Road should be quiet residential street. Mostly low density single dwellings, many heritage items • Residential access from Lang Road • Potential impacts to reduce impact of Eastern Distributor include: • Redirect through traffic onto regional (Moore Park Road) and state roads (Oxford Street) that are designed to carry heavy levels of traffic • Close Lang Road at the northern end or at Cook Road, so traffic can still access Fox Studios, SCG, SFS • Restricted parking on Lang Road to encourage public transport use • Enforce vehicle weight limits • Enforce speed limits

			• Improve signage • •
0099	Leichardt Council	O	• Objectives of EIS are too restrictive, project will have implications beyond immediate area • Project fails to meet objectives of *Action For Transport 2000*, by failing to reduce car dependency • Proposal does not provide for sufficient public transport improvements • Proposal moves congestion from central Sydney to surrounding areas, particularly Leichhardt • EIS does not adequately address the impact on Leichhardt, nor does it provide sufficient amelioration measures • EIS deficient in analysis of an Integrated Transport Solution • Full public transport network analysis should be developed prior to assessment and construction • Assessment should consider: • Expected noise & vibration impacts • Air quality impacts • Heritage & amenity impacts • Effects and cost on local street network caused by increase in Regional and State road capacity • Consent should include the following issues: • RTA should install appropriate traffic management and calming mechanisms throughout Glebe area to reduce through traffic to predicted no CCT levels • RTA should assess increased traffic impacts on Victoria Road and City West Link Road and install appropriate amelioration measures
099	*Strategic Environmental Planning*		• Environmental problems will be increased with increase of private motor vehicle transport.
0100	Action For Public Transport		• Does not accept either logic or findings of EIS as genuine • Problem definition and solution is biased towards an expansion of road capacity for private vehicles • Predicted "minor" modal shift to cars as result of tunnel is understated • Regrettable that public transport options have not been explored because of lack of suitable modelling • In project justification, no mention made of financially underperforming Eastern Distributor Tollway • Directly connecting tollway and CCT would improve tollway's performance • Forecast 13% reduction in vehicle-hours-travelled appears to ignore time-constancy travel, where higher average speeds tend to make for trips of longer distances, rather than of shorter duration • Kings Cross Tunnel "lid" is irrelevant. Building of it is in no way connected with tunnel proposal, only intended as a

			diversionary tactic
0101	Individual		• Strongly opposes unfiltered stacks proposed for M5 East, CCT & Lane Cove Road Tunnel • Unfiltered particulate matter & gaseous vehicle emissions generated deny residents right to clean air • Emissions detrimental to health, cause cancer & respiratory illness • Cost-effective filtration needed
0102	Individual		• Proximity of EIS submission deadline to Olympics minimised negative response • What will come out of proposed stack & what are health effects? • What impact will there be on local (Pyrmont) traffic patterns & journey times? • Insufficient pre-EIS analysis of local air quality or the effect of tunnel on local traffic flow • Pyrmont & Ultimo given no emphasis in EIS even though they will be among most highly affected areas • No details available on construction plans for merging of viaducts on western distributor, affecting Harris Street area • Removal of Harris Street access from Harbour Bridge & city westbound will significantly increase local journey times and pollution • Urgent analysis and a documented impact assessment required for this plan • Comparative assessment between potential gain from tunnels & loss to local community needed • EIS stack proposal only viable if dispersion of gases can be achieved • Several recent exceedences of EPA particulate goals • Local air & wind conditions around stack need to be considered in air quality modelling • This is not a roadside situation, emissions are from two lengthy tunnels, therefore Holmes Air Sciences modelling inappropriate • CSIRO heavily criticised previous RTA modelling reports • Holmes Air Sciences stated have little/no previous experience with wind tunnel use for measuring emissions • Several exhaust stacks needed • Any air quality improvements in central Sydney are at the expense of local conditions at Darling Harbour
0103	Individual		• Request for on site meeting

0104	Individual		• Objects to unfiltered emission stack, not to CCT • Meetings have shown that Pyrmont/Ultimo area will bear full brunt of emissions, and experience further increase in traffic pollution due to CCT re-routing proposal • Recent CSIRO report has shown the method of wind tunnel monitoring to be flawed • Objects to siting of single emission stack in Darling Harbour • Requests provision of more than one stack to spread load of polluting emissions • Objects to lack of any proposal for filtration system • Re-routing of traffic into Pyrmont will create further pollution from vehicle emissions • Objects to lack of air quality monitoring in area over a sensible period of time • Lack of confidence in wind tunnel statistics as advised in CSIRO report & from current experience with M5 East tunnel • Recent air quality monitoring report shows exceedences of air quality goals for PM10 are already occurring in area • Potential effects on health of surrounding community from long term exposure to vehicle emissions from stack
0105	Ultimo Precinct Committee		• EIS fails to adequately address all issues relevant to assessing environmental & health impacts of proposal • EIS totally fails to address specific issues ad they effect our locality, & it would appear that net impact to area will be demonstratively negative • Do not support EIS conclusion that model proposed has an acceptable impact level • Any proposal that entails negative impact on air quality or amenity in the area, no matter how marginal cannot be acceptable, especially when considered in light of availability of technology to reduce air borne contaminants • Reject conclusion that it meets worlds best practice criteria • Installation of ESP filtration or such technology as part of initial design & construction of CCT is only responsible & acceptable option, given uncertainties of predictions modelled in EIS & the potential for long term health risks • ESP filtration is proven technology which can contribute to improving local air quality & which can be implemented at modest cost to the project & could be funded from tolls levied on tunnel users • Only acceptable proposal is one which demonstrates improvements in air quality to all areas, and does not seek to benefit on to the detriment of the other
0106	Residents Against Polluting Stacks		• Flawed design criteria & environmental standards applied to CCT EIS repeat the same errors, use same discredited ventilation system & result in same unacceptable compromises as M5 East Tunnel. The DUAP conditions are unique in the world in banning ass emissions from tunnel portals yet allowing unfiltered emissions to escape through single point emission sources to which no meaningful standards are applied • Residents, workers and visitors to area expect that fumes from tunnel outlet/outlets will be filtered to protect health & amenity. With present knowledge about adverse health impacts of vehicle exhaust, they are entitled to make this demand & for it to be met. Every attempt should be made to treat toxins from these fumes & reduce their local &

			regional impact • EIS takes no position on in-tunnel gaseous emissions filtration technologies. The RTA tunnel Ventilation workshop showed that international tunnel filtration experience has advanced far beyond the Australian experience. Sustainable emission technologies are now available • Any pollution generated or "redistributed" by tunnel should be equitably shared, not concentrated onto one segment of population • Meaningful air quality goals & standards must be used to underpin design of ventilation system, measure & monitor acute & long term impacts of pollutants on local population • Supposed benefits of CCT should account for induced traffic, & the impact of tunnel on gov's policy to reduce vehicle kilometres travelled, as outlined in Action for Transport 2010 • Complementary strategies such as public transport, toll & traffic control strategies should be adopted to reduce vehicle dependence & its adverse health, environmental, social & economic impacts • Proponents & developers have a duty of care to local residents, as motor companies that stand to benefit financially from its through traffic. Health & aesthetic impacts on local populations must be factored into cost benefit equations & profit margins for motorway projects
0107	Individual	O	• Strong opposition to CCT, particularly with unfiltered exhaust fumes from stack • Tunnel not needed – public transport is viable option that will be used if it is efficient & cost effective • $400 million better invested in upgrading train & bus system, making CBD as vehicle free as possible • Cannot justify unfiltered emission stack with fumes from 50,000 cars per day, through one outlet, at lowest topographical point • Repeat of M5 east saga • Not morally, environmentally, or economically responsible to dump unfiltered toxic fumes on thousands of residents, workers or visitors • Links between vehicle exhaust and increases in death rates, cancer & respiratory illness • Design is not contemporary or friendly to city & its people • 39m high chimney does not belong in a 21st century urban city • Inequitable to redistribute fumes from 2 kms of tunnel in a valley. RTA should stop attempting to relocate problem to point of least resistance, and put resources into solving it • Inappropriate air quality goals – did not account for local or cumulative impacts, nor recent research into effects of fine particles and other vehicle pollutants. Use of averages and ambient measures is misleading & irresponsible • Current CCT design seems to replicate worst aspects of M5 East. It goes against fundamental values: clean air, good health, a beautiful, livable city that provides a fair go for all • What has RTA learnt from health and planning disaster that is M5 East stack?

0108	Joint submission from Darling Harbour Authority & Sydney Harbour Foreshore Authority	S	• Will the open space created to west of Harbour street remain the responsibility of RTA or become responsibility of DHA • Will exhaust stack be built on RTA or DHA land • Creation of open space through realignment of Harbour Street is supported, however project approval should be conditional upon SHFA being consulted and approving landscape design • In principle acceptance of proposed location & design of exhaust stack subject to satisfactory resolution of ownership interface and .....issues • Pedestrian access between darling Harbour and CBD critical to ongoing commercial function of Darling Harbour. Access must be maintained during construction and enhanced after CCT completion • SHFA supports: • Removal of pedestrian footbridge over Harbour Street between Druitt Street and Bathurst Street; • Maintenance of pedestrian footbridge over Harbour Street from Darling Harbour to Cockle Bay; • Connection of Darling Park footbridge to footway on northern side of King Street viaduct of Western Distributor; • Construction of a footpath on western side of realigned Harbour Street; and, • Relocation of footbridge over Harbour Street from northern side of Bathurst Street to southern side of Bathurst Street and connection of this footbridge to new footway to be constructed on southern side of Market Street viaduct of Western Distributor • To ensure adequate access during construction SHFA request several additional conditions of approval, relevant to pedestrian access • Concerned at significant reductions in average traffic speeds & intersection levels of service on Harbour Street • Harbour Street provides access to Cockle Bay, Imax, and Darling Walk back-of-house & McDonalds • EIS provides no detail on proposed access arrangements to these facilities. Therefore it is not possible to comment on the acceptability or otherwise of tunnel's traffic impact at Darling Harbour • More information should be provided on access arrangements for Darling Harbour • More information should be provided on implications of increased traffic on Harbour Street for Darling Harbour access • Accepts that proposed exhaust stack will not adversely impact on ground level concentrations of air pollutants if proposed design is adopted. However, there is concern over potential adverse air quality impacts at elevated receptors within Darling Harbour precinct & the potential for these to sterilise potential developable airspace • SHFA would like to know how increasing height of the stack would increase the amount of developable airspace, as EIS does not appear to discuss this. Request that various stack height options be investigated by RTA and provided for further comment and review before project is determined • How will increase in nitrogen dioxide accelerate corrosion of building materials

			• Given uncertainties surrounding air quality modelling results, further impact investigations should be carried out to satisfaction of the EPA, before project is approved • Maintaining safe pedestrian and cyclist linkages is a key design consideration. Concerned that the study area largely ignores the City West area. Therefore request that this area be analysed in relation to proposal so that any impacts can be determined • Links to Parramatta Road, the M4, Victoria Road & the southern arterial to airport need to be analysed in interest of longer term strategic planning • RTA must undertake to indemnify SHFA against any claims made by DHA tenants for loss of trade/business disruption due to construction of CCT
0109	Clover Moore MP Member for Bligh		• So far, public consultation has shown a rare positive response • However for consultation process to have any validity, alternatives & options popularly proposed by community should be seriously developed and incorporated as part of the brief to be assessed by PPK Environment and Infrastructure • EIS should address inducement effects of greater road capacity & initially less impeded travel, effective ways of limiting toll avoidance, while balancing the need to retain reasonable local access & the tendency for surface roads to reach capacity again • Serious consideration must be given to identifying location where ventilation stacks will have minimal health, environmental & visual impacts • All exhaust fumes from stacks & portals must be filtered to remove solid particles & treated to remove harmful chemicals such as nitrogen dioxide • EIS should address traffic effects on surrounding streets • Pedestrian links & access to New South Head Road are vital • It should be ensured that proposal does not prevent desirable future opportunities for the city. Examples include removal of Cahill Expressway & rejoining the Domain to the Botanic Gardens • As part of their assessment, PPK should obtain from the Govt the light rail study which was undertaken as a condition for the ED approval by Parliament • Ongoing appeals for William Street to be improved & replanned as the imposing boulevard it was meant to be • It is felt by many in community that opportunities provided by tunnelling the full length of William Street have not been fully exploited. Beautification is restricted to a superficial municipal council exercise of footpath widening, paving and tree planting. This is hardly revitilisation • Has been sustained criticism of a separate study being carried out by DUAP, which seemed to focus on blanket development opportunities in William Street. The brief for this study was prepared prior to proposal to extend the CCT under William Street & does not seem to have changed since then

			• Since Avis development controversy, community has been asking for controls to limit development which would extend canyon effect in street & maintain important views to city • Both alternative surface road impact studies & street amenity & opportunity studies need to be carried out & assessed before a final surface pattern can be decided. These are basic requirements before design work should be started • Once surface road pattern has been decided & protective development controls are in place, revitilisation of William Street should be subject of a competition to achieve most imaginative solution which would include a procurement & financing plan • ED project allows a review of many failures of consultation outcomes & environmental safeguards during construction • Consent condition needs to be quantifiable and enforceable, and a process established ensuring prompt action on amenity safeguards & environmental controls by the responsible Govt agencies • Consideration should be given to provision of a full time & independent community liaison officer with power to direct Govt. agencies and contractors to act
0110	Improve Sydney Public Transport (ISPUT)		• CCT good in theory, but will do nothing to unlock Sydney's traffic gridlock • New city railway needed underground • CCT will not reduce expectation that within 20 years, peak hour in Sydney will extend from 8 hours to 12 hours a day • Heavy rail can move more people than light rail, so network should be expanded • To build a road tunnel now will kill off any prospect of a new city railway • Construction of new city railway is crucial to overall expansion of rail network • CCT will do nothing to reduce near operating capacity of current city railway. EIS admits new city railway would relieve pressure on existing services • CCT cost is $400 million, while a new city railway would cost $300 million, and do far more to relieve overall congestion • EIS states 4,00 vehicles currently move east-west across central Sydney each day. CCT would attract more traffic onto central Sydney streets as people attempt to avoid toll • EIS states 20,000 passengers arrive at CBD stations during the morning peak, while 16,000 passengers depart in 15 minute periods between 4:00pm and 600pm • EIS does not state that a new city railway is ahead of CCT on environmental grounds, or ability to move volumes of people • CCT requires ventilation stacks, which railways do not need • Once built, railways are very cheap to run & move huge volumes of people

			• The Lane Cove Tunnel link is part of Sydney Orbital road network, while CCT is not • Importance of CCT to Sydney's road network is questionable • Some 38% of commuters from inner west predominantly use public transport for all/part of trip to work • Rail expansion would assist inner west commuters far more than proposed CCT • When advantages of new city railway are given equal consideration with proposed CCT it becomes clear that new city railway is better solution to transport ills • Bandaid solutions merely mask the problem from the cure
0111	Greenways		• CCT is another major project which will add to Sydney's environmental problems • Interested to know benefits gained from $400 million spent from 2 kilometres of road tunnel compared to $20 million spent on 3.1 kilometres of modern trams to Lilyfield • Greenways are developing programs for a real solution to Sydney's traffic chaos. These include: • Cross-city bus services needed between Eastern Suburbs and Inner Western Suburbs to provide alternative option for potential CCT users. These services would reduce bus changeover/travelling times and redirect several George & Elizabeth Street services, reducing congestion in those streets; • Modern trams needed on following routes: Central to Circular Quay, Lilyfield to Summer Hill, Central Sydney to Moore Park & Coogee Bay; • Reduced parking in CBD; and, • Upgrading Cityrail services. • Expressways built in last 20 years have had no lasting effect on reducing traffic congestion, with congestion increasing on surrounding suburban streets • Encouraging cars to travel to & through CBD is a major cost burden on local councils & residents of inner city suburbs • CCT will increase number of vehicles on Victoria Road and worsen traffic conditions in Glebe & Annandale
0112	Individual		• Objects to single, unfiltered stack at western end of tunnel • Toxic particulate & gases which will be released amounts to a breach of Gov's Duty of care to its constituents • RTA should release the readings that it should have collected of existing air quality in areas around this & other unfiltered stacks in Sydney • RTA should grant an extension of CCT's EIS process to allow concerned people to access, evaluate & respond to RTA documentation
0113	Millennium Tower Apartments		• Request clarification on following issues: • Is only one stack proposed to provide outlet for tunnel exhaust? • Details of air-filtering systems to ensure clean & safe air in proximity of Darling Harbour & Cockle Bay • Exact location of stack on brochure is not clear – where is it proposed in relation to Imax & various road islands

			• What is height of proposed stack & how much higher than Imax will it be? • What is diameter of proposed stack?
0114	Individual	O	• Objective of proposal is misconceived – money should be spent on public transport • Olympic Games demonstrated that with efficient public transport & administrative arrangements to discourage private car use, people will happily use public transport • Also demonstrated that deliveries can be made during night to city locations to reduce load on city road network • CCT would strongly encourage private transport at expense of public transport by: • Making private transport more efficient & faster • Making no contribution to improving public transport • Reducing likelihood of sufficient funds being available for investment in light or heavy rail public transport • Therefore, roads will become even more clogged with private cars
0115	Individual		• Severe impact of construction under Riley Street • EIS does not detail ameliorative measures to reduce impacts to acceptable levels • Only measure identified is the limiting of construction hours • Without proper mitigation, residents may have to vacate homes during construction & seek compensation • During ED construction, proponent extended construction hours several times, leading to intolerable conditions for many residents • Condition for limiting working hours should not provide proponent with simple mechanism of obtaining approval for extending working hours from the EPA, as was the case for ED construction. Minister should be consent authority, and application should be subject to public comment • Loss of trees on both sides of Riley Street, in section between William Street and Sir John Young Crescent, will have significant detrimental effect on streetscape • Every attempt should be made to retain these trees • If trees are lost, should be replaced with mature specimens • Emergency egress from tunnel under Riley Street is just outside unit • Concerned that egress has potential to impact on outlook, and that structure of egress roof could provide a point of access to residence, compromising security • Requests input into design of structure • Concerned that expressions of interest for CCT construction were called before closing date of EIS submissions. This questions objectivity of Minister's decision making process, and could provide determined opponents of project with basis for legal challenge

0116	Individual	S	• Endorses decision to have single stack at Western end in recognition of possible failure to meet air quality objectives at Eastern end with twin-stack options • Proposed site for Eastern dual stack is less than 100m from existing Eastern Distributor (ED) stack • Local Area Improvement Program should be put in place for CCT, as for ED • Possibility of reducing Palmer Street to single lane in each direction by re-allowing kerbside parking on Northbound side to discourage drivers from using surface streets & encourage use of underground link to Sir John Young Crescent • Advantage of promoting quieter, safer streets by removing surface traffic • Residents of Bourke & Palmer Streets have endured several years of noise from ED construction • Guarantee needed to ensure acceptable noise levels during CCT construction & limiting construction hours • Supports bus/bicycle lanes, widening & landscaping along William Street • However, landscaping/parkland promised as part of ED construction failed to materialise, therefore guarantee needed for planned greening of William Street • High toll will result in resistance to use CCT • Suggests system used for Melbourne's city-link project, where there was no toll for first couple of weeks, followed by phased increase • In favour of use of electronic tolling
0117	Individual		• CCT contradicts RTA's mission statement & is environmentally irresponsible • $400 million cost very large for one small section of road which does not balance needs of public transport users, motorists, cyclists & pedestrians • After initial benefits tunnel will induce more motorised traffic • Toll avoiders will create problems in surrounding streets similar to Eastern Distributor • Jobs created by construction are short term
0118	Bikesydney		• Extensive reference to Austroads 14 second edition, 1999 • Proposed tunnel should allow for alternate means of transport such as cycling, which will directly benefit from substantial reduction of traffic volumes • Druitt Street should provide for cyclists, with cycle lanes allowing access to Kent & Sussex Streets • By removing shoulders & directing cyclists to above streets, safety is being compromised • Route also incurs traffic lights & steeper gradients – unacceptable for cyclists • Kings Cross Tunnel is relatively flat & therefore appropriate for cyclists • Cyclists will continue to use Kings Cross Tunnel as it is most direct route • Welcomes involvement in all stages of CCT planning & construction • Request close consultation on all construction plans involving cycle facilities

0119	Individual		• Objects to stack without filter due to health reasons •
0120	Individual		• Objects to stack without filter due to health reasons •
0121	Individual		• Objects to stack without filter due to health reasons •
0122	Individual		• Resident of Darling Harbour • Objects to stack without filter due to health reasons
0123	Individual		• Objects to stack without filter due to health reasons •
0124	Individual		• Objects to stack without filter due to health reasons •
0125	Individual		• Objects to stack without filter due to health reasons •
0126	Individual		• Resident of Darling Harbour • Objects to stack without filter due to health reasons

0127	Individual		• Resident of Ultimo • Impact on residents and tourists • Objects to stack without filter
0128	Individual		• Objects to stack without filter due to health reasons
0129	Individual		• Objects to stack without filter due to health reasons
0130	Individual		• Objects to stack without filter due to health reasons
0131	Individual		• Objects to stack without filter due to health reasons
0132	Individual		• Objects to stack without filter due to health reasons
0133	Sydney Family Daycare		• Concerns about carcinogenic emissions and increased asthma near day care centre • No unfiltered stacks
0134	Public Infrastructure – Woollahra Council	S	• EIS does not consider impact on Woollahra Municipality • Traffic increases on the following roads is anticipated: • New South Head Road • Ocean Street, Woollahra • Edgecliff Road, Woollahra • Existing north south and east west corridors through the Paddington and Woollahra areas

			• Amenity and safety of conservation areas in Woollahra and Paddington will be degraded by this extra traffic • Predicts that the EIS is mistaken in assessments that traffic will decrease in New South Head Road and Ocean Street • Council refutes the conclusion that the increase in traffic in Paddington would bring traffic levels back to those existing before the Eastern Distributor • Council is concerned that the traffic management scheme designed to redirect traffic from local streets to main roads as outlined in the EIS will not be approved by the RTA • Construction will increase congestion along the William St. – New South Head Rd corridor • This is undesirable even for short periods of time • Increased traffic will result in increased emissions within the municipality, and these results are undesirable in such a residential environment • Public transport should be implemented in the scheme • A thorough and proper assessment should be carried out to determine and quantify the impacts that this proposal would have on the Municipality, especially the suburbs of Paddington and Woollahra
0135	Individual		• Air quality monitoring should be more consistent • Filtering the stack is the perfect opportunity to reduce vehicle emissions • Emission of carcinogens is unacceptable • Concerns for asthmatics and children • Cost should not be an issue
0136	Individual		• Concern at emission exceedences during monitoring in Harris Street • Concern at emission tower degrading the current use of Darling Harbour
0137	Individual		• Concern over emissions to Darling Harbour • Should be two filtered stacks
0138	Individual		• Air quality in Ultimo is already too bad; don't add to it • Pollution leaves ugly soot on pedestrian bridges • Concern over increases in asthma and cancer, especially in children • Electrostatic precipitators should be used

0139	Eric Wohl		• Closure of part of Druitt Street is likely to have a detrimental effect on business • It will impact on vehicular movements, including business representatives, maintenance vehicles, deliveries and clients • Recommends that the closure be omitted or modified from the CCT configuration • The concerns of this submission are shared by the Owners' Corporation of 278 Sussex St
0140	Harris Community Centre		• The current air quality for Ultimo and Pyrmont is extremely poor and any additional pollutants added from the CCT Emissions Stack is unacceptable • HCC is concerned that the EIS discounts the use of Electrostatic Precipitators as a means of filtering stack emissions when this technology is proven to remove particulate • Further investigation should be conducted into the feasibility of a second emissions stack • The CCT emissions stack could be used as an opportunity to improve air quality • The EIS does not address many other important air quality issues • Modelling is an estimated guess only and, as has been shown recently in the CSIRO's M5 East report, cannot be relied upon to provide an accurate means of predicting plume direction and effect on a local area • Placing an emission stack at Darling Harbour would be to the detriment of a growing city population and does not take into account their health and wellbeing
0141	Individual		• Exposure of population to carcinogenic particles • Cost of filtration should not be an issue • There should be two filtered stacks
0142	Sydneysiders Against Polluting Stacks (SAPS)		• Petition of 1700 to 2000 signatures • Petition protests the unfiltered exhaust stack because: • Decrease in local air quality • Health ricks associated with increased pollution levels for those living and working in the CBD, Darling Harbour, Haymarket, Pyrmont and Ultimo areas • Lack of air quality monitoring in the surrounding areas including Ultimo and Pyrmont to inform the Environment Impact Study • Demands the exhaust be filtered and monitored
0142 a	SAPS		• This is a very detailed submission – executive summary: • The EIS inadequately assesses the health impacts of stack emissions • The important opportunity to treat vehicle emissions, previously uncontrolled and dispersed at street level, and now to be contained within a stack, is being ignored • The opportunity for anti-pollution measures, such as filtration, to be put in place and paid for, not by the general

			public, but by the source of that pollution, the motorist, is being ignored • The RTA as a government agency is failing to act ethically and is out of step with current thinking by seeking to justify allegedly "marginal" decreases in air quality • The RTA as a government agency is failing in its duty by not incorporating in the initial design of the tunnel proven filtration technology • -Other significant points: • Impact of stack emissions on air pollution levels already exceeding air quality goals is not assessed • Health impact on sensitive sub populations (eg elderly) • EIS fails to consider effect of particles less than 2.5 microns (PM2.5) • EIS fails to consider long term effects of a decrease in air quality • EIS places unreasonable reliance on predictions of cleaner vehicle emissions • Above ground level receptors (eg Millennium Towers occupants) not fully assessed • High levels of existing background pollution ignored • Role of toxic hydrocarbons ignored • Doubtful predictions from computer models and windtunnel tests • Filtration option has been incorrectly assessed, with electrostatic precipitators deemed unsuitable and of "significant" cost • The EIS is deficient in that it has not given sufficient weight to the alternative of a two stack ventilation system • Measuring unfiltered stack emissions against NSW Air Quality goals is not appropriate.
0143	Sydney City Residents Against Polluting Stacks		• Extension required because of difficulty in procuring and disseminating information • Calls for a revision of the EIS especially regarding public transport options and air pollution modelling and reporting
0144	Individual	O	• Impact of induced traffic not adequately covered in EIS • Public Transport should be encouraged • EIS does not cover options for filtration adequately • Adverse impact of an unfiltered chimney on Sydney's reputation • Inequitable distribution of exhaust fumes • Air quality goals misleading
0145	Lend Lease Development	S	• Ventilation Stack: • Impact on tenants and patrons of Cockle Bay Wharf • Impact on tenants and patrons of Darling Park and the proposed Darling Park Tower 3 development • Current mechanical systems in the Cockle Bay Wharf and Tower complex may be affected by the increased

			concentrations in the atmosphere, necessitating upgrade • Potential to restrict the height of the proposed Darling Park Tower 3 because of the exhaust plume from the stack • Location of the exhaust tunnel connection from the western portal to the proposed ventilation stack may impact on the construction of the future Tower 3 • Western exit portal to be located in Day St. does not allow for sufficient access to the loading dock and carpark egress ramps at the Darling Park complex • The same exit portal will also affect the planned vehicular and pedestrian access ramp to the Tower 3 site • Construction impacts on owners, tenants and public of the Darling Park Complex: • Disruption of pedestrian and vehicle arrangements • Restricted access and egress to Darling Park Carpark and Tower 2 loading dock • Impact on the streetscape and frontage on the Darling Park complex • Potential damage to the building and basement structure • Potential to delay construction of Tower 3 and its connecting vehicular and pedestrian ramps
0146	Nature Conservation Council of NSW Inc.	O	• This is a very detailed submission • Increase in pedestrian accidents on Victoria rd. • Only environmental gains to the CBD, not greater Sydney are considered in EIS • Consideration of other options is flawed, especially with regard to public transport and traffic demand management • CCT is not value for money, especially when compared to trams • EIS fails to asses economic effects • EIS is questionable in its assessment of the impact of the ventilation stack, especially regarding filtration systems • EIS fails to incorporate ventilation system in its energy analysis • Emission stack in tourist area • CCT undermines sustainable transport planning for the rest of Sydney
0147	Eastern Suburbs Greens	O	• CCT will increase congestion by inducing more traffic in Sydney • Increased traffic will affect: • Congestion • Air Quality • Pedestrian and cyclist safety • Noise • Urban amenity • Emission stack results in unequal distribution of project costs and benefits • The proposal is contradictory to greenhouse gas reduction commitments

			• Money better spent on sustainable transport projects • The benefits of additional employment could be achieved through sustainable transport projects • Landscaping will not be realised as large trees will not grow on the slabs
0148	Department of Housing		• Very detailed submission • Affected Department properties are 38 units in a group of 9 terraces from 159-177 Bourke St., and a 4 storey block of 20 units at 169 Bourke St. to the rear of the terraces • Main construction impacts on residents and the DOH: • Air quality affected by construction. vehicles and dust • Noise from excavation and tunnelling as well as construction • Psychological affects on residents caused by continuous or out-of –hours disturbance • Access • Parking • Building damage caused by vibration and subsistence • Reduced amenity of properties resulting in high tenancy turnover • Major operational impacts on residents and the DOH: • Health risks from vehicle emissions and noise • Future development on neighbouring sites fronting William St. • Displacement of prostitution and drug activity from William St., leading to disturbance in surrounding areas • Disturbance from mitigation measures such as the fitting of double glazed windows • Long-term foundation settlement causing damage to properties • Potential positive impacts of the CCT: • Reduced traffic on William St. and some local roads • Improved visual amenity and safety of William St. • Provision of a cycleway and improved bus services along William St.
0149	Individual	O	• New roads are not needed in Sydney • General traffic growth model is inappropriate • Fixed trip matrix is inappropriate • Neglect of reassigned and induced traffic is unacceptable especially regarding modal shift between public and private transport • Support for the public transport option • Traditional cost benefit analysis is meaningless because in congested conditions journeys are measured in time, not distance

			• Calls for a Public Inquiry • Requests an extension of EIA review time
0150	Individual		• CCT is needed • Its selection over other projects is politically motivated • There is a need for comparison of CCT with other projects to determine economic benefits • Long term accessibility will be affected if the Cahill Expressway is removed • Objections to Waster Distributor passing traffic lights at Bathurst and Harbour Streets • Suggests "Alt.2 by City of Sydney" access points • At CCT feeding onto/ off the Western Distributor lane resurfacing, signposting and direction marking is needed • The CCT should be designated as "freeway" to avoid confusion • Overhead lighting and signage should be clear
0151	Individual		• Vehement opposition to ventilation stack • Eyesore in a tourist area • No filtration is a major public health risk • Cost of filtration should not be an issue • A 40m stack is not the solution
0152	Individual		• RTA demonstrated during ED EIS process that it ignores submissions • RTA erring on side of propaganda in its promotion of CCT • Southern distributor of County of Cumberland has again been ignored • Tolling of ED proven to be inappropriate, resulting in lost amenity & accessibility. CCT promises the same • Registration of interest for CCT now precedes any EIS approval? • Local area traffic management issues were ignored in ED EIS, and again in CCT • RTA misconstrues subject matter in submissions and not answer questions • Cynical of RTA processes for good reason • ED submission attached
0153	Individual		• Objects to single unfiltered emission stack • Concerned at resultant concentration of pollution in one location • Long term health risk to people living & working in area • Location in low lying area surrounded by high rise residential & commercial buildings whose air conditioners will take in contaminated air

			• Questionable "snapshot" air quality information provided in EIS • Exhaustive review of emission controls technology has not been undertaken • Plan for stack is morally, politically & environmentally indefensible
0154	South Sydney Council	O	• 11 October 2000 Council resolution to Oppose construction of CCT on following grounds: • Project of doubtful economic benefit to community, especially given perceived errors in EIS traffic modelling • Additional expenditure on inner-city road-based infrastructure of scale proposed for CCT would be better diverted to public transport systems and improvements to serve inner suburbs of Sydney • Proposal does not reduce dependency on private car transport in inner city area, failing to • Initial submission forwarded on 28 September 2000-12-19 RTA should be advised that in the event that overall final decision of Govt. is to allow project to proceed, conditions 1 to 45 on part 3 of September submission should be included as conditions of approval • RTA should accept supplementary submission from council on issues directly relating to William Street Revitilisation Strategy, including question of scale of development on residue sites such as site adjoining "Carroll's Hardware" building, after closing date of 16 October 2000
0155	Individual	O	• Increases road capacity & improve car travel times relative to public transport, inducing modal shift to cars • Facilitate access from Eastern Suburbs to under utilised parking on western fringe of city, making car driving more attractive • Encourage use of salary packing & commuter trips by car • Add to road congestion in eastern & inner western suburbs • Delays in bus travel times • Project contrary to RTA's "future directions", in which control of traffic growth is strongly advocated • Public transport should be upgraded, suggested methods: • Reinstate trams in exclusive lanes • Provide through-tickets between trams, buses, trains & ferries • Remove tax incentives for salary packaging which encourage provision of cars & parking • Use city parking tax to finance public transport initiatives
0156	Individual	O	• Seems to be tremendous pressure to have project approved regardless of concerns • Briefing session already held for potential contractors was premature • "data" should be referred to as a "guesstimate" • "community consultation" was "community manipulation" • Inappropriate deadline during Olympics • Unfiltered stack is unsound

0157	Australian Museum		• Concerned at vibration levels, especially at Old School Building • EIS drawing do not allow assessment of proximity of tunnelling operations • Further consideration and consultation should occur regarding proposal to narrow William Street between College and Yurong street
0158	Clover Moore, MP	O	• Tighter environmental controls needed for construction period • Effect construction monitoring program to prevent unacceptable impacts on local residents • Full traffic impacts and implications should be investigated & documented • Measures to ameliorate traffic impacts to be developed prior to project completion • Unless concerns can be addressed, has no option than to oppose construction of CCT
0159	Individual	O	• Unclear information on long term forecasts of city workers vs. city vehicles • No relation to other city tunnels in Australia/overseas • Increased vehicle air pollution in inner metropolitan Sydney • Increased vehicle noise pollution in inner metropolitan Sydney • Projected further increase in vehicles on main & local residential roads • No long term jobs created after construction • Increased Govt. costs & new payment tolls • Increased cost of local road maintenance with reduced public transportation • Paddington & Darlinghurst streets suffering increased traffic include: • McLachlan Avenue; • Boundary Street; • Lawson Street; • Glenmore Road; • Underwood Street; and, • Heeley Street. • Request inquiry into proposal
0160	BIKEast	O	• Increases in CBD traffic on streets including Elizabeth, Castlereagh, King, Bligh, Bent, Bridge, Grosvenor & Harbour • People living in northern CBD are well serviced, and should be discouraged from private car use, not encouraged • Substantial increases in traffic in Pyrmont and Paddington. EIS does not propose traffic strategy for dealing with forecasted 14% increase in Paddington • Tunnel will increase "vehicle kilometres travelled", conflicting State Govt policy. EIS attempts to justify this by saying pollution levels will be lower as traffic is not idling in city streets, however justification does not factor in pollution from cars idling in Paddington

			• Bicycle lane ceases at George Street and does not provide cycle connectivity to western part of the city. Should be continued into Druitt Street • Forward stop line needed at intersections for cyclists • Traffic speeds should be minimised to ensure cyclist & pedestrian safety • Proposed replacement of pedestrian bridge at Darling Harbour could be investigated to explore potential for cycle link • Cyclists travelling to city from east would lose access to Kings Cross Tunnel via road shoulder • Road design is unsatisfactory in terms of bike lane & bus lane
0161	Light Rail Association	O	• No more major road works should be undertaken until major expansion of light rail system occurs • Recent road constructions have stimulated traffic and worsened congestion • Make CBD extension of light rail first and scuttle CCT altogether
0162	Australian National Maritime Museum		• Increased levels of air pollutants are stated as within air quality goals for project, although these goals are significantly higher than those aimed for by the museum. Any increase would pose substantial risk to museum's floating collection of vessels rest of collection • Ventilation stack will increase level of pollutants, if assumption of changed fuel composition & emissions does not eventuate, will be substantial increase in level of pollutants • No air quality goal for hydrocarbons, although these contribute to photochemical smog and leukemia • EIS states increases in respiratory health impacts will occur, although these are assessed as small. However, more likely in people over 65 in age, a significant proportion of museum visitors • Impact of construction vibration
0163	Marrickville & South Sydney Bike user Group (MASSBUG)	O	• Increases in CBD traffic on streets including Elizabeth, Castlereagh, King, Bligh, Bent, Bridge, Grosvenor & Harbour • Noise increases will reduce CBD amenity • People living in northern CBD are well serviced, and should be discouraged from private car use, not encouraged • Substantial increases in traffic in Pyrmont and Paddington. EIS does not propose traffic strategy for dealing with forecasted 14% increase in Paddington • Tunnel will increase "vehicle kilometres travelled", conflicting State Govt policy. EIS attempts to justify this by saying pollution levels will be lower as traffic is not idling in city streets, however justification does not factor in pollution from cars idling in Paddington • Tunnel will not result in substantial travel time savings • Bicycle lane ceases at George Street and does not provide cycle connectivity to western part of the city. Should be continued into Druitt Street • Forward stop line needed at intersections for cyclists

			• Traffic speeds should be minimised to ensure cyclist & pedestrian safety • Proposed replacement of pedestrian bridge at Darling Harbour could be investigated to explore potential for cycle link • Cyclists travelling to city from east would lose access to Kings Cross Tunnel via road shoulder • Road design is unsatisfactory in terms of bike lane & bus lane • EIS does not address access & movement of cyclists during the construction period
0164	Airport Motorway Limited		• RTA should attempt to minimise impacts of CCT construction on ED • AML should be party to preparation of CCT construction plan, environment management plan, traffic management plan and other documents relating to ED • AML should give approval & final sign-off of plans for construction activities • AML should participate in traffic committees established to manage construction of CCT • CCT should be designed so that traffic along William Street is significantly reduced so that redesigned capacity is effective • EIS recommendations for William Street should ensure that traffic capacity at ED northbound exit at William Street is not reduced • Traffic signalling on William Street should be such that adequate priority is given to traffic entering and exiting ED • Any traffic signals for north-south traffic routes in vicinity of ED should give consideration to objectives of ED LAIP • LAIP to be prepared by RTA for CCT should incorporate objective that local residents are protected from any "rat runs" resulting from proposed Riley Street ramp • Design for ED northbound exit at William Street resulting from CCT proposal should ensure that there would be no queues forming in ED tunnel. RTA should include AML in planning, design and development of this aspect of CCT • AML should give approval to final design & signoff of final drawings • Design of CCT tollbooths should ensure OH&S issues are not caused to AML staff and operations • RTA should prepare a design solution that does not have the safety risks identified for traffic users of ED • AML should be involved in design of emergency egress points • Concerned that single lane for ED northbound exit at William Street remain open during construction • Impact of any construction work on ED ventilation system • If ED northbound exit at William Street is closed during construction, upon recommencement pollution monitoring should not be reactivated until AML determine effects of construction dust have abated • Access should be provided to ventilation rooms at all times • Support closure of southbound entry at Bourke street during construction. However, AML assumes that RTA will undertake "best endeavours" to minimise closure period • Construction should not disturb roof support structure of ED

			• RTA should make good any physical damage arising from construction, such as roof sag • RTA should provide acceptable design/construction solutions to avoid damage to ED from vibrations • Incident management plans should be developed • Supports preparation of CCT project specific SEPP to enable efficient approval • AML and RTA should jointly prepare a risk management strategy, to be completed prior to selection of tenderer • RTA should take due regard of any negative impacts arising from CCT on traffic levels of ED
0165	Jonathan Falk Planning Consultants Pty Ltd	O	• Title of EIS should be "proposed Several Sydney City Tunnels" • Unclear information on long term forecasts of city workers vs. city vehicles • No relation to other city tunnels in Australia/overseas • Increased vehicle air pollution in inner metropolitan Sydney • Increased vehicle noise pollution in inner metropolitan Sydney • Projected further increase in vehicles in metropolitan Sydney • No long term jobs created • Increased cost of proposed CCT with new payment tolls • Increased cost of local road maintenance with reduced public transportation • Proposes inquiry into CCT EIS
0166	Lord Mayor of Sydney Councilor Frank Sartor	S	• City is supportive of proposed tunnel • Wish to coordinate air quality monitoring program with RTA, especially in Ultimo-Pyrmont • RTA & EIS team should undertake further air quality modelling, focussing on background levels & forecasting impacts on Ultimo/Pyrmont • Benefits favour pedestrians, public transport users, service and other vehicles • CCT allows alternative & non polluting modes such as cycling to be considered in design of surface streets • Inadequate submission period • Differences between City's alternative CCT proposal and this on are: • Provision of a direct seamless link from CCT to north western precinct of central Sydney and the Harbour Bridge at its western end; and, • Provision of much needed infrastructure in terms of terminus facilities for road based public transport, coaches, services deliveries & retail public carparking • Delays caused by construction road closures of William-Park-Druitt-Bathurst Street route • Market & Kent Streets have potential to be severely congested in business and PM peaks • Western Distributor access will be affected by reduced traffic lanes on Market Street viaduct • For westbound traffic attempting to avoid congestion at Market Street viaduct, traffic increases expected on

			following routes: • Westbound along Pier, William Henry & Harris Streets to access western distributor; • Southbound along George Street exiting City via Broadway; and, • Further south along Foveaux Street/Eddy Avenue and Cleveland Street. • This assessment based on modelling using NETANAL, and SCATES traffic modelling systems • Closure of William/Bourke Street ED access will worsen traffic conditions on Macquarie Street • Vehicle turning movements at surface intersections immediately above, north & south of tunnel should be more accurately modelled, with NETANAL/SATURN systems • Construction vehicles from worksites east of Elizabeth Street should be prohibited from using Central Sydney streets • Alternate traffic management needed through Central Sydney for 2.5-year construction period. As condition of consent, traffic diversions and construction vehicle movements should be considered/monitored by joint State Govt/Council convened committee • Given short EIS submission period, Council cannot endorse final design of surface streets • Further consultation with council required following approval from Minister of DUAP • Council approval should be required for final design of surface street treatments covering roadways, footways, landscaping and urban design prior to implementation • Re-examination of surface treatments warranted to ensure toll diversion is minimised by surface system designed to cater for origin – destination traffic rather than through traffic • Bicycle lanes should be implemented along William Street • High potential for substantial volume of induced traffic being generated • Turning radii of single lane ramp connecting eastbound tunnel to southbound eastern distributor does not meet Austroads design guidance • No deceleration lane was provided for vehicles using ramp, despite the need to slow from 70 kp/h to 40 kp/h to manoeuvre exit ramp • Prudent to allow for future underground bus station facilities • Because of difficulty of redeveloping Woolworths site, highest priority should be inclusion of a stub off tunnel in vicinity of Hyde Park to allow for future bus station, and retail core service tunnel • Should consider how tunnel extensions could link to inner west road network, particularly Parramatta Road/M4, Victoria Road and southern arterial to airport • Comments on new public space at William Street/Darlinghurst Road intersection: • Proposed treatment is simplistic and suburban • Thorough re-design and conceptual analysis required

			• Reinstate historic name "Queens Cross" • William Street Boulevard • Potential identified since 1971 • Consider future potential tram links from CBD to Potts Point • Consider that Potts Point is densest urban housing area in Australia : William Street is link with city centre • Consider new relationship with side streets • Opportunity to plant proper larger urban trees further into street with wider canopies • Tree space should not be compromised by light poles etc • Consider optimum cross section analysis of William Street • Consider terminating boulevard planting at College Street • Consider the vista from Kings Cross ridge down William Street to Town Hall • The Stream • Consider stream running under William Street (see Stream Street in East Sydney) for potential historic interpretation • Hyde Park Footbridge • Consider pedestrian bridge on central pedestrian axis of Hyde Park linking two halves of park across William Street • Druitt-park street • Traffic management proposals should be reviewed in conjunction with City of Sydney proposals to improve accessibility and address of northern frontage of Town hall Precinct • Essential that City of Sydney is involved in design issues and ultimate treatment of William Street
0167	Uniting Church		• Requests response time for EIS to be extended to 30 Oct. 2000 as EIS is extremely large document which deals with complex engineering & scientific concepts • EIS brochure did not state all important issues, eg. that proposed vehicle emission stack would be unfiltered. • Has been serious lack of consultation within communities of non-English speaking background; in particular, Chinese community, very significant section of local community
0168	Ford Management Group P/L		• Resident of Pyrmont & business owner appalled that Govt. seriously contemplating installation of Unfiltered Emission Stack within Darling Harbour/Pyrmont precinct • Area is one of, if not the most densely populated in Sydney
0169	Pyrmont Ultimo Historical Soc. Inc.		• Emissions stack will have damaging effect on residents, children, business people to tourism industry, & heritage buildings • Sydney's heritage must be preserved
0170	Individual	O	• Olympic Games surely proved that people will use public transport if efficient • Harbour Tunnel has verified early studies that more roads built for private cars leads to more cars on roads

0171	NSW Health Dept.		• Significant increases in nitrogen dioxide level predicted at elevations above stack • While recognised modelling methodologies have been utilised with reasonable assumptions for background weather and air quality parameters, data on predictive accuracy of these models used in other local developments has not been presented to Dept. of Health • Planning approval has been given for Darling Park 3, a 70-m hotel and residential tower in area that may be impacted by stack emissions • Recommends that Tunnel proponent undertake monitoring for nitrogen dioxide; & that Dept. of Health be provided with reports comparing air quality modelling predictions & measured air quality levels from projects such as Eastern Distributor or City Link (Melbourne) • Monitoring of background air quality for project has highlighted specific areas where air pollution levels are already above health-based goals • Monitoring at Ultimo shows excessive levels of carbon monoxide & fine particle goals • Traffic forecasts in EIS predict increased traffic flows on Western Distributor. • Recommends that Tunnel proponent continues to monitor air quality in Ultimo/Darling Harbour area • Continued exceeding of health-based goals, particularly for carbon monoxide, would require measures to reduce traffic volumes in area • Construction noise levels will exceed EPA guidelines in suburbs of Woolloomooloo, Darlinghurst and East Sydney, for several months • Some residents have recently been adversely impacted by construction noise from Eastern Distributor • Levels of construction noise predicted are associated with hearing impairment, hypertension, sleep disturbance and psychological stress • Some residential areas affected by construction noise are predominantly occupied by people of lower socio-economic status, who may be more susceptible • Recommends that Tunnel construction employ all feasible routine & innovative noise control strategies • Proponent should engage in close consultation with communities affected by construction noise to decrease impacts through information, etc. • Rock drilling involved in constructing tunnel will produce dust containing silica, leading to silicosis. • Increased dust levels also associated with enhanced conditions for Legionella. • Recommends that dust control measures as outlined in Environmental Management Plan be followed. • Local government authorities & building managers in construction areas should be made aware that increased maintenance and surveillance of cooling towers is required, & that tunnel proponent be responsible for costs • Cost-benefit analysis incorporates greenhouse gas savings due to increased congestion of traffic. • Only 5% of energy or tunnel operation required to be derived from renewable sources.

			• Recommends that cost-benefit analysis include greenhouse gas and air pollution costs of tunnel's construction and operation • Net increase in VKT predicted due to tunnel's operation • *Action for Air* objectives include achieving shift from private cars to public transport, cycling or walking • Recommends that proposal includes measures to counter increase in VKT, & achieves shift from private car to other modes of transport • Benefits of proposal accrue principally to private vehicle drivers travelling east-west across CBD. • Net impact of tunnel operation on motor vehicle contributions to ambient air pollution, air toxins and greenhouse gases depends on balance between increased VKT, impacts of new engine design rules & fuel formulations • Recommends that imbalance of cost & benefit distribution be redressed • That greenhouse gas costs of proposal be reduced.
0172	Property Council of Australia		• Design of tunnel should not preclude: • Future demolition of Cahill Expressway; • Construction of an underground transport interchange; or, • Future extension of tunnel to Victoria/Parramatta Road. • Where efficient and effective innovative design solutions are put forward that are not envisaged under current EIS, design solution should be considered under framework of current EIS to greatest extent possible • RTA should consult directly with individual owners of identified properties to reduce any adverse impacts on existing buildings • Building owners ought to be compensated where development potential has been restricted • Adjoining developments should not be required first to get approval from RTA before lodging development application. • Definition of tunnel's "vicinity" and "zone of influence" should be clarified for greater investment certainty • Design of ventilation stack should permit its integration with a development • Project should be developed as a BOOT scheme • Government benchmarks from the tender evaluation process should be adjusted so that all tenders can be evaluated on same basis • Ensure strong and direct consultation with property owners during construction process
0173	Individual		• Has read EIS, which is superficially impressive, but: • Strains credulity when PPK and RTA reiterate that emissions from estimated 5500 vehicles per day can be collected from 2 tunnels running between Woolloomooloo and Darling Harbour, concentrated at one point, and discharged, untreated, with no appreciable impact on air quality • EIS's proposed "redistribution of vehicle emissions" seems akin to re-arranging deck-chairs on the Titanic.

			• Consultants, modellers, and statisticians should be answerable for accuracy of calculations • Indoor air quality of home will be compromised as result of unfiltered stack being placed near IMAX Theatre • Fans used in stack combined with funnelled tunnel noise will exceed EPA sound levels • Health will deteriorate as result of cumulative effects of particulates and gas emissions
0174	Individual		• Can expect emission of 51,000 vehicles per day into area • Lowest topographical point • Air quality concerns
0175	Individual	O	• Resident objects to proposed tunnel due to emphysema condition which development would grossly aggravate. Neighbour has asthma
0176	Darling Harbour City West Real Estate P/L		• Why does exhaust air have to be unfiltered? Tunnel will be operated as tollway – surely can cover installation & running costs of sustainable emission controls on stack • Darling Harbour is dumping ground for all unfiltered emissions from tunnel • Vehicle exhaust gases are potentially carcinogenic • EIS air quality information appears flawed for political expediency • Filtration technology available in many forms & should be installed by a responsible Government • Site of proposed stack is geographical "sink" providing hindrance to air-borne contaminant disposal
0177	Individual	O	• Proposal seems to be increasing supply (ie roads) to satisfy increasing demands (from motorists) • Induced traffic created by proposal will only result in more cars on roads • RTA should scrap proposal, or provide more equity in terms of expenditure for alternative forms of transport
0178	Individual	O	• Sydney is becoming untenable in face of congestion, pollution and 'dead' urban space • Light rail & Airport rail link are admirable start; but are these sustainable financially?
0179	Nomura Real Estate Development Co., Ltd	S	• Concerned about single ventilation stack • Single stack should be built in centre of tunnel, so that impact can be borne more equally by affected parties. Hyde Park is such a location
0180	EPA		• Construction Phase Recommendations: • That proponent commit to establishing independent monitoring & reporting of environmental performance against EIS commitments (as amended by consent & environment protection licence conditions) as part of project's management decision making process • That additional noise monitoring be undertaken in eastern & central precincts, to ensure post ED baseline conditions are known

			• Additional monitoring should be undertaken at Kings Cross and Woolloomooloo • That proposed noise mitigation measures outlined in *Technical Paper No. 18 – Noise and Vibration* be incorporated in any consent • Where unacceptable impacts persist despite noise mitigation action, proponent deal with matter by negotiation with affected parties • Proponent will be required to negotiate either improved mitigation or trade-offs with benefits • That proponent facilitate negotiations with community by establishing a mutually agreed framework for negotiating timely settlement of noise disputes with residents & other sensitive noise receptors • That rock breaking, rock hammering and other impact noise generating activities be scheduled to include respite period • The frequency & duration of respite periods should be negotiated with affected residents • That proposed construction time restrictions for noisy activities explicitly include restrictions on excavation spoil loading/unloading & transport activities • That potential night-time noise impacts from construction phase tunnelling related activities be assessed for tunnel portal areas & their environs and addressed in Representations Report • Scheduled night works should be undertaken in accordance with arrangements negotiated in advance with potentially affected residents • Noisiest activities, associated with unavoidable night works, should be undertaken before midnight • That, before proposed construction methods or times are varied, proponent negotiate a mutually acceptable settlement with affected residents and other noise sensitive receptors • That a reactive strategy for managing regenerated noise be developed in response to any significant community reaction • That the proponent prepare and implement construction noise & vibration environment management plan • That proponent arranges for processing and practical re-use of VENM and other excavation spoil generated in course of project • The proponent should also store surplus sandstone VENM not able to be re-used in tunnel project, and make it available for onselling or for use in other projects • VENM not to be disposed of in landfill • That proposed waste management plan include detail of the practical procedures to be used for classification of waste in accordance with EPA's Environmental Guidelines • That acid sulfate soil risk areas be subjected to comprehensive field testing & assessment as soon as practicable following any approval of proposal • That an Acid Sulfate Soil Management Plan is prepared

			• That dust suppression be undertaken • That comprehensive groundwater monitoring is implemented as soon as practicable to establish groundwater quality expected to be encountered during course of the project • Monitoring should identify risk areas • That stormwater re-use opportunities are explored and adopted, where practicable • Unavoidable stormwater discharges to Sydney Harbour must be managed to prevent changes in salinity levels likely to harm local marine life • That contingency plans be developed and implemented to ensure contaminated water is promptly assessed, classified and managed • Operation Phase Recommendations: • Representations Report should include outcome of a review of economic assessment to better account for threshold effects of travel time savings & induced traffic impacts • Environmental impacts of induced traffic were inadequately analysed ; some are outlined below: • Mode shift • Redistribution of traffic • Induced travel • Travel time switching from off-peak to peak • That traffic forecasts be reviewed with regard to comparatively lower traffic demand management value of electronic toll collection • Project may not deliver level of benefits projected in EIS • Air quality monitoring & analysis is considered generally appropriate and based on suitably conservative assumptions • Air emissions from tunnel ventilation stack will satisfy air quality goals, subject to its comments and recommendations concerning induced traffic impacts and measures required to mitigate these impacts
0181	NSW Heritage Office	S	• Construction should only occur on basis that no places/items of heritage significance be demolished • Not clear whether heritage items affected by proposal has been ascertained • Information related to Sewerage Pumping Station 12 is not correct. Building is listed as item of State heritage significance on State Heritage Register. Heritage Council is unable to approve total demolition of building • Approval of Heritage Council required for archaeological works, particularly along parts of William Street, in Bourke/Palmer Street area of Darling Harbour • Allowance should be made in construction scheduling for archaeological investigations • Consideration should be given to design of surface structures to ensure impacts are satisfactory in both heritage terms and visually

			• Requirements needed to ensure vibration and subsidence impacts do not have detrimental impacts on heritage items • Landscaping should have regard to heritage significance
0182	State Transit (STA)		• Improved bus operations are said to be a key objective in EIS, but other than modest time savings, few specific benefits are explored • Fig.2.3 should give date or explain that they are annualised figures • Fig.2.4 should have date of survey • Railway Square should include transfer to south and west services • In CBD deficiencies (2.5.5), no mention of difficulty imposed by one-way regime in streets adding to complexity of operations & reduced terminal space due to City projects • East-west bridge Street is probably biggest congestion point now – so congestion is not only north-south in Central Sydney • In Fig 2.13 & 2.14, services should be shown to Millers Point, and Alfred Street should not be shown as through street • Fig 2.18 discrepancy: mode share in Lower North is 43%, not 10% • Fig 2.26, route 11 should be shown in gold • In Table 4.9, no discussion of Oxford Street tunnel improvements on traffic levels on main east-west bus corridors as least as well as CCT • Signal timing cannot be changed to benefit both pedestrians and travel times • Few ideas were developed from STA strategic plan • Appropriate to list potential conflict between bus service and light rail projects • Transit buses should be exempt from tolls • Support several proposed extensions to bus lane network, however, no documented advantages or enforcement • Bus lanes may be used by taxis • Footpath widening on N/W corner of Druitt and York Streets must allow for buses to turn left • Failure to extend bus priority in congested situations weakens entire network, as will be the case eastbound on William Street at Palmer Street • Report does not address future bus stops. Wherever William Street bus stops are located, they will conflict with bicycle lanes • Two way traffic on Sussex Street would greatly improve potential for bus services to this growing area. Similar situation in King Street • Hard to imagine how potential 7% traffic growth on George Street could be accommodated

			• Reduced traffic in Liverpool & Oxford Streets gives potential for extension of bus lane hours • Impact of traffic growth on New South Head Road not adequately addressed • Bus operations require protection during construction • Determination should contain following requirements: • STA must be part of construction management plan • Treatment of bus stops in construction area must be resolved & shown on plans • Bus priority measures need to be developed in consultation with STA • Specification of bus priority measures & traffic signal adjustments to follow tunnel opening should be developed before project is released for tender • Performance measures for bus improvements should be developed for project
0183	Sydney Institute		• TAFE NSW Sydney Institute has a major college at Ultimo • Educational and cultural precinct at Ultimo is effectively isolated from pedestrian access, being totally bounded by arterial roads. Therefore supportive of tunnel proposal given the claim to provide amenity benefits • Concerned at proximity of unfiltered exhaust stack • Ultimo/Pyrmont area is projected to be major commercial, residential and entertainment zone • RTA should be encouraged to provide best possible outcome in terms of environmental sustainability of project, & its objective be to exceed Air Quality Standards • Supports concept of Cleveland/Wattle Street tunnels in order to improve amenity on Harris & Wattle Streets & reduce heavy vehicles on these streets • Immediate strategy should be implemented to improve pedestrian access and amenity • Also supportive of initiatives to achieve the following: • Improved outcomes for pedestrian and vehicle traffic related to ABC development • Pedestrian access between Institute campuses, to Broadway shops and street parking in Glebe • Improvement of local intersections • Reduction in through traffic • Improved lighting & covered access • Disabled /pram access • Improved pedestrian access to Haymarket • Also keen to see improved public transport routes to precinct • Description of Sydney Institute enclosed

0184	NRMA	S	• Submission to be publicly released by NRMA • Term "motorist" encompasses pedestrians, users of public transport, and general consumers • Extensive research has shown that the primary determinant for vehicular speed is horizontal geometry and lane width • Tunnel designers have created horizontal geometry of an "urban freeway", combined with the unusually steep grade down (10%), but have applied a 60 km/h limit • Consideration needs to be given to motorists exceeding limit during initial operation period • Govt. needs extensive speed limit signposting & publicity to warn motorists of limit • Benefits of stack is not evident to consumers • As part of EIS review process, separate exercise needed to emphasise technical benefits of stack location and performance to public • Stack should be fitted with high level of filtration treatment to ensure highly sensitive areas such as Darling Harbour are not significantly affected by vehicle emissions • At link of CCT off-ramp and ED, friction supply of pavements is considered critical. Pavements at such sites wear rapidly, and become contaminated with oil droppings. Resultant Critical (or slide-off) Speed of such slick pavements is around 38 km/h • Not considered that geometry of entry/exit ramps comply with RTA Road Design Guidelines with respect to speed differentials • Challenge remains to provide safe operational conditions for significant traffic volumes accessing Harbour Bridge from CCT • CCT should adopt an electronic tolling system. Absence of toll booth collection minimises travel time on relatively short length of roadway • Electronic tolling can be difficult for motorists from outer suburbs • Govt. should give consideration to several "cash only" booths • Alternatively, "day passes" may be made available • Issue of privacy: need to ensure rights of motorists, such as anonymity, are protected • NRMA policy is that all toll roads be provided with adequate non-tolled alternative route • EIS proposals for non-toll routes should be seen in context of ED experience. Changes to surface streets to improve amenity adversely affected reasonable alternatives to the ED • Traffic switching during construction should be adequately signposted & lit to prevent accidents • Full rehabilitation works should be budgeted in order that surface motorists are not disadvantaged in long term • Sufficient on-site, ad hoc engineering supervision needed to provide flexible and safe traffic management solutions during construction

			• Traffic modelling should incorporate a value of a motorist's perception of travel time • Expected time savings of CCT in relation to various tolling scenarios should be documented • Questions the flexibility of the "new" Sydney surface network to accommodate future developments • If successful tenderer was a privately funded operation, Govt. would need to ensure that no constraints be specified in relation to future developments, particularly public transport initiatives • Similarly, if a privately funded toll consortium was receiving lower than expected revenue, NRMA needs assurance that there would not be further capacity constraints on alternative routes to force reluctant motorists into tunnel • Special attention should be given to appropriate traffic facilities for pedestrians • Long section of William Street tunnel enclosed
0185	*NSW DEPT. OF PUBLIC WORKS*		• DPWS constantly searching for opportunities to obtain 'yellowblock" sandstone for the program of conserving the State's stock of "icon" sandstone buildings like the Art Gallery, Australian Museum etc., which, generally speaking, were constructed from sandstone quarried at Pyrmont.
0186	*Telstra*		• Telstra does not oppose proposal provide that: • Acceptable commercial terms agreed which provide for relocation of Network to be done by Telstra at RTA's cost & risk; & • Telstra's technical & safety requirements met • Anticipated that work of design & development for proposed realignment would take approx. 2-3 months & would involve: • Investigation & study of potholing previously carried out by RTA for this area, to ascertain veracity of this work • Inspection of whole area to ascertain position of jointing in cable at various manholes • Investigation with relevant Telstra departments, Council & RTA with regard to project & redesign if necessary • Investigation of all existing cables to ascertain current usage & any possible obsolescence in existing cables • Full study of cables which are in operation & their modes of operation (if necessary) • Full services search of area to ensure proposed Telstra works do not clash with other public utilities facilities which are in area at this time
0187	Woolloomooloo Residents Against Polluting Stacks	O	• Public transport option would represent major public transport proposal for Govt. at capital cost of up to approx. $275 million. • Such an interchange would realise significant public transport network benefits. • Regional traffic congestion caused by CCT would provide overall disincentive for public transport in favour of private transport • Tunnel would have minor effect on modelled travel timesaving on representative bus routes.
0188	Woolloomooloo Residents Against	O	• See above

	Polluting Stacks		
0189	Wolloomooloo Residents Against Polluting Stacks		• EIS prepared by company whose impartiality and objectivity has been questioned in both Qld & NSW parliaments • Inadequate submission period • Project focuses on movement of traffic not people • Extension of transit & bus lane network should happen now, not after future relocation of road space • Traffic congestion caused by road closures during construction • Predicted modal shift to car use and increase in vehicle kilometres travelled are contrary to Govt. policy to reduce car use • M5 East stack logic was proven to be false, however is still being used now • Construction of CCT will result in several economic impacts, which are difficult to quantify. These include disruption to businesses & noise impacts. Inclusion of these impacts would make the economic case a lot weaker • Far more would be achieved if $400 million was spent on public transport • Construction disruption would be far greater than for ED construction, as there is no park to temporarily be used for road bypass • CCT does not assist inn achieving any of the objectives outlined in *Action for Transport 2010* • CCT does not form a crucial link in RTA's broader regional road network or orbital routes • EIS section on existing transport network was based on 1998 traffic model, and did not account for ED • Claim that roads leading to CCT are at capacity is false, this only occurs in peak hours. Overall traffic on roads leading to the CBD will increase • Given that 60% of travel demand to CBD is for public transport, 60% of the $400 million should be spent on public transport • Traffic forecasts for CCT should not make the same mistakes as inaccurate ED forecasts • Public transport on George Street will suffer • Impact on Paddington and New South Head Road • Despite the wealth of overseas information covering induced traffic, the RTA is still pretending that induced traffic does not occur • Induced Traffic is likely to be limited due to the following: • Capacity constraints on approach routes; • Travel time savings are not enough to affect journeys beyond the inner western & eastern suburbs; and, • Toll avoidance. • Modelling shows CCT does have potential to attract some trips from outside the CBD, which have been avoided in the past due to congestion levels
0190	Sydney Water		• Under *Sydney Water Act 1994* (the Act), a Section 73 Compliance Certificate is S.W's. confirmation that proponent

			of a development that impacts on its water & wastewater systems. Thus S.W. has ensured that: • correctly sized water & wastewater mains are available for connection; • extensions or amplifications will be undertaken if required; • payment of S.W. water charges; and • completion of any other requirements (ie: asset relocation) identified • Essential that proponent of Tunnel complies with S.W's. Trade Waste Policy. • 3.0 Affected Sydney Water Stormwater & Wastewater Assets. See attached list • SW concerned about several issues regarding provision of adequate water services for firefighting and impact on water system of other activities associated with construction & operation of Tunnel • Responsibility of proponent to ensure that water main sizes have sufficient capacity to accommodate additional loads that will be required in event of a fire in tunnel. • Proponent will need to consult with S.W. before it proceeds with tunnelling within or near S.W. assets • Backflow prevention is also significant concern for S.W. Contact Alison Lawrie on tel. 9952 0470 • Technical Paper 12 (p5-3) of EIS states that the "... design of stormwater and wastewater systems are to meet the requirements of the Environment Protection Authority, relevant councils and other authorities". Assumed that S.W. is included as 'other authorities', but seeks confirmation that design of stormwater systems will meet S.W. requirements. • S.W. requires clarification about some unclear statements in EIS • S.W. seeks detailed timetable of the commencement, operation & conclusion of this program • S.W. requires clarification from proponent as to where wastewater will be discharged. • Section 9-42 of EIS states that "the receiving waters most likely to be affected by such discharges are Darling Harbour at Cockle Bay and Woolloomooloo Bay". S.W. seeks clarification from proponent of location of proposed discharge & discharge quantity • Tech. Paper 5 (p11) of EIS states that sediment traps "would be regularly maintained to ensure that oils and sediments are not re-entrained into the flow & transported to the pump pit". This statement raises several questions in regards to the design specifications, trap maintenance & disposal proposals, which will require resolution to the satisfaction of S.W. • S.W. will require completion of a Catchment Management Study • Adequate firefighting provisions & water service capacity will need to be undertaken • S.W. would like to discuss with RTA feasibility of constructing sewerage infrastructure along tunnel route • EPA is of view that Harbour Trunnel seepage water should be directed to sewer where it previously discharged to the harbour • S.W. will require payment of bond to Corporation

			• During construction, proponent may need to address heritage requirements • S.W. does not support choice of spotted gums as tree species proposed in EIS for landscaping purposes
0191	Sydney Light Rail Company		• Primary objectives of EIS are flawed. Reasons include: • Wording precludes in-depth, balanced consideration of alternatives, and presuppose the outcome of CCT as preferred option • Major elements of transport infrastructure cannot be assessed through set of primary objectives focussing on relatively localised area • No mention of potential impacts/ benefits outside central Sydney • Approach is contrary to best practice • Preclude potential of identifying options that serve trips to *and* across central Sydney, such as public transport options • Primary objectives should be broadened to better assess alternatives, investigate regional impacts, acknowledge importance of integrated transport, and include options serving to *and* across city • By not using available public transport models (such as Sydney Strategic Travel Mode), or not developing a suitable alternative, EIS failed to adequately assess options • Dispute traffic modelling assertion that trip characteristics of Journey to Work trips are indicative if total travel demand • EIS did not recognise strong link between transportation and land use, and so did not take advantage of opportunity to provide a solution which could advantage future land use • Table 5.7 of Technical Paper 3 is potentially very inaccurate, should not have been included in EIS because no information to support data • CCT provides limited impact on potential future light rail options. Potential light rail routes which could be established are included, with map • Before CCT is approved, Govt. should approve extension of existing light rail from Central Station to Circular Quay. This is important as improvements to north-south transit is cited as aim of CCT, and one of reasons given for delaying decision on this extension was approval of CCT • Strict limits should be set on traffic movements across central Sydney both via surface road network and cross city tunnel • If limits are approached, consent authority should be obliged to prevent limits being exceeded • Query EIS statement that there will only be small amounts of induced traffic • Risk of induced traffic is most significant potential impact. If reduction in congestion in east-west streets or north-south streets does induce traffic, CCT will bring no tangible improvements to potential light rail routes •

0192	NSW Department of Transport (DoT)		• Heaviest bus movements in Sydney are in north-south direction, on George Street, Pitt/Hunter/Castlereagh Streets, Phillip/Elizabeth Streets, Clarence Street and York Street • Important that CCT takes as much of the heavy east-west cross-town traffic off streets as possible • Greater priority needs to be given to north-south streets & buses on these streets • Elizabeth Street bus stop location could be returned to original location • Position of inbound bus stop in Druitt Street should be placed to minimise walking distance • Potential for a bus stop on Park Street between George & Elizabeth Streets • Consideration should be given to having additional bus stops on William Street • Potential for two-way Druitt Street allows for reduction in bus volumes • Intersection of York & Druitt Streets should ensure smooth traffic flows & optimum bus movements • Bus only section of Druitt Street needs careful policing • William Street may need combined cycle & bus lane • Impacts on Market Street need careful assessment • If current light rail system was extended northwards further into the CBD, could provide increased capacity for commuters & shoppers from Inner West, and an internal distribution function for people travelling north-south within CBD • Light rail extension would involve specific changes to traffic movements and bus routing, other than those mentioned in the CCT EIS. These should be discussed with DoT • May be opportunity to provide additional taxi facility in Bathurst Street heading east • Little/ no opportunity for bus stops within or directly associated with the tunnel itself. However, DoT is keen to work with RTA & City of Sydney & public transport operators to examine prospects for improved bus stops/interchanges in city, or preserve them for the future • Any changes to traffic signal phasing should not compromise pedestrian crossing times. In particular, where "scramble" crossings are in place, such as George and Park/Druitt Streets, every effort should be made to preserve signal phases • Aware of potential conflicts between cyclists and other road users • Instead of dedicated cycle lanes, sometimes may be preferable to mark one wide lane for shared use of cycles, public transport, or high occupancy vehicles. This would allow cyclists to pass buses which are pulled up, or faster vehicles to overtake slower cyclists within one lane
0193	North Sydney Council		• Council would only support the proposal if it achieved the following objectives: improve the quality of the streetscape, reduce traffic in residential areas, improve facilities and amenity for pedestrians, cyclists and residents and encourage public transport. • The proposal would increase traffic capacity for east - west motorists.

			• Upgrade streetscape at surface level for pedestrians and cyclists and public transport. • Council is concerned that investment in roads diverts much needed resources and investment away from public transport infrastructure.
0194 a)	The Honorable Richard Jones MLC Legislative Council		• Parliament has voted overwhelmingly to mandate particulate matter filtration on the M5East vent. • It will not be acceptable for the Darling Harbour vent to be built with out filtration.
0194 b)	The Honorable Richard Jones MLC Legislative Council	O	• The study does not adequately consider health effects • The EIS is inadequate as it does not consider impacts outside the CBD. • The construction and operation of the tunnel would be environmentally damaging.
0195	The Glebe Society		• Concerned about detrimental effects that this non-filtered, concentrated air pollution will have on Glebe. • Glebe is already exposed to 100,000 vehicle movements per day. The tunnel emission stack would compound Glebe's air pollution – especially with an easterly wind. • Decision not to filter would be offset by costs tot he wider community, including individual s and the health budget. • The capital cost of filtering would be partly offset by the savings from not building an exhaust stack. • The present proposal already embodies high operating costs due to the need to pump emissions from the eastern part of the tunnel to the exhaust stack at the western end. • It would be interesting to see the outcomes of a "whole of governmental approach".
0196	RAPI Royal Australian Planning Institute		• More study is needed on increased vehicular traffic, public transport alternatives, impacts on inner suburbs and real long term costs. • Potential for significant adverse impacts such as – increased traffic, noise and air pollution in localities east and western of the CBD. • There is a risk that congestion will simply be moved to other locations in nearby suburbs as drivers seek to botain access on to the arterial road system. • Benefit-Cost Analysis and traffic projections should consider long term trends, particularly in relation to incresing fuel costs and the need to meet greenhouse gas emission targets

APPENDIX B

Summary of Issues Raised at Community Meetings

Issued Raised at the Meeting arranged by the City of Sydney City Council

Wednesday, 30 May 2001, Ultimo Community Centre, Harris Street, Ultimo.

Significant Issues Raised

- Concern about portal emissions and need for clarification of when, how, why and associated impacts;
- Concern over using monitoring on Goat Island when Darling Harbour has a different air quality environment;
- Concern over lack of specific air quality data for Darling Harbour;
- Need to share air quality impacts;
- Heavy vehicles in Harris Street underestimated in EIS;
- Need for new car emission reduction technology;
- Why is stack in Darling Harbour when existing air quality at the Kings Cross end is better than that at Darling Harbour?;
- Question measurement of fine particulates; and
- Particulates less than 1 micron are not monitored;
- Inadequate public transport services;
- Impacts on local streets.

Issues Raised at the Public Meeting Arranged by Clover Moore

Tuesday 10 July 2001 – St Johns Church Hall, Victoria Street, Darlinghurst.

Clover Moore's Concerns

- release of emissions from tunnel portals (proposal modified to appease Darling Harbour businesses);
- need for filtration of ED and CCT stacks (note Kings Cross most densely populated area in Australia);
- need for light rail to be integrated into the CCT;
- cumulative impacts of ED and CCT;
- need for alternative modes and routes of transportation;
- impacts of toll avoidance on eastern suburbs;
- need for independent assessment and quick mitigation of structural damage to homes;
- use of surplus land resulting from ED and CCT;
- need for maximum achievable air quality mitigation;
- recommends DUAP condition CCT to require filtration of all other motorway stacks;
- need for overall Traffic Plan to be developed and implemented by Council in consultation with community;
- use toll to pay for tunnel ventilation; and
- need for full time 24 hour community consultation representative independent of RTA and contractors.

CCT Community Concerns

- will CCT emissions be emitted through existing stacks?;
- volume of emissions;
- emissions from induced traffic;
- relationship of study area used in EIS and actual area of affectation;
- construction of CCT stopping construction of CBD light rail;
- lack of community consultation / RTA deception in relation to ED;
- traffic calming diverts traffic problems elsewhere;
- need to consider extending area of traffic treatments if impacts extend outside of area;
- request copies of Post ED traffic studies (Clover Moore has copy – will distribute);
- concern over amalgamation of bicycle and bus lanes;
- need to provide more bicycle links as part of CCT;
- impacts of rat running and induced traffic on cyclists;
- noise impacts at tunnel portals;
- vehicles speeding within and as exiting tunnels;
- need for speed cameras at Kings Cross Tunnel portals and at Moore Park;
- traffic noise;
- can't locate stack in brochure diagram;
- need for heavy investment in public transport;
- use of competition clauses in operational contracts;
- definition of "favourable conditions" in relation to portal emissions;
- use toll to manage construction stage traffic impacts;

- need to implement operational local area traffic management measures prior to commencement of construction;
- need for full and extensive inquiry into transport needs of inner city instead of piecemeal projects;
- no more parliamentary inquiries as recommendations are not required to be considered;
- impacts of cut and cover sections;
- need for Local Area Improvement Programs;
- need for surplus land to be used for open space;
- what is the tunnel waste to be used for;
- need for 24 complaints handling with authority to stop noisy activities; and,
- feel betrayed by lack of extension to Eastern Suburbs Rail line.

Broader Community Concerns

- need for tunnel filtration;
- new Norwegian Conference Paper outcomes;
- emissions from tunnels much more detrimental to health than roadway emissions ("unique way tunnels concentrate emissions");
- involvement of Homes Air Sciences with all three CCT tenders;
- Value of community knowledge in relation to M5 project;
- emissions from portals more concentrated than stack emissions; and,
- no level of pollution acceptable.

APPENDIX C

Additional Air Quality Modelling for Alternative Stack Locations within Darling Harbour

Department of Urban Affairs and Planning
September 2001

HOLMES AIR SCIENCES

ADDITIONAL MODELLING FOR CROSS CITY TUNNEL

This brief report summarises additional modelling for the Cross City Tunnel carried out at the request of the New South Wales Environment Protection Authority (NSW EPA). The purpose of the modelling was as follows:

- To confirm that the predicted increase in tunnel traffic does not alter the conclusions of the EIS with respect to air quality impacts; and
- To undertake sensitivity testing to determine the effects of stack location, exit velocity and stack height on the impacts at the Millennium Tower and other sensitive receptors in the vicinity of the stack. The sensitivity testing was undertaken with the revised traffic numbers.

Effect of new traffic data on predicted pollutant levels

The modelling has been undertaken with new emission rates based on revised traffic numbers. From further discussions with Hyder Consulting, we have confirmed that the "congested mode" scenario refers to the estimated traffic numbers in the tunnel (as determined by the traffic modelling) assumed to be travelling in congested mode. For the same number of vehicles, total emissions are higher when the traffic is travelling in congested mode. This is not a realistic scenario but has been included to provide a level of conservatism to the modelling.

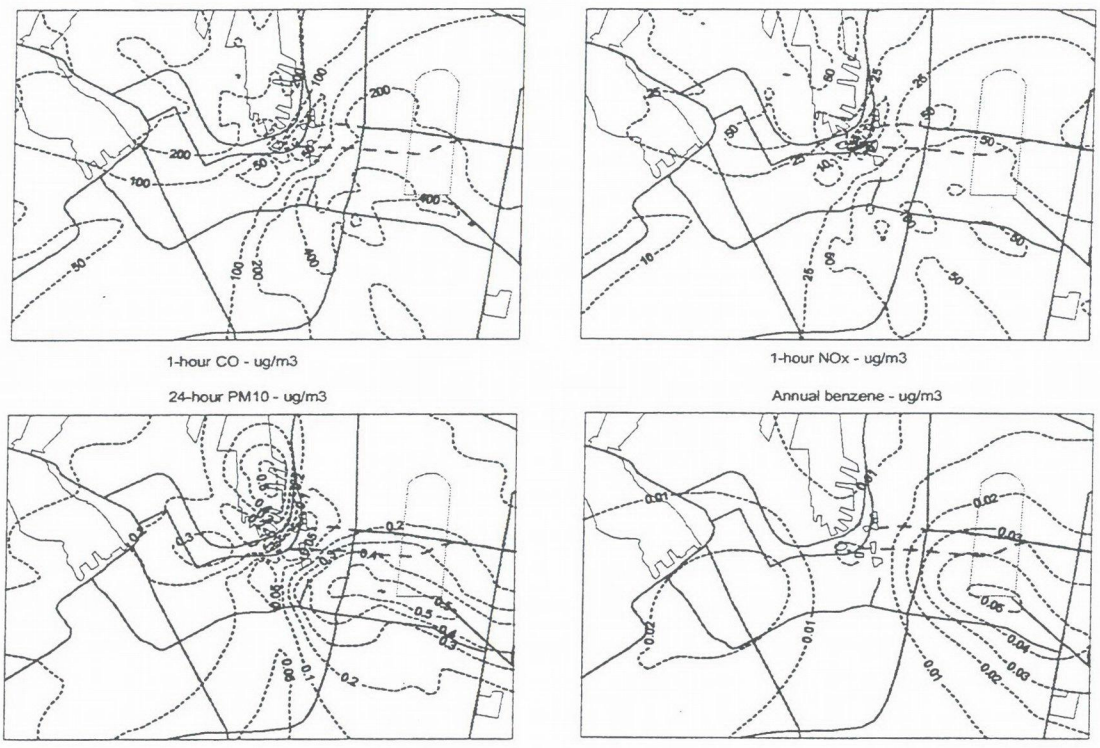
As discussed in earlier communications, this level of conservatism was sufficient to account for the increased emissions due to normal operating mode with increased traffic numbers. In the modelling presented here, a further conservative approach has again been adopted with increased emissions corresponding to the increased traffic numbers travelling in congested mode. A spreadsheet of emissions as supplied is attached in **Appendix A.** The main difference between the EIS and the revised traffic numbers is an increase in emissions during the afternoon peak hour. It has also been assumed that the peak traffic numbers in congested mode occur over four hours in the afternoon and three hours in the morning, again adding another level of conservatism to the modelling.

In summary, the assumptions on which the modelling presented in this report are based are as follows:

- Revised emissions have been calculated based on revised traffic numbers.
- The maximum traffic numbers during the respective morning and afternoon peak period have been used to calculate congested emissions, that is, emissions per vehicle were increased as if they were travelling in congested mode.
- This peak congested emission rate has been assumed to occur over three hours in the morning peak and four hours in the afternoon peak.

Presented in the figures below are predicted ground-level concentrations of CO, NO_x, PM_{10} and benzene. These results should be compared with EIS Technical Paper 16 Figures 7.3, 7.10, 7.17 and 7.66. Although the predicted levels are higher than in the EIS no significant

changes in impacts from the EIS are observed. Note that the model has been run with AUSPLUME 5.1 using the PRIME building wake algorithm.



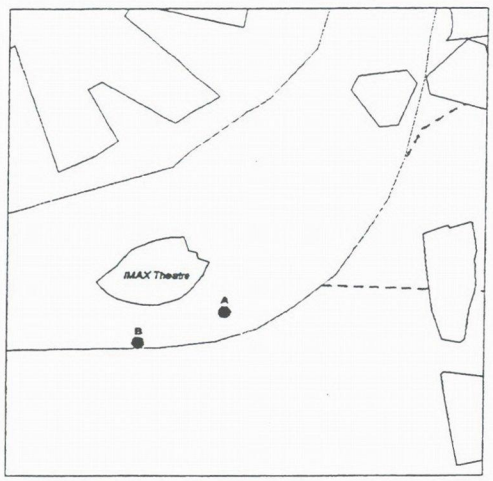
Maximum ground level concentrations - µg/m3
EIS 39 m stack location

Sensitivity testing of stack height, location and exit velocity

Further modelling was undertaken to see the effect of stack location, stack height and exit velocity. Stack location A is as presented in the EIS. Stack location B is to the south west of the location and is shown in the figure below (locations of stacks indicated by red dot). Stack heights of 39 and 44 metres were modelled. It should be noted that the respective tops of the 39 metre stack at Locations A and B are at the same AHD, that is 44 metres. The respective tops of the 44 metre stacks at both locations are at AHD 49 metres. Setting the minimum exit velocity to 10 metres per second was also considered as well as the exit velocities shown in the tables in **Appendix A.** Emissions were based on the revised traffic data with congested mode emissions over the peak hours as discussed.

Summary tables of the results of the different scenarios are attached in **Appendix A.**

In summary, the basic findings of the modelling are that moving the stack to location B provides a benefit of up to 50% for long-term averages at sensitive receptors at Millennium Towers. Increasing the stack height would also provide a benefit at this location and at the EIS location A.



Stack locations with ID

Table 1 summarises the predicted maximum concentrations of NO_2 for different stack configurations, based on revised traffic numbers, assuming 20% conversion of NO_x as was done in the EIS.

Table 1 : Effect of different stack configurations on NO_2 concentrations

Receptor	Height above ground level	Maximum NO_2 concentration, 39 m stack - top of stack 44 m (AHD) at location A $\mu g/m^3$		Maximum NO_2 concentration 44 m stack – top of stack 49 m (AHD) at location A $\mu g/m^3$		Maximum NO_2 concentration 39 m stack – top of stack 44 m (AHD) at location B $\mu g/m^3$		Maximum NO_2 concentration 44 m stack – top of stack 49 m (AHD) at location B $\mu g/m^3$	
		EIS exit velocity	10 m/s min exit velocity	7.7	10 m/s min exit velocity	EIS exit velocity	10 m/s min exit velocity	EIS exit velocity	10 m/s min exit velocity
IMAX	15 metres	8.0	1.6	21.6	0.6	7.7	3.2	1.5	1.5
IMAX	30 metres	30.8	2.0	42.9	0.6	21.6	4.0	12.7	1.5
Millennium Towers	40 metres	65.0	43.1	55.8	33.3	42.9	14.6	30.9	9.5
Millennium Towers	50 metres	103.1	79.6	90.8	63.7	55.8	52.2	50.9	36.5
Millennium Towers	60 metres	130.2	103.7	119.4	98.8	90.8	53.5	71.2	57.1
Millennium Towers	70 metres	150.0	150.0	46.4	132.3	119.4	119.4	99.3	98.6
Darling Park 2	145 metres	75.9	75.9	74.4	74.4	46.4	46.4	45.1	45.1

Results for the EIS stack location are similar to those reported in the EIS. Increasing the stack height to 44 metres (top of stack 49 metres AHD) at this location reduces all predicted concentrations at elevated receptors.

Moving the stack to location B, but keeping the same stack height as in the EIS results in decreased concentrations at all receptors compared to location A. Increasing the stack height at location B decreases the concentrations at all receptors. The benefits of setting a minimum exit velocity are not substantial at the more elevated receptors.

A comparison of predicted ground level concentrations at specific locations for stacks A and B at heights of 39 metres (top of stack 44 metres AHD) and 44 metres (top of stack 49 metres AHD) is presented in **Appendix B**.

Cancer risk

A further study has been undertaken of the aggregated cancer risks associated with stack emissions and the implications of different stack configurations on these risks. The EPA has calculated an estimated risk based on emissions of all the air toxics and calculated these values at different receptors based on EIS predictions. These are shown in **Table 2**.

Table 2 : Estimated risk based on emissions of all air toxics
(based on EIS modelling results)

Receptor height (Millennium Towers) (m)	Acetaldehyde + Formaldehyde Risk	Benzo(a)pyrene + 1,3 Butadiene Risk	Total risk
0	3.16E-07	2.24E-06	2.86E-06
40	1.34E-06	9.83E-06	1.27E-05
60	1.61E-06	1.11E-05	1.46E-05
70	1.47E-06	1.01E-05	1.31E-05

This is based on a constant exposure to the level assumed in the EIS over a 70-year period. This is a very conservative approach, as emissions are expected to decrease over this time due to improved emission control technology and stricter emission standards.

In the EIS, congested mode was not used to calculate the hydrocarbon emissions and subsequent air toxic emissions, as was done for the peak hour CO, NO_x and PM_{10} values. This is appropriate for long term averages as the peak hour congested traffic will not occur every day and will be offset by weekend and holiday traffic.

For the purposes of the current calculation in the spreadsheets, the peak hour congested emissions have been included in the modelling, and consequently higher concentrations are predicted than are likely to occur in reality. Predictions have also been carried out for non-congested mode travel at peak hours and the difference at elevated receptors is relatively small. They are summarised in **Table 3** and have been included in the risk calculation presented below.

However, regardless of the level of conservatism in this assumption or otherwise, the relative merits of the different options discussed below still hold.

Table 3 : Predicted annual average benzene concentrations with and without congested traffic assumption ($\mu g/m^3$)

Location and height above ground-level	Congested Benzene	Non-congested Benzene	%Change
IMAX at 15 m	0.0156	0.0106	-32.1
IMAX at 30 m	0.0361	0.0223	-38.2
Millennium Towers at 40 m	0.458	0.362	-21.0
Millennium Towers at 50 m	0.492	0.44	-10.6
Millennium Towers at 60 m	0.505	0.472	-6.5
Millennium Towers at 70 m	0.53	0.483	-8.9
Darling Park at 145 m	0.0413	0.0484	17.2

The following assumptions have been used to calculate the risk levels associated with exposure to emissions of air toxics from the CCT stack.

The 2006 emission rates have been assumed for the first ten years of the project. From 2016 onward the emission rates have been assumed to drop to approximately 42% of those assumed in 2006. This is based on relative emission estimates for carbon monoxide in 2006 and 2016 (see **Appendix A)** assuming that hydrocarbon emissions follow the same trend as carbon monoxide. This is a reasonable assumption. CO and HC emissions generally follow the same trend with speed, and are both reduced in a similar way by catalytic converters. Therefore the base case considered for the risk assessment is based on 50% of the predicted 2006 levels calculated as follows:

> 1/7*1+6/7*0.42, that is 10 of the 70 years (assumed for exposure to air toxics) at the 2006 emissions levels and 60 of the 70 years at the 2016 level.

In summary:

- 2006 emission rates without congested flow have been assumed for the first 10 years of the project;
- 2016 emission rates without congested flow have been assumed for the next 60 years;
- Risk levels for each air toxic compound 70 year exposure have been calculated on this basis; and
- Risk levels for all air toxics have been combined.

Modelling has been undertaken specifically for benzene. All other emissions are assumed to follow the same pattern. 70-year average concentrations of benzene at different sensitive receptors for a 39 metre stack (top of stack 44 metres AHD) at Location A are provided in column 1 of **Table 4**. Also presented are the concentrations for other air toxics, their risk levels and aggregated risk levels for all the toxics combined. Results for a stack at Location B are also presented.

Table 5 presents results for a 44 metre stack (top of stack 49 metres AHD) at location A and B. This represents the most extreme case with the lowest risk levels at the elevated receptors. In practice, because emissions will decrease over time to an extent that is not assumed in the modelling, the level of risk is likely to be at least a factor of 2 less than that shown in the Tables.

Table 4 : Revised concentrations of air toxics and associated risk factors for 39 metre stack (top of stack 44 metres AHD)

	Benzene		1-3 butadiene		Benzo (a) pyrene		Formaldehyde		Acetaldehyde		
Receptor	Concentration	Risk levels	Concentration	Risk levels	Concentration	Risk levels	Concentration	Risk levels	Concentration	Risk levels	Aggregated risk
Unit risk factor	$7.5x10^{-6}$ per µg/m^3		$2.8x10^{-4}$ per µg/m^3		8.7×10^{-5} per ng/m^3		$1.3x10^{-5}$ per µg/m^3		$2.2x10^{-6}$ per µg/m^3		
EIS stack location A											
15 m IMAX	7.80E-03	5.85E-08	9.80E-04	2.74E-07	3.06E-07	2.66E-08	3.18E-03	4.13E-08	5.76E-04	1.27E-09	3.61E-07
30 m IMAX	1.81E-02	1.36E-07	2.27E-03	6.36E-07	7.08E-07	6.16E-08	7.37E-03	9.58E-08	1.33E-03	2.93E-09	8.36E-07
40 m MT	2.29E-01	1.72E-06	2.88E-02	8.06E-06	8.99E-06	7.82E-07	9.35E-02	1.22E-06	1.69E-02	3.72E-08	1.06E-05
50 m MT	2.46E-01	1.85E-06	3.09E-02	8.65E-06	9.66E-06	8.40E-07	1.00E-01	1.30E-06	1.82E-02	4.00E-08	1.14E-05
60 m MT	2.53E-01	1.90E-06	3.17E-02	8.88E-06	9.91E-06	8.62E-07	1.03E-01	1.34E-06	1.86E-02	4.09E-08	1.17E-05
70 m MT	2.65E-01	1.99E-06	3.33E-02	9.32E-06	1.04E-05	9.05E-07	1.08E-01	1.40E-06	1.96E-02	4.31E-08	1.23E-05
145 m DP	2.07E-02	1.55E-07	2.59E-03	7.25E-07	8.11E-07	7.06E-08	8.43E-03	1.10E-07	1.52E-03	3.34E-09	9.54E-07
Stack location B											
15 m IMAX	1.01E-02	7.58E-08	1.26E-03	3.53E-07	3.94E-07	3.43E-08	4.10E-03	5.33E-08	7.42E-04	1.63E-09	4.64E-07
30 m IMAX	1.81E-02	1.36E-07	2.27E-03	6.36E-07	7.10E-07	6.18E-08	7.39E-03	9.61E-08	1.34E-03	2.95E-09	8.36E-07
40 m MT	1.17E-01	8.78E-07	1.47E-02	4.12E-06	4.59E-06	3.99E-07	4.78E-02	6.21E-07	8.63E-03	1.90E-08	5.41E-06
50 m MT	1.04E-01	7.80E-07	1.30E-02	3.64E-06	4.06E-06	3.53E-07	4.22E-02	5.49E-07	7.64E-03	1.68E-08	4.79E-06
60 m MT	1.01E-01	7.58E-07	1.27E-02	3.56E-06	3.96E-06	3.45E-07	4.12E-02	5.36E-07	7.45E-03	1.64E-08	4.67E-06
70 m MT	1.05E-01	7.88E-07	1.31E-02	3.67E-06	4.10E-06	3.57E-07	4.27E-02	5.55E-07	7.71E-03	1.70E-08	4.83E-06
145 m DP	1.25E-02	9.38E-08	1.57E-03	4.40E-07	4.91E-07	4.27E-08	5.10E-03	6.63E-08	9.22E-04	2.03E-09	5.78E-07

Table 5 : Revised concentrations of air toxics and associated risk factors for 44 metre stack (top of stack 49 metres AHD)

	Benzene		1-3 butadiene		Benzo (a) pyrene		Formaldehyde		Acetaldehyde		
Receptor	Concentration	Risk levels	Concentration	Risk levels	Concentration	Risk levels	Concentration	Risk levels	Concentration	Risk levels	Aggregated risk
EIS stack location A											
15 m IMAX	2.64E-03	1.98E-08	3.31E-04	9.27E-08	1.03E-07	9.00E-09	1.08E-03	1.40E-08	1.94E-04	4.28E-10	1.22E-07
30 m IMAX	7.20E-03	5.40E-08	9.04E-04	2.53E-07	2.83E-07	2.46E-08	2.94E-03	3.82E-08	5.31E-04	1.17E-09	3.33E-07
40 m MT	2.05E-01	1.53E-06	2.57E-02	7.19E-06	8.03E-06	6.98E-07	8.35E-02	1.09E-06	1.51E-02	3.32E-08	9.46E-06
50 m MT	2.42E-01	1.82E-06	3.04E-02	8.51E-06	9.50E-06	8.26E-07	9.88E-02	1.28E-06	1.79E-02	3.93E-08	1.12E-05
60 m MT	2.48E-01	1.86E-06	3.11E-02	8.70E-06	9.71E-06	8.45E-07	1.01E-01	1.31E-06	1.83E-02	4.02E-08	1.14E-05
70 m	2.54E-01	1.91E-06	3.19E-02	8.93E-06	9.97E-06	8.67E-07	1.04E-01	1.35E-06	1.87E-02	4.12E-08	1.17E-05
145 m DP	2.02E-02	1.52E-07	2.54E-03	7.10E-07	7.93E-07	6.90E-08	8.25E-03	1.07E-07	1.49E-03	3.28E-09	9.34E-07
Stack location B											
15 m IMAX	3.25E-03	2.44E-08	4.08E-04	1.14E-07	1.28E-07	1.11E-08	1.33E-03	1.72E-08	2.40E-04	5.28E-10	1.50E-07
30 m IMAX	6.35E-03	4.76E-08	7.98E-04	2.23E-07	2.49E-07	2.17E-08	2.59E-03	3.37E-08	4.69E-04	1.03E-09	2.94E-07
40 m MT	1.08E-01	8.06E-07	1.35E-02	3.78E-06	4.22E-06	3.67E-07	4.39E-02	5.70E-07	7.93E-03	1.75E-08	4.97E-06
50 m MT	1.06E-01	7.91E-07	1.33E-02	3.71E-06	4.14E-06	3.60E-07	4.31E-02	5.60E-07	7.78E-03	1.71E-08	4.88E-06
60 m MT	9.60E-02	7.20E-07	1.21E-02	3.38E-06	3.77E-06	3.28E-07	3.92E-02	5.09E-07	7.08E-03	1.56E-08	4.44E-06
70 m MT	9.90E-02	7.43E-07	1.24E-02	3.48E-06	3.89E-06	3.38E-07	4.04E-02	5.25E-07	7.31E-03	1.61E-08	4.58E-06
145 m DP	1.22E-02	9.15E-08	1.53E-03	4.29E-07	4.79E-07	4.17E-08	4.98E-03	6.47E-08	9.00E-04	1.98E-09	5.64E-07

Table 6 summarises the aggregated risks based on the modelled concentrations assuming new traffic data, stacks in two locations and a 39 metre stack (top of stack 44 metres AHD) versus a 44 metre stack (top of stack 49 metres AHD).

Moving the stack to Location B more than halves the risk. Raising the stack height by another 5 metres reduces the risk further.

Table 6 : Effect of different stack configurations on aggregated risk

Receptor	Height above ground level	Aggregated risk with stack at location A 39 m stack (top of stack 44 m AHD)	Aggregated risk with stack at location A 44 m stack (top of stack 49 m AHD)	Aggregated risk – with stack at location B 39 m stack (top of stack 44 m AHD)	Aggregated risk – with stack at location B 44 m stack (top of stack 49 m AHD)
Millennium Towers	40 metres	1.06E-05	9.46E-06	5.41E-06	4.97E-06
Millennium Towers	50 metres	1.14E-05	1.12E-05	4.79E-06	4.88E-06
Millennium Towers	60 metres	1.17E-05	1.14E-05	4.67E-06	4.44E-06
Millennium Towers	70 metres	1.23E-05	1.17E-05	4.83E-06	4.58E-06

It is important to provide a context for these estimated risks. The predicted levels of benzene (0.5 $\mu g/m^3$) at the top of the Millennium Towers due to stack emissions are about 10% of the average benzene levels measured by the EPA throughout Sydney (4 $\mu g/m^3$) and about 6% of average levels at the EPA CBD site (8 $\mu g/m^3$) (EPA, 1998). The mix of air toxics in emissions from the CCT stack would be similar to the mix of emissions from typical city roads and average arterial roads/highway through Sydney, therefore the other ambient pollutant levels should follow (approximately) the benzene levels measured by the EPA. It follows from this that the additional risk to the residents at the top of the Millennium Tower due to the CCT stack would be about 10% of the average risk that most of Sydney is exposed to from air toxics and about 6 % of the risks for residents at ground level in the CBD.

REFERENCES

EPA (1998)
"Pilot Air Toxics Project, Technical Report" ISBN 0 7310 3885 1, EPA 98/21.

APPENDIX A
EFFECT OF DIFFERENT STACK CONFIGURATIONS ON PREDICTED CONCENTRATIONS

Effect of different stack configurations on predicted concentrations

Annual average benzene concentration (µg/m³)

exit velocity	EIS exit velocity	EIS exit velocity	EIS exit velocity	EIS exit velocity	min 10m/s exit velocity	min 10m/s exit velocity	min 10m/s exit velocity	min 10m/s exit velocity
Stack location	A	A	B	B	A	A	B	B
Stack height (AHD)	39 (44)	44 (49)	39 (44)	44 (49)	39 (44)	44 (49)	39 (44)	44 (49)
IMAX 15 m	1.6E-02	5.3E-03	2.0E-02	6.5E-03	5.5E-03	1.0E-03	5.2E-03	1.1E-03
IMAX 30 m	3.6E-02	1.4E-02	3.6E-02	1.3E-02	5.7E-03	1.0E-03	5.5E-03	1.1E-03
Mill 40 m	4.6E-01	4.1E-01	2.3E-01	2.2E-01	3.1E-01	2.3E-01	5.2E-02	3.4E-02
Mill 50 m	4.9E-01	4.8E-01	2.1E-01	2.1E-01	5.3E-01	4.5E-01	1.4E-01	9.9E-02
Mill 60 m	5.1E-01	5.0E-01	2.0E-01	1.9E-01	6.7E-01	6.2E-01	3.0E-01	2.3E-01
Mill 70 m	5.3E-01	5.1E-01	2.1E-01	2.0E-01	6.8E-01	6.6E-01	3.9E-01	3.6E-01
Darling Park 145 m	4.1E-02	4.0E-02	2.5E-02	2.4E-02	3.8E-02	3.6E-02	2.4E-02	2.4E-02

1-hour maximum total NO_x concentration (µg/m³)

exit velocity	EIS exit velocity	EIS exit velocity	EIS exit velocity	EIS exit velocity	min 10m/s exit velocity	min 10m/s exit velocity	min 10m/s exit velocity	min 10m/s exit velocity
Stack location	A	A	B	B	A	A	B	B
Stack height (AHD)	39 (44)	44 (49)	39 (44)	44 (49)	39 (44)	44 (49)	39 (44)	44 (49)
IMAX 15 m	4.0E+01	4.2E+00	3.8E+01	7.7E+00	7.8E+00	2.9E+00	1.6E+01	7.7E+00
IMAX 30 m	1.5E+02	7.1E+01	1.1E+02	6.4E+01	9.9E+00	2.9E+00	2.0E+01	7.7E+00
Mill 40 m	3.3E+02	2.6E+02	2.1E+02	1.5E+02	2.2E+02	1.7E+02	7.3E+01	4.7E+01
Mill 50 m	5.2E+02	4.2E+02	2.8E+02	2.5E+02	4.0E+02	3.2E+02	2.6E+02	1.8E+02
Mill 60 m	6.5E+02	6.2E+02	4.5E+02	3.6E+02	5.2E+02	4.9E+02	2.7E+02	2.9E+02
Mill 70 m	7.5E+02	6.6E+02	6.0E+02	5.0E+02	7.5E+02	6.6E+02	6.0E+02	4.9E+02
Darling Park 145 m	3.8E+02	3.7E+02	2.3E+02	2.3E+02	3.8E+02	3.7E+02	2.3E+02	2.3E+02

24-hour maximum PM_{10} concentration (µg/m³)

exit velocity	EIS exit velocity	EIS exit velocity	EIS exit velocity	EIS exit velocity	min 10m/s exit velocity	min 10m/s exit velocity	min 10m/s exit velocity	min 10m/s exit velocity
Stack location	A	A	B	B	A	A	B	B
Stack height (AHD)	39 (44)	44 (49)	39 (44)	44 (49)	39 (44)	44 (49)	39 (44)	44 (49)
IMAX 15 m	1.7E-01	1.7E-02	1.9E-01	6.9E-02	5.4E-02	1.5E-02	1.5E-01	4.8E-02
IMAX 30 m	4.6E-01	2.0E-01	2.0E-01	8.8E-02	5.4E-02	1.5E-02	1.6E-01	4.8E-02
Mill 40 m	2.1E+00	1.8E+00	8.6E-01	6.7E-01	1.9E+00	1.5E+00	4.6E-01	3.1E-01
Mill 50 m	3.2E+00	2.7E+00	1.1E+00	9.8E-01	3.4E+00	2.7E+00	9.8E-01	7.3E-01
Mill 60 m	5.3E+00	4.6E+00	1.4E+00	1.2E+00	5.4E+00	4.8E+00	1.5E+00	1.3E+00
Mill 70 m	6.7E+00	6.5E+00	2.0E+00	1.8E+00	6.8E+00	6.6E+00	2.2E+00	1.9E+00
Darling Park 145 m	7.0E-01	7.5E-01	3.8E-01	3.8E-01	7.0E-01	7.5E-01	3.5E-01	3.3E-01

APPENDIX B
PREDICTED GROUND LEVEL CONCENTRATIONS
AT SPECIFIC RECEPTORS
FOR DIFFERENT STACK LOCATIONS AND HEIGHTS

39 m stack in location A
(top of stack 44 m AHD)

Table 10.11 **Predicted maximum ground-level concentrations due to ventilation stack emissions at selected site within and adjacent to the Darling Harbour Precinct (2006)**

	Predicted maximum concentrations due to stack emissions					
	Carbon monoxide (µg/m³)		Nitrogen dioxide (µg/m³)		Particulate matter (PM_{10} in µg/m³)	
Location	Concentration	% of goal	Concentration	% of goal	Concentration	% of goal
Day Street	0.05	0.2	2	0.8	0.06	0.1
Harbourside - Darling Harbour	0.19	0.6	7	2.9	0.16	0.3
Paddys Markets	0.34	1.1	14	5.7	0.31	0.6
Bridge Street/ Glebe Pt Rd, Glebe	0.04	0.1	2	0.8	0.10	0.2
William Henry/Harris Street, Pyrmont	0.09	0.3	3	1.2	0.12	0.2
Harris Street/Fig Street, Ultimo	0.13	0.4	5	2.0	0.24	0.5
King Street Wharf – Aquarium	0.27	0.9	11	4.5	0.47	0.9
Air Quality Goal	31 (1-hour maximum)		245 (1-hour maximum)		50 (24-hour maximum)	

Table 10.12 **Predicted annual average ground-level concentrations due to ventilation stack emissions at selected site within and adjacent to the Darling Harbour Precinct (2006)**

	Predicted annual average concentrations due to stack emissions					
	Carbon monoxide (µg/m³)		Nitrogen dioxide (µg/m³)		Particulate matter (PM_{10} in µg/m³)	
Location	Concentration	% of goal	Concentration	% of goal	Concentration	% of goal
Day Street	0.001	NA	0.13	0.2	0.00	0.0
Harbourside - Darling Harbour	0.003	NA	0.35	0.6	0.02	0.1
Paddys Markets	0.003	NA	0.36	0.6	0.01	0.0
Bridge Street/ Glebe Pt Rd, Glebe	0.003	NA	0.37	0.6	0.02	0.1
William Henry/Harris Street, Pyrmont	0.002	NA	0.27	0.5	0.01	0.0
Harris Street/Fig Street, Ultimo	0.006	NA	0.75	1.3	0.03	0.1
King Street Wharf – Aquarium	0.006	NA	0.85	1.4	0.04	0.1
Air Quality Goal	No long term goal		60		30	

Emission Data INCLUDING BACKGROUND LEVELS (Normal Operation) **Year 2016**

Hours starting	Exhaust Stack Air Flows m^3/s	Exhaust Stack Cross Section Area (m^2)	Exhaust Stack Velocities (m/s)	Total CO g/s	Total NO_x g/s	Total PM_{10} G/s
0	56	22.50	2.50	1.30	0.26	0.0073
1	56	22.50	2.50	1.37	0.28	0.0083
2	56	22.50	2.50	1.55	0.35	0.0099
3	56	22.50	2.50	2.04	0.52	0.0140
4	77	22.50	3.43	2.85	0.73	0.0195
5	130	22.50	5.76	4.78	1.22	0.0323
6	207	22.50	9.18	7.62	1.94	0.0624
AM Peak 0700	339	22.50	15.05	11.62	3.16	0.0765
8	326	22.50	14.48	10.52	3.16	0.0611
9	300	22.50	13.31	9.76	3.11	0.0645
10	299	22.50	13.29	9.74	3.11	0.0702
11	304	22.50	14.85	10.21	3.14	0.0774
12	275	22.50	12.24	9.05	2.20	0.0721
13	274	22.50	12.16	8.99	2.19	0.0722
14	290	22.50	12.89	9.53	2.32	0.0705
15	332	22.50	14.74	10.90	2.65	0.0737
16	396	22.50	17.61	13.02	3.17	0.0794
PM Peak 1700	350	22.50	15.54	12.90	3.28	0.0699
18	294	22.50	13.08	10.86	2.77	0.0558
19	197	22.50	8.75	7.27	1.85	0.0295
20	132	22.50	5.89	4.88	1.24	0.0156
21	97	22.50	4.32	3.58	0.91	0.0117
22	70	22.50	3.09	2.56	0.65	0.0078
23	56	22.50	2.50	1.72	0.40	0.0051

NOTE: (1) Background Concentrations agreed with AHS 17/3/00 are:
CO = 0.012 g/m3
NOx = 0.00075 g/m3
PM10 = 0.000045 g/m3

NOTE (2) Limits on exhaust velocites as agreed with Kerry Holmes 17/3/00:
Max Exhaust Stack Velocity, 20m/s

Emission Data INCLUDING BACKGROUND LEVELS (Congested Operation) **Year 2016**

Hours starting	Exhaust Stack Air Flows m^3/s	Exhaust Stack Cross Section Area (m^2)	Exhaust Stack Velocities (m/s)	Total CO g/s	Total NO_x g/s	Total PM_{10} g/s
0						
1						
2						
3						
4						
5						
6	352	22.50	15.67	14.91	4.38	0.1462
AM Peak 0700	352	22.50	15.67	14.91	4.38	0.1462
8	352	22.50	15.67	14.91	4.38	0.1462
9						
10						
11						
12						
13						
14						
15	351	22.50	15.62	17.44	4.34	0.1367
16	351	22.50	15.62	17.44	4.34	0.1367
PM Peak 1700	351	22.50	15.62	17.44	4.34	0.1367
18	351	22.50	15.62	17.44	4.34	0.1367
19						
20						
21						
22						
23						

NOTE: (1) Background Concentrations agreed with AHS 17/3/00 are:
CO = 0.012 g/m^3
NO_x = 0.00075 g/m^3
PM_{10} = 0.000045 g/m^3

NOTE: (2) Limits on exhaust velocities as agreed with Kerry Holmes 17/3/00:
Max Exhaust Stack Velocity, 20m/s
Min Exhaust Stack Velocity, 2.5m/s

Emission Data INCLUDING BACKGROUND LEVELS (Normal Operation) **Opening Year**

Hours starting	Exhaust Stack Air Flows m^3/s	Exhaust Stack Cross Section Area (m^2)	Exhaust Stack Velocities (m/s)	Total CO g/s	Total Nox g/s	Total PM_{10} g/s
0	56	22.50	2.50	2.23	0.40	0.0110
1	56	22.50	2.50	2.52	0.46	0.0133
2	56	22.50	2.50	2.97	0.57	0.0163
3	63	22.50	2.81	4.33	0.87	0.0242
4	89	22.50	3.97	6.12	1.22	0.0340
5	151	22.50	6.70	10.33	2.07	0.0563
6	242	22.50	10.74	16.56	3.31	0.1060
AM Peak 0700	416	22.50	18.47	24.11	5.17	0.1268
8	384	22.50	17.09	21.58	5.02	0.1013
9	353	22.50	15.70	20.04	4.92	0.1081
10	353	22.50	15.70	20.04	4.92	0.1185
11	378	22.50	16.80	20.47	4.95	0.1617
12	316	22.50	14.04	19.08	3.74	0.1254
13	314	22.50	13.93	18.93	3.71	0.1255
14	332	22.50	14.78	20.07	3.94	0.1233
15	380	22.50	16.90	22.96	4.50	0.1271
16	454	22.50	20.17	27.40	5.37	0.1338
PM Peak 1700	420	22.50	18.65	28.74	5.75	0.1238
18	345	22.50	15.31	23.61	4.72	0.0953
19	231	22.50	10.25	15.80	3.16	0.0492
20	155	22.50	6.89	10.63	2.13	0.0254
21	114	22.50	5.09	7.84	1.57	0.0191
22	82	22.50	3.66	5.65	1.13	0.0125
23	56	22.50	2.50	3.49	0.69	0.0075

NOTE: (1) Background Concentrations agreed with AHS 17/3/00 are:
CO = 0.012 g/m3
NOx = 0.00075 g/m3
PM10 = 0.000045 g/m3

NOTE (2) Limits on exhaust velocities as agreed with Kerry Holmes 17/3/00:
Max Exhaust Stack Velocity, 20m/s

Emission Data INCLUDING BACKGROUND LEVELS (Congested Operation) **Opening Year**

Hours starting	Exhaust Stack Air Flows m^3/s	Exhaust Stack Cross Section Area (m^2)	Exhaust Stack Velocities (m/s)	Total CO g/s	Total NO_x g/s	Total PM_{10} g/s
0						
1						
2						
3						
4						
5						
6	448	22.50	19.89	30.99	6.59	0.2494
AM Peak 0700	448	22.50	19.89	30.99	6.59	0.2494
8	448	22.50	19.89	30.99	6.59	0.2494
9						
10						
11						
12						
13						
14						
15	461	22.50	20.51	41.07	7.29	0.2616
16	461	22.50	20.51	41.07	7.29	0.2616
PM Peak 1700	461	22.50	20.51	41.07	7.29	0.2616
18	461	22.50	20.51	41.07	7.29	0.2616
19						
20						
21						
22						

NOTE: (1) Background Concentrations agreed with AHS 17/3/00 are:
CO = 0.012 g/m3
NOx = 0.00075 g/m3
PM10 = 0.000045 g/m3

44 m stack in location A
(top of stack 49 m AHD)

Table 10.11 **Predicted maximum ground-level concentrations due to ventilation stack emissions at selected site within and adjacent to the Darling Harbour Precinct (2006)**

	Predicted maximum concentrations due to stack emissions					
	Carbon monoxide (mg/m³)		Nitrogen dioxide (µg/m³)		Particulate matter (PM_{10} µg/m³)	
Location	Concentration	% of goal	Concentration	% of goal	Concentration	% of goal
Day Street	0.04	0.1	2	0.8	0.02	0.0
Harbourside – Darling harbour	0.13	0.4	5	2.0	0.13	0.3
Paddys Markets	0.26	0.8	10	4.1	0.29	0.6
Bridge Street/ Glebe Pt Rd, Glebe	0.04	0.1	2	0.8	0.09	0.2
William Henry/Harris Street, Pyrmont	0.08	0.3	3	1.2	0.09	0.2
Harris Street/Fig Street, Ultimo	0.09	0.3	3	1.2	0.19	0.4
King Street Wharf – Aquarium	0.18	0.6	7	2.9	0.38	0.8
Air Quality Goal	31 (1-hour maximum)		245 (1-hour maximum)		50 (24-hour maximum)	

Table 10.12 **Predicted annual average ground-level concentrations due to ventilation stack emissions at selected site within and adjacent to the Darling Harbour Precinct (2006)**

	Predicted annual average concentrations due to stack emissions					
	Carbon monoxide (mg/m³)		Nitrogen dioxide (µg/m³)		Particulate matter (PM_{10} µg/m³)	
Location	Concentration	% of goal	Concentration	% of goal	Concentration	% of goal
Day Street	0.000	NA	0.04	0.1	0.00	0.0
Harbourside - Darling harbour	0.002	NA	0.27	0.5	0.01	0.0
Paddys Markets	0.002	NA	0.32	0.5	0.01	0.0
Bridge Street/ Glebe Pt Rd, Glebe	0.003	NA	0.34	0.6	0.02	0.1
William Henry/Harris Street, Pyrmont	0.002	NA	0.22	0.4	0.01	0.0
Harris Street/Fig Street, Ultimo	0.005	NA	0.60	1.0	0.03	0.1
King Street Wharf – Aquarium	0.005	NA	0.68	1.1	0.03	0.1
Air Quality Goal	No long term goal		60		30	

39 m stack in location B
(top of stack 44 m AHD)

Table 10.11 **Predicted maximum ground-level concentrations due to ventilation stack emissions at selected site within and adjacent to the Darling Harbour Precinct (2006)**

	Predicted maximum concentrations due to stack emissions					
	Carbon monoxide (mg/m³)		Nitrogen dioxide (pphm)		Particulate matter (PM$_{10}$ in µg/m³)	
Location	Concentration	% of goal	Concentration	% of goal	Concentration	% of goal
Day Street	0.02	0.1	1	0.4	0.02	0.0
Harbourside – Darling harbour	0.19	0.6	7	2.9	0.29	0.6
Paddys Markets	0.34	1.1	14	5.7	0.33	0.7
Bridge Street/ Glebe Pt Rd, Glebe	0.06	0.2	2	0.8	0.10	0.2
William Henry/Harris Street, Pyrmont	0.37	1.2	15	6.1	0.27	0.5
Harris Street/Fig Street, Ultimo	0.06	0.2	3	1.2	0.13	0.3
King Street Wharf – Aquarium	0.21	0.7	8	3.3	0.39	0.8
Air Quality Goal	31 (1-hour maximum)		245 (1-hour maximum)		50 (24-hour maximum)	

Table 10.12 **Predicted annual average ground-level concentrations due to ventilation stack emissions at selected site within and adjacent to the Darling Harbour Precinct (2006)**

	Predicted annual average concentrations due to stack emissions					
	Carbon monoxide (mg/m³)		Nitrogen dioxide (pphm)		Particulate matter (PM$_{10}$ in µg/m³)	
Location	Concentration	% of goal	Concentration	% of goal	Concentration	% of goal
Day Street	0.000	NA	0.04	0.1	0.00	0.0
Harbourside – Darling harbour	0.004	NA	0.48	0.8	0.02	0.1
Paddys Markets	0.003	NA	0.42	0.7	0.02	0.1
Bridge Street/ Glebe Pt Rd, Glebe	0.003	NA	0.40	0.7	0.02	0.1
William Henry/Harris Street, Pyrmont	0.004	NA	0.54	0.9	0.02	0.1
Harris Street/Fig Street, Ultimo	0.004	NA	0.52	0.9	0.02	0.1
King Street Wharf – Aquarium	0.006	NA	0.73	1.2	0.03	0.1
Air Quality Goal	No long term goal		60		30	

44 m stack in location B
(top of stack 49 m AHD)

Table 10.11 **Predicted maximum ground-level concentrations due to ventilation stack emissions at selected site within and adjacent to the Darling Harbour Precinct (2006)**

	Predicted maximum concentrations due to stack emissions					
	Carbon monoxide (mg/m³)		Nitrogen dioxide (µg/m³)		Particulate matter (PM_{10} in µg/m³)	
Location	Concentration	% of goal	Concentration	% of goal	Concentration	% of goal
Day Street	0.02	0.1	1	0.4	0.01	0.0
Harbourside - Darling harbour	0.14	0.5	5	2.0	0.22	0.4
Paddys Markets	0.27	0.9	11	4.5	0.3	0.6
Bridge Street/ Glebe Pt Rd, Glebe	0.06	0.2	2	0.8	0.09	0.2
William Henry/Harris Street, Pyrmont	0.26	0.8	10	4.1	0.23	0.5
Harris Street/Fig Street, Ultimo	0.05	0.2	2	0.8	0.1	0.2
King Street Wharf – Aquarium	0.15	0.5	6	2.4	0.34	0.7
Air Quality Goal	31 (1-hour maximum)		245 (1-hour maximum)		50 (24-hour maximum)	

Table 10.12 **Predicted annual average ground-level concentrations due to ventilation stack emissions at selected site within and adjacent to the Darling Harbour Precinct (2006)**

	Predicted annual average concentrations due to stack emissions					
	Carbon monoxide (mg/m³)		Nitrogen dioxide (µg/m³)		Particulate matter (PM_{10} in µg/m³)	
Location	Concentration	% of goal	Concentration	% of goal	Concentration	% of goal
Day Street	0	NA	0.02	0.0	0	0.0
Harbourside - Darling harbour	0.003	NA	0.36	0.6	0.02	0.1
Paddys Markets	0.003	NA	0.37	0.6	0.02	0.1
Bridge Street/ Glebe Pt Rd, Glebe	0.003	NA	0.37	0.6	0.02	0.1
William Henry/Harris Street, Pyrmont	0.003	NA	0.44	0.7	0.02	0.1
Harris Street/Fig Street, Ultimo	0.003	NA	0.42	0.7	0.02	0.1
King Street Wharf – Aquarium	0.005	NA	0.61	1.0	0.03	0.1
Air Quality Goal	No long term goal		60		30	

APPENDIX D

EPA's Submission on the Representations Report

Our Reference : SR192/06;SRF4685
Contact : Penny Finlay 9995 6843

NSW EPA

Sydney Region

Mr M Hather
Department of Urban Affairs and Planning
GPO BOX 3927
SYDNEY NSW 2001

Dear Mr Hather

CROSS CITY TUNNEL REPRESENTATIONS REPORT

The Environment Protection Authority has received a copy of the Roads and Traffic Authority's report regarding representations to the Cross City Tunnel Environmental Impact Statement (EIS) as well as copies of submissions regarding the EIS. Further to our communication on issues related to this project, the EPA provides the following comments.

The EPA understands that with the information provided the Department intends to draft conditions for the Minister's approval under Part 5 of the Environmental Planning and Assessment Act 1979.

The EPA's principal concerns in relation to the construction phase are noise, dust and water quality impacts. Generally, the EPA considers that the environmental impacts associated with the construction are manageable to acceptable levels provided the appropriate controls and mitigation measures are undertaken. Consequently the EPA has determined that it would be able to issue an environment protection licence for the construction of the proposed motorway with conditions to address these issues, should the project be approved.

Local and regional air quality, road traffic noise and water quality impacts constitute the EPA's principal environmental concerns in relation to operation of the motorway. The attached comments expand on the EPA's review of the Representations Report.

If you would like to discuss any of the comments, please do not hesitate to contact Michael Crowley on 9995 6804.

Yours sincerely

4/9/01

ROSS CARTER
Executive Director Sydney Region
for Director-General

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ENVIRONMENT PROTECTION AUTHORITY COMMENTS

CROSS CITY TUNNEL REPRESENTATIONS REPORT

1. INTRODUCTION

These comments and recommendations should be read in the context of the EPA's earlier representations on the project EIS.

The construction and operational phases are dealt with separately.

Except where stated otherwise, any reference to an 'item' means an item listed in Table 8.1, pages 357 to 392 of Volume 1, of the Cross City Tunnel Representations Report.

2. CONSTRUCTION PHASE

Noise, spoil and water quality management issues remain significant sources of environmental concern with respect to the project.

2.1 environmental performance monitoring

Item 1.3 to 1.5 outlines the RTA's proposed environmental performance monitoring and auditing regime. The Proponent should commit to establishing independent monitoring and reporting of environmental performance against EIS commitments (as amended by consent conditions and environment protection licence conditions) as part of the project's management decision-making process. Environmental performance reporting needs to be linked to the community involvement program outlined in the Representations Report.

2.2 noise and vibration

2.2.1 Additional Ambient Noise Monitoring

Additional ambient noise monitoring is required to be undertaken in the eastern and central precincts, to ensure that post-Eastern Distributor baseline conditions are known (see the EPA's EIS recommendation 2.2).

The report titled "Cross City Tunnel Supplementary EIS Studies Construction Noise and Vibration Construction Work Sites" dated 3 April, 2001, states that additional noise monitoring has been carried out and will be documented in a subsequent report.

The RTA have undertaken to do this work however the EPA has not yet received ambient noise monitoring data. The EPA will require results of additional background noise monitoring prior to application for an environment protection licence.

2.2.2 General Noise and Vibration Management

Noise and vibration mitigation measures detailed in EIS Technical Paper No.18, the Representations Report and the report titled "Cross City Tunnel Supplementary EIS Studies Construction Noise and Vibration Construction Work Sites" dated 3 April, 2001, need to be incorporated into the consent conditions. All noise and vibration performance monitoring needs to be undertaken at the boundary of the most affected premises. The most affected premises means those most affected residential premises or such other sensitive receptor's premises as may be nominated by an authorised officer of the EPA having regard to the objective of achieving a reasonable acoustic environment.

2.2.3 Some Physical Mitigation Measures

Noise impacts from the construction work sites have been assessed in the report provided as Appendix 17 of the Representations Report. The report recommends mitigation and management practices that should be included in any consent for the project.

Noise and vibration management must be supplemented by industry best practice physical noise mitigation measures. However, some of the measures proposed in items 4.1 and 4.2 (including line of sight noise barriers) are likely to fall short of industry best practice and community expectations of a reasonable acoustic environment.

Specific attention must be given to the development of effective mitigation measures at tunnel access points during construction and fit out. Tunnel excavation spoil dumps must be managed to ensure that dust and noise are minimised. An example of industry best practice is the containment of spoil within the cavern of the Northside Storage Tunnel at Tunks Park ensuring spoil movements were only required during normal working hours.

2.2.4 Construction Noise Goals

The Proponent has incorrectly interpreted the EPA's construction noise goals. Throughout the report, the Proponent has assumed that construction noise impacts can exceed the background noise level by up to 20 dB(A) for a four week period, 10 dB(A) for a 26 week period and 5 dB(A) thereafter. The construction noise goals are determined based on the total duration of the project. For example, if the project duration is scheduled for 36 weeks, the appropriate construction noise goal is background plus 5 dB(A), for the entire duration. The only exception may be where particular residents are exposed to construction noise for short periods of time. For example, constructing a long section of freeway in a rural area may result in one set of residents being exposed to construction noise for a period of 10 weeks only. However, the total project duration may be more than 26 weeks. In this situation the goal may be background plus 10 dB(A) at these particular residents.

The EIS indicates that the majority of residents or other noise sensitive receivers will be potentially affected for a period exceeding 26 weeks. Therefore, the appropriate construction noise goal is background plus 5 dB(A). It is important that the Proponent use this lower goal as its target for assessing feasible and reasonable noise mitigation options.

The goals have been misinterpreted despite receiving the same EPA advice during the EIS assessment process. The consent conditions need to refer the Proponent to the EPA's construction noise guidelines and require the Proponent to manage construction noise with reference to the level of background plus 5 dB(A). The construction noise goal for activities that generate a noise having an impulsive or tonal characteristic, would be the local ambient noise level.

Further, where the Proponent considers that due to the circumstances of the case, proposed works are likely to generate noise levels above the relevant construction noise goal the Proponent must satisfy the EPA beforehand that:

(i) all practicable measures, including adopting the least noisy available construction methods, and equipment, would be used; and
(ii) additional systems compensatory measures (example: respite times) have been successfully negotiated with affected residents and other sensitive receptors.

2.2.5 Unacceptable Residual Noise Impacts

The Proponent's intended approach to address unacceptable impacts has not been clearly stated. However, it appears that the Proponent intends to rely upon management practices, regular monitoring and community consultation. The Proponent should develop a complaint management procedure that can resolve noise complaints on a 24 hour basis.

Whilst the proposed approach is recognised as practical and effective for most situations, there may be occasions where a formalised structure for addressing excessive impacts is beneficial. This will require the Proponent to deal with the matter by negotiation with affected parties and the complaint management procedure should provide for this. Specifically the procedure should provide a mechanism for the negotiation of either improved mitigation or trade-offs with benefits, as recommended in Section 8: Negotiation process of the New South Wales Industrial Noise Policy.

2.2.6 Sheet Piling and Other Impulsive Noise Sources

The Representations Report outlines practices for managing noise from sheet piling activities. One such practice is to restrict sheet piling to 8am to 12pm and 2pm to 5pm. Those restrictions are proposed to be supplemented by a minimum one hour respite period after periods of up to three hours of diesel or drop hammer sheet piling.

It is EPA experience that residents and other sensitive noise receptors would consider rock hammering, impulsive noise generated during tunnel fitout and other activities that generate impulsive noise, just as annoying as sheet piling. Therefore, sheet piling time restrictions and respite periods must apply to all activities that generate significant impact noise. The frequency and duration of respite periods must be negotiated with all affected residents and other noise sensitive receptors.

2.2.7 Time Restrictions

The Representations Report appears to adopt time restrictions for construction activities including spoil loading / unloading and transport activities.

The third dot point to item 4.2.3 proposes that surface construction activities can be undertaken, subject to EPA approval, outside the restricted construction hours if the work "would significantly delay traffic or cause traffic management problems if undertaken during the permitted hours." However, project surface works (example: William Street) are likely to cause significant traffic delays and traffic management problems throughout the construction phase. Accordingly, extended hours of operation justified merely on the basis of traffic delays or problems is considered too broad and all encompassing.

However, the EPA acknowledges that essential traffic re-routing works for the purposes of site establishment and road commissioning would be required to be undertaken outside normal surface construction times. The Representations Report also states that when night time work is required, the RTA will ensure that contractors carry out noisy work before midnight.

Proposed construction time restrictions must explicitly encompass restrictions on excavation spoil loading/unloading and transport activities. The RTA should be required to plan traffic management to minimise surface work outside normal construction times due to "work which would significantly delay traffic or cause traffic management problems if undertaken during permissible hours". The EPA would only approve such works after RTA has explored all possible alternatives for traffic management. Scheduled night works (example: establishment and commissioning works) must

only be undertaken in accordance with arrangements negotiated in advance with potentially affected residents.

2.2.8 Vibration and Regenerated Noise

It is EPA experience with similar projects that vibration and regenerated noise impacts are a major source of annoyance to residents and other sensitive noise receptors. The Proponent must develop a responsive strategy for managing regenerated noise, including measures to restrict activities that have unacceptable impacts on residents or other sensitive receptors.

2.2.9 Additional Site Compound

The proposed additional site compound and relocated tunnel control centre are likely to have a significant noise impact on surrounding residents, particularly as it is proposed to operate on a 24 hour basis at this site. The Proponent would be aware that Eastern Distributor construction activities have sensitised residents in this area to noise and other construction impacts.

Accordingly, the proposed variations to the EIS must be the subject of a detailed assessment of the nature and scope of predicted noise impacts and the mitigation measures proposed in the light of those predicted impacts. The proposed public address (Table 7.3.22 page 337) or any other amplified communication system should be explicitly addressed in this assessment.

Section 7.3.6 of the Representations Report proposes that the tunnel control centre be relocated from site 4 to site 3A. The noise mitigation benefit of constructing the control centre during the site establishment phase and using it as the site office throughout the construction phase of the project should also be considered.

Section 7.3.11 of the Representations Report proposes extensions to the existing noise barrier wall at the boundary of the Eastern Distributor on-load ramp from Bourke Street. The construction of these extensions could also be completed as part of the site establishment phase of the project.

2.2.10 Blasting

The EPA recommends that any blasting be undertaken in accordance with a blasting management strategy prepared, submitted to and approved by the EPA and the DUAP. The Australian and New Zealand Environment and Conservation Council (ANZECC) guidelines "Technical Basis for Guidelines to Minimise Annoyance due to Blasting Overpressure and Ground Vibration" must be taken into account when preparing the strategy. A strategy for blasting should include but not be limited to:

a) appropriate justification that blasting is required,
(b) identification of any potentially affected noise sensitive sites, including heritage buildings.
(c) establishment of appropriate criteria for blast over pressure and ground vibration levels at each category of noise sensitive site,
(d) determination of potential impacts from the blasting,
(e) best management practices, and
(f) a community consultation strategy including negotiations with special stakeholders such as the Australian Museum, the Rail Infrastructure Corporation, State Rail and emergency services.

Blasting must only be undertaken between the hours of 10:00am and 3:00pm (Monday to Friday) and 10:00am to 1:00pm on Saturdays and at no time on Sundays or Public Holidays, unless

otherwise approved by the EPA. Blasts shall be limited to one single detonation in any one day unless otherwise approved by the EPA.

2.3 clean excavation spoil

Item 9.1 addresses the management of excavated material. However, the EPA is not satisfied that the Proponent has adequately addressed the Government's waste management hierarchy adopted under the Waste Avoidance and Resource Recovery Act 2001.

All clean excavated natural material must be either re-used on the project, as proposed in the Representations Report, or otherwise made available for re-use elsewhere. It should not be disposed of to landfill. Contaminated material and clean excavated natural material must not be mixed.

2.4 waste management

Item 11.1 appears to adequately address most of the waste management issues. However demolition wastes must be managed in accordance with the waste management hierarchy where re-use is the preferred option and disposal to landfill is the last resort option.

2.5 dust suppression

Item 5.1 broadly addresses dust suppression issues. The development consent should require an effective dust suppression program at all surface construction and ancillary sites. The EPA will also impose appropriate licence conditions

2.6 groundwater

Item 6.1.3 addresses pre-construction groundwater investigations. However it omits any reference to groundwater quality monitoring during construction. Groundwater quality should be monitored throughout the construction phase to ensure appropriate management and disposal. Contingency measures must be developed to ensure contaminated groundwater is diverted, collected and treated to achieve an acceptable quality prior to disposal.

2.7 stormwater

Item 7.1 indicates that the Proponent intends to prepare a comprehensive water management plan. However, references to the EPA at the second dot points on both pages 372 and 373 are inappropriate and need to reflect the appropriate reference i.e. Department of Housing's guideline *Managing Urban Stormwater - Soils and Construction.*

2.8 storage of chemicals

The issue of chemicals storage has not been addressed. It is important that if chemicals, particularly flammable liquids, are to be used and stored on the project site, that the Proponent addresses the need for an appropriate roofed over, bunded storage facility with impervious floor to prevent spillage or leaching of these chemicals to the environment.

3. OPERATIONAL IMPACTS

3.1 performance audit

Actual operational impacts should be compared against those predicted in the EIS. The comparisons are required to validate EIS performance predictions and to facilitate learning as a basis for improved modelling and assessment of the impacts of future road infrastructure projects.

A comprehensive audit should be undertaken within 12 months of commissioning of the tunnel to compare environmental performance against the performance predicted in the EIS.

3.2 air quality

3.2.1 Stack location and height

Moving the stack from Location A to Location B is the most effective option for reducing carcinogenic health risks at elevated receptors. Because the levels of exposure are generally highest at elevated receptors the most significant improvements in air quality are gained by moving the stack. Increasing the stack height and increasing the exhaust velocity provide only minor additional benefits and only when done together.

Any request for approval to relocate the stack or change the design and/or operation of any component of the tunnel ventilation system must demonstrate that the predicted air quality impacts for all air pollutants are no greater than those presented for Location B in the EIS and supplementary documentation. Any change to the location and/or height of the stack should require the separate approval of the Director-General following consultation with the EPA and Department of Health and would require a full and comprehensive air quality impact assessment.

3.2.2 Emission limits and monitoring requirements

The sections that follow provide guidance on appropriate emission limits and monitoring requirements for the Cross City Tunnel. For the required number of in-tunnel, portal and ambient air quality and meteorological monitoring locations, the Proponent should prepare a proposal that provides a justification for the number of proposed monitoring sites and their specific purpose.

With respect to ensuring that the Proponent appropriately implements the approval conditions it is recommended that the conditions routinely require verification/auditing by an appropriately qualified independent person/organisation who is required to submit a report to the Director-General. The report must confirm the approval condition is complied with, and document the method by which the assessment was undertaken. The EPA can assist DUAP in reviewing these independent assessments if required.

3.2.3 Use of ambient air quality standards

The EPA has significant reservations about using ambient air quality standards for compliance purposes and our comments address this issue. The EIS Director-General's Requirements required that the tunnel ventilation system be designed with reference to the relevant air quality standards provided in the Ambient Air Quality National Environment Protection Measure.

The NEPM is a regional assessment and reporting tool that is not intended to be used for regulating air quality impacts from individual premises. The EPA's preferred approach is to develop site specific emission limits using the air quality assessment conducted for the EIS taking account

of ambient standards and existing background conditions. The reason for adopting this approach is that a pollutant present in ambient air will be emitted from a variety of sources and making one premises alone responsible for meeting an ambient air quality standard is problematic. In practice it is also technically difficult to determine compliance with conditions based on ambient standards especially in highly urbanised settings.

The EPA's preferred approach of setting stack limits provide a more stringent and accountable control of emissions from the stack than applying ambient standards as they incorporate the highest (worst case) background levels of pollutants. Further, this approach prevents the Proponent from polluting up to the air quality standard.

3.2.4 Stack emission limits

The mass of a pollutant discharged from the Cross City Tunnel Ventilation Stack must not exceed the mass limits specified for that pollutant in the table.

Table 1 – Opening year to 2016

Hour of Day	Units of measure	Averaging period	100% Limit NO_x (as NO_2)	100% Limit PM_{10}	100% Limit CO	100% Limit VOC
0	kg/hr	1-hour	1.44	0.04	8.03	0.79
1	kg/hr	1-hour	1.66	0.05	9.07	0.90
2	kg/hr	1-hour	2.05	0.06	10.69	1.08
3	kg/hr	1-hour	3.13	0.09	15.59	1.55
4	kg/hr	1-hour	4.39	0.12	22.03	2.20
5	kg/hr	1-hour	7.45	0.20	37.19	3.71
6	kg/hr	1-hour	23.72	0.90	111.56	11.16
7	kg/hr	1-hour	23.72	0.90	111.56	11.16
8	kg/hr	1-hour	23.72	0.90	111.56	11.16
9	kg/hr	1-hour	17.71	0.39	72.14	7.20
10	kg/hr	1-hour	17.71	0.43	72.14	7.20
11	kg/hr	1-hour	17.82	0.47	73.69	7.38
12	kg/hr	1-hour	13.46	0.45	68.69	6.88
13	kg/hr	1-hour	13.36	0.45	68.15	6.80
14	kg/hr	1-hour	14.18	0.44	72.25	7.24
15	kg/hr	1-hour	26.24	0.94	147.85	14.80
16	kg/hr	1-hour	26.24	0.94	147.85	14.80
17	kg/hr	1-hour	26.24	0.94	147.85	14.80
18	kg/hr	1-hour	26.24	0.94	147.85	14.80
19	kg/hr	1-hour	11.38	0.18	56.88	5.69
20	kg/hr	1-hour	7.67	0.09	38.27	3.82
21	kg/hr	1-hour	5.65	0.07	28.22	2.81
22	kg/hr	1-hour	4.07	0.05	20.34	2.02
23	kg/hr	1-hour	2.48	0.03	12.56	1.26
		Total kg/day	322.73	11.07	1613.01	162.21

3.2.5 Stack emission monitoring requirements

The applicant must monitor (by sampling and obtaining results by analysis) the pollutants and parameters specified in Column 1. The applicant must use the sampling method, units of measure, and sample at the frequency, specified opposite in the other columns:

Table 2

Pollutant	**Units of measure**	**Frequency**	**Method**[1]
NO	kg/hr	Continuous	CEM-2
NO_2	kg/hr	Continuous	CEM-2
NO_x (as NO_2)	kg/hr	Continuous	CEM-2
PM_{10}	kg/hr	Continuous	AS3580.9.8-2001[2]
CO	kg/hr	Continuous	CEM-4
VOC	kg/hr	Continuous	CEM-8
Speciated VOC[3]	mg/m^3	Annual	OM-2
PAH[4]	$\mu g/m^3$	Annual	OM-6
Parameter	**Units of measure**	**Frequency**	**Method**[1]
Flowrate	m^3/s	Continuous	CEM-6
Moisture	%	Continuous	TM-22
Temperature	K	Continuous	TM-2
Other	**Units of measure**	**Frequency**	**Method**[1]
Sampling locations	NA	NA	TM-1

Note: [1]NSW EPA, 2001, Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales

[2]Standards Australia, 2001, AS3580.9.8-2001, Methods for the Sampling and Analysis of Ambient Air – Determination of Suspended Particulate Matter – PM_{10} Continuous Direct Mass Method using Tapered Element Oscillating Microbalance Analyser

[3]Must include, but not limited to; Benzene, Toluene, Xylenes, 1,3-Butadiene, Formaldehyde and Acetaldehyde

[4]Must include, but not limited to; 16 USEPA priority PAHs, namely; Napthalene, Phenanthrene, Benz(a)anthracene, Benzo(a)pyrene, Acenapthylene, Anthracene, Chrysene, Indeno(1,2,3-cd)pyrene, Acenaphthene, Fluoranthene, Benzo(b)fluoranthene, Dibenz(a,h)anthracene, Fluorene, Pyrene, Benzo(k)fluoranhtene, Benzo(g,h,i)perylene

3.2.6 In-tunnel air quality limits

The concentration of a pollutant in the Cross City Tunnel must not exceed the concentration limits specified for that pollutant in the table.

Table 3

Pollutant	**Units of measure**	**Averaging period**	**100% Limit**
CO	ppm	Rolling 15-minute	87

3.2.7 In-tunnel air quality monitoring requirements

The applicant must monitor (by sampling and obtaining results by analysis) the pollutant specified in Column 1. The applicant must use the sampling method, units of measure, and sample at the frequency, specified opposite in the other columns:

Table 4

Pollutant	Units of measure	Frequency	Method[1]
CO	ppm	Continuous	AM-6
Other	**Units of measure**	**Frequency**	**Method[1]**
Siting	NA	NA	Note[2]

Note: [1]NSW EPA, 2001, Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales
[2]The siting of the instrument must be independently verified

3.2.8 Portal air quality monitoring requirements

The portals must be designed to avoid, to the extent practical, emissions from the portals. The Proponent should in consultation with the EPA, other agencies and representative community groups develop a Protocol for portal emissions. The Protocol must clearly detail the management regime for portal emissions and must include but not be limited to: duration; timing ;ambient air quality circumstances; existing and likely future landuse and development near the portals; justification with respect to energy savings; predicted impacts; monitoring; public notification; responding to residents concerns and any other matters as considered relevant by the EPA.

The Proponent must monitor (by sampling and obtaining results by analysis) the pollutants specified in Column 1. The applicant must use the sampling method, units of measure, averaging period and sample at the frequency, specified opposite in the other columns:

Table 5

Pollutant	Units of measure	Averaging Period	Frequency	Method[1]
NO	pphm	1-hour	Continuous	AM-12
NO_2	pphm	1-hour	Continuous	AM-12
NO_x	pphm	1-hour	Continuous	AM-12
PM_{10}	$\mu g/m^3$	24-hour	Continuous	AM-18[1] or AS3580.9.8-2001[2]
CO	ppm	15-minute, 1-hour, 8-hour	Continuous	AM-6
Other	**Units of measure**	**Averaging Period**	**Frequency**	**Method[1]**
Siting	NA	NA	NA	AM-1

Note: [1]NSW EPA, 2001, Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales
[2]Standards Australia, 2001, *AS3580.9.8-2001, Methods for the Sampling and Analysis of Ambient Air – Determination of Suspended Particulate Matter – PM_{10} Continuous Direct Mass Method using Tapered Element Oscillating Microbalance Analyser*

3.3 operational noise

3.3.1 Ventilation Stack Noise

Section 3.3 of the EPA's EIS comments relates to operational noise from the proposed tunnel ventilation system. The criterion adopted by the EIS is appropriate.

Whilst the EPA regarded the noise limits as achievable, it recommended that the stack noise mitigation be specified during the detailed design stage. A ventilation stack noise mitigation design report is required prior to commencement of construction of the ventilation system. The critical criterion is 53 dB(A) $L_{Aeq\ (15min)}$ during the night time measured at the most affected sensitive receptor.

3.3.2 Traffic noise

Section 3.4 of the EPA's EIS comments relates to the proposed traffic noise mitigation work. The EIS outlined a range of traffic noise mitigation options without an explicit mitigation strategy. The EPA recommended that the traffic noise mitigation work be specified at the detailed design stage and that all mitigation work be completed before or during commissioning of the tunnel. The EPA's comments do not appear to have been acknowledged in the Representations Report.

A traffic noise mitigation report must be prepared prior to commencement of construction and all traffic noise mitigation work should be completed prior to completion of the commissioning of the tunnel.

3.4 groundwater re-use

Item 7.2.1 refers to opportunities to re-use groundwater during the construction phase. Similar opportunities are likely to exist during the operational phase. Groundwater re-use would reduce reliance on costly potable water for non-potable uses. The Proponent should negotiate with local government and other open space managers to re-use groundwater seepage from the tunnel.

APPENDIX E

Technical Details on Calculation of Stack Limits

HOLMES AIR SCIENCES

18 September 2001

BASIS OF CROSS CITY TUNNEL VENTILATION STACK LIMITS

The following provides the basis on which the Cross City Tunnel ventilation stack limits have been determined. The limits are summarised in the following Table.

Pollutant	Carbon Monoxide	Total Oxides of Nitrogen (as NO_2)	PM_{10}	Volatile Organic Compounds
Maximum in stack limit mg/m^3 (1-hour rolling average)	109	19	1	11
Maximum annual loading in tonnes (annual average)	588	117	4	59

The in-stack limit for carbon monoxide is equivalent to the 87 ppm which has been set as a limit for the tunnel. The limits for the other pollutants are based on the ratio between the maximum predicted CO level in the tunnel based on traffic data (89 mg/m^3) and the corresponding maximum concentrations of NO_x, PM_{10} and VOCs which are respectively 15.8, 0.57 and 8.9 mg/m^3.

The stack emission rates and concentration for the various pollutants are presented in **Attachment A**. Modelling has been undertaken assuming that maximum emission rates as presented in **Table A3** can occur at any time of the day or night. The modelled results (Table below) show that the peak predicted levels are not significantly affected by the time of day at which they occur and that assuming the peak emission rate limits as in **Table A3** for the pollutants with short-term goals does not affect the impacts.

Comparison of predicted maximum concentrations in the EIS with:

Predicted maximum concentrations for a 44 metre stack (top of stack 49 m AHD) at Location B and

Predicted maximum concentration for a 44 metre (top of stack 49 m AHD) stack at Location B with emission rates constant at maximum level throughout the day

		CO (mg/m^3)	NO_2 ($\mu g/m^3$)
IMAX (30 m)	EIS prediction	2	80
	Location B: variable emission rates	0.32	13
	Location B: constant max emission rates*	0.14	5.6
Millennium Towers (70 m)	EIS prediction	5	140
	Location B: variable emission rates	2.5	99
	Location B: constant max emission rates	1.8	70
Darling Park 2 (145 m)	EIS prediction	1	40
	Location B: variable emission rates	1.1	45
	Location B: constant max emission rates	1.2	47

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The annual loadings are based on the daily traffic emission rates which in turn are based on traffic numbers with some allowance during peak hours for congested conditions. These numbers are the basis of the most recent dispersion modelling, which result in the concentrations shown in the attachment to the DUAP assessment report. These numbers have been multiplied by 365 to provide an annual loading for the ventilation stack. They are based on the emissions in **Table A1**.

ATTACHMENT A
SPREADSHEET CALCULATIONS
FOR CCT VENTILATION STACK EMISSION LIMITS

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Table A1 EIS emission rates with congested peak hours

Hours starting	Exhaust Stack Air Flows (m3/s)	Exhaust Stack Cross Section Area (m2)	Exhaust Stack Velocities (m/s)	Total CO (g/s)	Total NOx (g/s)	Total PM10 (g/s)	Total VOC (g/s)
0	56	22.50	2.50	2.23	0.40	0.011	0.223
1	56	22.50	2.50	2.52	0.46	0.013	0.252
2	56	22.50	2.50	2.97	0.57	0.016	0.297
3	63	22.50	2.81	4.33	0.87	0.024	0.433
4	89	22.50	3.97	6.12	1.22	0.034	0.612
5	151	22.50	6.70	10.33	2.07	0.056	1.033
6	448	22.50	19.89	30.99	6.59	0.249	3.099
7	448	22.50	19.89	30.99	6.59	0.249	3.099
8	448	22.50	19.89	30.99	6.59	0.249	3.099
9	353	22.50	15.70	20.04	4.92	0.108	2.004
10	353	22.50	15.70	20.04	4.92	0.119	2.004
11	378	22.50	16.80	20.47	4.95	0.132	2.047
12	316	22.50	14.04	19.08	3.74	0.125	1.908
13	313	22.50	13.93	18.93	3.71	0.126	1.893
14	333	22.50	14.78	20.07	3.94	0.123	2.007
15	461	22.50	20.51	41.07	7.29	0.262	4.107
16	461	22.50	20.51	41.07	7.29	0.262	4.107
17	461	22.50	20.51	41.07	7.29	0.262	4.107
18	461	22.50	20.51	41.07	7.29	0.262	4.107
19	231	22.50	10.25	15.80	3.16	0.049	1.580
20	155	22.50	6.89	10.63	2.13	0.025	1.063
21	115	22.50	5.09	7.84	1.57	0.019	0.784
22	82	22.50	3.66	5.65	1.13	0.013	0.565
23	56	22.50	2.50	3.49	0.69	0.008	0.349
			kg/day	1612	322	10	161
Annual limit (Tonnes per annum)				**588**	**117**	**4**	**59**

Table A2 **In-stack concentrations corresponding to EIS emission rates**

Hours starting	Exhaust Stack Air Flows (m3/s)	Exhaust Stack Cross Section Area (m2)	Exhaust Stack Velocities (m/s)	Total CO (mg/m3)	Total NOx (mg/m3)	mg/m3	Total VOC (mg/m3)
0	56	22.50	2.50	39.64	7.11	0.20	3.96
1	56	22.50	2.50	44.80	8.18	0.24	4.48
2	56	22.50	2.50	52.80	10.13	0.29	5.28
3	63	22.50	2.81	68.49	13.76	0.38	6.85
4	89	22.50	3.97	68.51	13.66	0.38	6.85
5	151	22.50	6.70	68.52	13.73	0.37	6.85
6	448	22.50	19.89	69.25	14.73	0.56	6.92
7	448	22.50	19.89	69.25	14.73	0.56	6.92
8	448	22.50	19.89	69.25	14.73	0.56	6.92
9	353	22.50	15.70	56.73	13.93	0.31	5.67
10	353	22.50	15.70	56.73	13.93	0.34	5.67
11	378	22.50	16.80	54.15	13.10	0.35	5.42
12	316	22.50	14.04	60.40	11.84	0.40	6.04
13	313	22.50	13.93	60.40	11.84	0.40	6.04
14	333	22.50	14.78	60.35	11.85	0.37	6.04
15	461	22.50	20.51	89.00	15.80	0.57	8.90
16	461	22.50	20.51	89.00	15.80	0.57	8.90
17	461	22.50	20.51	89.00	15.80	0.57	8.90
18	461	22.50	20.51	89.00	15.80	0.57	8.90
19	231	22.50	10.25	68.51	13.70	0.21	6.85
20	155	22.50	6.89	68.57	13.74	0.16	6.86
21	115	22.50	5.09	68.46	13.71	0.17	6.85
22	82	22.50	3.66	68.61	13.72	0.15	6.86
23	56	22.50	2.50	62.04	12.27	0.13	6.21
			mg/m3	89	16	1	9

Table A3 **Emission rates corresponding to stack limits based on 87 ppm CO =109 mg/m3**

Hours starting	Exhaust Stack Air Flows (m3/s)	Exhaust Stack Cross Section Area (m2)	Exhaust Stack Velocities (m/s)	Total CO (g/s)	Total NOx (g/s)	Total PM10 (g/s)	Total VOC (g/s)
0	56	22.50	2.50	2.72	0.49	0.013	0.272
1	56	22.50	2.50	3.08	0.56	0.016	0.308
2	56	22.50	2.50	3.63	0.70	0.020	0.362
3	63	22.50	2.81	5.29	1.06	0.030	0.529
4	89	22.50	3.97	7.47	1.49	0.042	0.747
5	151	22.50	6.70	12.61	2.53	0.069	1.262
6	448	22.50	19.89	37.84	8.05	0.305	3.784
7	448	22.50	19.89	37.84	8.05	0.305	3.784
8	448	22.50	19.89	37.84	8.05	0.305	3.784
9	353	22.50	15.70	24.47	6.01	0.132	2.447
10	353	22.50	15.70	24.47	6.01	0.145	2.447
11	378	22.50	16.80	25.00	6.04	0.161	2.500
12	316	22.50	14.04	23.30	4.57	0.153	2.330
13	313	22.50	13.93	23.12	4.53	0.153	2.312
14	333	22.50	14.78	24.51	4.81	0.151	2.451
15	461	22.50	20.51	50.15	8.90	0.319	5.015
16	461	22.50	20.51	50.15	8.90	0.319	5.015
17	461	22.50	20.51	50.15	8.90	0.319	5.015
18	461	22.50	20.51	50.15	8.90	0.319	5.015
19	231	22.50	10.25	19.29	3.86	0.060	1.929
20	155	22.50	6.89	12.98	2.60	0.031	1.298
21	115	22.50	5.09	9.57	1.92	0.023	0.958
22	82	22.50	3.66	6.90	1.38	0.015	0.690
23	56	22.50	2.50	4.26	0.84	0.009	0.427

Table A4 **In-stack concentrations for all pollutants based on CO limit of 109 mg/m3**

Hours starting	Exhaust Stack Air Flows (m3/s)	Exhaust Stack Cross Section Area (m2)	Exhaust Stack Velocities (m/s)	Total CO (mg/m3)	Total NOx (mg/m3)	Total PM10 (mg/m3)	Total VOC (mg/m3)
0	56	22.50	2.50	48.41	8.68	0.24	4.84
1	56	22.50	2.50	54.71	9.99	0.29	5.47
2	56	22.50	2.50	64.48	12.37	0.35	6.44
3	63	22.50	2.81	83.63	16.80	0.47	8.36
4	89	22.50	3.97	83.67	16.68	0.46	8.36
5	151	22.50	6.70	83.68	16.77	0.46	8.37
6	448	22.50	19.89	84.56	17.98	0.68	8.46
7	448	22.50	19.89	84.56	17.98	0.68	8.46
8	448	22.50	19.89	84.56	17.98	0.68	8.46
9	353	22.50	15.70	69.28	17.01	0.37	6.93
10	353	22.50	15.70	69.28	17.01	0.41	6.93
11	378	22.50	16.80	66.13	15.99	0.43	6.61
12	316	22.50	14.04	73.76	14.46	0.48	7.38
13	313	22.50	13.93	73.76	14.46	0.49	7.38
14	333	22.50	14.78	73.70	14.47	0.45	7.37
15	461	22.50	20.51	108.68	19.29	0.69	10.87
16	461	22.50	20.51	108.68	19.29	0.69	10.87
17	461	22.50	20.51	108.68	19.29	0.69	10.87
18	461	22.50	20.51	108.68	19.29	0.69	10.87
19	231	22.50	10.25	83.66	16.73	0.26	8.36
20	155	22.50	6.89	83.74	16.78	0.20	8.37
21	115	22.50	5.09	83.60	16.74	0.20	8.36
22	82	22.50	3.66	83.78	16.76	0.19	8.38
23	56	22.50	2.50	75.77	14.98	0.16	7.59
	Stack limit		**mg/m3**	**109**	**19**	**1**	**11**

APPENDIX F

National Environment Protection Council *"Need for* ***$PM_{2.5}$*** *Standard in Australia"*

National Environment Protection
(Ambient Air Quality) Measure

Issues Paper

The Need for a $PM_{2.5}$ Standard in Australia

Prepared for the National Environment Protection Council

May 2001

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1 OVERVIEW

1.1 INTRODUCTION

1.1.1 The Ambient Air Quality NEPM

The role of the National Environment Protection Council (NEPC) is to harmonise environmental protection approaches across Australia.

In 1998, Australia adopted an Ambient Air Quality National Environment Protection Measure (NEPM) that set national ambient air quality standards to apply in all States and Territories and over land controlled by the Commonwealth. These standards cover six criteria pollutants – particles (as PM_{10}), ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and lead.

The standards are the first step in developing a more consistent national approach to air quality management so that Australians can enjoy equivalent protection from the adverse health impacts of air pollution.

The NEPC Act confines the role of the NEPM to ambient air quality. That is, it can only deal with air quality outside buildings. Many Australians spend much of their time indoors and it might therefore be expected that indoor air quality might be a more significant health influence than ambient air quality. However, most of the epidemiological research on air quality (the relationship between community health and air pollution) relates to ambient air quality. Such relationships encompass some unknown degree of influence from indoor air quality.

1.1.2 Review of the Particles Standard

When NEPC made the Ambient Air Quality NEPM, it also agreed to a program of future actions, including a staged review of some NEPM standards. The future action program includes a review of the particles standard to commence by 2001, with a view for the need of a standard for $PM_{2.5}$.

The current particles standard relates to particulate matter of 10 micrometres or less in diameter. The review will consider the need for a standard for particles 2.5 micrometres or less in size ($PM_{2.5}$). It will focus on the importance of setting health based ambient air quality standards, and will draw conclusions regarding the desirability and feasibility of setting an Australian standard for $PM_{2.5}$.

1.1.3 This Issues Paper

The first step in the review has been the preparation of this issues paper.

The paper examines issues such as the health effects of $PM_{2.5}$, sources of $PM_{2.5}$, what is known in Australia regarding concentrations and composition of particles, recent overseas developments and methodologies for setting a standard.

The aims of the paper are to encourage discussion on the issues and to enable stakeholders to provide input into whether a new standard for $PM_{2.5}$ is needed. NEPC Committee is particularly interested in comments and information on the specific issues outlined in the paper. The feedback provided will help ensure the review is as robust as possible.

Information on how to make a written submission on the issues paper is contained in Chapter 7.

The outcomes of the review will be considered by NEPC later this year and a decision made then on whether to set a $PM_{2.5}$ standard. Should NEPC initiate an amendment to the existing Ambient Air Quality NEPM, then a statutory process for the variation of the NEPM would follow, including extensive public consultation on any proposed standard and its social, environmental and economic impacts.

1.2 What is $PM_{2.5}$ & Why is it Important?

Illustrations of the adverse health effects of particles date back to the dramatic pollution episodes in Belgium's industrial Meuse Valley (1930), Donora Pennsylvania, USA (1948), and London, England (1952). During the high pollution episode in London, 4,000 excess deaths occurred (Bascom et al., 1996).

Since these early episodes many studies have been conducted worldwide to investigate the effects of particles on health. These studies have used mainly TSP or PM_{10} as the measure of ambient particle levels, but more recently $PM_{2.5}$ and $PM_{10-2.5}$ have also been investigated. The results of these studies have shown that particles are associated with adverse health effects, such as increases in daily mortality or hospital admissions for respiratory or cardiovascular disease, even at current ambient levels which are considerably lower than those experienced during the early episodes in London, Belgium and the USA.

Health effects have been observed for all size fractions investigated. $PM_{2.5}$ however, penetrates deeper into the lung than either PM_{10} or $PM_{10-2.5}$ and is retained preferentially to the larger size fractions. This suggests that $PM_{2.5}$ may play a more important role in the long-term effects attributable to particles than either PM_{10} or $PM_{10-2.5}$.

1.3 The History of Monitoring for $PM_{2.5}$

Although monitoring of particles has been carried out for more than fifty years in Australia, regular and/or continuous monitoring commenced in most states in the late 1970s for TSP, and visibility (by the use of nephelometry which measures the light scattering from fine particles). During the 1980s monitoring of PM_{10} replaced TSP due to the emerging health studies indicating adverse health effects associated with this particle fraction. During this time monitoring of $PM_{2.5}$ was limited to campaign monitoring and nephelometry. Nephelometry data is highly correlated with $PM_{2.5}$ and, in most jurisdictions in Australia, significant databases exist extending back to the late 1970s.

With the introduction of TEOMs in the 1990s, some jurisdictions commenced continuous monitoring of not only PM_{10} but also $PM_{2.5}$ on a routine basis. This monitoring was introduced for two reasons. Firstly, to identify sources of particles within a given airshed and to develop appropriate management strategies to control particles and, secondly, the emerging information about the health effects associated with $PM_{2.5}$.

When the Ambient Air Quality NEPM was made, one of the future actions agreed was for jurisdictions to collect $PM_{2.5}$ data to allow an assessment of the need to develop a standard for $PM_{2.5}$. Although the health effects of $PM_{2.5}$ were acknowledged during the development of the NEPM, it was considered that a standard could not be set due to a lack of monitoring data in Australia at that time. Since then several jurisdictions have been monitoring for $PM_{2.5}$ and these data will inform the current review.

2 SOURCES OF PARTICULATE MATTER

2.1 NATURE OF PARTICULATE MATTER

Particulate matter consists of solid particles and liquid droplets, typically composed of elemental carbon, adsorbed organic compounds, sulfates, nitrates, metals and other trace elements. Secondary particles are formed from gases and include sulfates, nitrates, ammonium and hydrogen ions. Adsorbed organic components include toxic combustion products such as polycyclic aromatic hydrocarbons (PAHs), nitro-PAHs and oxidised PAH derivatives.

The State of Knowledge Report (EPA Victoria, 1998) notes that a complete description of particles includes density, concentration, size distribution, chemical composition, phase, morphology, diffusion, dispersion, air mass type, atmospheric transport, transformation, washout and deposition. Secondary particles formed from atmospheric processes can account for the bulk of particle mass in some situations.

There are a large number of components present in particles, including transient or short-lived components. Understanding the contributions of various sources to aerosol precursor concentrations, as well as aerosol transport and transformation processes in the atmosphere is currently an active area of research.

The various particle size components are generally defined as:

- PM_{10} – particles with an equivalent aerodynamic diameter of 10 µm or less;
- $PM_{2.5}$ – particles with an equivalent aerodynamic diameter of 2.5 µm or less;
- ultrafine particles – particles with a diameter of 0.1µm or less; and
- nanoparticles – particles with a diameter of 0.05 µm or less.

Gathering information on the smallest particle components (ultrafine particles and nanoparticles) is especially difficult due to the complexity of investigations, including instrumentation, measurement, modelling, data interpretation, exposure assessment and risk quantification (Morawska, 1999).

2.2 ANTHROPOGENIC SOURCES

2.2.1 Urban Areas

There is a wide range of sources in urban areas that emit particles. These sources vary greatly in terms of the particle size fractions emitted, particle composition and spatial and temporal distributions. Combustion sources of particles also emit gaseous pollutants such as carbon monoxide and oxides of nitrogen, which contribute to degraded air quality in urban areas.

Particles are produced by both combustion and mechanical processes. Coarser particles tend to be produced by mechanical processes (eg wind erosion), whereas the size distribution for combustion-derived particles (eg motor vehicle exhaust) is generally dominated by particles smaller than $PM_{2.5}$. Some examples of typical urban particle sources are shown in Table 2-1.

Table 2-1: Urban Sources of Ambient Particulate Matter

Combustion	Mechanical/Natural
• Motor vehicle exhaust (especially diesel vehicles) • Domestic wood combustion (heating/cooking) • Controlled burning • Industrial boilers/incinerators • Restaurant cooking • Lawn mowers • Power generation	• Vehicles travelling on roads (dust suspension, tyre/brake wear) • Wind erosion (material stockpiles, unvegetated areas) • Pollens • Sea salt • Bulk handling facilities (cement plants, ports, quarries) • Mining and minerals processing

2.2.2 Rural Areas

Sources of particles in rural areas are similar to those in urban areas, although the relative contributions made by the sources vary due to different activity levels in the urban and rural sectors. For example, important sources of $PM_{2.5}$ in rural areas would include off-road diesel machinery (eg tractors, headers), erosion of topsoil in dry conditions, dust generation from agricultural operations and dust generation from vehicle travel on unmade roads. In addition, rural areas can be significant sources of ammonia (eg dairy farms), which is an important precursor for the formation of secondary particles.

Mining can be a significant source of $PM_{2.5}$ in rural and remote areas (blasting, stockpiling, vehicle movement and materials handling). Particles from mining operations tend to be dominated by the coarser fraction, with $PM_{2.5}$ estimated to account for less than 10% of total emissions (Smith, 2000). There are numerous dust emission sources associated with mining and they depend on geology, operations, processes and climate. The size distribution and composition of particles vary temporally and spatially, with relatively minor contributions from combustion sources. Refining processes such as smelting can be an important source of finer particle fractions.

Burning of vegetation (bushfires, controlled burns, stubble burning) is an important source of particles in rural areas and on the urban fringe. $PM_{2.5}$ emissions from these sources can be transported over significant distances, impacting on both rural and urban areas.

2.3 Natural Sources

There are a number of important natural sources of $PM_{2.5}$. As with anthropogenic sources, natural sources show a wide variation in emission patterns and particle characteristics. Examples of natural sources include:

- sea salt – particle emissions are generated by the action of the wind on waves and are therefore dependent on wind speed. These emissions tend to be mostly fine ($PM_{2.5}$ and below) and are composed of elements such as sodium, magnesium, sulfur, chlorine and calcium;
- dust – soil particles are also generated by the mechanical action of the wind. Dry regions and sparsely vegetated areas are most prone to wind erosion. Other significant factors influencing emissions include the soil type (fine or coarse grained) and the geology, which determines the particle composition;
- bushfires – can generate very large amounts of particles that, in common with other combustion sources, are mostly in the fine size range. Bushfire events can be the

dominant source of low visibility events in urban areas due to the transport of smoke over large distances;

- biological particles – these include pathogens (bacteria, viruses and fungi), allergens (bacteria, pollen, spores, mould, mildew), dust mite faeces and animal/bird dander. Some of these, such as viruses, have health effects that are not related to their particle characteristics; and
- biogenic emissions – emissions of volatile organic compounds (VOC) from vegetation contribute to particles in the form of condensable products. Formation of secondary organic aerosol has been documented for a number of compounds. These compounds partition between the gas and particle phases and can constitute a significant fraction of particles. The contribution of biogenic sources to particle emissions has not been considered in Australian studies.

2.4 Secondary Particles

The sources described in the previous sections contribute both primary particle emissions and other material that undergoes atmospheric transformation to form what is referred to as "secondary PM" or "secondary aerosol".

The atmospheric transformation processes involved are complex and not completely understood. The rate of production of these particles depends on photochemical activity, which in turn is dependent on meteorological and climatic factors. In some regions, secondary particles may contribute the majority of particle mass under certain conditions (Allen et al., 2000). Some common secondary aerosol species and their origin are described below:

- ammonium nitrate and sulphate - formed from ammonia gas, typical sources of which include motor vehicle exhaust and agricultural operations;
- nitrate ion – formed by atmospheric reactions that begin with nitrogen oxides gas emitted from motor vehicles and other combustion sources;
- sulfate ion – formed from marine derived sulfate and also sulfur oxides emitted by diesel-powered ships and motor vehicles; and
- organic aerosol – results from the condensation of low vapour pressure products that are formed from primary gas-phase emissions of organic compounds.

2.5 Source Characterisation

2.5.1 Contribution of Different Sources to $PM_{2.5}$

In both urban and rural environments, there will be a large number of sources contributing to levels of $PM_{2.5}$. These sources emit different components of particles at different locations, rates and times. In addition, primary $PM_{2.5}$ emissions and other material may undergo transformation in the atmosphere to produce other components of particles. This complexity in source characteristics has delayed assessment of the relative importance of each source.

Local factors, such as source types, source activity (daily and seasonal), proximity to the coast, climate and soil types, all influence which particle sources are dominant in a particular area at a particular time. The sections below give some examples of the relative contribution of particle sources in areas of Australia and overseas. Australian studies have generally indicated a significant contribution from domestic wood smoke during autumn and winter, with motor vehicles and formation of secondary particles appearing to be the main contributors during summer (EPA Victoria, 1998).

2.5.1.1 Sydney, New South Wales

An aerosol sampling program was undertaken in NSW (ERDC, 1995) to identify and quantify sources of $PM_{2.5}$ in NSW. The main contributors to $PM_{2.5}$ mass in Sydney, Newcastle and Wollongong were found to be motor vehicles and wood smoke. Ammonium sulfate levels (secondary particles), an indicator of fossil fuel combustion and smelting processes in these areas, were also found to account for a significant proportion of $PM_{2.5}$.

The $PM_{2.5}$ measured in inland rural areas of NSW was dominated by coal combustion throughout the year. The contribution from motor vehicles and wood combustion was found to be variable in these areas.

NSW experienced severe bushfires in 1994 that burnt for a number of weeks. A dramatic increase in $PM_{2.5}$ was measured over this period.

2.5.1.2 Melbourne, Victoria

The Melbourne Aerosol Study (Gras et al., 1992) investigated the contributions to $PM_{2.5}$ mass from different sources during periods of reduced visibility. These reduced visibility events occur during the autumn and winter months.

Measurements were made over autumn and winter at Footscray (mixed industrial and residential) and Alphington (primarily residential). The contribution to $PM_{2.5}$ from motor vehicles was comparable between the two sites, however the smoke contribution at Alphington was approximately four times that for Footscray, due to differences in domestic wood burning activity.

Measurements made over the summer months at the two sites indicated lower overall $PM_{2.5}$ levels and a larger contribution made by secondary aerosol.

The recent update to the Port Phillip region air emissions inventory (EPA Victoria, 1998) reports that the relative source contributions to annual primary $PM_{2.5}$ emissions of were:

- domestic/commercial/rural (mostly domestic wood combustion) 56%;
- motor vehicles 25%;
- industry 15%; and
- other mobile sources 4%.

2.5.1.3 Perth, Western Australia

The Perth Haze Study (Gras, 1996) found that atmospheric particle loadings in Perth are similar to other Australian cities. The major sources, which vary temporally, spatially and seasonally are sea salt, soil, motor vehicle exhaust and smoke (domestic heating, controlled burns and bushfires). Secondary particles are important in summer. Industry and biogenic sources are minor contributors.

A strong seasonal cycle is apparent for different source contributions. Soil and sea salt account for much of the $PM_{2.5}$ mass during summer. Combustion sources (domestic wood heaters and motor vehicles) dominate during the winter, while bushfire smoke in spring is an important contributor.

A large variation in loadings is possible between locations and temporally, due to changes in motor vehicle fleet mix, biomass burning conditions and wood stove operating conditions.

2.5.1.4 Los Angeles Area, U.S.A

Allen et al (2000) report that during periods of moderate $PM_{2.5}$ concentrations and low photochemical activity, the ambient aerosol was found to be composed mainly of primary emissions. Major sources contributing to $PM_{2.5}$ measured downwind of central Los Angeles were motor vehicles, food cooking, marine sulfate, diesel-fuelled ships, agricultural ammonia emissions and stationary combustion sources.

During a period of high $PM_{2.5}$ concentrations, particle composition was measured downwind of a dairying area. The largest contributors to $PM_{2.5}$ during this experiment were agricultural ammonia emissions, motor vehicles, stationary combustion sources, food cooking, marine sulphate and diesel-fuelled ships. It is important to note that for this study period, secondary particles formed the bulk of the particle mass and the sources noted are responsible for the emissions of the precursor particle species.

The authors note that nitrate and ammonium ions are the largest contributors to the high 24-hour averaged $PM_{2.5}$ concentrations observed in this study, but these secondary particles are expected to be relatively smaller contributors to the annual concentrations. This suggests that different strategies may be required to control annual and 24-hour averaged $PM_{2.5}$ concentrations.

2.5.1.5 Wellington Area, New Zealand

Trompetter et al (2000) assessed the elemental composition of the major $PM_{2.5}$ sources in Wellington. Significant $PM_{2.5}$ sources were sea salt, soil, industry, domestic smoke and motor vehicles. An important conclusion of this study was that meteorology can act as both source and sink for emissions. For example, wind speed was found to be the most important factor controlling sea salt emissions.

2.5.2 Size Fractions

In general, combustion processes and mechanical processes result in particulate matter emissions of different size ranges. Particles generated from combustion processes are mostly smaller than 2.5μm, whereas particles from mechanical processes tend to be larger than 2.5μm. Small particles from combustion processes can also agglomerate with other particles to form larger particles. Secondary particles can range in size from below 0.1μm up to 10μm. Atmospheric humidity can play an important role in particle size because some aerosols absorb water from the atmosphere and increase in size.

Morawska and Thomas (2000) report that size distribution is a key characteristic of particles. Based on the different particle modes (size ranges) and sources of each mode, it is suggested that selection of $PM_{2.5}$ as a cut-off point for fine particles has been based largely on what data were available at the time, rather than on a scientific rationale. They consider that $PM_{2.5}$ cuts across the natural divisions in particle size distribution for particles from different sources. The authors conclude that aerosol science suggests that fine particles (ie combustion sources) are better represented by PM_1, whereas coarser particles (ie mechanical processes) are represented by the 1-10μm range. Such a division would therefore differentiate between combustion derived and mechanically derived particles, although the definition is still somewhat arbitrary. The selection of an appropriate particles size range for regulatory purposes is currently an area of research and debate, and has implications for emission control strategies.

In a study of particle size characteristics for Australian cities (Keywood et al., 2000), it was found that the urban aerosol in Sydney, Brisbane, Melbourne and Adelaide displayed a

bimodal distribution with coarse defined in this study as > 1μm and fine as < 1μm modes. The chemical compositions of these modes indicated that both mechanical and combustion processes were important to particle levels. In Launceston and Canberra, the urban aerosol was dominated by a single fine particle mode that was attributed to wood burning for domestic heating. It should be noted that for these two cities, topographical and meteorological conditions can lead to very poor dispersion conditions during the winter months (when wood heaters are being used) that result in high particle levels.

Another important issue is that of the number of particles in different size ranges, commonly termed the 'number concentration'. Particle number is not necessarily related to particle mass and is therefore not controlled through control measures based on $PM_{2.5}$ mass as applied in some jurisdictions overseas. Morawska (1999) reports that the majority of particle numbers in urban aerosol is in the ultrafine range (ie less than 0.1μm in diameter). For example, in the typical urban environment where emissions are dominated by motor vehicles, 80% of the number concentration of particles has been found to be in the ultrafine range, however, the contribution of these particles to total particle mass is insignificant. Occasionally there is correlation between particle mass and particle number, but the degree of correlation depends on local conditions. In general terms, measuring particle mass does not necessarily provide an indication of particle numbers. Some research suggests that health effects of particles may be related to particle number rather than particle size. In addition, it is thought that smaller particles may carry a higher burden of toxic materials compared to larger particles (Morawska, 1998).

2.5.3 Particle Composition

The three major components of particles are reported by Keywood et al (2000) to be:

- inorganic mass – particle components include sodium, magnesium, chlorine, sulfates and metals;
- elemental mass – particles composed of elemental carbon; and
- organic mass – condensed or adsorbed hydrocarbons and hydrocarbon derivatives, including known human carcinogens such as PAH.

Organic mass has been found to be the major component of the gravimetric mass of Australian urban aerosols although there is substantial temporal and spatial variation. Wood combustion and motor vehicles are important sources of organic compounds. Organic compounds can be used as tracers to help identify sources of fine particles, or can be used to indicate the toxicity of particles.

Vehicle emissions testing undertaken by the University of California (2000) indicates that elemental and organic carbon are primary constituents of petrol and diesel exhaust particles. Organic mass accounted for a larger fraction of total particle mass for petrol vehicle exhaust, with diesel vehicle exhaust having a larger elemental mass fraction. Emissions of PAH were higher for petrol vehicles than for diesel vehicles. Results also indicated that particle counts showed correlation with drive cycle phases, that is, higher counts were observed with engines under load or accelerating.

Madden et al (2000) report that the composition of diesel exhaust particles is dependent on a number of factors, including driving conditions. Higher engine loads tend to be associated with more toxic particle emissions.

Combustion of wood can also result in high levels of organic mass in the particles produced. Gras (1996) concluded that poor burning conditions in domestic wood heaters in Perth leads to elevated levels of organic compounds.

The PAH loading in urban aerosol is mostly from motor vehicles and smoke. The ratios between PAH species can be used to distinguish between these sources. Further investigations required in this area include real-time monitoring of particles of various size fractions, physical/chemical characterisation and comparison with observed health effects.

2.6 Levels of Particulate Matter in Residential Environments

Total particle mass, size fractions, particle numbers and particle composition would be expected to vary within and between residential areas. $PM_{2.5}$ in residential areas contains particles from mobile sources, stationary combustion sources, long-range transport from distant combustion sources and non-combustion sources.

Particle characteristics and levels experienced in residential areas would be influenced by ambient air quality, however localised sources may also play a significant role. Examples of local sources include major transport routes near residential areas and domestic wood heaters in neighbouring houses. In general, coarser particles tend to impact most at near source receptors, whereas smaller particles may be transported a significant distance from the source. Particle levels will also be influenced by local topography and meteorology.

Studies undertaken in Australia indicate that $PM_{2.5}$ may account for the majority of particle mass in urban areas (ACARP, 1999). In terms of particle numbers, ultrafine particles have been shown to dominate in areas that are strongly influenced by motor vehicle emissions (Morawska, 1999).

Subbalakshmi (2000) reports that suitable indicators are not yet readily available to assess the overall composition of urban particle emissions and relate to known sources. Research is currently being undertaken to determine tracer compounds that can be used to identify particle sources. An example of this is the use of cholesterol to track particle emissions from restaurant cooking, which is a significant source in the Los Angeles area (ARB, 1994).

The quality of indoor air is a critical issue in terms of exposure to particles, because people spend most of their time indoors. Measurements of the exposure of residents to $PM_{2.5}$ in Perth households (Na et al., 2000) indicated that that there are significant correlations between personal and indoor particle levels, with low correlation of personal with outdoor particle levels. In a study of exposure to particles less than 1μm in a building near a busy road (Jamriska et al., 2000), it was concluded that the quality of the indoor air is governed by the quality of the outdoor air.

The findings of these studies reinforce the fact that there is still much uncertainty surrounding $PM_{2.5}$ emissions and human exposure. It is important to appreciate that the various components of $PM_{2.5}$ are different in terms of sources, chemical composition, physical characteristics, environmental behaviour/fate and exposure pathways, which will impact on health implications. The setting of a $PM_{2.5}$ standard must take these differences into account to achieve the best environmental outcome.

2.6.1 Emissions Inventory Data

Particulate matter emissions inventory data from Australian studies are presented in Table 2-2.

Table 2-2: PM_{10} and $PM_{2.5}$ Emissions from Various Source Types
Yearly Averages (% contribution)

Airshed	Mobile Sources %	Industrial Point Sources %	Area Based Sources %
NSW: Sydney PM_{10}	30	34	36
NSW: MAQS Region 92 PM_{10}	16	67	16
Vic: Melb & Geelong PM_{10}	18	36	46
$PM_{2.5}$ (95/96)	29	15	57
Queensland: SE PM_{10}	18	65	17
WA: Kwinana PM_{10}	8	68	24
Perth PM_{10}	13	44	43
SA: Adelaide PM_{10}	9	23	68
Port Pirie PM_{10}	2	94	4
Tas: Launceston PM_{10}	1	2	97

5 • **Wood heaters and motor vehicles are major anthropogenic sources of $PM_{2.5}$ in urban areas. Are there any other significant $PM_{2.5}$ sources?**

2.7 REFERENCES

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3 WHAT DO WE KNOW IN AUSTRALIA?

3.1 MONITORING METHODS FOR $PM_{2.5}$

$PM_{2.5}$ can be monitored by gravimetric methods such as the high volume samplers and TEOMs, or by light scattering methods such as the nephelometer. Use of nephelometers to determine the aerosol scattering coefficient (β_{sp}) in a number of Australian airsheds has a history of more than two decades. Although the scattering coefficient, as determined by a nephelometer, is an integral property of the aerosol size distribution, the physics of the interaction between aerosol particles and visible radiation is weighted towards particles that are less than 1 micrometre in size (Ayres et al., 1999).

Nephelometer measurements are undertaken by drawing air into the integrating nephelometer chamber after being heated and then illuminating it by a beam of light centred on a wavelength of 530 nanometres. Suspended fine particles in the air stream (0.1 to 2 micrometres) cause this light to be scattered. A photometer produces an electrical output proportional to the scattering, calibrated in what are called β_{sp} units. Hence the nephelometer measurement units are quite different to those from gravimetric devices and the nephelometer output needs to be calibrated to give equivalent measurements.

In some airsheds comparison measurements have shown good correlation (0.99) between $PM_{2.5}$, PM_{10} and nephelometer data. However, this needs to be substantiated over time at particular locations to have confidence in the results. The AFP Study (Ayres et al., 1999) confirmed that linear relationships can be found between β_{sp} (measured by nephelometers) and $PM_{2.5}$ (measured by TEOM) in each city studied. However, differences in the scattering-mass relationships were identified, caused by site-specific aerosol size distribution characteristics. Thus if β_{sp} were to be used as a surrogate historical record for $PM_{2.5}$, the relationship would have to be determined for each site.

An additional complication is that at any given site this relationship may vary with the season so jurisdictional data used in harmonising the historical β_{sp} data records with new and ongoing $PM_{2.5}$ records would need to take this into account. Other complicating matters are the significant dependence of nephelometer output on humidity, and the strong implication from the TEOM results that humidity reduction by heating, often used for nephelometers as well as for the TEOM, may not be appropriate (Ayres et al., 1999).

An 18-month study conducted by EPA Victoria has shown that the relationship between β_{sp} and $PM_{2.5}$ mass is dependent on both season and location of the monitoring site. In general measurements of β_{sp} and $PM_{2.5}$ were highly correlated.

Ultrafine particle number concentration is also readily amenable to continuous measurement and such measurements were included in the AFP Study. The AFP Study data show that ultrafine particle number concentrations do not correlate with the ambient mass-based data normally reported, such as PM_{10} and $PM_{2.5}$ (Ayres et al., 1999).

The TEOM consists of two units. The sensor unit contains the sample inlet (PM_{10} or $PM_{2.5}$) and the TEOM microbalance. The microbalance provides the sensitive mass measurement. As particles land on the filter, the filter mass change is detected as a frequency change in the oscillation of the tube. Combining the mass change with the flow rate through the system provides a measure of the particle concentration and is capable of providing real time values. Measurements of $PM_{2.5}$ by TEOMs need corrections to be applied to make them comparable to data collected by other gravimetric methods, due to loss of volatiles arising from the heating of the sample with TEOMs.

Sequential samplers can be used to obtain daily $PM_{2.5}$ measurements. The USEPA has established this as its reference method for monitoring $PM_{2.5}$ to overcome the measurement difficulties associated with use of TEOMs. Issues related to the monitoring of $PM_{2.5}$ would be explored further in the development of an impact statement if a variation of the Ambient Air Quality NEPM proceeds.

3.2 $PM_{2.5}$ Databases

3.2.1 Ambient Concentrations

Fine particle monitoring began in Australia in the 1950s in Sydney and in the 1960s in Melbourne when the measurement and reporting of "black smoke" commenced. TSP monitoring networks were set up in Melbourne, Sydney and Brisbane in the late 1970s to early 1980s, and were introduced into other major cities during the 1980s. PM_{10} monitoring commenced in the 1980s in Melbourne, Sydney, Adelaide and Brisbane using high-volume samplers with a size-selective inlet. These samplers run for twenty-four hours on a six-day cycle. Similar systems were set up in Perth in 1990. Very little particle monitoring has been conducted in Tasmania, with the bulk of the information being collected in Launceston during a study on the health impacts of air pollution in the Tamar Valley (Lyons et al., 1996). There is no regular monitoring of particles in the Northern Territory although there has been a recent Northern Territory University/CSIRO study during the dry season of 2000, for PM_{10}. The ACT has two nephelometers monitoring fine particles.

In recent years, continuous particle monitoring using Tapered Element Oscillation Microbalance (TEOM) monitors has been introduced in most States. Networks have been set up to measure both PM_{10} and $PM_{2.5}$. Appendix 1 details the monitoring methods employed.

Although jurisdictions agreed to commence or continue programs for monitoring particles less than 2.5 micrometres in major airsheds to provide the basis for NEPC to review the need for a related standard, this has not occurred in all jurisdictions.

3.2.2 New South Wales

Currently there are eighteen permanent sites monitoring $PM_{2.5}$ using nephelometers and TEOMs. Table A2-1(Appendix 2) lists the sites that have conducted $PM_{2.5}$ monitoring using nephelometers from 1998 to 2001.

PM_{10} sampling commenced in 1988 using high volume samplers with size selective inlets at two sites and by the end of 1996 this had expanded to fourteen sites. In 1993, as part of the expansion of the air monitoring network associated with the Metropolitan Air Quality Study (MAQS), TEOM instrumentation was introduced to undertake additional PM_{10} measurements. In 1996, $PM_{2.5}$ monitoring using TEOMs commenced.

Almost all of the sites have continued to operate. Currently PM_{10} is monitored using TEOM monitors at 18 sites within the MAQS network (covering Sydney, Illawarra and Lower Hunter regions). $PM_{2.5}$ is measured using TEOM monitors at 10 sites as shown in Table A2-2 (Appendix 2).

3.2.3 Queensland

Monitoring of particles has been conducted in Queensland for many years. Nephelometer monitoring began in 1978 at three sites, namely Eagle Farm, Fortitude Valley and Rocklea. By the end of 1999, seven stations (Eagle Farm, Brisbane CBD, Rocklea, Flinders View, Targinie, Gladstone and Mackay) were in operation. PM_{10} and $PM_{2.5}$ monitoring has been undertaken using high volume samplers as well as TEOMs and Australian Nuclear Science and Technology Organisation (ANSTO) designed instruments. Monitoring using high volume samplers began in 1986 and has continued over the last decade, with nine sites currently operational. The first TEOM monitoring commenced in 1992 for PM_{10} with ten sites currently operational. $PM_{2.5}$ monitoring using TEOMs began in 1998. ANSTO instruments have been operational since 1995 for $PM_{2.5}$ monitoring. Table A2- 4 (Appendix 2) shows details of this monitoring.

3.2.4 South Australia

PM_{10} monitoring has been conducted with high volume samplers with size-selective inlets in Adelaide since 1988 and in Port Pirie since 1984. In 1999, four sites were operating in Adelaide, three in Port Pirie and one in Whyalla. There are currently no $PM_{2.5}$ data collected by any method in Adelaide. However, there are plans to install nephelometers at three sites co-located with TEOM PM_{10} monitors, one of which will also have a TEOM $PM_{2.5}$ monitor. There will be a fourth site with TEOM PM_{10} and $PM_{2.5}$ monitors co-located. The timing of this plan depends to some extent on the service provider as ambient monitoring has been contracted out.

3.2.5 Tasmania

The Department of Primary Industries, Water and the Environment (DPIWE) conducts ambient air monitoring in Tasmania. To date, there has been limited monitoring of $PM_{2.5}$ in Tasmania's ambient air, as follows:

- between June 1994 and June 1995, 24-hour average $PM_{2.5}$ monitoring was conducted in the Hobart suburb of Moonah for four months (1 in 6 day cycle), with 72-hr average samples collected for nine months;
- between June and September 1992 and May to August 1993, 72-hour average $PM_{2.5}$ samples were collected in the Launceston suburb of Glen Dhu; and
- monitoring of $PM_{2.5}$ in Hobart and Launceston has been undertaken using a dichotomous sampler.

An analysis of the $PM_{2.5}$ data and a consideration of the filter preparation procedure indicate that the monitoring results for $PM_{2.5}$ in Hobart and Launceston may be suspect (DELM, 1997). Lyons (1996) has documented $PM_{2.5}$ monitoring results for Launceston.

3.2.6 Victoria

Nephelometry data has been collected since the late 1970s. PM_{10} monitoring using high volume samplers began in Melbourne and the Latrobe Valley in the mid-1980s. By the end of 1995, all high volume samplers, which measure TSP, were fitted with size-selective inlets that measure PM_{10}. A TEOM instrument measuring PM_{10} was introduced at Alphington in December 1994. TEOM instruments can provide a continuous measure of particles - including PM_{10}, $PM_{2.5}$ and PM_1. PM_{10} TEOMs were introduced in the Footscray and Brighton air monitoring stations in late 1996. At the same time $PM_{2.5}$ monitors were introduced at

Alphington, Brighton and Footscray. A PM_1 monitor was also installed at the Footscray site. In early 1998, PM_{10} TEOMs were installed at the Dandenong and Box Hill air monitoring stations.

By the end of 1999 there were 5 stations (Alphington, Footscray, Brighton, Dandenong and Box Hill) where PM_{10} TEOM data were collected. Three stations (Alphington, Footscray and Brighton) have been collecting $PM_{2.5}$ data since 1998. The PM_1 monitor installed at the Footscray site collected data from November 1996 until September 1998. Table A2- 5, Table A2- 6 and Table A2- 7 (Appendix 2) show this monitoring data.

3.2.7 Western Australia

Particle measurement in Western Australia is undertaken by several methods. High volume samplers have been used to measure PM_{10} and TSP for several years. TEOM monitoring was introduced into the network in 1994 for $PM_{2.5}$ monitoring and in 1996 for PM_{10} monitoring. $PM_{2.5}$ monitoring using nephelometers began in the late 1980s with a total of three sites across the state. By 1999 there were nine stations in the network conducting monitoring with nephelometers. TEOM monitoring for $PM_{2.5}$ began in 1994 at Caversham. Further sites became operational during the following year. Table A2- 8 and Table A2- 9 (Appendix 2) show this monitoring data.

3.2.8 Industry Databases

There is very little data gathered by industry that would be of assistance to the review as any monitor would be located nearby a source of $PM_{2.5}$ to provide a measure of impact. These near source monitors are essential for assessing the control strategy at a particular facility but would provide an unrepresentative estimate of regional $PM_{2.5}$ levels. These data, however, may be useful for estimating particle emission rates for industrial processes.

3.2.9 Other Data

The Australian Nuclear Science and Technology Organisation (ANSTO) has been collecting $PM_{2.5}$ data at various sites within New South Wales for the last ten years. Data have been collected on the elemental composition of particles and may provide a useful database in the development of a standard for $PM_{2.5}$.

3.3 Particle Composition

Studies of fine particle composition have been undertaken in recent years in Australia and detailed in the report "Australian Fine Particle Study" (AFP) (Ayres et al., 1999). These studies show that in locations such as Launceston, the winter time aerosol measurements of particle mass below 2.5 micrometres are dominated by chloride, nitrates and sulfates using ion chromatography analysis. Studies in Brisbane, Canberra, Melbourne and Sydney show high levels of sulfate using the same technique, while Adelaide had high nitrate levels. This is a somewhat simplistic observation of a complex process and the reader is referred to the AFP report for detailed analysis. The main conclusion to be drawn from these studies is that the sources change with season and are dominated by domestic heating emissions in cold climates. It is likely that hourly measurements of particle composition would indicate significant diurnal variation.

3.3.1 Source Reconciliation Studies

Studies of source reconciliation of particles were also undertaken in the AFP report (Ayres et al., 1999). These studies show that in locations such as Canberra and Launceston the winter time aerosol measurements are dominated by emissions from solid fuel home heating, while the major cities have a greater fractional contribution from motor vehicles. The study

provides evidence of the strong role played by wood smoke in dominating the particle mass measurements below 2.5 micrometres.

3.4 $PM_{2.5}/PM_{10}$ Ratio Studies

The ratio of $PM_{2.5}/PM_{10}$ is generally about 0.5 based on annual averages, but there can be wide variations depending on season and airshed. Results from an ANZECC study of $PM_{2.5}/PM_{10}$ ratios in a number of airsheds are shown in Table 3-1. The results indicate that $PM_{2.5}$ as a percentage of PM_{10} concentration varies with season, being higher in winter than summer. Data from Duncraig in Western Australia (a wood smoke impacted area) for 1997 shows that the higher the particle concentration, the greater the contribution from $PM_{2.5}$.

Analysis of existing PM_{10} and $PM_{2.5}$ co-located data from New South Wales, Victoria and Western Australia shows that on days when the ambient PM_{10} standard is exceeded, the ratio of $PM_{2.5}$ to PM_{10} varies depending on season and location, and can range from 30% to 90%.

Table 3-1: Comparison of Particle Size Fractions in Australian Cities

City	Ratio ($PM_{2.5}$ as a % of PM_{10})	Ratio ($PM_{2.5}$ as a % of PM_{10})
	Winter	Summer
Brisbane	44	26
Melbourne	60	40
Sydney (a)	80	41
Sydney (b)	58	41

3.5 Regional Environmental Differences

Measurements of $PM_{2.5}$ in urban areas indicate that peak 24-hour average levels are around 30 to 40 $\mu g/m^3$. However, some regional centres (eg Launceston and Armidale) and metropolitan suburbs (eg Duncraig, Perth) impacted by wood smoke may have significantly higher $PM_{2.5}$ concentrations.

$PM_{2.5}$ concentrations vary with season, the higher values generally occurring in the autumn/winter months. This is when wood combustion for domestic heating is at its greatest and most of the fuel reduction burns and other large scale burning takes place. In addition, the weather patterns during these months favour the build-up of pollution because of poor dispersion. In areas where wood smoke from domestic fires dominates, particle levels higher than 150 $\mu g/m^3$ (24-hour average) have been recorded on occasions, with $PM_{2.5}$ being a major contributor. Nephelometer readings in areas dominated by wood smoke indicate that, on still cold nights, $PM_{2.5}$ levels consistently climb to high values. Readings of β_{sp} of 5 to 10 units are common. Using the Sydney Pollution Index as a guide, readings greater than 2.1 β_{sp} units (daytime visibility equivalent to 10 km as an hourly average) are considered high. In Victoria, the acceptable objective is a β_{sp} of 2.35 units, which has a daytime visibility equivalent to 20 km as an hourly average. The doubling in visual difference with a 12% increase in β_{sp} units provides evidence of likely regional differences.

Air quality is determined by a combination of pollutant emissions and meteorology that is complicated in some cases by physical factors such as topography and urban form.

NEPC has previously considered the relevance of regional environmental differences in Australia in setting national air quality standards. While recognising the wide variation in

climatic and other environmental conditions and taking into account the wide variation in physiological responses across any community, NEPC concluded that there is no practical way of reflecting regional environmental differences in ambient air quality standards with the present state of knowledge.

3.6 REGIONAL DATA

Data tend to be collected in areas where the largest exposure may occur, such as Sydney and Melbourne. There is a large proportion of the population in areas that are monitored so that it should be possible to estimate the overall impact and any averted health costs and control costs involved in setting standards. Areas of lower population are generally not monitored but may have lower levels in general.

NSW EPA has undertaken campaign monitoring of $PM_{2.5}$ in a number of regional centres. In collaboration with local councils, monitoring using nephelometers was undertaken over several winters in Armidale, Orange, Lithgow, and Cooma. In Orange and Armidale local councils are still operating nephelometers. In late 2000, NSW EPA began campaign monitoring of PM_{10} using TEOM instruments in Bathurst, Tamworth and Albury. Similar monitoring is planned for Wagga Wagga. These campaigns will contribute useful information to the knowledge of $PM_{2.5}$ levels in regional areas.

There will always be regions that are not monitored either because it is not practicable or because there is insufficient reason to do so.

3.7 SUMMARY

Five jurisdictions currently undertake regular monitoring for $PM_{2.5}$. As indicated in Table 3-2, the majority of the Australian population is contained in these states, however these population figures are only indicative of those exposed to $PM_{2.5}$ levels as airshed composition varies widely.

Table 3-2: Nephelometers and TEOMs in Jurisdictions

Jurisdiction	Population Millions	Nephelometers	TEOMs	TOTAL	Instruments per million
NSW	6.7	23	10	33	4.9
Victoria	4.9	12	3	15	3.0
WA	1.9	9	4	13	6.8
Queensland	3.7	7	2	9	2.4
ACT	0.34	2	0	2	5.9
TOTAL	17.5	53	19	72	4.0

New South Wales and Victoria contain the largest number of monitors with more than half of the total. There are two and half times as many nephelometers as TEOMs, although TEOM monitoring is growing and becoming more reliable. Table 3-2 indicates the number of nephelometers and TEOMs in each jurisdiction. The value of this monitoring is that it is continuous and, in the case of nephelometers, has been carried out over a long period of time.

Measurement correction issues associated with TEOMs have not been addressed for $PM_{2.5}$ at this stage, although they have for PM_{10}. It is likely, however, that $PM_{2.5}$ measurements will entail decreased measurement precision, compared to PM_{10} measurements, because on average only half as much particle mass will be sampled (CSIRO, 2001).

$PM_{2.5}$ levels exceed 20 µg/m³ as a 24-hour average on about 20 days per year in some jurisdictions reducing to about 4 exceedences of 30 µg/m³ as a 24-hour average depending on individual years.

Data gathered by industry is unlikely to be of assistance to the review as monitoring would include the direct impact of sources of $PM_{2.5}$.

- **Can current and future challenges associated with measuring $PM_{2.5}$ be resolved?**
- **Will regular monitoring of $PM_{2.5}$ be a better measure of public health impacts if measurement problems can be resolved?**
- **Should the setting of a $PM_{2.5}$ standard in Australia be delayed by the lack of data in some urban and regional areas?**
- **Are there any industry data that are relevant to the review?**

3.8 REFERENCES

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4 HEALTH EFFECTS OF PARTICLES

4.1 INTRODUCTION

The health effects of the criteria air pollutants have been known for many years. This information has been derived mainly from controlled human exposure and population based epidemiological studies, as well as animal toxicological studies.

Unlike the other criteria pollutants, particles are a broad class of chemically and physically diverse substances. They exist as discrete particles spanning several orders of magnitude in size - 0.005 to 50 μm. They are emitted from a wide range of sources both anthropogenic and natural. The biological effects of particles are determined by the:

- physical and chemical nature of the particles;
- physics of deposition and distribution in the respiratory tract; and
- physiological events that occur in response to the presence of particles.

Interest in airborne particles, in particular PM_{10} and $PM_{2.5}$, has increased significantly over recent years. Much of this interest has arisen from the results of epidemiological studies worldwide that have attributed increases in adverse health outcomes to increases in particle air pollution. Extensive reviews of these studies can be found in NEPC (1998) and USEPA (1996).

The health effects of particles include increases in daily mortality, hospital admissions and emergency room (ER) attendances, and exacerbation of respiratory symptoms and asthma. These effects have been found in studies in many parts of the world with differing climates and socioeconomic factors. Populations that have been shown to be susceptible to the effects of particles include the elderly; people with existing respiratory disease such as asthma, chronic obstructive pulmonary disease (COPD) and bronchitis; people with cardiovascular disease; people with infections such as pneumonia; and children. Results of epidemiological studies have provided no evidence for the existence of a threshold value below which no adverse health effects are observed, and there is still a question over the biological mechanism(s) that give rise to these effects.

There have been extensive studies into the health effects of particles conducted in various parts of the USA that experience differing levels of particles and pollution mixes. These studies have been conducted using mainly TSP or PM_{10} as the exposure metric, as monitoring data for $PM_{2.5}$ has been limited. More recent studies have used $PM_{2.5}$ data in addition to PM_{10}, and in some cases data on the coarse fraction ($PM_{10-2.5}$) has also been utilised. The results of the earlier studies of PM_{10} were fairly consistent across the US. The dose response relationships derived from these studies indicated that a 1% increase in daily mortality was associated with a 10 $\mu g/m^3$ increase in daily PM_{10}.

The US studies have been used to make some compelling arguments in support of a causal link between short-term increases in particle pollution and adverse health effects. These studies have been conducted in locations with substantial variability in type and concentrations of other pollutants and meteorology, with the only consistent factor being the particle concentration. Studies from the eastern US and Canada have had to deal with a mix of summer pollutants which include particles, SO_2 and O_3, as well as acid aerosol. Concentrations of these pollutants are correlated to a greater or lesser extent depending on the location. Recent studies have shown that increases in daily particle levels, PM_{10} and TSP,

are associated with increases in heart rate, plasma fibrinogen, blood pressure and pulse rate (Ibald-Mulli et al., 2001; Pekkanen et al., 2000; Peters et al., 1999; Pope et al., 1999; Peters et al., 1997). All these factors increase the risk of cardiovascular conditions and may relate to the changes in cardiovascular autonomic control. This may explain the associations observed between increases in daily mortality and hospital admissions for cardiovascular disease and PM_{10} that have been reported in epidemiological time-series studies.

Recent work conducted in the US as part of the National Morbidity, Mortality and Air Pollution Study (NMMAPS) (Samet et al., 2000) has investigated the association between particles and daily mortality in twenty US cities using a standardised statistical approach (NMMAPS I). The results of this study have shown that there is substantial variability in the observed associations and effect estimates between study locations. Combining the results of the individual analyses yielded an overall effect estimate for the cities studied of 0.34% per 10 $\mu g/m^3$ increase in daily PM_{10}. The results of this study also found that the observed associations were more similar for locations close to each other than for cities further away. There is evidence that the association between PM_{10} and mortality in the western US was larger than in the east or south. A similar analysis undertaken for ninety US cities (NMMAPS II) found stronger effects in the north-east US than observed in NMMAPS and the meta-analysis indicated that a 0.5% increase in daily mortality was associated with a 10 $\mu g/m^3$ increase in daily PM_{10}.

The UK Department of Health reviewed the studies that relate air pollution in the UK to adverse health effects (UK Department of Health, 1998). This report quantifies the health effects in Great Britain that can be attributed to air pollution. As far as possible the effect estimates have been based on UK or European studies, however where this was not possible the WHO estimates have been used.

Studies conducted in Europe as part of the 'Air Pollution and Health: A European Approach' (APHEA) program have shown that although associations are observed between particles and adverse health effects, the results are not as consistent as those observed in the US studies. In general the effect estimates observed in the UK and Europe are lower than those observed in the USA. The reason for this is unclear but may be due to high levels of acid aerosols in the USA, or possibly the use of black smoke in the UK and European studies (UK Department of Health, 1998).

The results from a meta-analysis of the APHEA studies, where a variety of measures of particles were used, revealed a 0.44% increase in daily mortality per 10 $\mu g/m^3$ increase in PM_{10}. It has been estimated that in Great Britain there are 8,100 premature deaths and 10,500 hospital admissions for respiratory disease per year that can be attributed to exposure to PM_{10} (UK Department of Health, 1998).

There have been several studies conducted in Australia to investigate the health effects associated with exposure to air pollution. All of these studies have used nephelometry data as a surrogate for $PM_{2.5}$. The association between daily mortality and air pollution has been investigated in Sydney, Brisbane and Melbourne (Morgan et al., 1998a; Simpson et al., 1997; Simpson et al., 2000; EPA (Vic) 2000). Sydney, Brisbane and Melbourne, like most Australian cities, experience very low levels of SO_2 which means that confounding by this pollutant is unlikely.

The Sydney study (Morgan et al., 1998a) showed a 2.6% increase in daily mortality associated with an increase in PM_{10} (calculated from nephelometry data) of approximately 25 $\mu g/m^3$.

Daily mortality was also found to be associated with O_3 and NO_2, but when all pollutants were considered in the same model, the effect of particles dominated.

The mortality study conducted in Brisbane (for the period 1987 to 1993) found similar results to the Sydney study (Simpson et al., 1997). Significant positive associations were found for daily mortality and particles and O_3. Maximum 1-hour and 8-hour βsp as well as 1-hour and 8-hour O_3 were associated with total mortality, especially in the summer. The effects of SO_2 and NO_2 on daily mortality were not significant. When all pollutants were considered in the model, O_3 and particles remained significant suggesting that the effects were independent. The associations were more significant for the elderly and for mortality from cardiovascular causes. An increase in particle levels corresponding to a 10 $\mu g/m^3$ increase in PM_{10} was associated with an increase in daily mortality of between 1.2 to 1.3%.

A recent study conducted in Melbourne (Simpson et al., 2000) found that ambient particle levels in Melbourne were not significantly associated with daily mortality in whole year models. In contrast however, significant associations were observed with same day 1-hour maximum and 24-hour average βsp in the warm season. These effects were observed for all cause and respiratory mortality in the all ages and 65+ age groups. No significant associations were observed for cardiovascular mortality in either of the age groups examined. In this study the effects of ozone and nitrogen dioxide were found to be the most significant.

An earlier study conducted in Melbourne investigated the association between asthma attendances at the Emergency Department of the Royal Childrens' Hospital and nephelometry data from the EPA's air monitoring network (Rennick and Jarman, 1992) during smog days. Peak asthma attendances occurred during the winter months. A statistically significant association was found between asthma attendances and days with high levels of particles (reported as API). A lag effect was noted with associations observed up to two days after the occurrence of a smog day. Asthma attendances were also associated with API levels up to two days prior to the smog day. No association was found between asthma attendances and ozone levels during summer smog periods.

Hospital admissions for COPD and heart disease in Sydney have been found to be associated with daily maximum 1-hour particle levels as measured by nephelometry (Morgan et al., 1998b) for the period 1990-1994. Increases of 3% for COPD and 2.5% for heart disease have been found for an increase in particle levels (PM_{10}) of approximately 25 $\mu g/m^3$.

A study in conducted in Brisbane found significant positive associations between ambient particle levels and hospital admissions for asthma and respiratory disease in summer (Petroeschevsky et al., 2000). These effects were observed in the 15 to 64 age group and for total admissions. After controlling for other pollutants the association observed for the 15-64 age group lost significance.

A further study in Brisbane found that rural dust events impact on asthma severity in Brisbane (Rutherford et al., 1999). This study investigated the effects of dust storms on hospital emergency attendances and peak expiratory flow (PEF) and respiratory symptoms as recorded through a diary study. The results indicated that a number of dust events were associated with changes in asthma severity, but general relationships could not be determined.

Corbett et al., (1996) investigated hospital admissions and emergency room attendances for asthma during the NSW bushfires which occurred in 1994. During the eight-day period of the fires, PM_{10} levels were consistently high and peaked at 250 $\mu g/m^3$. No increase was observed in hospital attendances or emergency room attendances during the bushfire period, but this may have been due to the short duration of the event that may not allow for small changes to be detected.

A further study investigating the health effects of particles associated with the bushfires found no association between decreases in PEF in children (Jalaludin et al., 2000). Children with a history of wheeze were enrolled in a longitudinal study and completed a daily asthma diary. No significant associations were found between mean PM_{10} and PEF. The maximum daily PM_{10} level peaked at 210 $\mu g/m^3$ during the study period.

A study was conducted in Launceston and the Upper Tamar Valley, Tasmania, during 1992 and 1993 to assess the impact of air pollution in the region on respiratory health (Lyons et al., 1996). Launceston experiences high particle levels during the winter months due to a combination of meteorology and wood smoke from domestic heating. Hospital admissions data for asthma, bronchitis and COPD were assessed together with two control non-respiratory conditions - appendicitis and myocardial infarction. PM_{10} measurements were collected and averaged over five sites in the Launceston area. Hospital admissions for respiratory disease were found to be higher in winter and exhibited a general upward trend between 1991 and 1993. Air pollution levels are also higher during the winter months. Statistical analysis showed no correlation between the hospital admissions data and PM_{10} levels in Launceston. Similar results were found for emergency room attendances. This finding needs to be interpreted carefully due to the small amount of air monitoring data and the small study population.

A diary study was conducted in Brisbane on behalf of the Asthma Foundation in Queensland, to investigate the association of bioaerosols and air pollution on the incidence of asthma (Simpson et al., 1995). Between 100 and 120 subjects with asthma kept daily diaries of symptoms, lung function (PEF) and medication use for the period April 1994 to September 1995. Hospital attendance data were also collected during this period. Preliminary results have shown a significant association during the spring between the incidence of asthma severity with elevated levels of particles and pollen. Biomass burning during this period is a major source of respirable particles. No association was found between asthma and particles during the winter months when particle levels are at the lowest levels. Weak, but significant, effects were noted during the autumn period. Particles were measured as PM_{10} and βsp and the strongest association between asthma severity and particle air pollution appeared to be with PM_{10}. βsp was correlated at only one site during 1994. Time series analysis has shown that PM_{10} at both Brisbane South and Ipswich and βsp at Ipswich are associated with decreases in PEF.

Respiratory symptoms in children have been associated with PM_{10} levels in Newcastle and Wollongong in New South Wales (Lewis et al., 1998). Statistically significant associations between particle levels and chest colds and night-time cough were observed in children aged between 8 and 10 years. For a 10 $\mu g/m^3$ increment in annual average PM_{10} levels odds ratios of 1.43 for chest colds and 1.34 for night-time cough were observed. There was no significant association observed for SO_2 for any of the health outcomes investigated. Annual average PM_{10} levels ranged between 18.6 and 43.7 $\mu g/m^3$ across the study regions. Excluding the areas with the highest PM_{10} levels increased the odds ratio for chest cold, 2.05 compared with

1.43 for the whole area. The authors concluded that this result suggests that the dose-response for PM_{10} has a greater impact at lower levels.

The results of the studies outlined above have shown that the effects observed overseas are also observed in Australia even though air pollution levels in Australia are generally lower than those observed in the US and Europe.

In spite of the large body of literature on the health effects of particles there are still questions regarding the biological mechanisms responsible for the observed effects. As most of the studies to date have been conducted using either PM_{10} or TSP there are still questions as to what size fraction is responsible for the effects observed in epidemiological studies. The extent of confounding by other pollutants and the role of particle composition in the observed health effects is also unresolved.

4.2 Confounding by Other Pollutants and Weather

Attempts to attribute effects to only one pollutant have prompted questions as to whether it is possible to do so. In particular concern has been raised about the ability to separate the effects of particles from those of SO_2. Evidence to support an independent effect of particles has come from US studies that have been performed in locations where there is only minimal concern about the effects of these co-pollutants. For example, Salt Lake City in the Utah Valley experiences high levels of particles during the winter months that arise mainly from a local steel mill, and very low SO_2 levels. Ozone is only of concern during the summer and therefore does not confound the effects of particles during winter. The number of confounders is further reduced as the population is predominantly a Mormon community, and only 6% are smokers.

The studies conducted have looked at increases in daily mortality, hospital admissions, decreases in lung function, increases in respiratory symptoms and increased school absenteeism using a variety of statistical methods.

The dose-response relationships obtained from these studies are higher than those obtained from the US as a whole. These findings have provided strong evidence that there is an independent effect of particles on health.

The results of Australian studies have also provided evidence of an independent effect of particles. As previously mentioned, SO_2 levels in Australian cities are low, so confounding by SO_2 is unlikely. The studies in Sydney and Brisbane both showed independent effects of particles (Morgan et al., 1998; Simpson et al., 1997). The studies conducted in Newcastle and Wollongong investigating the effects of air pollution on the respiratory health of children also found independent effects of particles and SO_2 (Lewis et al., 1998).

It has also been claimed that the observed effects may be due to confounding by meteorological variables such as temperature or humidity. It is well documented that extremes of temperature do cause adverse health effects such as increases in daily mortality. In the majority of the time series studies conducted to investigate the health effects of air pollution, the impact of meteorological variables on the health outcomes is controlled before the analysis of the pollutant effect is undertaken. These studies have shown that even after controlling for these parameters there is an independent effect of particles. In some cases the statistical approach used for the control of the meteorological variables can affect the size of the effect estimate, but in general the results are robust within the statistical method used for analysis.

Similarly, epidemics of diseases such as influenza can also confound the effect attributable to particles. Where the information is available, these episodes are also controlled for in the statistical analysis.

4.3 What Size Fraction is Responsible for the Observed Effects?

To date the majority of epidemiological studies investigating the health effects of particles have been conducted using PM_{10} or TSP as a measure of particle air pollution. Studies using $PM_{2.5}$ are limited, as routine monitoring of this size fraction has not been conducted on a regular basis. Studies that have assessed the effect of $PM_{2.5}$ have not, in most cases, been able to evaluate the impact of the coarse fraction of PM_{10} in parallel. This has led to a situation where the relative impacts of the fine and coarse fractions have been able to be assessed directly in only a limited number of studies.

The results of some of studies conducted with $PM_{2.5}$ have indicated that this size fraction may be more important than total PM_{10} for explaining the health effects attributed to exposure to particles. The strongest evidence for this has come from an analysis in a study conducted in six US cities (Schwartz et al., 1996), where daily mortality in these cities was strongly associated with short-term increases in $PM_{2.5}$ concentrations. The associations observed for total PM_{10} and the coarse fraction of PM_{10} ($PM_{10-2.5}$) were weaker than those observed for $PM_{2.5}$ alone. It should be noted that in this study PM_{10} levels were dominated by the fine fraction with only very low levels of the $PM_{10-2.5}$ fraction observed. A recent re-analysis of this data (Klemm et al., 2000) confirmed the findings of the original analysis. A 1.3% (95% confidence interval (CI): 0.9-1.7%) increase in daily mortality was associated with a 10 $\mu g/m^3$ increase in daily average $PM_{2.5}$. By contrast for the coarse fraction $PM_{10-2.5}$ the observed association was 0.4% (95% CI: 0.2 - 0.9%).

Studies conducted in the US to investigate the effects of $PM_{2.5}$ on the respiratory health of children (Schwartz and Neas, 2000; Neas et al., 1999) have also shown that the effects of $PM_{2.5}$ are stronger than those attributed to the coarse fraction $PM_{10-2.5}$. In a re-analysis of the Six Cities Diary Study, lower respiratory symptoms were associated with an odds ratio of 1.29 for a 15 $\mu g/m^3$ increase in daily average $PM_{2.5}$ but not with $PM_{10-2.5}$ (odds ratio 1.05 (95% CI: 0.9-1.23) per 8 $\mu g/m^3$ increase in daily average $PM_{2.5}$). In a study conducted in Uniontown, Pennsylvania, reductions in PEF were associated with $PM_{2.5}$, in particular fine sulfate particles, but not with $PM_{10-2.5}$. These studies were conducted in areas where the airborne particle mass is dominated by $PM_{2.5}$.

Studies conducted in other parts of the world have also shown adverse effects associated with $PM_{2.5}$ (Ilbaca et al., 1999; Tittanen et al., 1999; Borja-Aburto et al., 1998; Delfino et al., 1997; Romieu et al., 1996). Borja-Aburto et al (1998) found that daily average $PM_{2.5}$ levels were associated with increases in daily mortality in Mexico City. The effects were stronger in the elderly and for deaths from cardiovascular and respiratory disease. The association observed for $PM_{2.5}$ was independent of the effects of other pollutants. This supports the results of an earlier study in Mexico City which found that both PM_{10} and $PM_{2.5}$ were associated with increases in lower respiratory illness in children aged 5 to 7 years who were mildly asthmatic. PM_{10} was also strongly associated with PEF.

In a study from Santiago, Chile (Ilbaca et al., 1999), both PM_{10} and $PM_{2.5}$ were found to be associated with respiratory related emergency visits for children. The effects of $PM_{2.5}$ were stronger than those observed for PM_{10}. Strong associations were observed for visits for pneumonia with a 6.7% increase in visits per 45 $\mu g/m^3$ increase in $PM_{2.5}$. Associations were also observed for NO_2 and SO_2.

Delfino et al (1997) investigated the associations between PM_{10}, $PM_{2.5}$, sulfates and aerosol acidity on ER visits for respiratory illness. Both PM_{10} and $PM_{2.5}$ were associated with ER attendances for the elderly with the strongest association found for $PM_{2.5}$. The effect estimates from this study were 0.20 ER visits/$\mu g/m^3$ increase in PM_{10} and 0.26 ER visits/$\mu g/m^3$ increase in $PM_{2.5}$. The effect of PM_{10} and $PM_{2.5}$ were much greater than that observed for sulfate, 0.005 ER visits/$\mu g/m^3$ increase in sulfate. No association was found for aerosol acidity.

A study conducted in Finland to investigate the effects of particles on PEF and respiratory symptoms in children with chronic respiratory symptoms has shown that no single particle measure or size could explain all the observed associations (Tittaten et al., 1999). The results of this study found that $PM_{2.5}$ (1-day lag) was associated with morning PEF, while particle numbers in the size range 0.1 to 1 µm were associated with evening PEF. PM_{10}, $PM_{2.5}$ and $PM_{10-2.5}$ were all associated with increased risk of cough. The results of this study highlight that each particle measure can be associated with adverse health effects.

Studies conducted in Helsinki (Ponka et al., 1998), Coachella Valley, California (Ostro et al., 1999) and Phoenix, Arizona (Mar et al., 2000) have indicated that the coarse fraction of PM_{10} ($PM_{10-2.5}$) is associated with increases in daily mortality. These studies have been conducted in areas where particle levels are dominated by crustal particles in the coarse fraction. A follow-up study in the Coachella Valley (Ostro et al., 2000) has confirmed the findings of the previous study. In this study PM_{10}, $PM_{2.5}$ and $PM_{10-2.5}$ were investigated for their impact on daily mortality from all causes, cardiovascular and respiratory disease. Consistent associations were found for PM_{10} and $PM_{10-2.5}$ and cardiovascular mortality. No associations were found for $PM_{2.5}$ and any health outcome.

Hospital admissions for asthma in Seattle were found to be associated with PM_{10}, $PM_{2.5}$ and $PM_{10-2.5}$, with the strongest effects observed from PM_{10}. However, similar effect estimates were observed for $PM_{2.5}$ and $PM_{10-2.5}$. Carbon monoxide was also found to be associated with increases in hospital admissions for asthma.

Other studies have shown that the coarse fraction may be important for asthma and upper respiratory illnesses (Vedal, 1997; Gordian et al., 1996; Choudbury et al., 1997). Studies conducted in Anchorage, Alaska, have shown correlations between doctors' visits for asthma, bronchitis and upper respiratory illness associated with daily fluctuations in PM_{10} (Gordian et al., 1996; Choudbury et al., 1997). PM_{10} in Anchorage is dominated by the coarse fraction with 80% of total PM_{10} in the $PM_{10-2.5}$ fraction, of mainly crustal or volcanic origin. Doctors' visits for asthma were found to increase by 3-6% per 10 $\mu g/m^3$ increment in PM_{10} while attendances for upper respiratory disease were found to increase by 1-3% for the same increment.

The issue of particle size was considered by the USEPA in the review of the US air quality standards (USEPA, 1996b). It concluded that '*while the relative toxicity of fine and coarse fraction particles is not clearly established, both the physical and chemical toxicological considerations suggest that fine particles are likely to be more toxic for several, but not all, of the relevant effects categories than are coarse fraction particles*'. With respect to the results of the epidemiological studies associating exacerbation of asthma with PM_{10} and the relative importance of the coarse fraction in the response, these results are consistent with the site of deposition of the coarse fraction in the airways. $PM_{2.5}$ penetrate deeply into the lung whereas the coarser fraction tends to deposit in the tracheobronchial region, the area where asthma attacks are triggered.

However, recent studies have also shown that the coarse fraction is also associated with increases in daily mortality.

4.4 ULTRAFINE PARTICLES

There has been a case made that ultrafine particles (particles less than 0.1 μm in diameter) are the most pathogenic fraction and are largely responsible for the associations observed in epidemiological studies (Orberdorster et al., 1995). This case is based on theoretical arguments and the results of animal studies.

Toxicological studies using animals exposed to high concentrations of aggregates of ultrafine particles have demonstrated that these particles can cause lung damage as reflected by increases in lung inflammation (Orberdorster et al., 1992) and lung fibrosis (Orberdorster et al., 1994). In these studies exposure to ultrafine particles did not cause death in the animals. Further experiments (Orberdorster et al., 1995), with unaggregated ultrafine particles showed that exposed rats developed lung inflammation and died from pulmonary oedema.

Ultrafine particles rapidly agglomerate into larger particles which may lead to significant numbers of ultrafine particles not reaching the portion of the lung susceptible to the effects of this size fraction. Recent work has shown that only low concentrations of ultrafine particles are resident in human lungs (Churg and Brauer., 1997), implying that either these particles do not reach those portions of the lung, or if they do, they are not retained either because they are soluble or are transported. The results of this study indicated that $PM_{2.5}$ was retained by the lung and therefore should be the focus of any studies into the long-term effects of particles. A more recent study by Churg and Brauer (2000) found that particles of between 0.3 and 0.6 μm are retained in the airways and that $PM_{2.5}$ is retained rather than PM_{10}. This study also found that the majority of particles found in the airways of Vancouver residents were in fact crustal in origin, with particular accumulation of silica in the airways.

Osuyana et al (2001) investigated the effects of PM_{10} and numbers of ultrafine particles on PEF and respiratory symptoms in patients with COPD. The results of this study showed that the changes in daytime PEF and increases in symptoms, such as shortness of breath and cough, were associated with PM_{10} but not with ultrafine particles. The conclusion of this study was that the coarse fraction of PM_{10} should not be dismissed as making a contribution to the observed associations between particles and adverse health effects.

A recent study in Finland (Pettinen et al., 2001a) found non-significant inverse associations between particle number concentrations (ultrafine particles) and FVC, FEV_1 and PEF in a cohort of adult asthmatics. A previous study in Finland has shown that the effects of particles on PEF increased with decreasing particle size with the strongest effects observed for ultrafine particles (Pettinen et al., 2001b). Peters et al (1997) also found associations between ultrafine particle concentrations and PEF in asthmatic subjects.

There are very few epidemiological studies that have been conducted to look at the effects of ultrafine particles. The results of studies to date show conflicting results and provide no clear evidence as to the role of ultrafine particles in the health effects attributed to particles.

4.5 LONG-TERM HEALTH EFFECTS

The long-term impact of particles on health is still an area where there is much uncertainty. The Six Cities Study (Dockery et al., 1993), a prospective cohort study, investigated the long-term effects of air pollution on mortality for a group of 8111 adults aged between 25 and 74

years of age for the period 1974 to 1990. The cities studied had significantly different levels of airborne particles ranging from an average of PM_{10} of 18.2 $\mu g/m^3$ in Portage, Wisconsin, to 46.5 $\mu g/m^3$ in Steubenville, Ohio. After controlling for smoking and other risk factors such as age, weight, and educational level, strong associations were found between mortality and levels of PM_{10}, $PM_{2.5}$ and sulfate particles. The observed association was related to pollution levels in each city and was strongest in the most polluted city. Associations were found for death from lung cancer and cardiopulmonary disease but not from other causes considered together. The strongest associations were found for $PM_{2.5}$ and sulfates. The adjusted mortality-rate ratios between the least and most polluted cities, were found to be 1.26 (all cause), and 1.37 (lung cancer or cardiopulmonary disease).

One of the largest studies to date investigating the chronic effects of particulate matter on mortality is a prospective study carried out between 1982 and 1989 in 151 metropolitan areas in the US (Pope et al., 1995). This study relied on data for 552,138 men and women drawn from the American Cancer Society (ACS) Cancer Prevention Study II, an ongoing prospective mortality study of approximately 1.2 million adults. An association between mortality and $PM_{2.5}$ was observed and this association persisted after controlling for age, sex, race, cigarette smoking, cigar and pipe smoking, exposure to passive cigarette smoke, occupational exposure, education, body mass index, and alcohol use. The associations held for all cause and cardiopulmonary mortality. Lung cancer appeared to be more strongly associated with sulfate levels than with $PM_{2.5}$. Estimated pollution-related mortality risk was as high for non-smokers as it was for smokers and as high for women as for men. The authors estimated that eight deaths per year per 100,000 persons were associated with $PM_{2.5}$. A difference of between 15% and 17% in mortality risks was observed between the least and most polluted cities, a range of daily concentrations from 9 to 33.5 $\mu g/m^3$.

A re-analysis of the Six Cities Study and the ACS study was undertaken by the Health Effects Institute. The re-analysis replicated the general findings of the two studies.

The effect of long-term exposure to airborne particulate matter on the symptoms and development of COPD in non-smoking Seventh-Day Adventists in California has been investigated (Euler et al., 1987; Abbey et al., 1995). Seventh-Day Adventists form a sub-population whose response to air pollution may differ from the general population due to their abstinence from cigarette smoking and alcohol. In addition they have very low exposure to in-home passive smoke. These studies indicated that exposure to TSP concentrations exceeding 200 $\mu g/m^3$ was associated with the development of COPD, chronic bronchitis and asthma in a non-smoking population. Ozone and other measures of particles (PM_{10} and $PM_{2.5}$) were also found to be strongly associated with all health outcomes. Whether these responses would be observed at lower exposures is unclear at this time. A more recent study of the California Seventh Day Adventists has shown that long-term exposure to $PM_{2.5}$ is more strongly associated with mortality than the coarse fraction $PM_{10-2.5}$ (McDonnell et al., 2000).

4.6 Role of Particle Composition

The role of particle composition is another area which is still unclear. The evidence from epidemiological studies that would favour a role for chemical composition is not convincing (Vedal, 1997). Although particles from combustion sources appear to be more important than crustal particles, in terms of mortality at least, it is not clear that this difference is not due merely to the difference in size fraction. However, recent studies have also shown that crustal particles are also associated with increases in daily mortality. Combustion particles are predominantly in the fine fraction whereas crustal particles predominate in the coarse

fraction. The studies in Alaska (Choudbury et al., 1998; Gordian et al., 1997) have indicated that crustal particles may be important with respect to exacerbation of asthma and upper respiratory illness but this may be due again to the size of the particle and the site of deposition in the airway.

A study in Helsinki has indicated that crustal particles may also be important with respect to daily mortality (Ponka et al., 1998). Helsinki has high levels of PM_{10} that arise mainly from erosion of fine sand on roads. This means that the PM_{10} composition is predominantly crustal in origin. The results of this study showed a strong correlation between PM_{10} levels and daily mortality from both all cause and cardiovascular disease. A 3.5% increase in daily mortality (all cause) and 4% increase in cardiovascular mortality per 10 $\mu g/m^3$ increment in PM_{10} were observed. This study has raised some questions regarding the relative toxicity of crustal versus combustion particles.

A toxicological study has been conducted to assess the relative toxicity of various particle types in rats (Murphy et al., 1998). This study compared the relative effects of diesel particles, carbon black, respirable crystalline silica and amorphous silica on rat epithelium. The results of this study indicated that diesel particles were less damaging than either of the silica particles and that the surface chemistry was more important than ultrafine size in explaining the biological reactivity.

Amorphous silica was found to cause transient lung damage and had limited fibrogenic potential. In contrast respirable crystalline silica had a progressive effect on the lung with the worst damage present twelve weeks after exposure. Increases in lung permeability and persistent inflammation were observed. Neither diesel nor carbon black particles were as damaging as either of the silica particles. There was little or no effect on lung permeability, epithelial markers or inflammation. Carbon black was found to be well distributed throughout the lung and was found to accumulate in the lymph nodes. For the other substances the distribution was not as well defined but swelling and inflammation of the lymph nodes were observed.

A number of recent studies have been conducted to investigate the relative toxicity of PM_{10} and $PM_{2.5}$ (Osuyana et al., 2001; Soukup and Becker, 2001; Monn and Becker, 1999; Churg and Bauer, 2000). These studies have not been able to define which particle size fraction is responsible for the associations observed in the epidemiological studies.

A study by Monn and Becker (1999) has shown that significant toxicity and cytokine production (inflammatory mediators) is introduced by ambient coarse particles ($PM_{10-2.5}$) but not by $PM_{2.5}$ or particles collected indoors. Ambient $PM_{10-2.5}$ induced 20 times the amount of interleukin-6 and interleukin-8 than $PM_{2.5}$.

A further study by Soukup and Becker (2001) investigated the effects of water soluble and insoluble particles on the functional capacity of alveolar macrophages. The alveolar macrophage is the central lung cell in the regulation of the immune response to inhaled pathogens and the development of inflammation. Additionally, it is central to non-specific host defence through phagocytosis of foreign material such as particles (Holian, 1997). It has been proposed that the macrophage may play a central role in the observed responses arising from exposure to particles. Soukup and Becker (2001) found that the functional capacity of alveolar macrophages is selectively modulated by insoluble components of $PM_{10-2.5}$. Soluble $PM_{10-2.5}$ were more active than insoluble $PM_{2.5}$. Soluble $PM_{2.5}$ was inactive with respect to the functional capacity of alveolar macrophages.

Laden et al (2000) used elemental composition of size-fractionated particles to identify several distinct source related fractions of $PM_{2.5}$ and examined the associations with daily mortality in each of six eastern US cities. In a combined analysis, a 10 $\mu g/m^3$ increase in $PM_{2.5}$ concentrations from mobile sources accounted for a 3.4% increase in daily mortality (95% CI, 1.7 - 5.2%). The equivalent increase in $PM_{2.5}$ from coal combustion sources accounted for a 1.1% increase (95% CI, 1.7 - 5.2%). $PM_{2.5}$ crustal particles were not associated with daily mortality.

In summary, the results of studies to date have not shown a clear role for particle size or composition in the health effects observed in epidemiological studies. Adverse health effects, such as increases in daily mortality and increases in hospital admissions, have been associated with PM_{10}, $PM_{2.5}$, $PM_{10-2.5}$ and ultrafine particles. Studies conducted using $PM_{2.5}$, and to a greater extent $PM_{10-2.5}$, are limited due to the lack of monitoring data in these size fractions, making it difficult to accurately assess the relative importance of each size fraction. The role of particle composition in the observed health effects is also unclear, with adverse effects attributed to both crustal and combustion particles.

4.7 Biological Mechanisms

There is a considerable amount of research currently underway to investigate the potential mechanisms by which particles may cause adverse health effects. A large amount of this work has been focused on the effects on the cardiovascular system. A study conducted by Godleski et al (1996) was the first animal study that showed effects in animals similar to those observed in epidemiological studies. In this study both healthy rats and rats with bronchitis were exposed to concentrated ambient $PM_{2.5}$ from Boston air. The rats were exposed for six hours on two consecutive days. An increase in mortality was observed in rats with bronchitis. A similar effect was not observed in healthy animals. Biopsies of the lungs of these animals indicated that inflammation as well as airway constriction was important in the observed response.

In a more recent study, Godleski exposed dogs to 100 to 200 $\mu g/m^3$ of $PM_{2.5}$ in an exposure chamber for six hours per day for three days (Godleski et al., 1997). The results of this study showed electrocardiogram changes in the dogs that are risk factors for arrhythmia. Instillation of 250 µg of combustion particles into the lungs of rats produced arrhythmia and deaths (Watkinson et al., 1998). In humans particles have been associated with increases in plasma viscosity (Peters et al., 1997), increased risk of elevated heart rate (Pope et al., 1999) and changes in heart rate variability (Shy et al., 1997; Schwartz et al., 2000).

The biological effects of a particle are determined by the physical and chemical nature of the particle, the physics of deposition and distribution in the respiratory tract and physiological events that occur in response to the presence of the particle. Particle size is the most important characteristic influencing deposition in the airways. Particles greater than 5µm in diameter deposit in the upper airways or larger lower airways. Particles smaller than 5µm in diameter deposit in the smaller airways such as the bronchioles and alveoli.

A study by Kim and Kang (1997) has investigated the lung deposition of $PM_{2.5}$ in normal subjects and in subjects with COPD. They compared the response of non-smokers, smokers, smokers with small airways disease; asthmatics and patients with COPD to the inhalation of 1µm particles. The results of this study showed that the deposition fraction was 103% greater in patients with COPD than in non-smokers and that the deposition increased with the severity of airway obstruction. Compared with asthmatics the deposition rate in COPD

patients was roughly double. It was concluded that patients with COPD accumulate a greater particle burden more rapidly than the healthy population and that this may explain the susceptibility of this group observed in epidemiological studies.

The role of the macrophage in the observed responses is emerging as a key issue. In a recent study (Holian et al., 1998), human macrophages exposed to particles from urban air underwent apoptosis (cell suicide). The particles used in this study were a mix of both crustal and combustion particles. There are two types of macrophages in the lung - stimulatory and suppressant. The stimulatory macrophages cause the immune system to respond to the presence of foreign material and try to remove it. An excess of stimulatory macrophages can cause damage to the lung in the process of removal of the foreign material. Suppressor macrophages are present to stop this from happening. The results of the study by Holian showed that the suppressor macrophages underwent apoptosis when exposed to particles from urban air causing an imbalance of the stimulatory macrophages leading to an inflammatory response. It is thought that if such a response occurred in humans then this could explain some of the effects observed in epidemiological studies. Asthmatics and people with other chronic lung diseases have approximately one third the suppressor macrophages of people with healthy lungs. The conclusion was that this imbalance would make these groups more susceptible to the type of mechanism observed in isolated cells.

One area that has received a lot of attention is the role of diesel particles in the observed responses to particles. The Health Effects Institute in the US (HEI, 1995) concluded that the major mode of action of diesel particles appeared to be alterations in macrophage lung clearance mechanisms. The results of studies conducted on rats showed that there was evidence of impairment of particle clearance from the broncho-alveolar regions of the rats.

A more recent study (Miyabara et al., 1998) exposed mice to diesel particles and then challenged them with allergen. The results of this study showed that exposure to diesel increased neutrophil and macrophage numbers in bronchoalveolar lavage fluids. Evidence of enhanced airway inflammation and hyper-responsiveness on allergen challenge was also observed.

4.8 SUMMARY

Epidemiological studies show a correlation between exposure to particles and adverse health effects. At this time there is no conclusive evidence regarding the role of particle size in the response. Studies investigating the effects of different size fractions have shown that associations are observed with PM_{10}, $PM_{2.5}$ and $PM_{10-2.5}$. As adverse health effects are observed with all size fractions, control of each size fraction by adopting ambient air quality standards for both PM_{10} and $PM_{2.5}$ should be considered.

At this time the results of toxicological studies indicate that crustal particles can be as damaging as combustion particles for a given size range. There is no clear evidence of a role for particle composition. The biological mechanisms giving rise to the effects observed in epidemiological studies are still unclear although some information is emerging regarding a possible mechanism for cardiovascular effects.

There is no evidence, based on epidemiological data, that there is a threshold concentration of either PM_{10} or $PM_{2.5}$ below which adverse health effects will not be observed. The differences observed in the results from the studies conducted in different parts of the world suggest that the dose response relationships determined within a particular country or region may not be readily transferable to other areas.

- **How significant are the results of recent overseas epidemiological studies on the health effects of $PM_{2.5}$?**
- **How significant are the results of recent Australian epidemiological studies on the health effects of $PM_{2.5}$?**
- **How critical is the role of particle composition in terms of public health impacts?**
- **Are crustal particles just as damaging as combustion particles for the same size fraction?**
- **How critical is the role of particle size in terms of public health impacts?**
- **Is there sufficient health risk data for $PM_{2.5}$ to justify the setting of a $PM_{2.5}$ standard?**
- **What health benefits can be expected by setting a $PM_{2.5}$ standard?**
- **What significance should be placed on the fact that epidemiological studies do not show evidence of a threshold value below which no adverse health effects are observed?**

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5 DO WE NEED A STANDARD FOR $PM_{2.5}$

5.1 STANDARDS FOR PARTICLES - THE WORLDWIDE SITUATION

While PM_{10} standards are quite common overseas, of the major jurisdictions, only the USA and, more recently, Canada have introduced a $PM_{2.5}$ standard.

The reason for this is that until recently monitoring of particles has focused on TSP and PM_{10}, so the epidemiological studies have been conducted with these size fractions. This situation is likely to change as $PM_{2.5}$ is monitored on a more routine basis and the epidemiology is indicating that $PM_{2.5}$ has an important role in the adverse health effects associated with particles (New Zealand Ministry of the Environment, 2000).

5.1.1 USA

The latest review of National Ambient Air Quality Standard (NAAQS) for particles was completed in 1997. In this review, the PM_{10} standards were retained and two new primary $PM_{2.5}$ standards were introduced; set at 65 $\mu g/m^3$ (24-hour average) and 15 $\mu g/m^3$ (annual average). These standards were introduced to provide increased protection against the particle-related health effects found in community studies (USEPA, 1997a; USEPA, 1997b).

USEPA concluded that much of the total annual risk associated with short-term exposures is likely to result from days when the particle levels are in the low-to-mid range, below the 24-hour peaks. As a result, lowering a wide range of $PM_{2.5}$ concentrations through an annual standard, as opposed to focusing on controlling peak 24-hour concentrations, was considered to be the best way to reduce total $PM_{2.5}$ risk. USEPA also believes that the 24 hour standard will provide additional protection for days with high $PM_{2.5}$ concentrations, localised "hot spots" and risks arising from seasonal emissions, such as wood smoke in the winter (USEPA, 1997b; Ministry of the Environment NZ, 2000).

However, the $PM_{2.5}$ standards, together with new standards for ozone, were recently challenged in the US Supreme Court. The US Supreme Court at the time did not question the science behind the setting of the $PM_{2.5}$ standards, but overturned the standards based on a legal issue surrounding the ability of the USEPA to implement the standards.

Following an appeal by the US EPA, a landmark unanimous decision of the full bench of the United States Supreme Court on 27 February 2001 upheld the importance of setting health based ambient air quality standards including those for $PM_{2.5}$. The Court found that the US Clean Air Act bars consideration of costs when setting ambient standards. This in effect means that standards should be set so that the community knows whether the air is safe or not and that costs should be subsequently considered when determining the strategies to meet the standards and not in setting the standards themselves.

5.1.2 Canada

Canada recognises the fine fraction of particles as having the greatest effect on human health. In June 2000, the Governments of Canada, the Provinces and Territories (except Quebec), set a $PM_{2.5}$ standard of 30 $\mu g/m^3$ averaged over 24 hours (to be achieved by 2010). A planned review of this standard is to be completed in 2005 (Environment Canada, 2000; Canadian Council of Ministers of the Environment, 2000).

The Canada-Wide Standards (CWS) also recognise that health effects are associated with the coarser fractions, and recommends that individual jurisdictions continue to apply their

existing air quality objectives, guidelines or standards for the coarser fraction of particles to guide management actions. It notes that a standard for the coarser fraction may be a useful addition to the Canada-Wide Standards at a later date (Canadian Council of Ministers of the Environment, 2000).

While the CWS for $PM_{2.5}$ differs from the standard set by the USEPA, and appears to be much stricter as first glance, overseas air quality objectives often contain monitoring specifications or safety factors and this is usually the reason behind the variation in the levels specified in goals or guidelines.

In a USEPA Fact Sheet (dated 17 July 1997) on monitoring requirements for particulate matter, the design of monitoring networks was to include peak stations to be located in areas reflective of the highest measured values within each metropolitan area for comparison to the 24-hour standards. Hence the US $PM_{2.5}$ standard of 65 $\mu g/m^3$ (24 hr) is much more stringent than it first appears, possibly reflecting a $PM_{2.5}$ standard (using performance monitoring networks with no peak stations) of approximately 30 $\mu g/m^3$ (24 hr).

5.1.3 New Zealand

The Ministry for the Environment (MfE) in New Zealand is currently reviewing their Guidelines for Ambient Air Quality. MfE are proposing an interim guideline for $PM_{2.5}$ of 25 $\mu g/m^3$ (24-hour average). The introduction of an interim guideline is due to the fact that many Regional Councils do not monitor for $PM_{2.5}$. An interim guideline would however provide a basis on which to assess the results of any air monitoring. The Air Quality Guidelines are due for completion in late 2001. A guideline of 50 $\mu g/m^3$ (24-hour average) is proposed for PM_{10}.

5.1.4 United Kingdom

The National Air Quality Strategy sets standards and objectives based on recommendations made by the Expert Panel on Air Quality Standards, comprised of medical and air pollution experts. For particles, the dose response relationship derived by WHO (see below) has been used to set a level which, in the opinion of the Expert Panel, poses a minimal risk to the population.

The UK has not established a $PM_{2.5}$ standard, choosing to continue with their current standards for PM_{10} of 50 $\mu g/m^3$ (24-hour average) and 40 $\mu g/m^3$ (annual average). The Expert Panel, in considering the most appropriate particle fraction on which to develop air quality standards, has reaffirmed its view that the PM_{10} standard provides an appropriate level of protection for public health, with a close correlation existing between levels of PM_{10} and $PM_{2.5}$ (UK Department of the Environment, Transport and the Regions, 2000).

However, the Expert Panel has also recognised that $PM_{2.5}$ might be a better representative of the toxic fraction of particle air pollution, and that a $PM_{2.5}$ standard may be a desirable objective. However, in 1999 it reported that there was insufficient evidence on which to base such a standard (UK Department of the Environment, Transport and the Regions, 2000).

5.1.5 World Health Organization

World Health Organization (WHO) guidelines are set to protect public health from adverse effects of environmental pollutants, and for eliminating or reducing to a minimum, contaminants that are known or likely to be hazardous to human health and well being. In developing air quality standards from these guidelines, consideration must be given to local social, economic and environmental issues.

The WHO approach to setting guidelines for particles is contrary to their general approach for other air contaminants, such as lead and O_3. The WHO has decided not to set guidelines for particles, for the reason that there is no threshold concentration below which adverse health effects are not observed (WHO, 2000; NZ Ministry of the Environment, 2000).

The WHO has identified dose-response relationships that can be used to determine the risk of particle exposure to a given population. This approach allows an assessment by each jurisdiction that requires judgement on what is an acceptable risk on a case-by-case-basis.

5.1.6 Australia

The National Health and Medical Research Council (NHMRC) has established a goal for total suspended particles, which may have a size range up to 50 μm. While there are no NHMRC goals for $PM_{2.5}$ in Australia, Victoria and NSW have implemented visibility goals and these ambient objectives are shown in Table 5-1.

Table 5-1: Existing Australian Ambient Particle Objectives

State	Type	Measure	Value
Victoria	standard	visibility reducing particles	20 km (1hr)
NSW	goal	visibility reducing particles	10 km (1hr); $PM_{2.5}$ equiv = 60μg/m³ $PM_{2.5}$ equiv 24 hr = 35μg/m³
QLD	goal	visibility reducing particles	20 km (1hr)

In June 1998, NEPC set a national ambient PM_{10} standard of 50 μg/m³ (24-hour average). In the absence of a threshold concentration below which no adverse health effects occur, the standard was set at a level which, in the judgement of the NEPC, posed a minimal risk to the Australian population.

At that time, NEPC concluded that there was inconclusive evidence to support the setting of a standard for finer particles ($PM_{2.5}$ and PM_1). The lack of control cost data, challenges with the $PM_{2.5}$ measurement techniques, and the fact that a PM_{10} standard can act as a surrogate for a $PM_{2.5}$ standard in most instances, were also cited as reasons for setting a single PM_{10} standard. It was reported that the PM_{10} standard would be the equivalent in some air sheds to a 20 to 30 μg/m³ standard for $PM_{2.5}$ (NEPC, 1998).

However, NEPC did note the increasing evidence suggesting that the $PM_{2.5}$ fraction was the major area of concern with regard to adverse health effects, and that within a short period of time, could be the most appropriate indicator of public health impacts. To support a future review of the particles standard, jurisdictions were requested to continue or commence monitoring of $PM_{2.5}$ to ensure adequate data were available (NEPC, 1998).

5.2 Is PM_{10} an Adequate Surrogate for $PM_{2.5}$?

The characteristics and sources of $PM_{2.5}$ and PM_{10} can be very different. $PM_{2.5}$ result from fuel combustion activities (ie motor vehicles, power generation and industrial facilities), residential fireplaces and solid fuel (wood) heaters. $PM_{2.5}$ can also be formed in the atmosphere from gases such as sulfur dioxide, nitrogen oxides and volatile organic compounds. $PM_{10-2.5}$ on the other hand are generally emitted from sources such as vehicles

travelling on unpaved roads, bulk handling facilities, mining activities, crushing and grinding operations, and windblown dust.

The USEPA scientific review concluded that $PM_{2.5}$ is a better surrogate for those components of particles most likely linked to mortality and morbidity effects at levels below the previous standards, while high concentrations of coarse fraction particles are linked to effects such as aggravation of asthma. The US Clean Air Scientific Advisory Committee made a near unanimous (19 of 21 members) recommendation that new standards for $PM_{2.5}$ be added while retaining PM_{10} standards as an indicator for coarse fraction particles (USEPA, 1997a; USEPA, 1997b). Recent studies however have shown that the coarse fraction of PM_{10} is also associated with adverse health effects.

The Canada-Wide Standards note that reductions in ambient PM_{10} levels will occur as ancillary benefits from reducing $PM_{2.5}$. However, recognising the health effects associated with the coarser fraction of particles (PM_{10}-$PM_{2.5}$), the CWS recommends that individual jurisdictions continue to apply their existing air quality objectives, guidelines or standards for the coarser fraction of particles to design air quality management programs for PM_{10} (Canadian Council of Ministers of the Environment, 2000).

The WHO has reported an increasing body of information on $PM_{2.5}$, pointing to the most recent studies that show, in general, $PM_{2.5}$ to be more strongly correlated with health effects than PM_{10}. The WHO also point to emerging evidence that constituents of $PM_{2.5}$, such as sulfates and strongly acidic particles, are sometimes better predictors of health effects than $PM_{2.5}$ (WHO, 2000).

A pilot Australian study analysing particle data has shown a strong structural relationship between PM_{10} and $PM_{2.5}$, with the variability in PM_{10} found to be dominated by variability in the $PM_{2.5}$ fraction rather than the PM_{10}-$PM_{2.5}$ fraction (CSIRO & ANSTO, 1999). The study concluded that this relationship provides an argument for an ambient standard for $PM_{2.5}$ rather than PM_{10}.

5.3 Is a PM_1 Standard More Appropriate?

There are two important decisions relating to setting the standard for fine particles - the size fraction selected ($PM_{2.5}$ or PM_1) and the choice of measurement method (gravimetric methods such as TEOM or Hi Vol samplers or light scattering measured by nephelometry). In selecting an option, the primary factors to consider are consistency with health data, potential for intrusion of mass from the other modes (ie size fractions) and availability of monitoring technologies (USEPA, 1996).

During the review of US National Ambient Air Quality Standard for particles, the USEPA concluded $PM_{2.5}$ to be the most appropriate measure as it encompasses all of the potential agents of concern associated with PM_1, including most sulfates, acids, metals and organics, and ultrafine particles, and includes most of the aggregate surface area and particle number in the entire distribution of atmospheric particles (USEPA, 1997a).

The USEPA (1997a) noted that PM_1 had not been used in health studies (primarily due to lack of available monitoring data) while $PM_{2.5}$ had been measured directly since the early 1980s. The available data have shown significant associations between $PM_{2.5}$ concentrations and mortality, hospital admissions, cough, upper respiratory infection, lower respiratory infection, asthma status, and pulmonary function changes.

Difficulties in measuring PM_1 were also highlighted. While a PM_1 indicator could reduce the intrusion of coarser particles, it might also omit portions of hygroscopic particle components that would be picked up by $PM_{2.5}$ measurements. Further, while PM_1 sampling technologies have been available, these have not been widely used in the field to date, and there are some concerns about the loss of certain organic materials in available models relative to an instrument with a larger size cut (USEPA, 1997a).

In Australia, high correlations have been found between PM_1, PM_1-$PM_{2.5}$ and $PM_{2.5}$ measurements, with PM_1 offering no clear advantage over $PM_{2.5}$ measurements as a mass-based indicator of potential health effects of ambient particles (CSIRO & ANSTO, 1999). A study by EPA Victoria, where PM_{10}, $PM_{2.5}$ and PM_1 TEOMs were co-located for a twelve month period found that, although the $PM_{2.5}$ was dominated by PM_1, the 'noise' associated with PM_1 was much greater than that observed for $PM_{2.5}$ (Bardsley et al., 1999).

- **Does the existing PM_{10} standard provide adequate protection from $PM_{2.5}$?**
- **Is a PM_1 standard more appropriate?**
- **How applicable are existing international $PM_{2.5}$ precedents to Australia?**
- **Nephelometry data is closely correlated to $PM_{2.5}$ but statistical relationships have not been derived for all airsheds. Can this be done and can nephelometry data then be used as a surrogate for $PM_{2.5}$?**

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6 METHODOLOGIES FOR SETTING STANDARDS

The process of setting an air quality standard involves a range of environmental, health, technical, social, economic, political, legislative and cultural considerations. Standards can be set by a variety of methods including:

- health risk assessment;
- adopting standards from other countries; and
- use of informed judgement, such as expert panels.

Each of these is discussed below.

6.1 HEALTH RISK ASSESSMENT

The use of risk assessment in the setting of air quality standards has been investigated by the NEPC Risk Assessment Taskforce (report available on NEPC website). Health risk assessment is usually a four-stage process which assesses the health impacts arising from exposure to a pollutant. The four stages of health risk assessment include hazard identification, dose response assessment, exposure assessment and risk characterisation.

Risk assessment is a systematic approach to characterising the nature and magnitude of the human health risks associated with environmental hazards, where hazard is the *'potential for harm'* and assessment of risk comprises *'an estimate of the likelihood of adverse effects occurring'*. The evaluation of the human health risks of air pollution requires information on exposure levels to various air pollutants, the number of people exposed, including sensitive groups, and knowledge of the quantitative relationship between exposure and health effects. The availability of appropriate air pollution data is critical to any risk assessment. For the criteria air pollutants, air monitoring data are routinely collected by environmental agencies and quite extensive databases exist. For air toxics the existing data are not as consistent nor as extensive. In utilising health risk assessment as an air quality management tool at a local level, where possible local health, population and exposure data should be used.

In assessing the risks from air pollution on human health no one approach will be applicable to all pollutants. The approach taken will be specific for each pollutant and will depend on how the dose-response data have been obtained, whether the pollutant has an identified threshold for adverse effects or not, and whether, as in the case of lead, the health effects are related to a biological marker (eg blood lead levels).

In the development of air quality standards in the US, different approaches are taken for each pollutant. The approaches taken by the WHO also differ with each pollutant. For example, air quality guidelines for NO_2 and SO_2 are developed from a threshold or no observed adverse effects level (NOAEL), while an assessment of the health risk from particles is left up to individual countries using dose-response relationships recommended by the WHO. This approach requires a determination of 'acceptable levels of risk' and the decision on what is acceptable varies from country to country. Potential risks from carcinogenic air pollutants are assessed using unit risk factors and an assessment of 'acceptable risk'. For carcinogenic air pollutants various jurisdictions have defined levels of acceptable risk. Acceptable risk is not so clearly defined for non-carcinogenic pollutants.

6.2 STAGES OF RISK ASSESSMENT

A risk assessment framework is generally comprised of four stages - hazard identification, dose response assessment, exposure assessment and risk characterisation. These stages are outlined below.

6.2.1 Hazard Identification

Hazard identification involves determining the type(s) of adverse health effects that may be caused by the pollutant and how quickly problems might be experienced. This stage involves extensive review of available toxicological and epidemiological data, taking into account the strengths and weaknesses of the information being reviewed.

Identification of the population at risk is another step in the hazard identification. In general terms, the population at risk is that part of the population that is exposed to enhanced concentrations of air pollution (WHO, 1999). Each population has sensitive groups or sub-populations that are at a higher risk for developing health effects following exposure to air pollutants. These sensitive groups include people with existing disease, the elderly and children. Other groups that have been identified to be at higher risk are outdoor workers and athletes as these groups are subject to greater exposure to air pollutants.

6.2.2 Dose Response Assessment

Dose response assessment involves an evaluation of toxicity and/or epidemiological data to determine the incidence of adverse effects occurring at different exposure levels. For carcinogens the risk assessment usually requires extrapolation of dose-response relationships from animal studies or from occupational data where workers have been exposed to high concentrations of the chemical in question. This extrapolation introduces a considerable amount of uncertainty in the quantified risk. For criteria air pollutants much of the health effects data have been derived from either population based epidemiological studies or from controlled human exposure data.

6.2.3 Exposure Assessment

Exposure assessment determines the frequency, extent and duration of exposure in the past, present and future through identification of air pollution levels, exposed populations, sensitive sub-groups and potential exposure pathways. The exposure assessment process is the most critical part of any risk assessment. Approaches to estimating the exposure to air pollution can range from simply averaging the air quality data obtained from ambient air monitoring stations, through to very complex analysis of time-activity patterns for the population, personal exposure assessments (including an assessment of indoor air quality) as well as ambient air quality data to obtain an accurate assessment of the exposure of a population to particular pollutants. The approaches taken can vary with the pollutant, the health outcome being assessed, and the type of exposure data used.

6.2.4 Risk Characterisation

Risk characterisation details the nature and potential human health effects for the exposure conditions specified in the exposure assessment. This stage brings together the knowledge about health impacts, dose response and exposure to calculate how many people are likely to be affected from specified levels of the identified pollutants.

A risk assessment may be either quantitative or qualitative. Quantitative risk assessment is widely used in the assessment of carcinogenic (cancer) risk and involves a mathematical estimation of the risk associated with exposure to a carcinogenic (cancer-causing) compound. There is considerable uncertainty in all stages of a risk assessment and this needs to be

clearly described and limitations well documented. It is critical that there is public involvement in all stages of a risk assessment to ensure that the results obtained are understood and accepted by all stakeholders.

In situations where there is insufficient data to conduct a full exposure assessment and risk characterisation, the hazard identification and dose-response assessment stages can inform the development of air quality standards through a qualitative approach to risk assessment.

All of the above stages lead to a 'risk management' stage during which social, political, economic and cultural issues need to be considered in the final recommendation of an air quality standard.

6.3 Adopting Standards from Other Countries

Setting standards takes into account scientific, medical and epidemiological information (on, for example, the health effects of pollutants) and social and economic impacts in relation to particular legislative frameworks. Whilst health effects may often be expected to be similar from one country to another, the social, legislative and economic environments vary widely. Selection of standards from other countries may be useful where there is limited science available to support new standards. Problems may be encountered in implementing the standards if different socio-economic profiles exist in the country where the standards were developed. For example:

- the adoption of standards from another country without taking into account the necessary finances or institutional robustness to implement them; and
- different socio-economic profiles leading to different health profiles.

6.4 Use of Informed Judgement

In some countries around the world air quality standards are set by utilising panels of professionals with a variety of expertise in environmental and health issues. In some situations, such as in the UK, an expert panel may be established to develop and recommend standards. Such a panel may consider all aspects of the pollutant, its health effects, and population exposures. This process may utilise the outputs from various sources, including health risk assessment if appropriate. Depending on its terms of reference, an expert panel may also consider risk management issues in recommending standards. A limitation of the expert panel process is that it tends to lack transparency and does not, in many cases, involve adequate community consultation.

It should be noted that in adopting standards from other countries or using informed judgement in the development of standards, aspects of a risk assessment approach are included. In adopting these approaches there is inherent acceptance of the risk assessment approach used and in some cases the level of acceptable risk in that jurisdiction. This may or may not be appropriate in the Australian context.

6.5 Possible Approaches for Development of a $PM_{2.5}$ Standard in Australia

As mentioned in Chapter 5, the USA and Canada have developed standards for $PM_{2.5}$, and New Zealand is proposing an interim guideline. These standards are set at levels that range from 25 $\mu g/m^3$ (New Zealand) to 65 $\mu g/m^3$ (USA) as a daily average. The US standard is designed to measure peak exposures rather than average exposure levels and is therefore not suitable for adoption as a $PM_{2.5}$ standard in Australia. The Canadian and New Zealand standards might be considered a feasible range for setting a $PM_{2.5}$ standard in Australia.

Both health risk assessment and the use of an expert panel may be appropriate if a transparent process is adopted. The NEPC Risk Assessment Taskforce Report recommends that public involvement be conducted at all stages of a risk assessment process. In the use of an expert panel to set a standard it would be critical that a similar level of public involvement be undertaken to ensure that stakeholders have sufficient understanding as to how the standard was derived. It is also critical that stakeholders have sufficient opportunity to input into the standard development.

The extent to which risk assessment could be applied may be limited by availability of $PM_{2.5}$ data. In some jurisdictions there is sufficient data for risk assessment to be a feasible approach. However data is not available in a number of jurisdictions. This lack of data may limit a risk assessment to being qualitative rather than quantitative unless the data existing in the larger jurisdictions is considered adequate to represent exposure to the Australian population.

6.5.1 Standards Based on Nephelometry

A $PM_{2.5}$ standard could be set that was based on nephelometry units such as β_{sp}. Studies of the association between particles and daily mortality have been conducted in Australia (Morgan et al., 1998; Simpson et al., 1997; Simpson et al, 2000; EPA (Vic) 2000) where the original data sets were based on nephelometry monitoring results. For the Sydney study (Morgan et al., 1998) these data were converted to PM_{10} data by correlating with gravimetric measurements of particles. It was estimated in the study that PM_{10} air pollution accounts for 397 premature deaths out of 21,500 deaths per annum in Sydney. Another study in Brisbane for the period 1987 to 1993 found similar results (Simpson et al., 1997).

6.6 Precautionary Principle

Although applied more broadly, the Precautionary Principle has been emerging during the past ten years primarily in the context of environmental policy. It was explicitly recognised during the UN Conference on Environment and Development in Rio de Janeiro (1992) and included in the "Rio Declaration". Since then the Principle has been implemented in a number of environmental instruments, particularly in global climate change, ozone depleting substances and biodiversity conservation (Commission of the European Communities, 2000).

The Precautionary Principle aims to protect the environment and human health by adopting precautionary approaches even where the information about potential risks is incomplete.

The Schedule in the Intergovernmental Agreement on the Environment attached to the National Environment Protection Council Act 1994 requires that the Principle should be used to inform policy making and program implementation in NEPC activities. Section 3.5.1 states:

> *"Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, public and private decisions should be guided by:*
>
> *(i) careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment; and*
>
> *(ii) an assessment of the risk-weighted consequences of various options."*

In considering the need for a $PM_{2.5}$ standard, NEPC will give consideration to whether there is enough evidence to suggest that there are serious health risks associated with this size fraction that warrants the setting of a standard.

- What methodology should be used to set a $PM_{2.5}$ standard in Australia?
- Can a health risk assessment approach be used as input into the development of a $PM_{2.5}$ standard in Australia?
- Are there any overseas particle exposure models and dose-response relationships that may be applicable to Australia?
- Is it feasible to develop an Australian particles exposure model?

7 WHERE TO FROM HERE?

7.1 YOUR VIEWS ARE IMPORTANT

7.1.1 Making a Submission

The first step in the review has been the preparation of this issues paper. A Non-Government Organisation (NGO) Advisory Group and a Jurisdictional Reference Network (JRN) have been involved in its development.

It is expected the release of the issues paper and any subsequent feedback on its contents will lead to a better-informed review of the particles standard.

NEPC Committee encourages you to make your views on the need for a $PM_{2.5}$ standard known, and to make available any information that you consider pertinent to the review. Your input will ultimately ensure that when NEPC makes a decision, that decision can be made on the basis of the best possible information available.

Written submissions should be sent to:
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The closing date for submissions is **Wednesday, 30 May 2001.**

All submissions are public documents unless clearly marked "confidential" and may be made available to other interested parties, subject to Freedom of Information Act provisions.

7.1.2 Form of Submission

An electronic form for lodging comments is available. The form can be emailed to you by the NEPC Service Corporation or downloaded from the NEPC website (*www.nepc.gov.au*). This form can be filled out and submitted electronically. Consideration of your submission will be facilitated if it is provided, if possible, in this format.

Should you wish to provide your comments in another format, submissions may be made:

- in hardcopy;
- on a 3.5 inch floppy disk; or
- emailed to *mgilbey@nepc.gov.au*.

To allow ease of photocopying, hardcopy submissions should be unbound. Electronic submissions should preferably be provided as a Word for Windows file.

APPENDIX 2 - PARTICLES MONITORING IN AUSTRALIAN JURISDICTIONS

Table A2-1: Stations in NSW Conducting Monitoring Using Nephelometers

Station	1998	1999	2000	2001
Beresfield	X	X	X	X
Newcastle	X	X	X	X
Wallsend	X	X	X	X
Wollongong	X	X	X	X
Blacktown	X	X	X	X
Wentworth Falls	X	X	Decommissioned September	
Orange	X	X	Operated by Council	
Oakdale	X	X	X	X
Lithgow	X	X		
Griffith	X	X	Decommissioned July	
Earlwood	X	X	X	X
Bringelly	X	X	X	X
Cooma	Commissioned June	X	Decommissioned November	
Liverpool	X	X	X	X
Randwick	X	X	X	X
Richmond	X	X	X	X
Rozelle	X	X	X	X
St Marys	X	X	X	X
Bargo	X	X	X	X
Westmead	X	X	X	X
Woolooware	X	X	X	X
Albion Park	X	X	X	X
Kembla Grange	X	X	X	X

Table A2-2: Stations in NSW Conducting TEOM PM2.5 Monitoring

Station	1998	1999	2000	2001
Blacktown	X	X	X	X
Bringelly	X	X	X	X
Campbelltown	X	X	X	X
Earlwood	X	X	X	X
Lidcombe	X	X	X	X
Liverpool	X	X	X	X
Richmond	X	X	X	X
Westmead	X	X	X	X
Woolooware	X	X	X	X
Warrawong	X	X	X	X

Table A2-3: Stations in Queensland conducting Monitoring Using Nephelometers

Station	1997	1998	1999
Eagle Farm	X	X	X
Brisbane CBD	X	X	X
Rocklea	X	X	X
Flinders View	X	X	X
Targinie	X	X	X
Barney Point, Gladstone	X	X	X
Mackay		X	X

Table A2- 4: Queensland $PM_{2.5}$ Monitoring Using TEOM and ANSTO Instruments

Station	Instrument	1997	1998	1999	2000
Brisbane CBD	ANSTO	X	X	X	X
Rocklea	ANSTO	X	X	X	X
Rocklea	TEOM		X	X	X
Springwood	TEOM			X	X

Table A2- 5: TEOM Monitoring Stations Mearsuring $PM_{2.5}$ in Victoria

Station	1997	1998	1999
Alphington	X	X	X
Footscray	X	X	X
Brighton		X	X

Table A2- 6: TEOM Monitoring Stations Measuring PM_1 in Victoria

Station	1997	1998	1999
Footscray	X	Up to Sept	

Table A2- 7: Monitoring Stations Using Nephelometers In Victoria

Port Phillip Control Region	1997	1998	1999
Alphington	X	X	X
Dandenong2	X	X	X
RMIT	X	X	X
Footscray	X	X	X
Pt Cook	X	X	X
Paisley	X		X
Brighton	X	X	X
Geelong South		X	X
Box Hill	X	X	X
Latrobe Valley Control Region			
Traralgon	X	X	X
Moe	X	X	X

Table A2- 8: Stations in WA using Nephelometers

Station	1997	1998	1999
Bunbury	X	X	X
Busselton	X	X	X
Caversham	X	X	X
Duncraig	X	X	X
Hope Valley	X	X	X
Leeming	X	X	X
Queens Buildings	X	X	X
Quinns Rocks	X	X	X
Swanbourne	X	X	X

Table A2- 9: Stations in WA Conducting TEOM Monitoring of $PM_{2.5}$

Station	1997	1998	1999
Bunbury	X	X	X
Caversham	X	X	X
Duncraig	X	X	X
Leeming	X	X	X

APPENDIX G

Report on Performance of Electrostatic Precipitators by Norwegian Authorities

Department of Urban Affairs and Planning
September 2001

Particle Cleaning in Norwegian Urban Road Tunnels

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ABSTRACT: Norways road network has become more and more dependent on tunnels. The challenge of planning and construction road tunnels in urban areas implies environmentally friendly approach. Particle cleaning of the air in long and heavy traffic tunnels in densely populated areas have been used in Norway for more than ten years. It have been seen as a possible measure, both for improving the visibility in the tunnels and for reducing the disharge to the air both inside and outside the tunnels. Three different types of layout system for particle cleaning equipment have been used in Norway. The paper discuss the experience and status for the particle cleaning technology since the opening of the sub-sea Oslo Tunnel in 1989. In general there is no principal difference whether using a particle cleaning system in ordinary or sub-sea road tunnels.

1 INTRODUCTION

An increasing number of complaints from individuals, and invidious coverage in the mass media about poor environment in road tunnels have been noticed in Norway the last years. In some cases they are more due to "fear" based on misunderstanding than concrete conditions which are injurious to health. Such fears can in the long run be a greater strain on one`s health than tunnel air itself. The majority of people react to visibility because of small particles in the air, and smell. "Positive" road-user information is important to create realistic attitudes to the "environment risk" that driving in road tunnels represent.

The Norwegian Public Roads Administration has through the R&D project "Tunnels for the citizen" focused on traffic safety, environment and the long ownership of tunnels.

Norwegian road tunnels are by no means homogeneous. They exhibit great variation in many key respects. Factors at variance include tunnel length, traffic volume, subsea tunnels, one or two lane traffic, wall material, road surface material, lighting, air cleaning measures, ventilation, and more. These factors in turn demand different approaches depending on many things, for instance cleaning cycles.

In a road tunnel there occurs - by contrast with road traffic on ordinary streets and highways - a concentration of traffic pollution in a small volume. Therefore attempts have been made, with variable success, to separate the pollutant particles and gases in the ventilation air before it is released to the surroundings. In general it must be said that the chances of success are limited, due to the great volumes of air involved, the complexity of the systems, and the high costs.

The ideal goal in the pollution control and environment protection legislation is to render our surroundings and environment as free from pollution as possible. Measures to counter pollution demand resources in competition with other worthy causes. In special pollution situations, especially those causing local traffic problems, the environmental standards we strive for will be a measure of how much we are willing to pay.

As for traffic pollution and, in particular, suspended particles, then this is a problem with aspects peculiar to Norway. In Norway the bulk of the airborne dust is due to road wear from use of studded tyres, and this phenomenon is largely a winter situation.

2 ENVIRONMENT AND SAFETY ASPECTS

Norway have long experience with longitudinal ventilation of road tunnels. Particle cleaning of the air in long and heavy traffic tunnels in densely populated areas have been used in Norway more than ten years. Electrostatic filters with high extraction rate have been seen as a possible measure, both for improving the visibility in the tunnels and for reducing discharge to the air outside. In association with that it had to be mentioned that the demand for particle cleaning in Norwegian road tunnels to a high degree has been political motivated by environmental reasons.

An evaluation of methods to scrub particles out of air in or issuing from road tunnels in Norway is based on two fundamentally different factors:

1. Safety and environment aspects connected with tunnel users and their perception of reduced air quality. This is particularly apparent in winter when stud wear and mineral dust combined with exhaust and combustion particles (soot) can severely reduce visibility.

2. Particle emissions from high-density tunnels may cause discomfort, irritation over time, and represent a potential health and environment problem for third-parties - particularly groups of persons in the population who are especially vulnerable - and the external environment.

Both these factors come under the heading particle pollution, but the approach is rather different. Depending on the public's perception of such pollution and the real level of risk to health, environment and safety, the authorities may require cleaning of such emissions. Such requirements have been statuted and must be taken into account in many situations in Norway, for instance where industrial activities cause particulate pollution.

As for the use of high-efficiency cleaning plants (either combined gas/particle units in tunnels, or either type in isolation), one prior assumption ought to be that the benefit is reasonably proportionate to the total investment and operating cost of the plant. (In some case these facts have not been the only statement of reasons in the decisions of using electrostatic filters).

The use and level of separation of such cleaning plants must be properly specified and documented. Standards for audit and documentation of the cleaning efficiency of

relevant filters, both for laboratory tests and for aftercare in the field are now beeing worked out. This is decisive for establishing the right guarantee specifications to require, and the manner in which tests are conducted.

3 ELECTRSTATIC FILTERS IN NORWEGIAN ROAD TUNNEL

It has been gathered important experience and documentation of cleaning technology with electrofilter and mechanical filter in tunnels with traffic both in one and two directions. Depending of what is the object of the cleaning, the electrofilter system can be installed in a bypass system, in a shaft connected to the traffic tunnel, or the polluted air can be cleaned in different stages along the length of the traffic tunnel (f.i. electrofilter in the ceiling of tunnel).

Because of the climatic conditions in Norway, extensively use of studded tyres have been practised in the winter time. Because of the wear and tear of these tyres the particle concentrations are far higher in the winter than in the summer, something that can give rise to visibility system. As a result of that the need for extracting particle pollutions (mineraldust and soot) is much higher in the wintertime than in the summer. Visibility problems are closely linked with the type and quality of road surface, cleaning procedures and running time of fans, in addition to climatic and traffic conditions.

Particle cleaning of tunnel air with the help of a cleaning passage with electrofilter was thought to be a possible measures, both for improving visibility and for reducing discharge to the air outside. On the other hand gas cleaning is interesting measures, but for the moment considered a lesser possibility in normal road tunnels seen from a cost/usefulness/health risk evaluation. However the latter can have its use in reducing discharge in special situations.

So far, it have been installed electrostatic filters in three separate tunnels in the Oslo area, one tunnel outside Trondheim and one in Bergen, and not to forget in the world longest tunnel, the 25 km long Lærdal Tunnel. Particle cleaning system are also being installed in some other road tunnels.

Three fundamental different types of solution for the lay-out of particle cleaning system, with both electrostatic and mechanical filters, are choosen in Norway:

The Oslo Tunnel, that is a 2,2 km long two tubes sub-sea highway tunnel under the center of Oslo, was opened in january 1990. The purpose with the dust cleaning system was here to improve the air quality in the city. The particle separator (mechanical coarse filter and electrostatfilter) which is positioned in conjunction with the exit via the shaft tower, will service quantities of polluted air of up to 2,2 mill m^3/hour. Visibility and particle conditions in the tunnel are not affected by the cleaning.

In the Granfos Tunnel (1000 m) and the Ekeberg Tunnel (1500 m) in Oslo the particle cleaning equipment is installed in a cleaning circuit (bypass system). The main purpose was here to achieve better visibility conditions in the tunnel, but also to reduce the discharge to the air outside the tunnel.

In the Hell Tunnel, that is a 4 km long tunnel with two-way traffic outside Trondheim, the cleaning system was installed at three individual stations in the ceiling of the tunnel, making a distance between the stations approx. 1 km. This concept was based on both improving the visibility by reducing the particle cencentration and also reduce the discharge to the environment outside. About 1/3 of the air ventilating the tunnel pass through the cleaning stations.

In the Nygård Tunnel in Bergen (950 m long, traffic in one directions)) the cleaning of particles is based on electrofilter in the ceiling of tunnel, like in the Hell Tunnel. 80% (250 m^3/s) of the total air volume is passing through the electrofilter system.

4 PARTICLE POLLUTION

In a road tunnel the sight-reducing particles consist of soot and diesel smoke, mineral and metallic particles and mist. Soot and smoke consist of very small, and respirable particles. More than 95% of these particles are less than 1 micron (1/1000 mm) in size. But they can bunch together gradually and become larger particles. The mineral particles consist of larger particles, 90% larger than 1 micron, including a relatively large portion that are not respirable. The particle concentration and particle size of the mineral airborne dust depends on different things, including what type of rock materials which are used in the pavements.

Mist can periodically be a problem, especially near tunnel entrances. Diameter of mist particles are in the region of 10-45 micron. The amount of dust produced, and the distribution of particles are directly related to the quality of road surface, cleaning frequency, ventilation and the traffic situation.

From the magnitude of the readings the SINTEF measurements show that the dust level in road tunnels in winter can consist of some 70-75 per cent by weight of mineral dust and 25-30 per cent by weight of organic materials (soot, non-combusted oil residues, etc). In summer the ratio of mineral to organic dust is roughly reversed. In other words the mineral complement (inorganic fraction) predominates in winter, whereas products of combustion and other organics predominate in summer. In terms of volumes of course the organic component is equal in summer and winter assuming the same Annual Traffic Density.

In high-density tunnels with traffic in both directions particulate concentration of total suspended particles (TSP) as measured on cold winter days was up to 18-20 mg/m^3 compared with 1-1.5 mg/m^3 in summer. The very high concentrations of suspended particles in winter are due mainly to the whirling up of large volumes of heavy mineral particles by the air flow (piston effect) when vehicles going in opposite directions pass each other. In tunnels with one-way traffic the dust concentrations are generally lower than in a two-way tunnel under otherwise identical conditions. The relative size of the fine-dust fraction is often higher in one-way tunnels than is the case in two-way tunnels.

5 MEASUREMENTS AND EXPERIENCES

In the sub-sea Oslo Tunnel it has been carried out by SINTEF extensive studies over a long period of time. It was found relation between air velocity over the electrofilter and the extraction rate. With air velocity as high as 4-5 m/s the extraction rate was remarkable reduced. By increasing the air velocity through the electrofilter, without renouncement of cleaning effectiveness, the necessary filter area to clean the same volume of polluted air will be reduced.

The measurements indicated that, during the initial hours after a successful wash, it was possible to achieve a level of separation approaching 90-95 per cent with one shaft fan (of three available) in operation (air velocity 2.8-5 m/s). After 35-40 hours in operation the separation efficiency fell to 50 per cent. With two shaft fans in operation (air velocity 8.5-9.5 m/s) it would no doubt be possible to keep the separation efficiency above 50 per cent for 10-15 hours after a successful wash. Use of the electrostatic filter beyond the times indicated would result in decreasing and essentially "unsatisfactory" separation efficiency.

In all series of measurements a highly variable efficiency was found for the electrostatic filter, and even over different points of the filter area, differences were found. In the first two series at several measurement points the level of particle removal was logged as negative. Part of the reason was that the potential had been applied to the electrostatic filter for a long period without the shaft fans running, and without scouring the filter before readings were taken. There was also a great deal of dust deposited on floors and surfaces in the shaft fan room. Once the fans were turned on during particle readings large volumes of dust were pulled off the prefilter and electrostatic filter, as well as from the floor of the shaft room. Also significant sparking and electrical discharge was noted during the first two reading series. Also faulty connections were found, causing, in part, some filter sections to be without applied potential.

In the Oslo Tunnel the whole volume of the polluted air from the tunnel passed through the electrostatic filter (square area 70 m^2) before leaving the tunnel through the shafts at the outlet of the tunnel.

The wash-and-dry cycle for the electrostatic filter unit was complex and time-consuming, and represented an operational problem and limited the use of the unit. This fact, combined with the design air velocity over the electrostatic filter being too high, and the lower part of the filterunit being located too close to the road lane, were key reasons why the separation efficiency was unsatisfactory.

In the Ekeberg and Granfos Tunnel (one way traffic) it was calculated an extention rate (cleaning effect) of 45-50% on the total air volume passing through the tunnels. The dust measurements showed such low concentrations that, if they were representative, a dust cleaning system would have virtually very little effect on visibility and pollution in the tunnel or emission of particles to the external environment. The low dust concentrations must be related to the short tunnel length, which means that the build-up of dust levels from the entrance to the cleaning loop, and thence to the tunnel exit, were modest. This was also what we saw in practice. It was a contributing reason why we considered use of a significant amount of energy to clean such small dust quantities an economic non-starter.

In the two-way traffic Hell Tunnel it has been, like in the Oslo Tunnel, carried out extensive measurements over a long period of time to calculate the extraction rate in different operational situations. The total (or effective) extraction rate for the full cleaning station (which means the total cleaning efficiency, equal to the percentage difference in particulate concentration 20 m before and after the cleaning niche) overall was low: on average 15 per cent (variation 0-64 per cent) for all measurement series. The low "effective" extraction rate which in several measurement series was actually negative was due to the piston effect of passing vehicles and unsuitable flow design and smoothing of the cleaning rebate and exit fans. At the same time we must remember that only a fraction (1/3 - 1/4) of the air volume in the tunnel actually passes the cleaning unit during normal traffic, the rest passes without cleaning. Due to that the total extraction rate for the electrostatic cleaning plant will be very low. If you f.i. clean 1/3 of the total air volume in a tunnel with an extraction rate of 50%, the total cleaning effect on the total air volume wll be only 16%. As low total extraction rate will have very low positive effect on the visibility og particles from the road-users point of view.

Moreover it seems difficult to identify other connections between ventilation and cleaning plant status and the cleaning efficiency that results. This must be due to the different numbers of power packs that were unserviceable during the different measurement series.

Analysis of dust deposits on corona plates in the electrostatic filter in the winter period when using studded tires showed 86 per cent inorganic/ mineral dust and 14 per cent organic (soot). This shows that the percentage share of inorganic/ mineral dust deposited in the electrostatic filter is higher than the corresponding ratio in the tunnel air.

The stated maximum dust deposit (saturation load) on each corona plate is 9.9 grams. Samples of deposited dust on the plates at the presumed saturation load showed 5.3 grams per plate, which was lower than the manufacturer's stated saturation load.

Analysis of the dust deposited on the corona plates in the winter period showed that 80 per cent of dust had a particle size of less than 30 microns. Approx 30 per cent of the deposited particles were larger than 20 microns. This is a coarse particle fraction, the level of which should have been reduced more effectively in the prefilter.

CONCLUSION

Valuable and important experience on the use of cleaning equipment (electrofilter an mechanical filter) for particles in Norwegian road tunnels have been gathered through different studies and investigations. These documentation represents a very good basis in projecting and constructing new particle cleaning plant and equipment in road tunnels with traffic both in one and two directions.

The different studies varies much in size and perfomance. In spite of that some common feature have been found:

- The practical extraction rate (cleaning effect) for the different system have been lower than expected, and also lower than the figure given by the supplier.

- Break-down of power packs for the electrostatic filter in operational situation have been a problem.
- For some electrostatic plant the wash-and-dry cycle (system) was complex and timeconsuming, and because of that represent an operational problem.
- Some details connected to the flow of air passing by or through the particle filter (leakage, resirculation of air, piston effects from traffic and starting fans, location of fans, shaping of bypass-system or niche, incresing/decreasing areas for air stream, etc. were not optimal.

* From a practical, trafical, environmental and economical point of view our investigations and measurements indicate that use of electrostatic filters in in road tunnels with heavy two-way traffic (f.i. Hell Tunnel) or short one-way traffic tunnel (f.i. Granfos, Ekeberg and Nygård Tunnel) should not be recommended.

Owing to these fact the electrostatic filter system in the Oslo Tunnel, the Granfos Tunnel and the Hell Tunnel have not been in use for some time. In the Ekeberg Tunnel the system is also under a cost/usefulness/health risk evaluation.

New guidelines for evaluation and documentation of extraction rates for electrostatic filters are now beeing worked out based on the information from the different studies and measurements.

New projects are looking on alternative measures to electrofilters, f.i. using measurements of the visibility and particles concentration to regulate the ventilation fans.

APPENDIX H

Summary of Katestone Peer Review of the RTA's Air Quality Assessment

Department of Urban Affairs and Planning
September 2001

The key criticisms of the RTA's assessment and the RTA's response in the Representation Report is summarise as follows:

i) **Katestone Criticism:** The vent plume is likely to be affected by the aerodynamic wakes from the stack itself and nearby building especially for low exit velocities. Neither the Ausplume or dispersion modelling can treat these accurately. This relates strongly to the justification of the height of the stack.

RTA Response: A range of stack heights were tested. A taller stack is an option.

ii) **Katestone Criticism:** For evaluation of very local air quality, computational fluid dynamics may be a better approach to assess impacts within 200 metres of the stack. However the production of a suitable computational grid involving all buildings is a significant task.

RTA Response: Computational fluid dynamics is not warranted before the design of the tunnel is finalised

iii) **Katestone Criticism:** the likelihood of foreseeable adverse conditions (eg traffic queuing at Darling Harbour to enter the tunnel with slowly moving traffic in the tunnel during negative buoyant conditions, is difficult to ascertain from the report.

RTA Response: Under congested conditions the exhaust would be warmer than the ambient air and is therefore unlikely to be negative buoyant

iv) **Katestone Criticism:** the odour, visibility and ozone impact of the stack plume have not been quantified. Residents at elevated locations may perceive some haze when looking through the ventilation plume near the stack. Ozone generation within the plume may occur and the likely impact on health and ozone exceedance statistics should be addressed.

RTA Response: There are three road tunnels stacks in Sydney, none of which have visible plumes. Ozone is unlikely to be an issue close to the stack where there is excess NOx in the plume and further away the ozone would not be substantially different from that generated by the CBD roadway emissions.

v) **Katestone Criticism:** the report omits consideration of traffic generated suspension of road dust. PM10 increments may therefore be underestimated by a factor of 50-100%.

RTA Response: The Hyder calculations took into account grade and speed. Emissions from tyre and brake wear are less than 10% of total PM10 emissions.

vi) **Katestone Criticism:** local air quality monitoring in Darling Harbour has not yet been monitored for a sufficient period of time to establish reasonable estimates for background air quality at key receptors. This may reduce the margin of safety for NO_2.

RTA Response: If background levels of pollutants were increased to incorporate the maximum levels measured, this would not substantially change the impacts.

vii) **Katestone Criticism:** local air quality modelling has not taken account of congestion and road grade on the influence of elevated roadways

RTA Response: As the extent of grade and elevation would be the same with or without the tunnel the relative changes would not alter. Therefore local air quality modelling has taken into account congestion and road grade as well as the elevated roadways.

viii) **Katestone Criticism:** the maximum 20% value for the proportion of NO_2 in NOx may not be sufficiently conservative for days with higher ozone levels or for residents living in high rise apartments. Katestone suggest 40% at the point of maximum plume impact would be more conservative.

RTA Response: The sensitivity analysis combined worst case predictions with worst case background ozone and NO_2 levels. This was undertaken to the satisfaction of the EPA and showed similar or slightly less conservative results than those estimated in the EIS.

ix) **Katestone Criticism:** Use of strict goals at near-road locations has the potential to provide an overly pessimistic view of health risks to the community.

RTA Response: Agreed

x) **Katestone Criticism**: No mention about sub micron particles.

RTA Response: There are no goals for sub-micron particles in NSW or elsewhere in Australia. At present the PM10 goal acts as a surrogate for the mixture of particles of less than 10 microns

xi) **Katestone Criticism:** The buffer volume recommendations for restrictions on heights for nearby buildings are based mainly on wind tunnel results not the dispersion modelling. The values are likely to be critically dependent on assumed background air quality and anticipated emission rates. Further consideration of the dispersion modelling issues should be undertaken before the recommendations are accepted for local area planning.

RTA Response: The buffer volume analysis considered both wind tunnel and dispersion modelling. It is agreed however that for any future buildings the results of both types of modelling should be considered.

APPENDIX I

Schedule of Minimum Traffic Requirements

2.	**ACCESS AND TRAFFIC**
12.1	**Pre-construction**
12.1.1	The agreement reached with the main contractor for the construction and operation of the Project would not contain any terms which preclude future public transport developments.
12.1.2	Advance notice of traffic alterations would be given to the public through advertisements and signage.
12.1.3	Prior to commencement of construction, a traffic management plan ("TMP") would be prepared for overall traffic arrangements during the construction period, and approved by the RTA's Transport Management Centre. The TMP would include, with respect to the project as a whole: • measures to manage traffic flows through and surrounding the project, including regulatory and direction signposting, line marking and variable message signs; • management of the Sydney Co-ordinated Adaptive Traffic System (SCATS) to optimise traffic flow efficiency at all times, particularly during peak periods; and • the introduction of regulatory measures to improve the efficiency of traffic conditions and reduce traffic conditions.
12.1.4	As part of the TMP, individual traffic control plans ("TCPs") for each area to be affected by construction would be prepared, after consultation with relevant local councils and other agencies, and approved by the RTA's Transport Management Centre prior to commencement of construction affecting that area. The individual TCPs would include the following, with respect to that area: • impacts on all existing traffic (including pedestrians, vehicles, cyclists and disabled persons), including the staging of construction works to minimise road closures and delay or detours to traffic; • access to construction sites and site compounds, including minimising the disruption from construction vehicles entering and leaving construction sites and site compounds; • number and width of traffic lanes; • temporary traffic arrangements, including the identification and promotion of alternative routes; • provision of barriers between working and trafficked areas; • the impact on pedestrian and bicycle facilities, including measures to ensure safe pedestrian and cycle routes and access at all times, and the provision of alternative facilities and locations for pedestrians and cyclists; • the provision of safe and convenient access to all bus stops; • signposting; • stormwater drainage; • methods for implementing the TCP; • access to side streets; • access to adjoining properties, which would be maintained at all times; • road or lane closures; • the use of cranes on public roads; • deliveries to construction sites and site compounds; and • a response plan which sets out the proposed response to any traffic, construction or other incident.
12.1.5	The TCPs would include maintenance, as a minimum, of the following traffic conditions:

Streets Affected	Proposed Minimum Traffic Conditions During Construction	Implications/ Additional Requirements
Kings Cross Tunnel	Maintain two lanes in each direction.	
Ramps between Darlinghurst Road and William Street	Maintain one lane in each direction.	

William Street between the Kings Cross Tunnel and Bourke Street	Provide a minimum of 5 through traffic lanes generally allocated as three lanes in the major flow direction with two lanes in the opposing direction.	A tidal flow scheme may be introduced to manage traffic flow at this location. The "T2" Transit lanes in William Street, both directions, would be removed at this location. The existing road capacity in William Street, in both directions, including "T2" Transit lanes would be reinstated prior to the removal of the dual right turn lanes from William Street into Riley Street northbound.
William Street at Forbes Street		The existing pedestrian traffic control signals at Forbes Street would be temporarily removed and replaced by a temporary footbridge.
Bourke Street	South of William Street, maintain a minimum of 3 traffic lanes on the approach to William Street, 2 in the northbound direction & 1 in the southbound direction for the duration of construction.	The traffic control signals at William and Bourke Streets would be retained, however, during certain periods traffic movements in Bourke Street would be limited to left in and left out only.
	North of William Street, maintain a minimum of 3 traffic lanes on the approach to William Street, 2 in the southbound direction and 1 in the northbound direction for the duration of construction (except for a maximum period of 6 months during which it may be closed between William Street and the on-ramp to the Eastern Distributor for construction of the cut and cover tunnel section).	Pedestrian movements across William Street may also be restricted during cut and cover tunnel construction in William Street.

William Street between Bourke and Palmer Streets	Maintain two continuous through lanes and a third eastbound kerbside lane for minimum of 40m. The kerbside lane to be designated as a bus only lane. Maintain three continuous westbound through lanes plus one right turn lane. One of the through lanes is to connect with a through traffic lane east of Bourke Street, the right turn lane is to be a minimum of 40m in length.	A tidal flow scheme may be introduced to manage traffic flow at this location. The right turn movement into Palmer Street northbound may not be permitted at certain times. The existing road capacity in William Street, both directions, including dual right turn lanes into Palmer Street northbound would be re-instated prior to the removal of the dual right turn lanes in William Street into Riley Street northbound.
William Street at Palmer Street		The pedestrian crossing in William Street, west side, at Palmer Street would be removed. The intersection phasing would be modified to suit the new configuration.
Northbound Eastern Distributor Off-ramp to William Street		Closed for a number of months. Traffic movements from the off-ramp would also be restricted to left turn only.
Eastern Distributor entry ramp from Bourke Street		Closed for a number of months.
William Street between Palmer and Crown Streets	Provide 4 continuous westbound traffic lanes between Palmer and Crown Streets. Maintain 3 eastbound traffic lanes in William Street, the kerbside lane to be designated as left turn only buses excepted.	The eastbound "T2" transit lane to be removed at this location.
Palmer Street between William Street and Sir John Young Crescent		Traffic management may be introduced to minimise traffic flow at certain times.
William Street at Riley Street	Provide two westbound right turn lanes, one of the right turn lanes to be connected to the fourth (median) lane at Crown Street when the right turn storage capacity in William Street, westbound, on the approach to Palmer Street is reduced. Maintain existing eastbound traffic arrangements in William Street.	

Riley Street between William Street and Sir John Young Crescent	Operate as one way northbound. Provide two continuous northbound lanes between William Street and Sir John Young Crescent when the right turn storage capacity in William Street, westbound, on the approach to Palmer Street is reduced. Retain access to side streets and property access.	On-street parking to be retained, where possible.
Sir John Young Crescent	Maintain two traffic lanes in both directions between Crown and Palmer Streets. Maintain two northbound and one southbound traffic lanes between Riley Street and Crown Street.	
Clarence Street between Druitt and Market Streets	Provide two left turn lanes from Clarence Street to Market Street westbound.	Additional traffic and pedestrian management measures, including the removal of the pedestrian crossing in Market Street (west side of Clarence Street) may be required. Restriction of on-street parking on a full or part-time basis, both sides, and the relocation of the existing bus lane, may be required.
Kent Street between Liverpool and Market Streets	Upgrade capacity of twin left turn lanes into Market Street westbound.	Remove the pedestrian crossing in Market Street, west side, at Kent Street. Restriction of on-street parking on a full or part-time basis, both sides, between Liverpool and Market Streets may be required.
Druitt Street between Kent and Sussex Streets	Retain access to properties. Retain two lanes westbound, one bus lane and one general traffic lane.	
Druitt Street viaduct	Maintain two lanes, one bus lane and one general traffic lane.	
Sussex Street	Maintain two lanes southbound at all times. Introduce two northbound lanes between Liverpool and Druitt Streets.	Restriction of on-street parking on a full or part-time basis, both sides, between Liverpool and Market Streets.
Day Street	Retain access to Darling Park 2 and Park Royal Hotel for buses and deliveries.	

	Market Street		Provision of additional on-street parking restrictions on a full- or part-time basis, both sides, between Sussex and Elizabeth Streets.
	Market Street viaduct	Maintain two lanes.	One traffic lane may be permitted at times subject to RTA approval.
	Bathurst Street	Maintain three lanes at all times between Harbour Street and Day Street. The Bus Lane is to be retained.	
	Harbour Street	Maintain two through lanes southbound and one left turn lane to Bathurst Street. The left turn lane is to be a minimum of 200 metres in length.	
		Maintain two through lanes northbound and at least one right turn lane to Day Street. Where possible, two right turn lanes to Day Street are to be retained/provided.	
		Maintain taxi and coach access to the drop-off area on the eastern side of the IMAX Theatre.	
	Construction sites and compounds	Access to be generally left in and left out only.	Signal controlled access may be possible subject to RTA approval.
12.1.6	The TMP and TCPs would comply with the following documents: • RTA Specification DCM G10; • AS 1742.3 (1996) – Traffic Control Devices for Works on Roads; • Section 4.14 of the RTA's "Interim Guide to Signs and Markings" Manual; and • Traffic Control at Work Sites (RTA).		
12.1.7	The TMP and TCPs would be regularly reviewed, and if necessary, amended.		
12.1.8	The TMP and TCPs would be prepared and implemented under the supervision of an experienced traffic manager engaged full-time on the project.		
12.1.9	The RTA's Transport Management Centre would be kept advised at all times of any matter which is likely to affect or is affecting the free flow of traffic in the area of the project.		
12.1.10	The RTA's Transport Management Centre would monitor the performance of all of the project traffic arrangements, including the impact on bus operations.		
12.1.11	The TMP would include provisions on any urgent unplanned closure of any lane, road, footpath or cycleway. This would include a requirement to immediately notify the RTA's Transport Management Centre of the closure and the schedule for reopening and a requirement to reopen the lane, road, footpath or cycleway as soon as possible.		
12.1.12	All businesses potentially affected by altered traffic arrangements would be consulted with a view to minimising potential impact. This consultation would take place prior to commencement of construction, and during construction.		
12.1.13	The Park Royal Hotel would be consulted regarding maintaining access to the Hotel at all times and the provision of sign-posting of altered access.		
12.1.14	A Central Sydney Public Transport Working Group, a committee to assess public transport impacts of and opportunities presented by the project, would be established. In addition, the committee or another appropriate group would consider the need to re-route the 311 bus service to Cathedral and Crown Streets for the duration of the closure of Bourke Street.		

12.1.15	Consultation would be undertaken with the road based public transport operators, including Sydney Buses, the Bus and Coach Association and the NSW Taxi Council, in relation to investigation of: • measures to maintain reasonable bus travel times along routes affected by the construction of the project; and • measures to facilitate public transport usage without unduly worsening travel conditions for other road users. Sydney Buses would be approached to provide specific resources to the project to ensure an integrated investigation process.
12.1.16	In consultation with South Sydney Council and the Royal Botanic Gardens and Domain Trust, a new ramp to the Domain Carpark for service and emergency vehicles would be designed and constructed, to replace the existing access which would be removed as part of the project.
12.1.17	A temporary pedestrian bridge would be constructed in William Street near Forbes Street to facilitate the safe crossing of William Street during construction.
12.1.18	A temporary pedestrian bridge would be constructed over Harbour Street, to maintain pedestrian connections to Darling Walk and replace the connection from Bathurst Street to Cockle Bay which would be removed. The existing Darling Park pedestrian connection from Druitt Street to Cockle Bay would be retained.
12.1.19	Trucks would not be permitted to queue along any secondary roads adjacent to construction sites or site compounds prior to the start of construction activities in the morning.
12.1.20	Where construction activity will take place on, over or adjacent to public pathways, an alternative pathway would be provided or identified, and signposted.
12.1.21	During the detailed design process, provision at intersections of a forward stop line for cyclists would be investigated.
12.1.22	The design of the local area traffic management measures proposed for Paddington would be detailed and implemented in consultation with the local council, the community, and Sydney Buses, and the environmental impacts assessed.
12.1.23	All construction workers would be required to comply with any traffic direction or instruction given by the RTA, the NSW Police Service or any other regulatory authority.
12.1.24	Operational needs of the Sydney Light Rail and the monorail would be taken into account when planning construction activities.

APPENDIXJ

Urban Design Review – Urban Design Advisory Service

Department of Urban Affairs and Planning
September 2001

Urban
Design
Advisory
Service

Proposed Cross City Tunnel
Urban Design Review (Phase 1)

Prepared for the Department of Urban Affairs and Planning
by the Urban Design Advisory Service

September 2000

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Introduction

The Urban Design Advisory Service (UDAS) was engaged by the Development and Infrastructure Branch of the Department of Urban Affairs and Planning (DUAP) in August 2000 to provide the Department with an independent assessment of the urban design component of the Cross City Tunnel EIS.

The Cross City Tunnel proposal is for the construction of twin 2km tunnels comprising dual lane carriageways from Kings Cross to the Western Distributor at Darling Harbour. The tunnels are beneath William, Bathurst and Druitt Streets; with eastern and western portals in the Kings Cross Tunnel and at the Western Distributor (in Harbour Street and Druitt Street) respectively. The proposal includes an exit portal for westbound CCT traffic to Sir John Young Crescent. There are proposed underground links for eastbound CCT traffic to the Eastern Distributor (southbound) and vice versa. The proposal also includes surface improvements to William and Park Streets.

The Minister for Urban Affairs and Planning has a formal approval role for this project and DUAP is required to provide the Minister with an independent assessment report before the proposal can be determined.

Objectives

The primary objective of the commission is to provide the Department with an independent assessment of the urban design component of the proposal to assist in DUAP's assessment process and to ensure that appropriate environmental standards are adopted for the project in a cost effective manner.

DUAP has identified two project phases of the project to meet the objectives:

- Phase 1 involves a *review* of the relevant parts of the EIS and Working Papers and the *identification of key issues* for discussion with DUAP and the RTA; and
- Phase 2 involves the *assessment* and reporting of the key issues raised in phase 1 and the RTA's response from phase 1.

Methodology

This report addresses Phase 1 of the project. The scope of Phase 1 is to provide an initial response noting key urban design issues that require further clarification or assessment by the proponent.

Since urban design relates largely to qualitative rather than quantitative issues, particular care is required to ensure an objective review. To this end the assessment method is based on:

- A comparison of the proposal to existing conditions facilitated by a site visit of the proposed route and photographic recordings;
- A review of the proposal in relation to a range of urban design assessment criteria;
- Comparison of the proposal to the outcomes of the William Street Revitalisation Strategy

Assessment Criteria

UDAS has identified criteria for the assessment of linear road proposals these criteria have been effectively used on the assessment of major Motorways including the Eastern Distributor and the M5 East Motorway. The criteria are listed below and defined at the end of this report:

- Integration
- Physical Impact
- Community links and accessibility/severance
- Visual impacts and views
- Community facilities and open space
- Vegetation and landscaping
- Built elements
- Noise
- Signage and Advertising
- Finishes and Materials

Key Issues

All references to Diagrams and page numbers are in relation to Technical Paper No.6 - Urban Design

Integration

Issue 1:
Impacts on local area north of Kings Cross Tunnel

Discussion:
The urban design component of the EIS is limited to the area between Harbour Street and The Kings Cross tunnel and does not address the urban design implications of the Motorway on the local area to the north of Kings Cross.
What are impacts of increased traffic volumes on:

- Edgecliff shopping centre and Double Bay shopping centre on New South Head Road generally;
- pedestrian access from Paddington to Rushcutters Bay Park;
- are additional or upgraded pedestrian connections across New South Head Road required

In addition no equivalent amelioration of the eastern tunnel portal is proposed as per the eastern tunnel portal

Physical Impact

Issue 1:
Impact on open space areas in the area bounded by Bathurst Street, Market Street viaduct and Park Royal Hotel.

Discussion:
The large green space in front of the Park Royal Hotel has been significantly reduced in size to accommodate new traffic movements, including:

- the CCT exit to Harbour Street; and
- Day Street has been closed north of the Park Royal Hotel (the EIS proposes a large circular turnaround in front of the Hotel presumably to compensate for the closure of Day Street).

The result is an overall loss in green space and existing trees in the area in front of the Park Royal. This loss is to some degree compensated for by increases in front of Darling Walk. However justification is required as to the road configuration and how it might be improved to minimise the loss of green space in this area.

Issue 2:
Impact of portals off the northern side of William Street

Discussion:
Figure 4.4.1 show two ramps proposed both of which are open to the sky:

- Ramp from CCT to ED for southbound traffic (located on the northern side of William Street); and
- And the north bound ED connection to the westbound CCT (located on the southern side of William Street)

In both situations the ramps are in cut and likely to require stabilisation of the walls. On the existing exit ramp from the ED to William Street the ramp walls have been treated with "shotcrete" over large parts of the exit ramp walls. The preferred solution for both ramps is that they be located underground to minimise the impact. This applies equally to the ED ramp to William Street.

Visual character and views

Issue 1:
Definition of character for Park Street through Hyde Park

Discussion:
Figures 3.2 and 3.3 (pp.9-12)diagrammatically show William and Park Streets to be one continuous precinct to Elizabeth Street. The EIS accordingly deals with the two areas under one Chapter (Part 4 William and Park Streets and Associated Works). Figures 4.2.3 (p.14) show William Street to be concave in long section whereas Park Street east of College Street is on a ridge and is concave or sloping gently east. Previous proposals for the Cross City Tunnel have shown treatments to Park Street through Hyde Park as different in character to William Street one proposal was to close Park Street and make Hyde Park continuous.

A preferred approach to the design of Park Street through Hyde Park is where the streetscape design responds to the adjoining parklands more strongly than what is proposed (refer also Streetscape, Pedestrian Connections and Materials and Finishes below)

Issue 2
View down Bathurst street affected by proposed pedestrian bridge

Discussion:
Figure 6.7 (p.36) shows the existing and proposed view looking west down Druitt Street. The proposed view shows a new pedestrian bridge which has a greater visual impact upon the view when compared to the existing. There is an opportunity to improve the existing view down Bathurst Street by realigning the proposed bridge so that it does not extend into the Bathurst Street view corridor.

Streetscape

Issue 1:
Proposed streetscape improvements for William Street

Discussion:
The William Street Revitalisation Strategy (WSRS) has identified a number of opportunities for streetscape improvements to William Street. While the EIS and the WSRS are generally consistent there a number of elements proposed in the WSRS that have not been adopted in the EIS. The EIS proposes footpath widening on both sides of the road (Figure 4.2.4). In contrast the WSRS proposes footpath widening only on the southern side so that kerb-side parking can also be accommodated (southern side only). The principle is that increased pedestrian traffic and car parking will enhance the viability of small businesses/retail activity along the southern side of William Street. This side is also the sunny side and therefore has the greatest amenity.

While it is acknowledged that there are issues in relation to kerb-side parking (such as bus stops and cycle ways) that need to be resolved the preferred outcome is that the EIS adopt kerb-side parking to the southern side of William Street.

Issue 2:
Proposed streetscape improvements to Park Street through Hyde Park

Discussion:
The EIS proposes to narrow Park Street by three metres (Figure 4.2.9) and to provide low planting to the verge and median. This proposal does not fully address the opportunities to enhance the park character of the Street and reduce the overall impact of the road. In relation to discussions above under *Visual Character and Views* a preferred approach would see Park Street designed with a wider central median (min. 3 metres) for planting of large trees (this will require retention of existing footpath widths which are adequate).

Community links and accessibility

Issue 1:
Loss of direct pedestrian link between Druitt Street and Market Street Viaduct (Western Distributor)

Discussion:
Figure 6.1 (p.32) does not show an existing pedestrian link which runs along the southern side of the Market Street viaduct and under the Druitt Street viaduct via the open space area in front of the Park Royal Hotel to connect with Druitt Street at the intersection of Sussex. The proposed pedestrian over Harbour Street makes this connection significantly longer with two additional signalised pedestrian crossings.

The EIS provides no justification as to why the existing link has not been retained and does not provide a viable alternative connection.

Issue 2:
Omission of pedestrian bridges over Park Street to connect Hyde Park South and Hyde Park North

Discussion:
Numerous studies and proposals exist which have explored a range of alternatives for the provision of safe pedestrian connections over Park Street to connect the two halves of Hyde Park. The EIS does not address this issue and provides no exploration of options.

There is a significant opportunity for well designed pedestrian bridges that are located to the side and outside of the view corridor between the Argyle Fountain and the Anzac Memorial.

Community facilities and open space

Issue 1:
Suitability and appropriateness of open space over Kings Cross tunnel portal

Discussion:
The EIS proposes an open space area and a café over the Kings Cross Tunnel portal (pp.20-21). The William Street Revitalistion Strategy has identified a number of concerns in relation to the proposed open space area at Kings Cross. The concerns include:

- the appropriateness of a soft landscape;
- the cost of maintenance of a roof garden;
- the café provides no surveillance over the park;
- safety and security;
- the significance of the views from the area.

It is also noted that traffic movements on Victoria and Darlinghurst Roads have not been improved and access to the open space area by pedestrians is therefore limited. The location and context is not dissimilar to the old "Gilligan's Island" at the intersections of Oxford, Flinders and Bourke Streets.

The issues related to open space, pedestrian and traffic movements and built form are complex in this area and the successful resolution is a key opportunity for the surface improvements related to the Cross City Tunnel. The EIS has presented the concept of open space as the means to address the above issues however it is likely that there will be considerable community concern. From an urban design point of view there are similar concerns.

Discussions to date in the William Street Revitalisation Strategy have indicated that a design competition may be an appropriate way to achieve an acceptable outcome.

Vegetation and landscaping

Issue 1:
Proposed landscaping on Park street through Hyde Park

Discussion:
The EIS proposes no new tree planting in Park Street through Hyde Park (Figure 4.2.9, p.17). The proposal is for low planting in the median and road verges. With reference to the discussion above under *Visual Character and Views* and *Streetscape* a preferred approach would be a central median which is wide enough (min. 3 metres) to accommodate large trees that are compatible in character with planting in Hyde Park. The opportunity is to develop a "park-like" character compatible with Hyde Park.

Issue 2:
Suitability of planting along William Street

Discussion:
The EIS proposes Spotted gum (p.17) as the preferred tree for William Street. Two issues require further clarification:

- Is the tree suited to the shaded conditions on the northern side of William Street; and
- Is the tree compatible in character with the existing Plane trees on William Street

Issue 3:
Loss of existing trees along Riley Street north of William Street

Discussion:
Figure 8.1 shows Riley Street to be part of the construction zone as the result of a cut and cover type tunnel connection to Sir John Young Crescent. Page 27 notes that this will result in the loss of existing Plane trees along both sides of the street. A site inspection found that the trees on the eastern side of Riley Street are semi-mature (possibly 5-10 years old) and could be replaced with new trees with minimal impact. The trees on the western side are mature specimens possibly 20+ years old. While these trees are not significant by species or age they will take along time to replace, that is a new tree may take 10-15 years to gain the equivalent height. It is therefore likely that these trees will be a point of community concern.

Further discussions are required in relation to this matter to determine whether it is possible to protect the trees through modifications to the tunnel design and construction.

Built elements

Issue 1:
Design and location of exhaust stack

Discussion:
The EIS proposes an exhaust stack (39.5 metres tall) to be located to the south east of the IMAX Theatre (p.39). The Schedule of Finishes and Materials notes that the stack will have a form and finish complementary to the IMAX Theatre (p.40). Figures 6.4 to 6.7 show views of the stack from a range of points.

The EIS has not addressed the broader urban context in which the stack is located. The new stack relates functionally and visually to the sewer vent pipe at the top of Bathurst Street in Hyde Park. The sewer vent is designed as an obelisk and is clearly visible from the bottom of Bathurst Street at eye level. The EIS proposes an architectural relationship between the IMAX and the stack however the Imax theatre is an architecturally discrete object that bears no relationship functionally or otherwise to the proposed exhaust stack.

A preferred approach would locate the new stack in an axial relationship to the sewer vent in Hyde Park and that the design, finishes and materials also reflect this relationship.

The EIS shows the stack set in a park (Figure 6.3). In order to achieve the proposed outcome all plant and other equipment for the stack must be located underground for the proposal to be achieved. This issue requires further clarification as to the intent.

Issue 2:
Orientation and design of the pedestrian bridge over Harbour Street

Discussion:
There are a large number of pedestrian bridges connecting the city with Darling Harbour over the Western Distributor each of these bridges have their own distinct architectural style. The EIS proposes that the new bridge over Harbour Street be designed in a similar style as the Darling Park footbridge (p.34). In urban design terms this is not an appropriate response. A preferred outcome would be that the proposed bridge over Harbour Street be designed by an architect to ensure the new bridge is well designed (particularly in relation to the Bathurst Street view corridor) and has its own distinct style.

Noise

Issue:
Possibility of noise walls on tunnel portals

Discussion:
There appears to be no discussion about the possibility of noise walls particularly on ramps and portals to the tunnels. Clarification is sought as these built elements will have an impact on the proposal and should be addressed early in the process

Signage and advertising

Issue 1:
No reference to a policy on outdoor advertising

Discussion:
Clear Policy required which does not allow any new advertising on built elements within or visible from the proposal including pedestrian bridges, portals, walls and any other element

Issue 2:
Require principles for location and design of road and directional signage as part of EIS.

Discussion:
With reference to other similar projects such as the Eastern Distributor and the M5 East it is preferable that the EIS address the issues associated with traffic signs. For example:

- signs are often very large and may have adverse impacts such as blocking a view corridor; and
- signs may be in large numbers and if not properly located and integrated can cause clutter and adverse visual impacts.

Finishes and materials

Issue 1:
Materials and finishes in Park Street through Hyde Park

Discussion:
More resolution required as to materials and street furniture along Park Street in relation to discussions above under *Visual Character and Views* and *Streetscape*. The preferred solution is granite paving as per the western section of Park Street.

Issue 2:
Relationship to Forbes Street Square

Discussion:
The established palette of materials in Forbes Street Square including bollards, tree grates, paving and seating, should form a benchmark for future treatment of William Street

Definitions of Criteria

The issues/assessment criteria are defined below to ensure consistency of assessment and clarity of purpose.

Integration

This issue aims to ensure that the proposed road is integrated into its local context and responsive to the wider city setting. The proposed road will see the introduction of a major new element into the city fabric, and disruption of existing uses and urban patterns. It is important that such intervention is minimised in its impact and mitigatory measures adopted to advance the 'fit' of the road into its environment. Detailed consideration of the context of the route and residual lands are particularly important in this regard, as is the cooperation of a wide group of stakeholders.

Physical impact

This issue deals with the scale of the proposal and its impact upon the existing urban fabric and environment. It excludes impacts of traffic such as congestion and air pollution which are outside the realm of influence of this urban design study.

Community links and accessibility/severance

The roadway proposal will impact on existing community links such as frequently-used crossings over existing recreational land, as well as accessibility to community facilities and services including rail stations. Severance relates to the impact the roadway has on the nature and quality of connection within an area and access between both sides of the proposal. Severance may also affect the "sense of place" and character of a locality.

Visual impact and views

Visual impact is a key issue of concern with regard to Motorways. Visual impact can be defined as the composite impact of a range of elements within a visual catchment including the road structure itself and related elements. Visual impact is related to other issues including materials, physical impact and views.

Community facilities and open space

The change in use and loss of facilities which will result from a road proposal may affect community access to facilities.

Vegetation and landscaping

Vegetation and landscaping are a issue where the proposal includes the removal of existing vegetation, and because the ability of the proposal to ameliorate visual impact and street edge conditions will be determined by vegetation and landscape proposals.

Built elements

Built elements issues relate to the impact of new structures and buildings including ventilation stacks, air intakes, tunnel portals, abutments and retaining walls.

Noise

Noise impacts are identified as an issue for their potential to impact on and result in the degradation of urban quality.

Signage and advertising

Signage deals with the visual impact of the size, location and profusion of road signage (especially motorway standard signage) along and approaching the roadway. The placement of promotional/commercial advertising has also been a controversial issues in many areas because of the visual impact of advertising upon the roadway and locality.

Finishes and materials

Finishes and materials relates to the treatment, materials and finishes of the proposal. The finishes of ramps, ramp walls, portals, tunnel walls, and noise barriers are all important.



Proposed Cross City Tunnel
Urban Design Review (Phase 2)

Prepared for the Department of Urban Affairs and Planning
by the Urban Design Advisory Service

July 2001

BACKGROUND

The Urban Design Advisory Service (UDAS) was engaged by the Development and Infrastructure Branch of the Department of Urban Affairs and Planning (DUAP) to provide the Department with an independent assessment of the urban design component of the Cross City Tunnel EIS. This study is the second phase of a two phase review process. The Phase 1 review was completed in September 2000.

OBJECTIVES

The primary objective of the commission is to provide the Department with an independent assessment of the urban design component of the proposal to assist in DUAP's assessment process and to ensure that appropriate environmental standards are adopted for the project in a cost effective manner.

Phase 2 involves:

- the assessment and reporting of the key issues raised in phase 1 and the RTA's response from phase 1;
- Review of urban design issues raised in representations to the exhibition of the EIS;
- Review the adequacy of the urban design assessment undertaken in the EIS and determine whether it is sufficient to give conditional approval; and
- Identify appropriate urban design conditions

INTRODUCTION

Overall the level of detail presented in the EIS is generally adequate in terms of urban design. Given that the route is mostly in tunnel the main areas of concern in terms of urban design are at the tunnel entry and exit portals and surrounds, the vent stack location. The CCT also offers major benefits to the CBD such as the public domain improvements along William Street and Park Street as part of the CCT construction. It is therefore considered that a *general condition* requiring the RTA to produce detailed plans for key precincts to the satisfaction of the Director General will be adequate to ensure an acceptable outcome for the overall route.

In regard to particular issues that have either not been addressed or not addressed adequately in the EIS this report recommends *specific conditions*. Specific conditions are identified where there is enough information available at the current time to identify practicable and feasible outcomes and that require conditioning to ensure the desired outcome.

In addition there are a number of issues in the EIS that are complex and where sufficient information is currently not available to enable conditions to be formulated. Most of these issues were raised in the UDAS phase 1 review however no further discussion has taken place in the period between EIS and Representations Report. In these cases this report identifies the need for *further information* and discussions with the RTA and a range of stakeholders to determine appropriate and feasible outcomes. The report also identifies *recommended outcomes* to form the basis of consultation and discussions with the RTA.

1.0 Recommended General Conditions

1. A detailed Urban Design and Landscape Plans for the proposal shall be prepared in consultation with relevant local Councils to the satisfaction of the Director-General and incorporated into the Operational EMP. The Plans shall be prepared by a multidisciplinary company with the appropriate experience in urban design, landscape architecture and architecture.

2. The plans shall be prepared according to appropriate precincts and addressing the entire surface work component of the proposal. The precincts shall include but not limited to:

- Kings Cross tunnel precinct
- William Street/East Sydney
- The Domain
- Park Street/Hyde Park
- Park Street/CBD
- Darling Harbour

3. The Plans shall include but not be limited to the location and design all aspects of the proposal.

Built Elements including:

- Tunnel portals;
- Bridges and other structures;
- Retaining walls;
- Noise walls;
- Toll infrastructure;
- Control building;
- Substations;
- Ventilation stack and substation.

Motorway and road furniture including:

- safety barriers;
- kerbs;
- paving;
- signage and lighting;
- medians;
- emergency phones;
- breakdown facilities.

Pedestrian and cycle elements

- footpaths and paving;
- pedestrian bridges and foot ways;
- cycleways;
- pedestrian crossings;
- street furniture and fixtures including tree guards, seating lighting, fencing, signage.

Landscape elements

- proposed treatments, finishes and materials of exposed surfaces. Colours, specifications and samples should be detailed;
- proposals if any for community art or interpretation in public spaces along the proposal;
- the location, type, number per sqm, and pot size of new plants and trees;
- details of hard landscape elements including paving, walls, retaining walls.

4. The Plans shall consist of a report with accompanying annotated plans, sections, photo montages and other illustrative material at an appropriate scale and level of detail to accurately convey the

proposal.

5. Information regarding timing and staging of works; methodology; monitoring and maintenance.

2.0 Specific Conditions

2.1 Darling Harbour access and circulation

Discussion:
Impacts on pedestrian and cycle access between Darling Harbour and the CBD was identified as a key issue as part of the Phase 1 review of the CCT EIS. In order to determine the full impacts of the CCT EIS proposal UDAS was engaged by DUAP in January 2001 to prepare an Urban Design Study examining existing pedestrian and cycle links, pedestrian desire lines, and the impacts of the CCT EIS Proposal. The study found that the CCT EIS Proposal provided a number of new and important pedestrian links however it also severed existing links or omitted other key links. The UDAS study also found that the CCT EIS Proposal did not adequately address cycle links in the area.

In response to the UDAS report the RTA prepared a number of design options for providing the a new footway link form Bathurst Street across Harbour Street, through Darling Harbour and linking to Harris Street (to replace the proposed removal of the Western Distributor footway). Since the preparation of the RTA options ongoing discussions have taken place between the RTA, DUAP/UDAS, SHFA and SCC to determine the most appropriate option in this regard as well as the following:

- the existing footpath along the western frontage of the Park Royal Hotel is very poor and narrow and requires upgrading
- The lack of signalised pedestrian crossing at the intersection of Liverpool Street and Harbour Street

Recommended Conditions:
Discussions with the RTA have lead to the identification of the following conditions:

- RTA to provide a new continuous 3.6m wide at-grade pedestrian footpath from Druitt Street to Bathurst Street including the western frontage of the Park Royal Hotel. The footpath should be of a standard and finish to the satisfaction of Sydney City Council.
- RTA to provide new signalised pedestrian crossing at the intersection of Liverpool Street and Harbour Street connecting footpaths along the eastern side Harbour Street as part of CCT project.
- RTA to investigate full signalised pedestrian crossing at the Liverpool and Harbour Street intersection.
- Any pedestrian bridge crossing Harbour Street from Bathurst Street to Darling Walk must be designed and located so that the bridge is not within the Bathurst Street view corridor (looking west). The design and location of the pedestrian bridge should in no way compromise the at grade pedestrian access along the southern side of Bathurst Street or western side of Harbour Street.
- Any new pedestrian bridges shall be designed by an architect with appropriate experience in bridge design. The bridge will be of a high architectural quality in terms of form, finishes and materials. A benchmark for the bridge design is the existing pedestrian bridge from King Street to Darling Harbour.
- RTA to provide at-grade pedestrian link into Darling Harbour from the end of Bathurst Street as part of CCT project. Link should be of a high quality and amenity including new paving and lighting?
- the RTA in consultation with Sydney City Council will provide an on road cycleway along Sussex or Kent Street to link the proposed cycleway along William Street (provided as part of CCT surface works) with the existing cycleway over Pyrmont bridge/King Street as part of the CCT project.

2.2 Treatment of eastern portal of Kings Cross Tunnel

Discussion:
It is noted that the EIS/Preferred Activity Report proposes to upgrade the western portal of the Kings Cross tunnel with terraced gardens as well as upgrading the existing Kings Cross tunnel internal fitout to match CCT fittings. The issue is that the CCT Proposal does not provide an equivalent amelioration of the eastern tunnel portal. The eastern portal is a gateway to William Street and the CBD and as such should form part of the William Street surface works/CCT Proposal and be consistent in treatment to William Street.

Recommended Conditions
Provide terraced gardens or the equivalent to the eastern portal of the Kings Cross tunnel portal. The gardens should be designed to reduce the size and impact of the tunnel entry, relate in character to the western portal, and enhance the gateway experience to William Street from New South Head Road.

2.3 Proposed pedestrian crossing relocation at Druitt Street

Discussion
The Preferred Activity Report proposes to locate the pedestrian crossing at the intersection of Sussex Street and Druitt Street in an alignment that does not follow the pedestrian desire line from the CBD to Darling Harbour. The proposed crossing would require pedestrians walking down the northern side of Druitt Street to cross Sussex Street and then Day Street in order to gain access to the Darling Park walk way. Recent RTA surveys indicate that this route is a major access point to Darling Harbour with pedestrian volumes in excess of 1000 on weekends over a 12 hour period and more than 3000 people on weekdays using the Darling Park walkway.

Representations
Sydney City Council have also noted their concern for the crossing in a letter dated 29th May from Richard West (SCC) to K Sharman (RTA).

Recommended Condition
Relocate Sussex Street pedestrian crossing to align with pedestrian desire line along Druitt Street to the Darling Park Footway

2.4 Street tree selection for William Street

Discussion
The EIS proposes Spotted Gum (*Eucalyptus maculata*) as the preferred tree for William Street. This tree is not considered appropriate for a number of reasons:

- the tree is not suited to the shaded conditions on the northern side of William Street;
- the tree is not compatible in character with the existing Plane trees on William Street
- the tree is not suitable for a major urban boulevarde

Representations report and Preferred Activity Report
The Preferred Activity Statement has not modified the EIS proposal where Spotted Gum remains the preferred tree species.

A number of representations noted concerns with regard William Street:
Rep. No. 96/8 – concerned that proposed tree planting not appropriate. Suggest central median with tree planting rather than tree planting to kerb;

Rep. No. 154/27 (local government) – native Eucalyptus species are inappropriate for a major urban boulevard.

Recommended Conditions
RTA to select appropriate street trees for William Street in consultation with SSCC and SCC and to the satisfaction of the Director General

2.5 Finishes and materials for William Street

Discussion
Forbes Street Square is a small urban space at the western end of William Street on the southern side of the road. The design and construction of the Forbes Street Square project was undertaken as a demonstration project as part of the William Street Revitalisation Strategy (WSRS).

Recommended conditions
The palette of materials used in Forbes Street Square on William Street including bollards, tree grates, paving and seating, should form a benchmark for future public domain treatment of William Street.

3.0 Request for further information

3.1 Loss of existing trees along Riley Street north of William Street

Discussion:
Figure 8.1 shows Riley Street to be part of the construction zone as the result of a cut and cover type tunnel connection to Sir John Young Crescent. The EIS notes that this will result in the loss of existing Plane trees along both sides of the street. A site inspection found that the trees on the eastern side of Riley Street are semi-mature (possibly 5-10 years old) and could be replaced with new trees with minimal impact. The trees on the western side are mature specimens possibly 20+ years old. While these trees are not significant by species or age they will take along time to replace, that is a new tree, even if planted as a mature specimen, may take 10-15 years to gain the equivalent height.

Representations Report
Rep. No. 103/1 (individual) – noted concerns over loss of existing trees along Riley Street

Recommendations
Further discussions are required in relation to this matter to determine whether it is possible to protect the trees, particularly those on the western side of the street, through modifications to the tunnel design and construction.

3.2 Appropriateness of landscape and urban design for Park Street through Hyde Park

Discussion:
The EIS proposal for Park Street through Hyde Park is as follows:

- Reduce width of Park Street carriageway by three metres;
- Increase footpath widths by1.5m to 1.8m both sides;

- extend existing 1.5 metre wide median to 2.4 metres; and
- provide low planting to the verge and median.

The UDAS Phase 1 review of the CCT raised the following concerns with regard to the CCT EIS proposal for this section of Park Street:

- The proposal does not fully address the opportunities to enhance the "park-like" character of this section of Park Street and thereby differentiate it from the existing character of Park Street through the CBD and the proposed character of William Street;
- The proposal does not significantly reduce the overall impact of the road on Hyde Park;
- The proposal does not provide for the long discussed pedestrian bridges over Park Street to connect Hyde Park South and Hyde Park North (assessed as an option in the EIS);
- The EIS proposes no new street tree planting on Park Street through Hyde Park (the proposal is for low planting in the median and road verges);
- The paving materials and finishes in proposed for Park Street through Hyde Park (asphalt and granite borders) are not appropriate and do not acknowledge the relationship to Hyde Park and the transition into the CBD.

Representations Report

The Preferred Activity Report makes no changes to the EIS proposal for Park Street through Hyde Park except for minor changes to the intersection of Elizabeth and Park Streets.

Typical representations regarding this issue are:

- Rep. No.17/1 (Individual) – EIS does not propose building of level walkway over Park Street
- Rep. No.23/1 (Individual) – EIS does not incorporate joining of two halves of Hyde Park
- Rep. No.47/2 (Individual) – existing footpath widths adequate
- Rep. No. 154/26 (local government) – the footway treatment should break from the William Street treatment and acknowledge the north-south axis of Hyde Park

Recommendations

The preferred outcome with regard this issue is:

- The provision of new pedestrian bridges between Hyde Park north and south to reduce impacts of road and provide continuous pedestrian link between two halves. Design resolution should be in consultation with council and to the satisfaction of the Director General;
- The provision of a continuous central median to a minimum of 3 metres wide to accommodate tree planting that is compatible in character with planting in Hyde Park and thereby assist with reduction of overall impact of road and enhance park character of road.
- Review paving and finishes to Park Street footpath. Two options are appropriate at this stage: granite paving as per the CBD section of Park Street; or alternatively paving to match that used in Hyde Park. Resolution should be in consultation with SCC and SSCC and to the satisfaction of the Director General

3.3 Appropriateness of proposed streetscape improvements for William Street

Discussion:

The UDAS Phase 1 review of the CCT raised the following concern with regard to the proposed streetscape improvements to William Street:

- The William Street Revitalisation Strategy (WSRS) identifies a number of opportunities for streetscape improvements to William Street. While the EIS and the WSRS are generally consistent there the EIS does not provide kerb side parking to William Street. The EIS proposes footpath widening on both sides of William Street while the WSRS proposes footpath widening only on the southern side so that kerb-side parking can also be accommodated (southern side only). The principle is that increased pedestrian traffic and car parking will enhance the viability of small

businesses/retail activity along the southern side of William Street. This side is also the sunny side and therefore has the greatest amenity.

Representations Report and Preferred Activity Report
The Preferred Activity Statement has not modified the EIS proposal. Kerb-side parking is not proposed on William Street.

A number of representations noted concerns with regard William Street:
Rep. No.72/14 (Business) – respondent suggests that parking be restored to William Street;
Rep. No. 82/4 and 82/9 (Interest Group) – respondent calls for provision of parking on the southern side of William Street;
Rep. No. 81/2 – respondent suggests footpath widening not necessary;
Rep. No. 96/9 (Business) – call for street parking to encourage human scale activities along William Street;
Rep. No. 154/21 (local government) – the respondent supports the concept of parking along William Street to create an "eat street";

Recommendations
The preferred outcome for William Street is kerb-side parking to the southern side of the road. Parking would be designed as parking bays within the extended kerb with bus stops at kerb extensions allowing buses to stop and not conflict with parking cars. Further discussions with the RTA and other stakeholders required.

3.4 Suitability and appropriateness of proposed open space and retail/café over the Kings Cross tunnel portal

Discussion:
The UDAS Phase 1 review of the CCT raised a number of concerns with regard to the proposed open space and café over the Kings Cross tunnel portal:
- the appropriateness of a grassed open space in such a location;
- the café provides no surveillance over the park or Darlinghurst Road;
- the café is poorly located for passing pedestrian traffic along Darlinghurst Road; and
- the proposal does not provide a covered pedestrian connection along Darlinghurst Road.

Representations Report
The Representations Report does not propose any modifications to the EIS proposal in this regard.

A number of public representations note concerns with regard to the proposed design:
- Rep no. 82/10 – the two major open space at either end of the tunnel are inadequate and require more considered design input;
- Rep no. 100/6 (interest group) – the respondent fails to see the relevance of the Kings Cross tunnel "lid"; and
- Rep. No. 154/26 (local government) – further consultation required to develop acceptable design criteria for the "lid".

Recommendations
The issues related to open space, pedestrian and traffic movements, built form and community concerns are complex in this area and the successful resolution is á key opportunity for the surface improvements related to the Cross City Tunnel. The preferred outcome in urban design terms would include:
- All proposed grassed areas to be replaced with paved areas to create a pedestrian plaza with trees;

- Possibly a public art element or other landmark element to terminate the William Street view corridor
- The Café/retail outlet (if determined to be appropriate) should be designed and located to address in part Darlinghurst Road as well as any other public area so that some degree of passive surveillance is provided; and
- Possibly some form of covered pedestrian way along the Darlinghurst Road frontage.

3.5 Design and location of exhaust stack

Discussion:
The EIS proposes an exhaust stack (39.5 metres tall) to be located to the south east of the IMAX Theatre. The EIS notes that the stack will have a form and finish complementary to the IMAX Theatre.

Three main issues arise:

- The EIS has not addressed the broader urban context in which the stack is located. The stack will be a significant urban element and should be designed and located as such. An example of this approach is the sewer vent pipe at the top of Bathurst Street in Hyde Park. The sewer vent is designed as an obelisk, built in sandstone and is located at the end of Bathurst Street terminating the view corridor as a significant monument. This approach contrasts strongly with the approach which attempts to minimise the impact of the element.
- The EIS proposes an architectural relationship between the IMAX building and the stack, by using the same form and materials as the Imax building. The Imax Theatre however is an architecturally discrete object that bears no relationship functionally or otherwise to the proposed exhaust stack.
- The EIS shows the stack located in a park setting with no substation

Representations Report
While a large number of representations note health and pollution related concerns for the stack a number of public representations also refer to the poor design of the stack:

- Rep. No. 9/1 – the respondent suggests designing the stack as a monument
- Rep. No.9/2 – the respondent suggests holding a design competition for the stack
- Rep. No. 151/1 (individual) – concerned that the proposed stack will be an eyesore

Recommendations
Ongoing discussions with RTA required to resolve issues of design and location. Preferred outcomes include:

- stack is to be designed as a discrete architectural object/landmark element that reflects its function and location;
- the new stack should be located so as to create a landmark, terminate a view corridor or other location to respond appropriately to its urban context
- all plant and other equipment for the stack should be located underground or within an existing structure to minimise impacts on open space, access and circulation in Darling Harbour.

3.6 Toll building relocation and design

Discussion:
UDAS supports in principle the relocation of the CCT control building to Palmer Street. However it is clear that the building in this location is constrained to providing car parking at ground level rather than basement car parking because of the ED Motorway Tunnel under. There is concern therefore that the building:

- will not perform the role of providing informal street surveillance adequately;

- the building may potentially impact on pedestrian safety and amenity.

While the building is generally acceptable in scale and architectural resolution the building does not provide active ground level uses particularly to Palmer Street. In addition the laneways are dominated at ground level by roller shutters for car parking bays which are accessed directly from the street as per garages.

Representations
None at this stage

Recommendations
Further discussions with the RTA required to determine whether the building design may be amended to:

- maximise active uses at ground level particularly along Palmer Street;
- minimise vehicle access points and roller shutters; or
- whether there is an alternative location

3.7 Built Elements Generally

Discussion:
The EIS does not describe in detail the location and design of the built elements. Of key concern at this stage is the location and design of:

- noise walls
- retaining walls
- substations
- fencing
- tolling infrastructure
- VMS signage and other signage

Recommendations
RTA to provide architectural and/or engineering drawings showing the location, heights and other relevant information for the main built elements of the tunnel infrastructure noted above.



Urban
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Proposed Cross City Tunnel

Pedestrian and Cycle Access to Darling Harbour
Urban Design Study

Prepared for the Department of Urban Affairs and Planning
by the Urban Design Advisory Service

February 2001

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Executive Summary

The key objective of the study is to investigate, identify and provide alternatives and options for improving pedestrian and cycle access between the CBD and Darling Harbour. The overall goal is to ensure walking and cycling between the two precincts is more coherent (legible), direct, safe, comfortable and attractive as a result of the Cross City Tunnel Project (CCT).

The study finds that the existing situation in terms of pedestrian and cycle access is poor:

- Darling Harbour is currently separated from the CBD by **physical and visual barriers** such as major roads, the Western Distributor and buildings such as Darling Walk; and
- Darling Harbour is also separated from the CBD by the **high volumes of traffic** that use Harbour and Bathurst Streets.

Furthermore:

- There is no coordinated pedestrian strategy to improve pedestrian and cycle access in and through the study area; and
- There is no overall strategy to achieve safe and effective cycle links between the CBD and Ultimo/Pyrmont and beyond;

The concern that the CCT EIS proposal would exacerbate the existing conditions is supported by this study. The proposal appears to prioritise vehicle movements over pedestrian access. The proposal caters for all possible vehicular movements including both retaining existing vehicular movements and introducing a number of new traffic movements as a result of the proposed tunnel portals and ramps.

This report finds the main impacts of the CCT EIS Proposal in relation to pedestrian and cycle access would result from the ***westbound exit ramp*** connection to Harbour Street. This ramp is proposed to intersect at grade with the existing intersection of Bathurst and Harbour Streets form a five-way intersection.

The overall result of the CCT EIS Proposal is a degradation of pedestrian conditions and connections (when compared to the existing situation) particularly in the vicinity of the Bathurst/Harbour Streets intersection and along Harbour Street generally.

In order to balance the potential benefits of the CCT between pedestrian, cycle and vehicular access this study provides two options. In both options the modifications relate only to the westbound exit ramp component of the CCT EIS Proposal.

Option A provides for a significant improvement upon both the existing situation and the CCT EIS proposal while Option B provides for optimal pedestrian access conditions between Darling Harbour and the CBD.

1 Introduction

Background

The Environmental Impact Statement (EIS) for the proposed Cross City Tunnel (CCT) was exhibited from 19 July 2000 to 10 October 2000.

The Minister for Urban Affairs and Planning has an independent approval role for this project under Division 4 Part 5 of the Environmental Planning and Assessment Act 1979. In deciding whether or not to recommend approval, the Minister is required to take into account an independent environmental impact assessment report by the Director-General of the Department of Urban Affairs.

The Department of Urban Affairs and Planning (DUAP) has undertaken a preliminary review of the EIS and has expressed concern to Roads and Traffic Authority (RTA) about the impact of the CCT proposal on the regional planning objectives for Darling Harbour. DUAP has requested more information from the RTA regarding the resolution of pedestrian and cycle access arrangements including further consideration of alternatives and/or off-set measures.

In addition DUAP is currently preparing a Harbour REP that will provide further impetus for improving pedestrian and cycle linkages between the CBD and Darling Harbour and further west to Ultimo-Pyrmont (City West). The need to improve these linkages is made more urgent because of the current residential growth in the southern part of the Sydney CBD as well as in the City West.

The Urban Design Advisory Service (UDAS), as part of an ongoing role in the assessment of the CCT EIS, has been engaged to provide the Department with an independent urban design study. The aim of the study is to assist with the assessment process and to ensure the appropriate planning objectives with regard pedestrian and cycle access are met.

Objectives

The key objective of the study is to investigate, identify and provide alternatives and options for improving pedestrian and cycle access between the CBD and Darling Harbour. The overall goal is to ensure walking and cycling between the two precincts is more coherent (legible), direct, safe, comfortable and attractive.

Scope

Figure 1 shows the extent and location of the study area. To ensure that the area is dealt with in adequate detail the study has been limited to the area of surface works for the Cross City Tunnel and the surrounding streets.

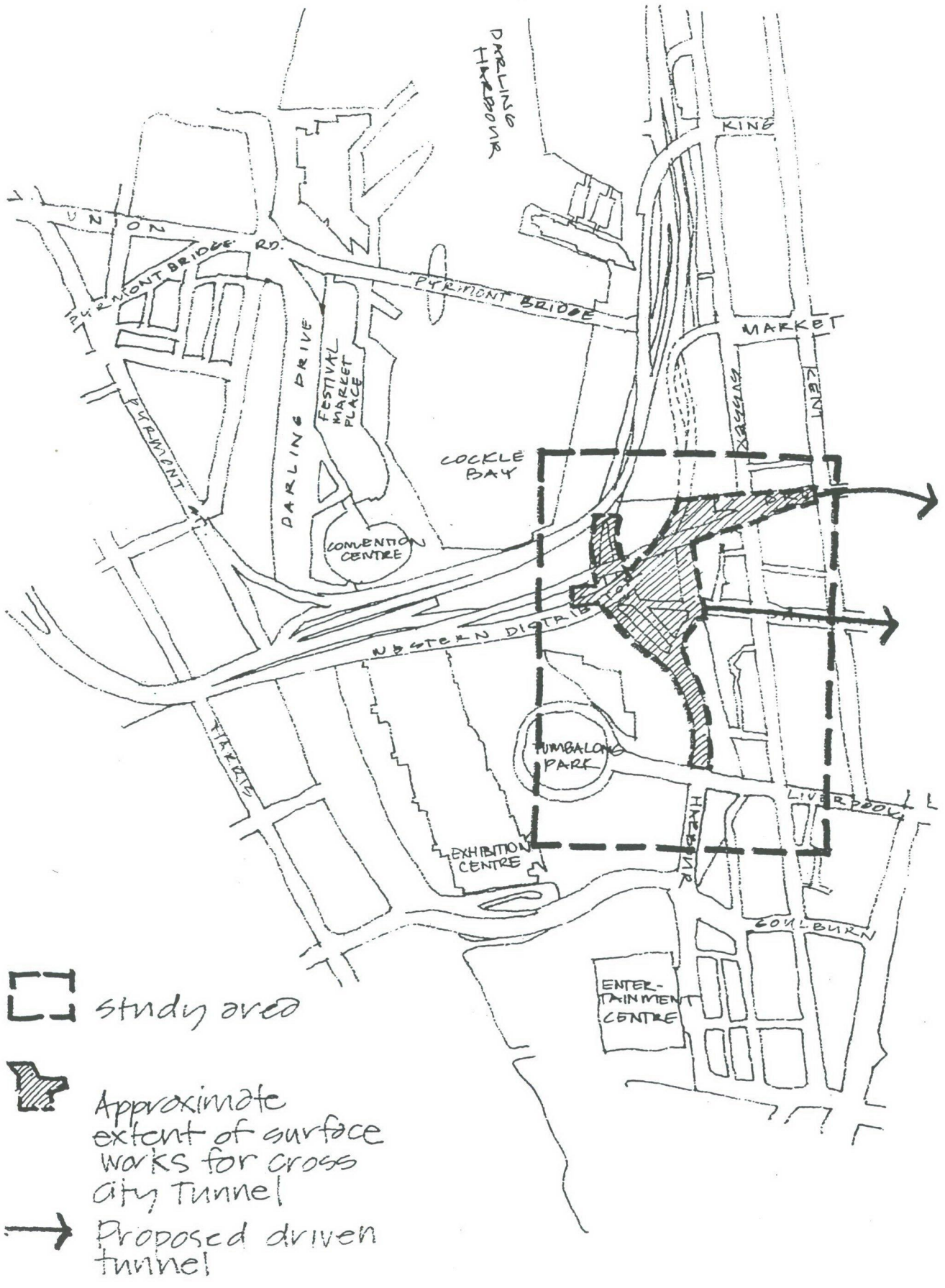
The scope of the study is also limited to exploring options for ***at grade connections***, including signalised pedestrian crossings, as opposed to pedestrian bridges. The reasons for this are as follows:

- At grade connections can only be achieved through good planning and design whereas pedestrian bridges can be located to overcome problems arising from poor design;
- Pedestrian bridges tend to detract from the visual environment;
- Pedestrian bridges do not generally assist with the legibility and permeability of and environment; and
- Pedestrian bridges are not always accessible to disabled people and cyclists.

Report structure

This report is structured as follows:

- The ***Introduction*** opens the document;
- Chapter 2 ***Strategic Context*** summarises the general opportunities and constraints for the study area in relation to pedestrian links and amenity identified from a review of background documents;
- Chapter 3 documents the ***pedestrian desire lines*** that traverse the site both from east to west and from north to south;
- Chapter 4 describes in detail the ***existing pedestrian connections***;
- ***The Cross City Tunnel EIS Proposal*** is examined and assessed in detail in chapter 4;
- Chapter 5 proposes ***two modified options for the Cross City Tunnel***; and
- The ***Appendix*** contains details of the review of background documents that inform Chapter 2.



CROSS CITY TUNNEL EIS REVIEW
Pedestrian and Cycle Access to Darling Harbour

Figure 1 Study area

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2 Strategic Context

The strategic context of the site has been determined through a review and summary of current and past studies relevant to the site, the details of which are documented in the Appendix of this report.

The review found that pedestrian and cycle access in the study area is poor due to:

- The lack of pedestrian, cycle or public domain studies that address improving links within the study area;
- a range of stakeholders, landowners and agencies responsible for pedestrian and cycle access in the area and a lack of an overall or coordinated strategy to address the issue.

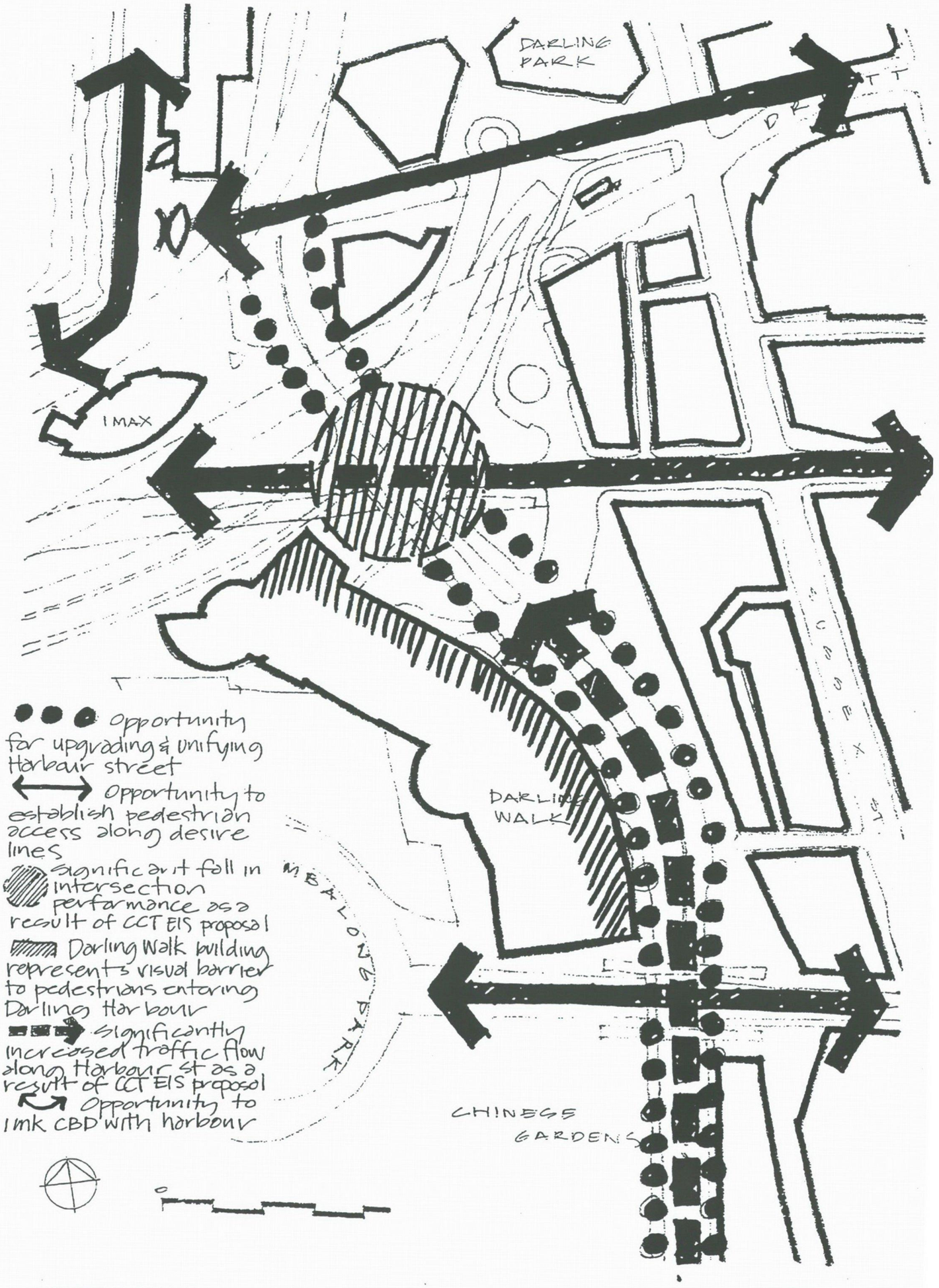
The Cross City Tunnel project has the potential to be the catalyst for improving pedestrian and cycle access between the CBD and Darling Harbour and ensuring a coordinated approach between agencies and stakeholders. The document review, undertaken as part of this study, has identified a range of issues relevant to the study area. They are summarised in the form of opportunities and constraints in Figure 2 and may form the basis of a pedestrian strategy for the site:

- ***opportunity*** - upgrade and unify Harbour Street in terms of pedestrian amenity (identified by DUAP and SSC);
- ***opportunity*** - enhance pedestrian access along the key east west desire lines from Bathurst, Liverpool and Druitt Streets (identified by UDAS);
- ***opportunity*** - enhance links to the harbour foreshore (SREP 56);
- ***constraint*** - the poor performance of the Bathurst/Harbour Street intersection proposed in the Cross City Tunnel (CCT) EIS will further limit pedestrian access to the foreshore and Darling Harbour via Bathurst Street;
- ***constraint*** - the increased traffic volumes along Harbour Street proposed in the CCT EIS will further limit pedestrian access to the foreshore and Darling Harbour; and
- ***constraint*** - Darling Walk represents a visual barrier to pedestrians wishing to enter Darling Harbour.

Summary of issues

The key issues arising are:

- There is a significant conflict between the Bathurst Street pedestrian desire lines identified by UDAS and the vehicular circulation proposed in the CCT EIS for the intersection of Bathurst and Harbour Streets.
- The increase in traffic volume along Harbour Street conflicts with the desire expressed by DUAP and Sydney City Council for the upgrading of Harbour Street in terms of pedestrian amenity and cycle access.
- The increase in traffic volume along Harbour Street conflicts with at grade pedestrian and cycle access from Liverpool Street to Darling Harbour and vice versa.
- Bathurst Street provides the best available option for at grade access to Darling Harbour and access to the Harbour foreshore. The current access points through Darling Walk are not appropriate because the entrances are difficult to find and circuitous.



CROSS CITY TUNNEL EIS REVIEW
Pedestrian and Cycle Access to Darling Harbour

Figure 2 Strategic context

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3 Pedestrian desire lines

Since urban design relates to largely qualitative rather than quantitative issues, particular care is required to ensure objective assessment. To this end the assessment method is based on a comparative analysis against an optimal scenario.

Pedestrian desire lines represent the shortest practicable route between two destinations. Desire lines also represent the predominant or desired movement patterns of people, as opposed to those routes that people must take because there is no other available, or because there is a major barrier to movement. For this reason ***pedestrian desire lines*** are used as the optimal pedestrian access scenario with which to make comparisons to the existing pedestrian conditions and the proposed CCT EIS Proposal, and thereby develop options for improving access.

Figure 3 shows the pedestrian desire lines that are required in order to maximise at grade access between Darling Harbour and the CBD. Three main desire lines through the site, linking the CBD with Ultimo Pyrmont and further west to Glebe, have been identified (UDAS, 1999). An additional desire line has been identified in the course of this study linking Haymarket and the Entertainment Centre with Cockle Bay via Harbour Street.

3.1 Druitt Street desire line

There are two desire lines along Druitt Street to Cockle Bay one along the footpath on the southern side of Druitt Street and one along the footpath on the northern side of Druitt Street:

- The existing Darling Park walkway caters for the desire line from the north side of Druitt Street to Cockle Bay.
- From the southern side of Druitt Street direct access to Cockle Bay is not possible (blocked by Western Distributor and new substation) and the most direct route is via the walkway to the north of the Park Royal and along a diagonal line to the Bathurst Street desire line (see 3.3 below).

In addition to the two desire lines noted above there is a third desire line along Druitt Street linking to the Market Street viaduct (Western Distributor) and connecting south to Ultimo:

- An existing walkway on the southern side of the Western Distributor provides a direct link between the CBD and Ultimo and on to Glebe

3.3 Bathurst Street desire line

There are two desire lines along Bathurst Street one along the footpath on the southern side of the street and one along the northern footpath:

- From the northern side of Bathurst Street the most direct route to Darling Harbour is straight down Bathurst Street and across Harbour Street to the IMAX Theatre and Cockle Bay; and
- From the southern side of Bathurst Street the desire line crosses Day Street and Harbour Street and links with Darling Harbour along the northern edge of Darling Walk.

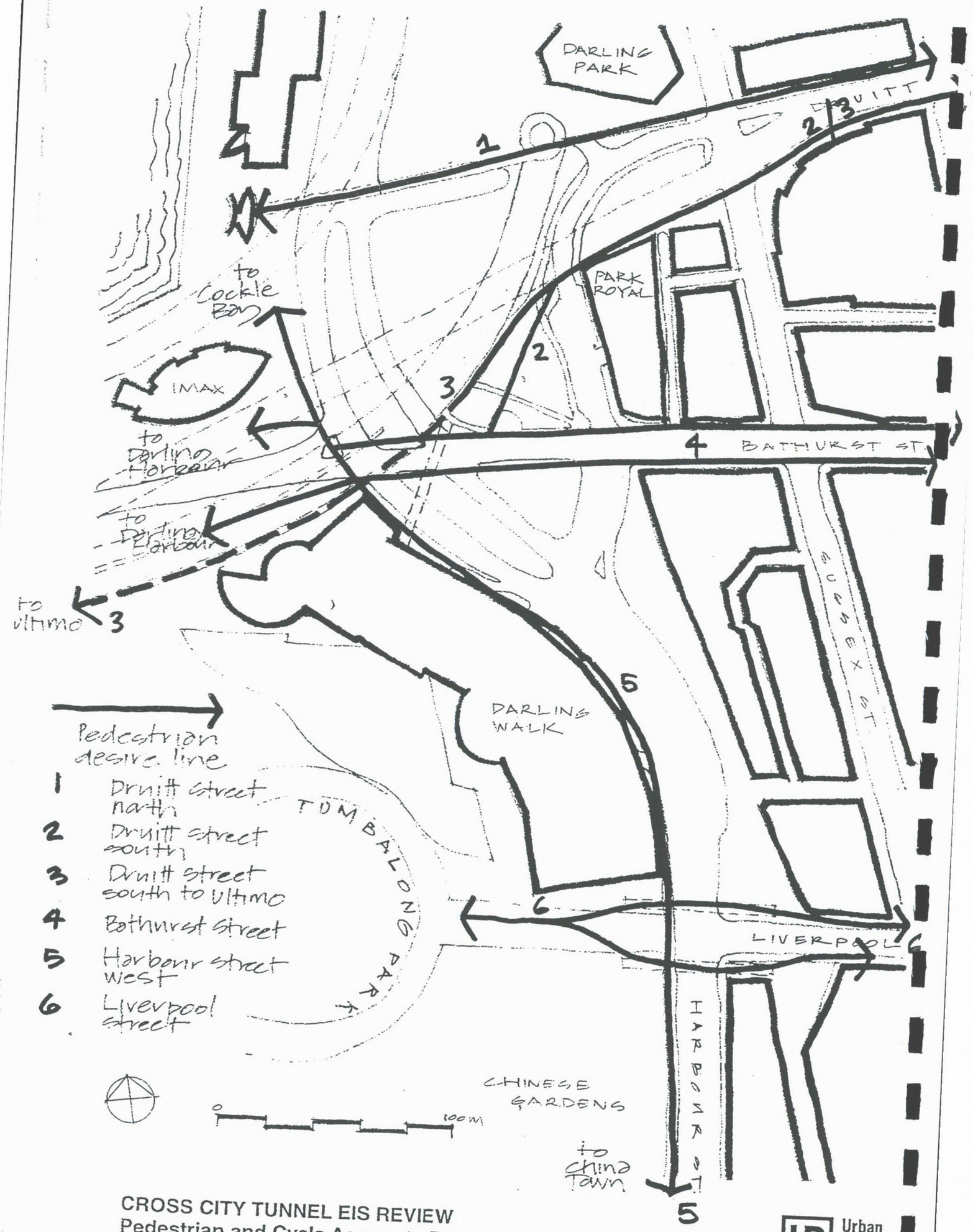
Currently **neither route is accessible** as there is no signalised pedestrian crossings at the Harbour Street intersection and there is a staff car park at the northern end of Darling Walk.

3.4 Harbour Street desire line

The desire line between Cockle Bay and Haymarket runs along the western side of Harbour Street via the Entertainment Centre and Darling Walk. Currently **this route is not accessible** as there is no footpath along the front of Darling Walk and there is no signalised pedestrian crossing at the Harbour/Bathurst Street intersection.

3.5 Liverpool Street desire line

The desire line from Liverpool Street crosses over Harbour Street and connects to Tumbalong Park (Darling Harbour). Currently this route is accessible via two bridges one to the north and the other to the south side of Liverpool Street over Harbour Street.



CROSS CITY TUNNEL EIS REVIEW
Pedestrian and Cycle Access to Darling Harbour

Figure 3 Pedestrian desire lines between Darling Harbour and CBD

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4 Existing Pedestrian Connections

Darling Harbour is a recreational, entertainment, educational and tourist precinct of regional significance. It also provides important commuter walking and cycling routes from the City West and inner western suburbs to Sydney CBD.

Currently there is very poor at grade access between Darling Harbour and the CBD when compared to the pedestrian desire lines.

The Darling Harbour is currently separated from the CBD by ***physical barriers***. On the eastern (CBD) side of Darling Harbour the barrier is in the form of major roads (Harbour Street) and the Western Distributor freeways (King Street, Druitt Street and Market Street Viaducts) and buildings such as Darling Walk which form a visual barrier. This is exacerbated by the vehicle access arrangements to the retail facilities at the Darling Walk frontage and resulting poor pedestrian safety.

Darling Harbour is also separated by ***high volumes of traffic*** using Harbour and Bathurst Streets. At the intersection of these two roads there are no signalised pedestrian crossings, the result is that pedestrians wishing to access Darling Harbour from Bathurst Street must use an indirect system of paths and pedestrian bridges.

An additional factor that is confusing to pedestrians is the access points via Darling Walk to Darling Harbour. The entries are very hard to see and the building acts as a ***visual barrier*** to pedestrians rather than a gateway. During site visits it was observed that a number of people had difficulty finding the Darling Walk/Darling Harbour access points and *would ask for directions* to Darling Harbour although it was only 100 metres away.

Figure 4 shows the routes currently available to pedestrians moving between the CBD and Darling Harbour.

3.1 From Bathurst Street

The three routes currently available to pedestrians to access Darling Harbour from Bathurst Street are:

- Route A - an indirect pedestrian bridge that crosses Harbour Street into Darling Walk at the upper level;
- Route B - an indirect access way and bridge structure that crosses Harbour Street north of Bathurst and connects with a pedestrian bridge at Darling Park; or
- Route C - via Day Street and across Harbour Street to enter Darling Walk at ground level.

Issues/comments:

- Currently there is ***no direct at grade pedestrian access*** to Darling Harbour for pedestrians walking down Bathurst Street;
- Both routes A and B are not ideal as Darling Walk is a significant visual barrier to pedestrians wishing to enter Darling Harbour;

- Route C is a particularly poor access way with very poor safety and amenity; and
- There is continuous access along the Western Distributor over Darling Harbour for pedestrians walking to Wentworth Park or Glebe

3.2 From Druitt Street

The three routes currently available to pedestrians for access to Darling Harbour from Druitt Street are:

- Route D from the northern side of Druitt Street via a walkway/pedestrian bridge at the southern end of Darling Park;
- Route E from the northern side of Druitt Street via Day Street and thence to routes A,B or C described above; or
- Route F from the southern side of Druitt Street via a narrow walkway between the Market Street viaduct and the Park Royal Hotel and thence to routes A,B or C.

Issues/comments:

- Access from Druitt Street to Darling Harbour is very direct via the walkway along the southern edge of Darling Park. Although this access is not at grade the pedestrians access is successfully integrated via a ramp and disabled access via an elevator;
- Route F is narrow with little surveillance however it has been recently upgraded with lighting and new paving;
- Public access along the front of the Park Royal is poor with a very narrow footpath (less than 1 metre); and
- The footpath along the western side of Day Street is not continuous and a pedestrian crossing is required.

3.3 From Liverpool Street

The routes currently available to pedestrians for access to Darling Harbour from Liverpool Street are:

- Access from the northern and southern side of Liverpool is very direct via pedestrian bridges over Harbour Street (route G).

Issues/comments:

- ***No at grade pedestrian access across Liverpool Street*** at Harbour Street intersection
- Access from Liverpool Street to Darling Harbour is generally good as the pedestrian bridges use the change in levels in the area to form more or less at grade crossings.

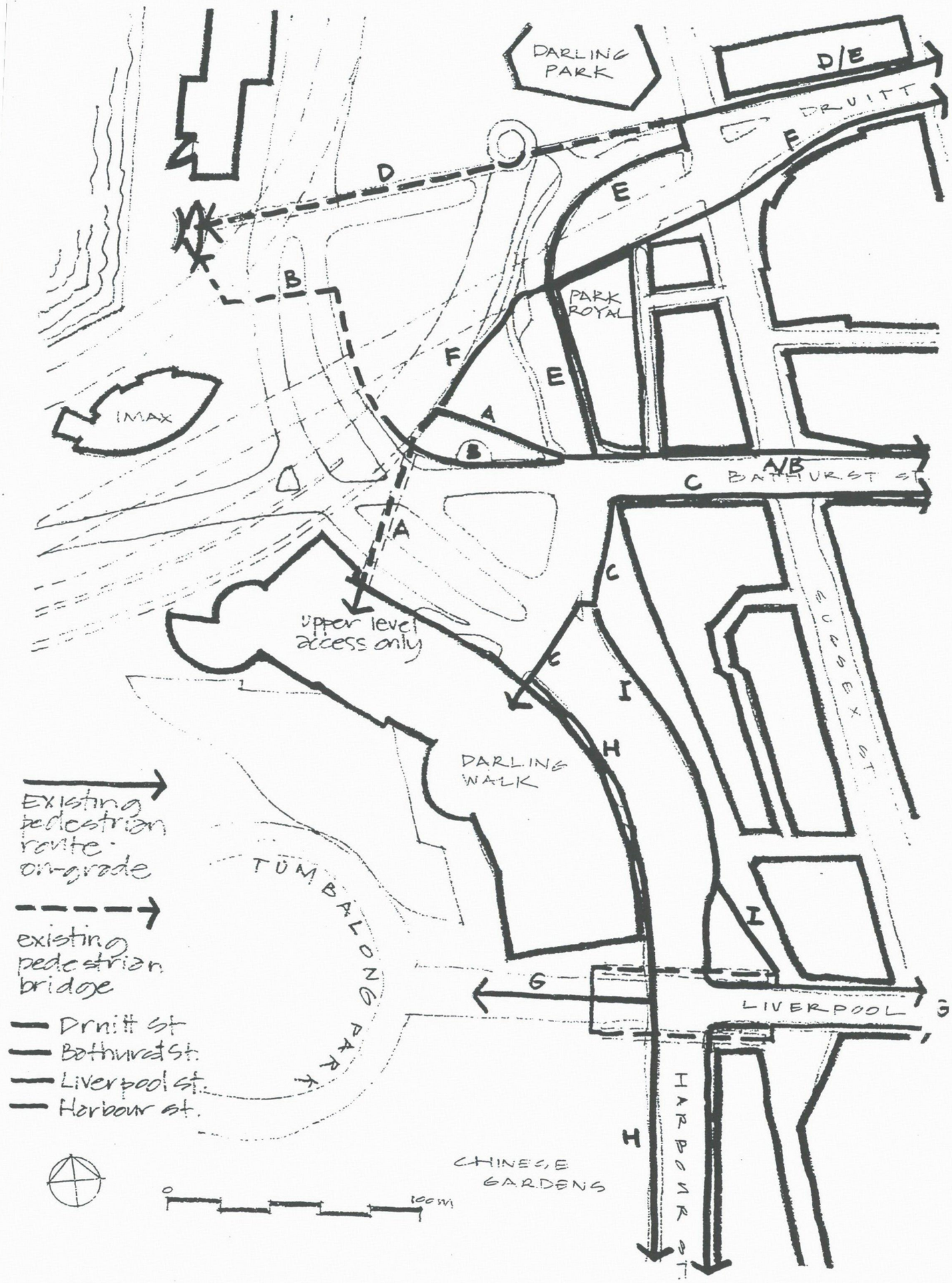
3.4 From Harbour Street

The routes currently available to pedestrians for access to Darling Harbour from Harbour Street are:

- Route H along the western side of Harbour Street provides direct access into Darling Harbour at Liverpool Street and at Darling Walk; and
- Route I along the eastern side of Harbour Street is an indirect route connecting with the pedestrian bridges over Harbour Street (route G) or with route C.

Issues/comments:

- There is ***no pedestrian access along the western side of Harbour Street*** to Cockle Bay.
- The lack of signalised crossings at the intersection of Liverpool/Bathurst Streets has the following implications:
    - pedestrians cannot walk safely along the eastern edge Harbour Street (route I) between Goulburn and Bathurst Street;
    - pedestrians walking along the eastern side of Harbour Street wishing to access Darling Harbour are forced to walk up an indirect route to Liverpool Street to the pedestrian bridges; and



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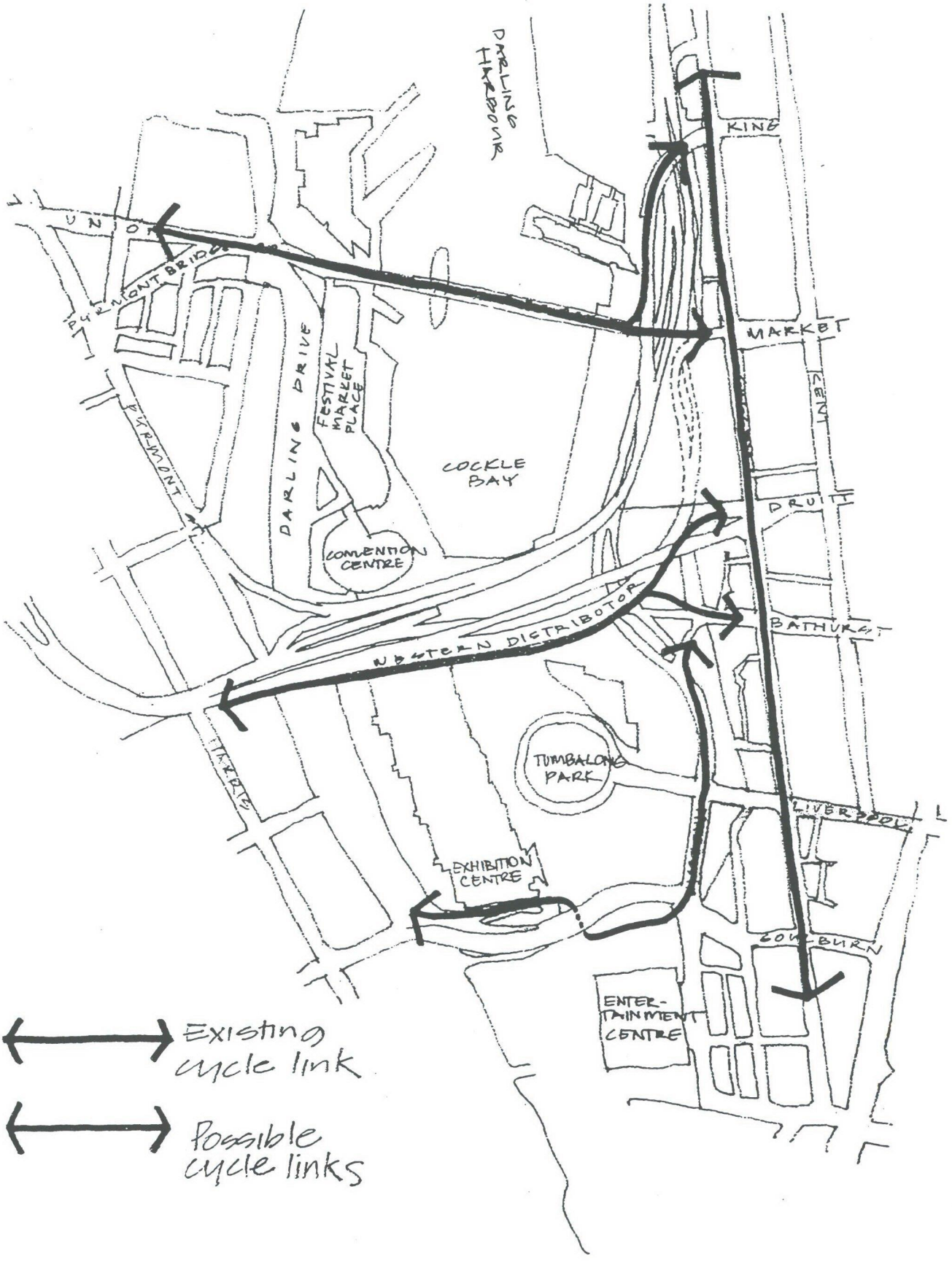
Figure 4 Existing pedestrian routes between CBD and Darling Harbour

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5 Cyclist circulation - opportunities

The review of the background documents found very little information regarding cycle links and more importantly found ***no overall strategy*** to achieve safe and effective cycle links between the CBD and Ultimo/Pyrmont. It is therefore difficult to determine the impact of the Cross City Tunnel on cycle access in the area. There are however a number of opportunities that have arisen during discussions between DUAP and Sydney City Council, these have been documented in Figure 5 and may form the basis for assessment of the impacts of the CCT EIS Proposal. They are as follows:

- ***opportunity*** for shared pedestrian cycleway on the southern side of the Market Street viaduct linking directly with Druitt and Bathurst Streets. The link may be provided as part of the CCT proposal which is proposing to reconstruct the existing walkway as part of the works. The extra work required would involve the construction of a wider walkway (total width 3-3.5m) than what is proposed in the EIS.
- DUAP has identified ***opportunity*** for a possible east west link between Ultimo and the CBD via Harbour Street and Little Pier Street. This would require the inclusion of cycle lanes on both sides of Harbour Street and Day Street as part of the CCT proposal.
- SSC has identified ***opportunity*** for possible cycleway along the western edge of the CBD via Sussex Street linking Haymarket and Walsh Bay.



CROSS CITY TUNNEL EIS REVIEW
Pedestrian and Cycle Access to Darling Harbour

Figure 5 Cycle links - opportunities

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6 Cross City Tunnel EIS Proposal

As documented in previous chapters access to Darling Harbour, particularly for pedestrians and cyclists, is currently constrained by the surrounding busy road network. Furthermore, there are concerns that the Cross City Tunnel EIS Proposal will exacerbate the problem particularly within the study area.

In general terms the EIS identifies a number of potential benefits to the CBD environment. On the other hand the EIS proposes a westbound exit ramp at Harbour Street that would off-load 1000 vehicles per hour or 40% of the total eastbound tunnel traffic into an area which currently provides a major pedestrian access point between the CBD and Darling Harbour. To add to this some of the traffic may well have been travelling in tunnel at high speed from as far away as Liverpool via the M5 and the Eastern Distributor. Traffic exiting at Bathurst Street will be poorly prepared to enter city traffic conditions increasingly dominated by pedestrians..

The CCT proposal, as described in the EIS, also involves an entry to the tunnel at Harbour Street. A further increase in the volume of traffic on Harbour Street is anticipated as a result, thus potentially increasing the current problem of it being a major pedestrian barrier. The proposal also includes a pedestrian bridge linking to Darling Harbour, relocated to the southern side of Bathurst Street from its present location on the northern side of Bathurst Street.

At first glance there does appear to be some benefits arising for pedestrians from the CCT EIS proposal as it provides at grade access from Bathurst Street to Darling Harbour via new pedestrian crossings at the intersection of Harbour and Bathurst Streets. However, there are a number of other factors to consider before the overall benefits of the CCT proposal can be assessed, such as intersection performance.

Figure 6 summarises the CCT proposal including existing pedestrian crossings to be retained, proposed new footpaths and crossings; existing routes to be removed; and desire lines that are severed as a result of the Cross City Tunnel.

The following discussion identifies the elements of the Cross City Tunnel proposal that have either *benefits* for or *impact negatively* on existing pedestrian access. The discussion assesses the performance of the CCT proposal against the *key desire lines* between Darling Harbour and the CBD established in chapter 3. The assessment is in terms of whether the CCT provides safe access along the desire line or whether it severs or cuts a desire line.

6.1 Druitt Street

- the westbound portal and ramp to the north of the Park Royal would ***sever*** the Druitt Street south desire line to Ultimo via the Western Distributor; and
- The westbound portal and ramp would reduce the amount of open space in front of the Park Royal and thereby ***sever*** the Druitt Street south pedestrian desire line and possible cycle link to Bathurst Street.

6.2 Bathurst Street

- the new five way intersection at the intersection of Bathurst and Harbour Streets would ***sever*** the Bathurst Street north desire line to Darling Harbour; and
- the proposal would provide for the Bathurst Street south desire line to Darling Harbour however this access would be significantly compromised by the effects of the LoS F for the intersection.

6.3 Liverpool Street

- the eastbound ramp and portal in the centre of Harbour Street would cause a significant increase in traffic flow thereby limiting the opportunity to narrow Harbour Street and develop it as a more pedestrian friendly environment; and
- proposal may further limit opportunity for signalised pedestrian crossings at the intersection with Liverpool Street.

6.4 Harbour Street west

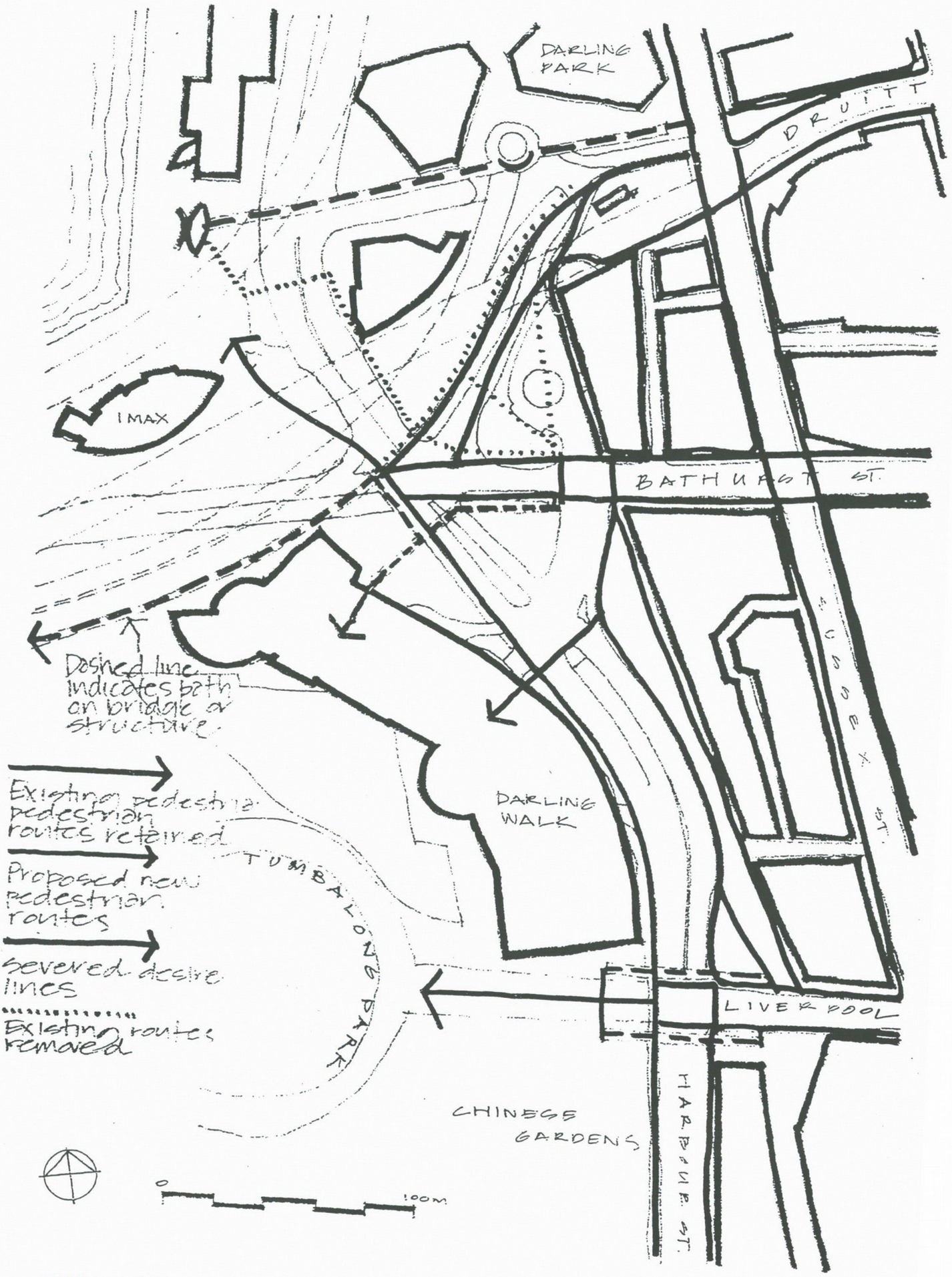
- relocation of Harbour Street slightly to the east would create opportunity for an enhanced pedestrian environment in front of Darling Walk; and
- the narrowing of Bathurst Street between Harbour and Day Streets would create opportunity for an enhanced and safer signalised pedestrian crossing to Darling Harbour thereby enabling a footpath along the Harbour Street west desire line.

6.5 Summary

The CCT EIS proposes a new footpath along the Harbour Street west desire line including a signalised pedestrian crossing at Bathurst Street and a new signalised crossing at Harbour Street on the Bathurst Street south desire line. However, both these proposed links would have considerable problems because of the traffic volumes and poor predicted performance of the intersection, and the resultant long waiting times for pedestrians wishing to cross.

The CCT EIS proposal would further degrade existing pedestrian and cycle access by cutting off the footpath along the Market Street viaduct connecting to Druitt and Bathurst Streets.

The overall result is a ***degradation of pedestrian conditions and connections*** (even when compared to the existing situation which is far from ideal) particularly in the vicinity of the Bathurst/Harbour Streets intersection and along Harbour Street generally.



CROSS CITY TUNNEL EIS REVIEW
Pedestrian and Cycle Access to Darling Harbour

Figure 6 Cross City Tunnel EIS proposal - proposed pedestrian access between Darling Harbour and CBD

Urban Design Advisory Service

7 Modified Cross City Tunnel options

Analysis and assessment in the preceding chapters of this report has found the main impacts of the CCT EIS Proposal in relation to pedestrian and cycle access ***would be a result of the westbound exit ramp connection to Harbour Street.*** This ramp is proposed to intersect at grade with the existing intersection of Bathurst and Harbour Streets creating a five-way intersection with the following results:

- very poor performance of the proposed intersection that will impact on pedestrian movements through extended waits at signalised crossings, if crossing is in fact possible at all;
- the westbound ramp would sever a number of key desire lines between the CBD and Darling Harbour including the Bathurst Street desire lines and the Druitt Street pedestrian and cycle desire line.

In order to balance the potential benefits of the CCT between pedestrian, cycle and vehicular access two options are presented below. In both options the modifications relate only to the westbound exit ramp component of the CCT EIS Proposal. The option of removing the Harbour Street eastbound portal was considered as part of this study however it was considered the benefits of the portal in terms of vehicle access to the CCT from Harbour Street outweighed the potential benefits to pedestrian access. The northbound portal on Bathurst Street would have benefits for public access by reducing traffic on Bathurst Street.

7.1 Modified option A

Figure 7 illustrates modified option A. The proposed modifications to traffic movements include:

- Delete westbound ramp exit to Harbour Street (southbound);
- Retain westbound ramp exit to Bathurst Street (eastbound) and relocate portal to the south (approx. 40m) near the corner of the Park Royal Hotel; and
- Relocate westbound exit portal and ramp to Harbour Street (northbound) to the north of Bathurst Street.

Overall the net impact of these modifications, in terms of traffic circulation, is the loss of ***one*** turn:

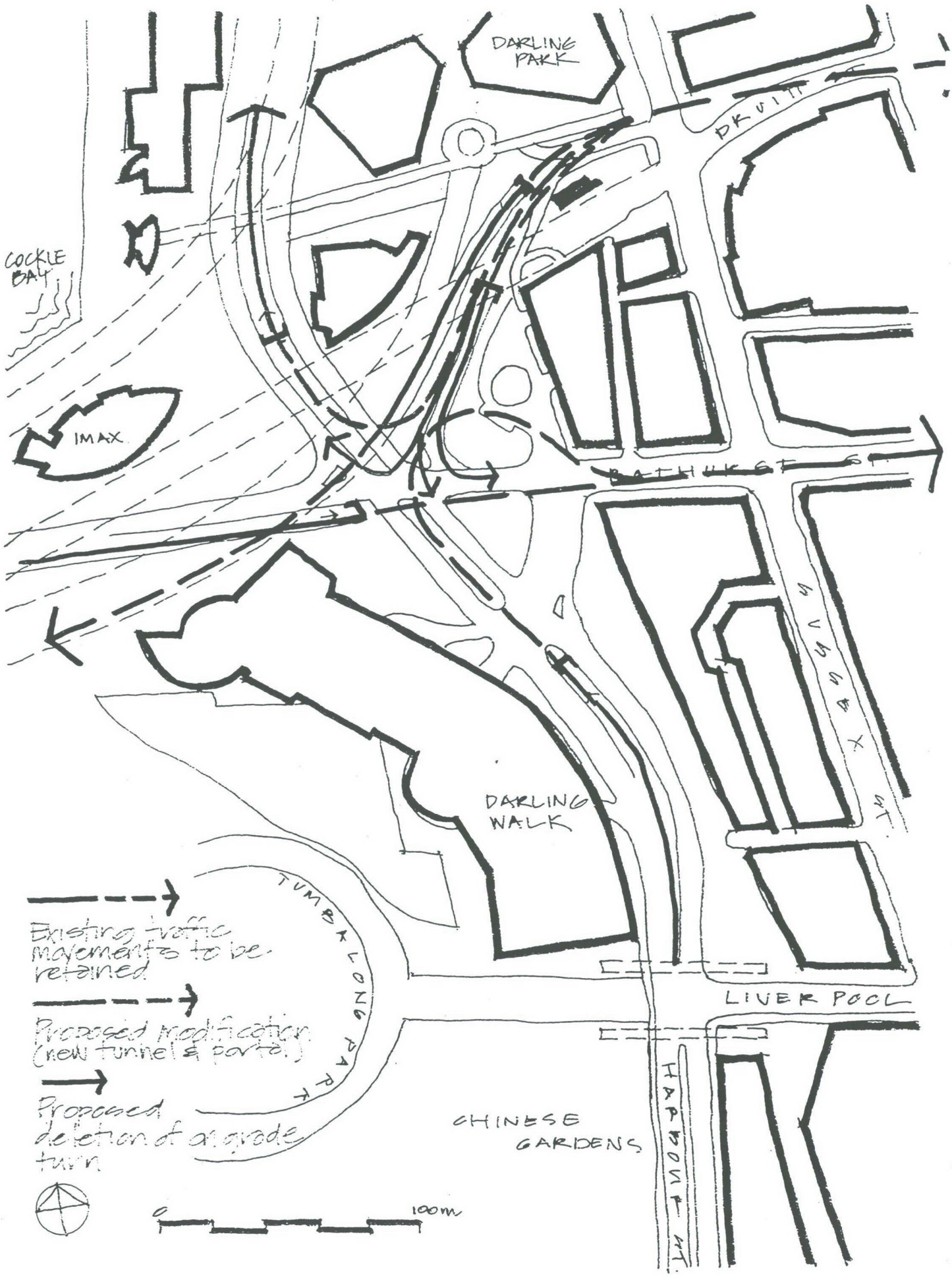
- the loss of an on-grade left turn into Harbour Street (southbound) from the westbound portal.

Figure 8 shows the range of pedestrian links that would result from modified option A. The Figure shows the option may exclude one minor link between Bathurst Street and the north east corner of the Park Royal Hotel.

In terms of the useability of the links option A provides ***less than optimal pedestrian connections*** (when compared with option B) between Darling Harbour and the CBD. However it should be noted that option A is a significant improvement when compared to the CCT EIS proposal and also the existing situation.

The main disadvantage of modified option A is the discontinuous nature of the Bathurst Street north desire line, which is interrupted by the westbound exit ramp onto Bathurst Street. This

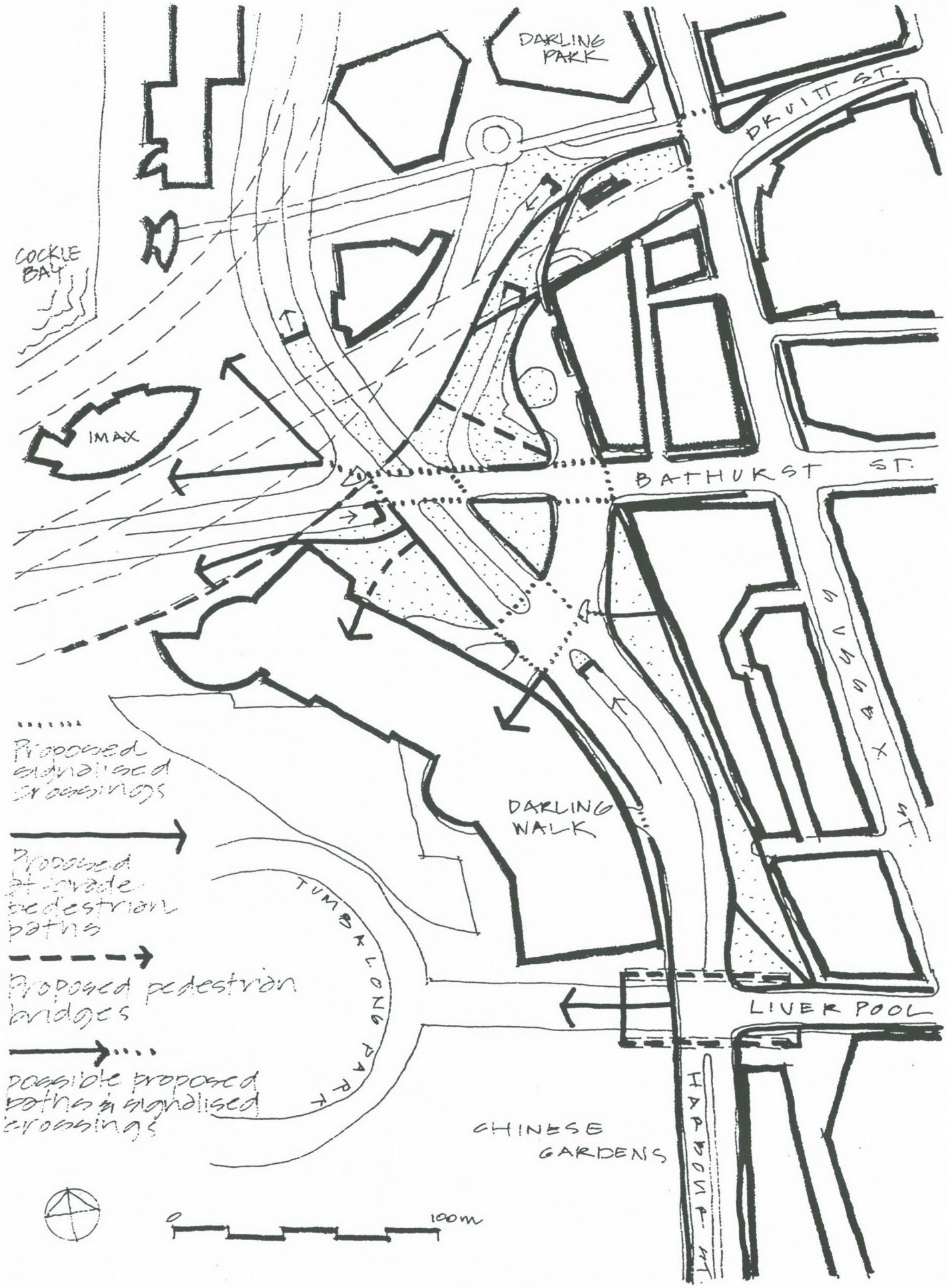
crossing will require signalisation and should be syncronised with the Bathurst/Harbour signals to minimise interruptions to pedestrian traffic. The safety of pedestrians at this point will be critical as traffic is exiting from high speed tunnel conditions with minimal transition onto CBD streets. These measures will also affect the performance of the intersections in terms of vehicle movements. All the above will require further testing to check feasibility.



CROSS CITY TUNNEL EIS REVIEW
Pedestrian and Cycle Access to Darling Harbour

Figure 7 Modified CCT option A - vehicular circulation

Urban Design Advisory Service



CROSS CITY TUNNEL EIS REVIEW
Pedestrian and Cycle Access to Darling Harbour

Figure 8 Modified CCT option A - pedestrian access

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7.2 Modified option B

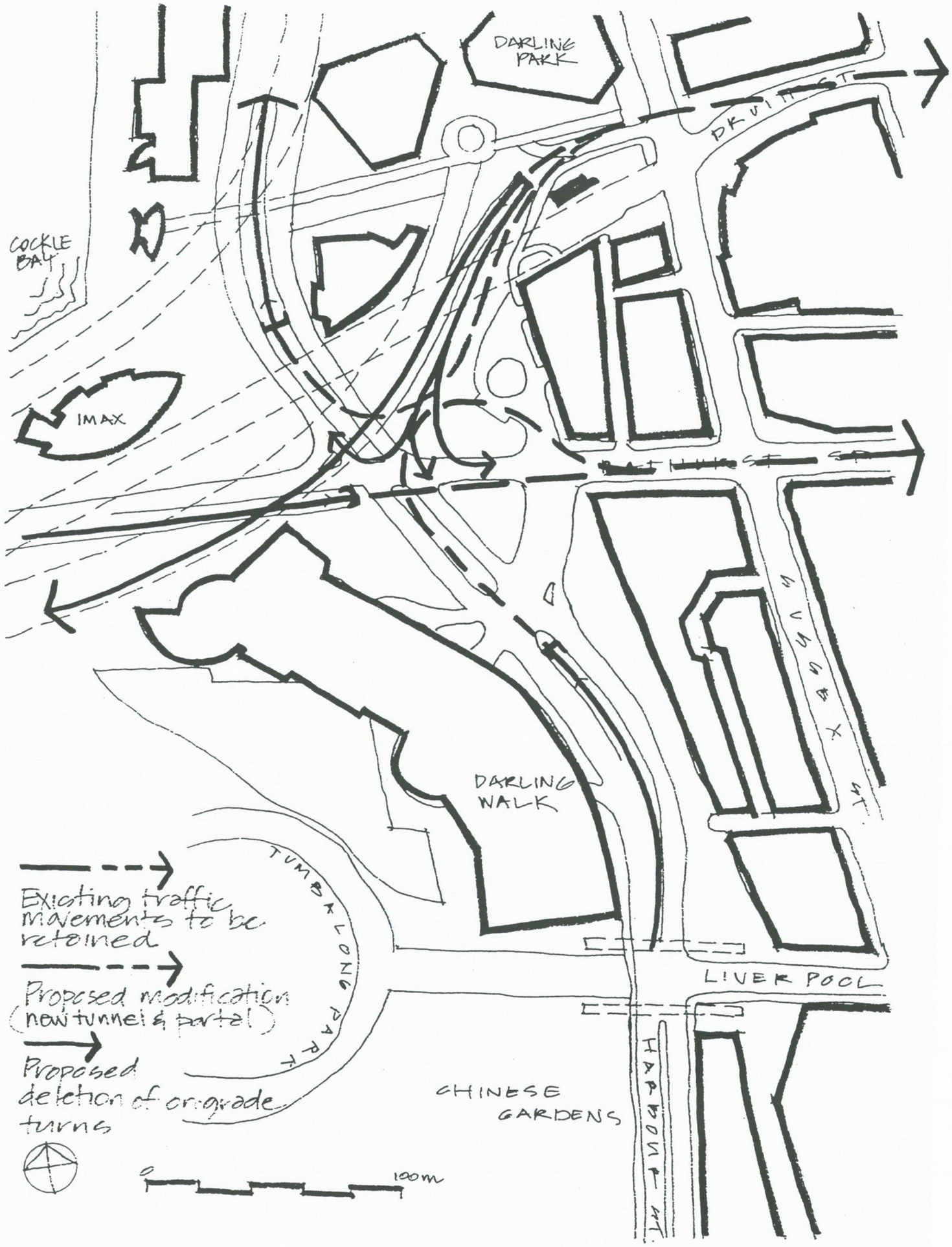
Figure 9 illustrates the modified option B. The proposed modifications to traffic movements include:

- Delete westbound ramp exit to Harbour Street (southbound);
- Delete westbound ramp exit to Bathurst Street; and
- Relocate westbound exit portal and ramp to Harbour Street (northbound) to the north of Bathurst Street.

Overall the net impact of these modifications, in terms of traffic circulation, is the loss of ***two*** turns namely:

- the loss of an on-grade left turn into Harbour Street (southbound) from the westbound portal; and
- the loss of an on-grade left turn into Bathurst Street (eastbound) from the westbound portal.

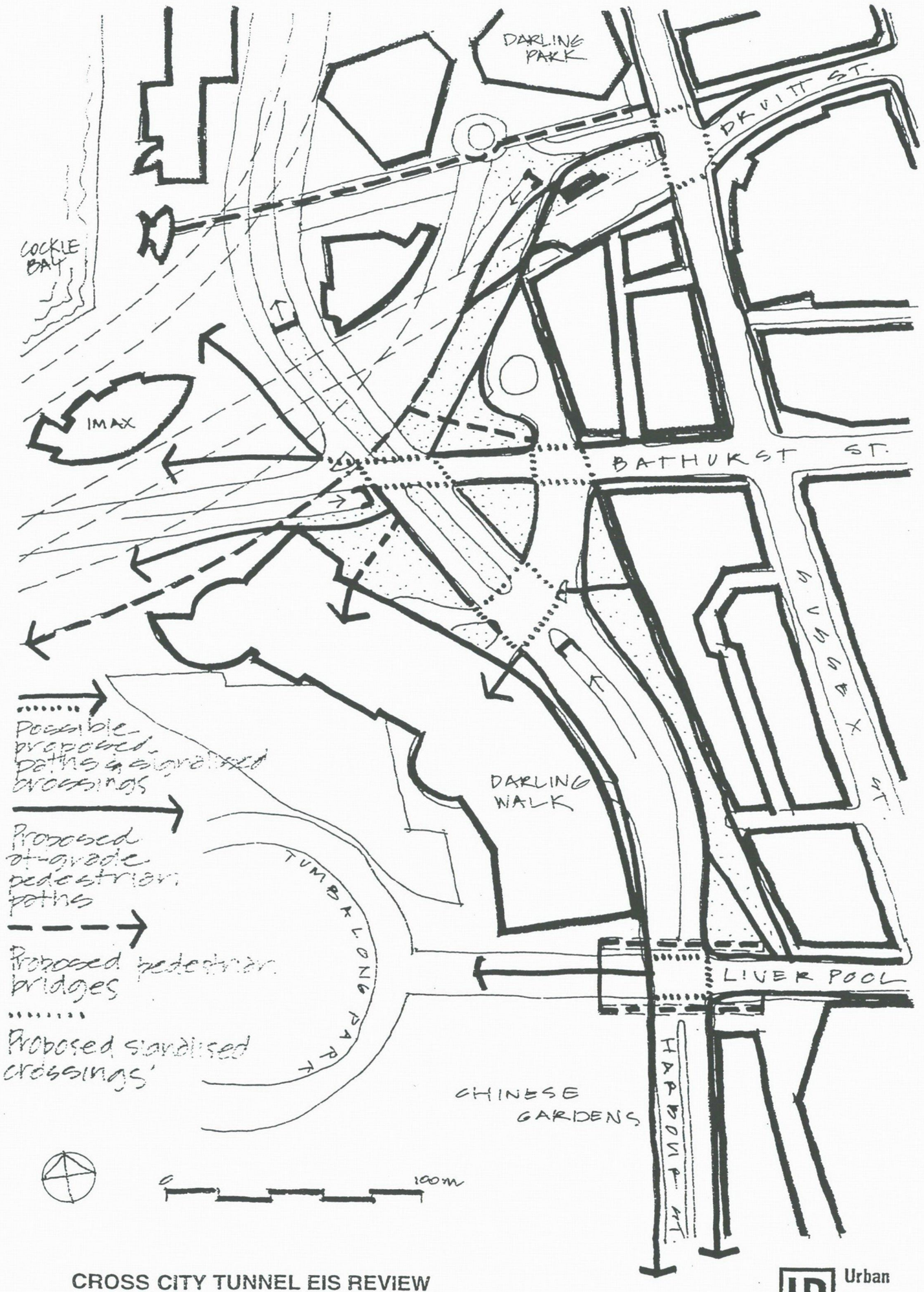
Option B provides ***optimal pedestrian access*** between Darling Harbour and the CBD. Figure 10 illustrates the benefits to the pedestrian access network. The main advantage of option B over option A is that all identified desire lines are accessible. Another advantage is the improvement in performance (LoS) of Bathurst/Harbour Streets intersection (to be confirmed) that would allow safer and more frequent at grade access to Darling Harbour from both the north and south sides of Bathurst Street. In addition the improved traffic conditions in option B would allow for a four way signalised crossing at Bathurst and Harbour intersection.



CROSS CITY TUNNEL EIS REVIEW
Pedestrian and Cycle Access to Darling Harbour

Figure 9 Modified CCT option B - vehicular circulation

Urban Design Advisory Service



CROSS CITY TUNNEL EIS REVIEW
Pedestrian and Cycle Access to Darling Harbour

Figure 10 Modified CCT option B - pedestrian access

Urban Design Advisory Service

APPENDIX

Review of relevant documents

In the course of the research the following documents were reviewed:

- Cross City Tunnel EIS
- Final Comments, Questions and Information requests - Cross City Tunnel EIS. DUAP response to EIS, 16th January 2001
- SREP 56
- South West City Links. Background, Key Findings and Next Steps. Urban Design Advisory Service, August 1999.
- GPO and AML and F Sites Master Plan
- Urban Design Objectives for Pedestrian Connections between Darling Harbour to City and Ultimo Pyrmont, Sydney City Council/City Projects (no date)
- Master plan Review Summary of Findings. Report by Darling Harbour Authority, Jan 1994
- Urban Development Plan for Ultimo-Pyrmont Precinct. DUAP, 1999 Update.
- City West Draft Regional Environmental Plan No.26 and Draft Urban Development Plan. DUAP, 1991.
- City West Draft Regional Environmental Plan No.26 (Amendment no.8) - 1999 Update.
- Strategic Transport Study for Ultimo Pyrmont. UPTTAPS Stage 2, April 1997.
- Cross City Tunnel Alternative Scheme. Sydney City Council, April 1999.

Summary of issues

The following are notes pertaining to issues effecting pedestrian and cycle access in the study area. Only studies that specifically address the study area are summarised here, all other documents reviewed made no relevant references to the study area or its context.

Cross City Tunnel EIS

The following issues arise from the EIS:

- The EIS proposes a new walkway on the Market Street viaduct. It is not clear from the proposal how far the walkway extends. Also there is no indication of width and whether it will cater for both cycle and pedestrian use.
- The EIS shows that Bathurst and Harbour Street intersection has a LoS F in all periods down from LoS B (Sydney CBD Intersection Performance 2016). This is a dramatic fall in performance that will significantly affect the pedestrian accessibility of the intersection.

- The EIS shows significant increases on Harbour Street south of Bathurst Street (2016 CCT Forecast Daily Traffic Flow Changes). More detail has been provided by the RTA (refer attached Table).

Final Comments, Questions and Information requests - Cross City Tunnel EIS. DUAP response to EIS, 16th January 2001

This report raises the following issues relevant to this study:

- The west bound tunnel exit onto Harbour Street has a second order impact on further isolating Darling Harbour from the CBD and therefore the strategic and economic implications of removing the exit should be explored.
- Pedestrian access to Darling Harbour is recognised as poor. The CCT should assist with the long term goal of improving access to the foreshore (as per SREP 56) and not just maintain existing levels or decrease accessibility.

South West City Links. Background, Key Findings and Next Steps. Urban Design Advisory Service, August 1999.

The aim of the UDAS report was to lay the groundwork for a coordinated pedestrian strategy, for an area which comprises a number of council and State government development authority boundaries. The following opportunities and constraints were identified:

- Defines the difference between existing pedestrian movements and desire lines the former being where people can move given existing barriers and access ways and the latter being where people would like to move. Bathurst, Druitt and Liverpool Streets are identified as key desire lines connecting the CBD with Pyrmont/Ultimo and Glebe.
- The Western Distributor, Darling Walk and Harbour Street are major barriers (both physical and perceived) to pedestrian movement.
- Harbour Street is an area of perceived vulnerability (personal safety) the area is neglected and offers limited amenity and surveillance opportunities for pedestrians.
- One of the conclusions is that Darling Harbour is poorly integrated into its city context and offers a poor pedestrian environment in the area around Harbour Street/Western Distributor. In this area there are limited surveillance opportunities, perceived and actual vulnerability and poor amenity resulting from the freeway viaducts, and limited active edges.

SREP 56

A guiding principle of SREP 56 is to increase public access to and use of land on the foreshore (of Sydney Harbour).

Urban Design Objectives for Pedestrian Connections between Darling Harbour to City and Ultimo Pyrmont, Sydney City Council/City Projects (no date)

This document makes the following recommendations:

- remove the existing complicated footbridge linking lower Bathurst Street to Darling Harbour/Sega World;

- develop a unified landscape boulevard treatment of Harbour Street whilst providing a generous clear pedestrian path adjacent to Harbour Street;
- widen footpath along Druitt Street and Bathurst Street; and
- in the long-medium term provide direct on grade connection from Druitt and Bathurst Streets through to Darling Harbour.

Urban Development Plan for Ultimo-Pyrmont Precinct. DUAP, 1999 Update.

- Identifies Western Distributor as key commuter cyclist link between Ultimo/Pyrmont and the CBD. However the actual route is not determined nor is where the route connects in the CBD.

2.2 Meetings and discussions

Department of Urban Affairs and Planning

Discussions with Sheridan Blunt and Eva Cermak from DUAP Sydney Region Central have raised the following issues:

- The EIS does not provide any studies into pedestrian and cycle desire lines;
- The UDAS document SW City Links provides an excellent summary of the pedestrian issues in the study area however it does not address the cycling issues;
- Harbour Street requires improvements to pedestrian safety and amenity including traffic calming measures;
- Provision of a cycleway along Harbour Street connecting to Little Pier Street and on to Ultimo;
- Provision of a cycle way on the Western Distributor connecting to Ultimo/Pyrmont.

Sydney City Council (SSC)

In a meeting with SSC represented by Allen Hughes (Acting Director City Projects) and traffic planners the following comments were made:

- SSC support the maximisation of vehicular movements in tunnel ie minimisation of new on-grade turns;
- SSC support the removal of the slip lane onto Bathurst from the westbound portal. They require that any exit ramps from the tunnel unload onto arterial or sub-arterial roads (Western Distributor and Harbour Street) rather than local city streets such as Bathurst Street;
- SSC support the extension of the westbound tunnel to exit in the centre of Harbour Street north of Bathurst Street and thereby negate the need for the proposed on-grade right turn into Harbour Street;
- Maximisation of on grade pedestrian access between CBD and Darling Harbour;
- SSC indicated that after very preliminary investigations Sussex Street may form part of a cycle route around the CBD; and
- SSC support a cycleway link on Western Distributor Viaduct.

CCT Project – Hourly Traffic Flow Forecasts

Period	Option	Period	Harbour Street between Liverpool and Goulburn		Bathurst between Day and Sussex Streets		Day Street between Bathurst and Harbour Sts	
			NB	SB	EB	WB	NB	SB
2006	No CCT	AM Peak	1196	1035	2999	0	1210	0
		Bus Period	937	431	1656	0	739	0
		PM Peak	1478	953	1538	0	613	0
	With CCT	AM Peak	1067	1535	1756	0	182	0
		Bus Period	804	740	1024	0	94	0
		PM Peak	1494	1223	632	0	27	0
2016	No CCT	AM Peak	1337	1070	3299	0	1173	0
		Bus Period	896	239	1814	0	637	0
		PM Peak	1588	490	1923	0	333	0
	With CCT	AM Peak	1158	1700	1975	0	222	0
		Bus Period	926	930	1142	0	102	0
		PM Peak	1899	1198	995	0	24	0

Level of Service Harbour and Day Streets Intersection – this is level of service A with and without CCT

Level of Service Harbour and Bathurst Streets Intersection – design still under review however indications are that with some intersection modifications and phasing changes LoS can be maintained to that presently experienced ie B/C – this is to be detailed in reps report.

APPENDIX K

Addendum Report – Modified Pedestrian Access in Darling Harbour Precinct

Department of Urban Affairs and Planning
September 2001

Cross City Tunnel EIS Supplementary Environmental Impact Assessment – Modified Pedestrian Access in Darling Harbour Precinct

Roads & Traffic Authority of NSW

July 2001 Rev B
58L120B PR_5769

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B Agency Submissions
C Pedestrian Surveys
D Detailed Plans of Preferred Option

1. Introduction

1.1 Background

The Environmental Impact Statement (EIS) for the Cross City Tunnel proposal was publicly exhibited in accordance with the *Environmental Planning and Assessment Act 1979* from 2 August to 6 October 2000. The proponent, the Roads and Traffic Authority (RTA) has prepared a Representations Report as required under Clause 91 of the *Environmental Planning and Assessment Regulation*. As a result of representations made during and following the exhibition period, the RTA seeks to modify the proposed access arrangements for pedestrians at the western end of the project (that is, in the vicinity of Darling Harbour).

Pedestrian access facilities which are proposed as part of the Cross City Tunnel project are described in *Technical Paper Nos. 5 and 6* and *Chapters 7* and *10* of the Main Volume of the EIS.

The proposal would require the modification of existing pedestrian access facilities in the Darling Harbour area, to allow for construction and operation of the tunnel. The proposal includes alterations and additions to the existing pedestrian access network in this area, which comprises at-grade and grade-separated footways with the primary role of conveying pedestrians between Darling Harbour and the Sydney CBD, and vice versa.

The RTA has reviewed the proposed arrangements for pedestrians and cyclists included in the EIS and considers that modifications are required to better align the facilities with key pedestrian needs and urban design objectives for the Darling Harbour precinct and surrounds.

The principal feature of the modified access arrangements involves the construction of an elevated pedestrian footway from Harris Street, Ultimo, to the Darling Harbour central pedestrian spine, with stair access to Pyrmont Street and Darling Drive. The EIS had proposed a footway from Ultimo at a higher level, adjacent to the Market Street viaduct, and extending to the eastern side of Harbour Street.

The proposal would be erected on or over land owned by the Sydney Harbour Foreshore Authority, and the Council of the City of Sydney.

1.2 Proposed Modification of the Activity

The proposed modification of the activity as described in the EIS, seeks to include the use of land at Darling Harbour to erect pedestrian access facilities in conjunction with the Cross City Tunnel project.

Details of the modification including the effect on pedestrian and cycle movements, visual amenity, construction hours, access arrangements and other issues such as use of resources are included in *Section 3* of this report. Detailed plans of the pedestrian facilities, the subject of this modification, are shown in *Attachment D*.

The modification would have the effect of modifying the pedestrian access facilities to and from Darling Harbour, from those envisaged and proposed in the EIS. The principal change would be that where the current (and EIS proposed) facilities provide a means for pedestrians to make a direct connection between Harris Street, and Bathurst Street, via an elevated footway, the modified proposal would require pedestrians to make the connection:

- partly via a new elevated footway (although at a lower level) to and from Harris Street;
- partly at grade through the Darling Harbour precinct bisecting the central pedestrian spine; and
- partly via a new elevated footway to and from Bathurst Street located between the Western Distributor viaducts and the Darling Walk building.

The modification results in the above Ultimo to Sydney CBD connection being less direct. However, relatively few pedestrians use this direct link despite its close proximity to the Sydney CBD. The modification has been proposed as a result of gaining a better understanding of pedestrian movements in the area.

The benefits of the proposal, compared to the pedestrian connections proposed in the EIS, include:

- less length of overhead pedestrian connections, with a corresponding lesser impact upon visual amenity in the Darling Harbour zone;
- a new pedestrian connection from the Ultimo/Pyrmont neighbourhood into the Darling Harbour central pedestrian spine, with provision for access by persons with a disability or persons who are less mobile;
- new pedestrian connections from Darling Drive and Pyrmont Street to the Darling Harbour central pedestrian spine;
- a new and more direct pedestrian connection between Bathurst Street (near the intersection of Day Street) and the Darling Harbour central pedestrian spine; and
- a pedestrian access network at the western end of the Cross City Tunnel project which provides the best balanced access solution, providing improved connections to where pedestrians want to go.

1.3 Purpose of this Report

This report provides an assessment of the environmental impacts resulting from the construction of modified pedestrian access facilities at the western end of the Cross City Tunnel project. It describes this activity (which is a modification to the proposed activity for the Cross City Tunnel as described in the EIS), assesses the impacts and proposes management measures to mitigate any adverse impacts.

This report should be read in conjunction with the assessment of local impacts in the Darling Harbour Precinct, for the Cross City Tunnel project as a whole. This assessment is contained in Chapter 10 of the main volume of the EIS.

2. Site Details

2.1 Location of the Site and Surrounds

The site that is the subject of the proposed modification is located at the western end of the proposed Cross City Tunnel, and affects the movement of pedestrians and cyclists between the Sydney CBD, Darling Harbour and Ultimo, in the general vicinity of the Western Distributor viaducts.

The location of the site is shown in *Figure 2.1*.

The site for proposed construction activities is adjacent to or within the area used by the Western Distributor viaducts and within the road reserves of Fig Street, Pyrmont Street, Darling Drive, Harbour Street, Bathurst Street and Day Street.

2.2 Site Description and Ownership

Existing pedestrian access facilities surrounding the Western Distributor viaducts are shown in *Figure 2.2*.

The proposed pedestrian access facilities would traverse and/or be erected in the air space above Fig Street (east of Harris Street), Pyrmont Street, land used for light rail and monorail facilities, Darling Drive, Darling Harbour, and above land within the road reserves at Harbour Street, Bathurst Street and Day Street. At grade facilities would be located wholly within Darling Harbour. The land is owned either by the City of Sydney or the State Government (under the control of the Sydney Harbour Foreshore Authority).

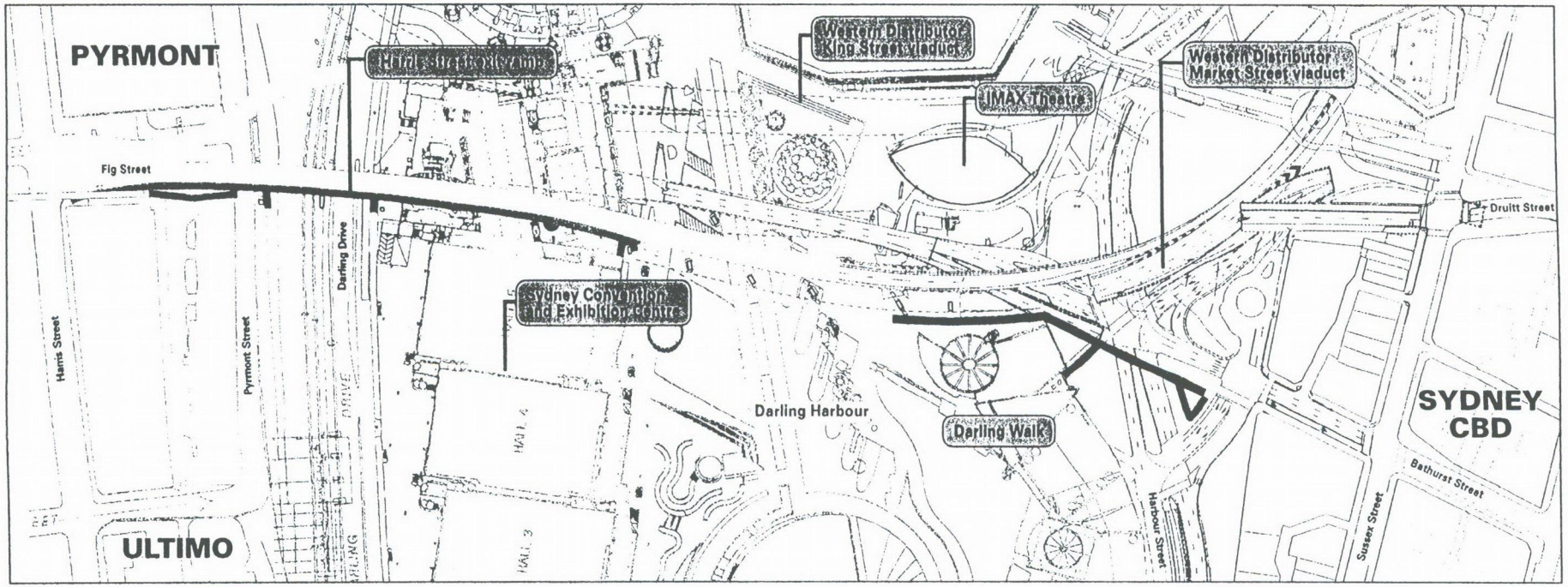


Figure 2.1 **Site Location**

Proposed elevated pedestrian structures

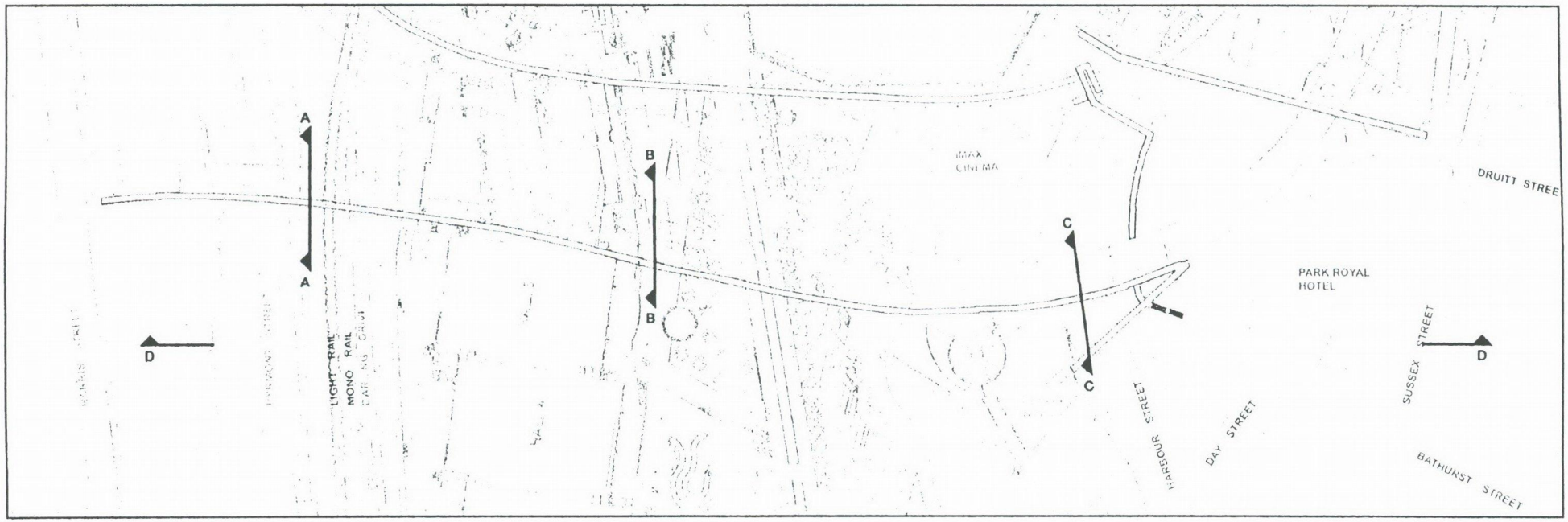


Figure 2.2 **Existing Pedestrian Access**

Elevated footway

Existing footway

Existing stair

3. Description of the Modification

3.1 Background

3.1.1 EIS Proposal

The Cross City Tunnel proposal would involve changes to the configuration of surface streets and consequent vehicular, pedestrian and cycle access and management along its length. This is particularly so on surface streets near the tunnel portals, where tunnel traffic intersects, diverges from or merges with existing roads.

The Cross City Tunnel EIS proposed all existing pedestrian facilities and crossings to Darling Harbour in the vicinity of the project to be replaced (page 7-39 of Volume 1 of the EIS). Specifically, the following access arrangements for pedestrians and cyclists were proposed to serve the Darling Harbour area, as a result of tunnel construction activities:

- removal of two existing grade-separated pedestrian bridges in the vicinity of the Bathurst Street/Harbour Street intersection (and maintenance of at least one pedestrian bridge across Harbour Street during the construction period);
- construction of new, grade-separated pedestrian bridges comprising:
  - an elevated connection from the southern side of Bathurst Street, west of Day Street, direct to the Darling Walk building, on the western side of Harbour Street;
  - an elevated connection from the footbridge described above to the Market Street viaduct footway; and
  - connection of the Darling Park/Blackwattle Place pedestrian bridge to the northern Western Distributor footway (on the King Street viaduct).
- removal of the existing Market Street viaduct footway, to enable an additional traffic lane to be provided, and construction of a new footway adjacent to the traffic lane, thus maintaining elevated pedestrian access between Bathurst Street and Harris Street;
- removal of the at grade pedestrian footpath providing direct connection from the Sussex Street/Druitt Street intersection to the Market Street viaduct footway;
- provision of an at-grade pedestrian footpath on the western side of the realigned Harbour Street, between Liverpool Street and Cockle Bay (near the IMAX Theatre); and
- provision of at-grade pedestrian crossings on the southern and western sides of the proposed intersection of Harbour Street/Bathurst Street/Cross City Tunnel westbound exit ramp. Signal phasing would be adjusted to allow sufficient green time for pedestrians at these crossings while allowing for traffic flows.

The Cross City Tunnel EIS proposed that cyclists would be prohibited from using the Cross City Tunnel, because of the need for traffic to merge within the tunnel. In the western section of the Sydney CBD, cyclists would be required to share bus lanes or otherwise use dedicated cycle lanes. No specific cycle facilities were proposed in conjunction with the Cross City Tunnel works in the vicinity of Darling Harbour, and are also not proposed in this modification. Further discussion on the impacts on cycle access are discussed in *Section 6.1.3*.

3.1.2 Need for the Modification

The proposed modification of pedestrian facilities has been initiated as a result of the need to widen the carriageway for westbound traffic on the Market Street viaduct and as a result of representations received from agencies regarding improved pedestrian access to and from Darling Harbour. The Cross City Tunnel westbound exit would merge with the westbound traffic on the Western Distributor (Market Street viaduct) in the vicinity of Harbour Street. Detailed analysis of the viaduct carriageway has concluded that it cannot sustain anticipated traffic flows in its current configuration without causing congestion and compromising road safety and additional traffic lanes need to be accommodated on the viaduct.

This would necessitate the removal of the existing pedestrian footway on the southern side of the Market Street viaduct which currently provides an elevated, grade-separated connection between Harris Street, Ultimo and the intersection of Bathurst and Harbour Streets, on the western side of the Sydney CBD. The viaduct footway accommodates pedestrian movements between the southern Sydney CBD and the Ultimo/Pyrmont area, near the intersection of Harris Street and Fig Street.

Additionally, both the Department of Urban Affairs and Planning and the Sydney Harbour Foreshore Authority have requested the Roads and Traffic Authority consider amendments to the EIS pedestrian access scheme to create more at-grade links to and from Darling Harbour.

3.1.3 Design Options

Several options to improve pedestrian access to, from and through Darling Harbour were considered as part of determining an optimum pedestrian access layout. These included:

- Option 1: full replacement of upper level footway on Market Street viaduct between Harbour Street and Harris Street, supported on cantilevered steel 'outriggers'. This option is the EIS proposal.
- Option 2: as for option 1, except the footway would hang beneath the Market Street viaduct in an 'underslung' arrangement, would provide a direct access to the Darling Walk building, and would provide direct vertical links to the Darling Harbour pedestrian forecourts.
- Option 3: provides a direct pedestrian ramp on the level of Harris Street, adjacent to the Harris Street exit viaduct, to a point just east of the Sydney Convention and Exhibition Centre, where the link connects to the Darling Harbour central pedestrian spine by stairs and a lift. Access between Darling Harbour and the

CBD would utilise existing connections via Blackwattle Place pedestrian footbridge, Darling Walk pedestrian footbridge, Liverpool Street pedestrian footbridges or, ultimately, through a future at-grade link direct to Bathurst Street through the existing car parking area on the northern side of the Darling Walk building.

- Option 4: with regard to access between Darling Harbour and Harris Street, as for Option 3. Access between the Darling Harbour central pedestrian spine and the CBD would be provided in the form of a new pedestrian ramp and bridge starting immediately to the north of the Darling Walk building and then adjacent to the Market Street and Druitt Street viaducts. This arrangement of footways and stairs would provide direct vertical links between Darling Harbour and:
  - the intersection of Druitt and Sussex Streets (southern side);
  - the intersection of Bathurst and Day Streets (northern side);
  - the eastern façade of the Darling Walk building.
- Option 5: as for Option 3, in terms of access between Darling Harbour and Harris Street, and as for Option 4, in terms of an elevated pedestrian footway north of the Darling Walk building, except that the footway would follow the southern side of the Bathurst Street alignment (rather than adjacent to the viaducts). This option provides for a pedestrian bridge over Harbour Street generally in the location proposed in the EIS and avoids new structures being situated in the Bathurst Street view corridor.

Attachment A contains an evaluation of the various options according to design objectives, including plans and images of the respective options.

Option 5 is the preferred option and is more fully described in *Section 3.2*.

3.2 Modification of Pedestrian Access Facilities in the Darling Harbour Area

The proposed pedestrian access arrangements would incorporate all of the elements described in *Section 3.1.1*, incorporating the following modifications:

- the Market Street viaduct footway, providing direct elevated pedestrian access between Harris Street, Ultimo and Bathurst Street, would not be replaced in its current form. Instead, two pedestrian footways would be constructed:
  - one (the western elevated footway) on a lower level adjacent to, and to the south of, the Harris Street exit viaduct, which would connect Harris Street to the Darling Harbour central pedestrian spine, via a lift and stairs at the front of the Sydney Convention and Exhibition Centre. The footway would also provide for a separate ramp connection to the existing Harris Street pedestrian bridge, new 2.5 metre wide passageway to the existing pedestrian subway, and a new 1.1 metre wide stairway to connect to the Harris Street pedestrian bridge;

  - the second (the eastern elevated footway), to the north of the Darling Walk building and over Harbour Street, which would connect the central pedestrian spine and Darling Walk to the intersection of Bathurst and Day Streets, via ramps and stairs;
- separate (1.5 metre wide) stairs are to be provided to connect both Darling Drive and Pyrmont Street to the western pedestrian footway, thus allowing pedestrian access between these streets and Harris Street or the Darling Harbour central pedestrian spine;
- removal of some landscaping and provision of new paving at ground level within Darling Harbour, to the east of the proposed lift tower, to allow pedestrians to conveniently access both the proposed elevated footways; and
- some minor reconfiguration of the at-grade car park north of Darling Walk, but with no net loss in the number of parking spaces.

A concept plan for the preferred option is shown in *Figure 3.1*. Detailed plans of the preferred option are shown in *Attachment D*.

3.3 Construction Hours

Construction working hours for the Cross City Tunnel would remain the same as described in the EIS. The normal work hours would be between 7.00 am and 6.00 pm Monday to Friday; 7.00 am and 1.00 pm Saturday (8.00 am on Saturday if audible at residences); and no work on Sundays and public holidays. These hours are generally considered as "daytime" working hours and are in line with Environment Protection Authority requirements and working hours of other construction projects around the Sydney CBD area.

Work outside these normal hours would be required in connection with activity carried out on the Harris Street exit ramp and the footbridge construction over Harbour Street. Such work would require a permit to be approved by the Environment Protection Authority. Local residents would be informed of the timing and duration of any work outside normal hours prior to the work commencing.

3.4 Construction Access Arrangements

Figure 3.2 shows the proposed extent of land required by the RTA in the Darling Harbour area as a construction site for the Cross City Tunnel project. In terms of the construction of the proposal described in this report, the main areas affected would include:

- footpath and road areas underneath and adjacent to the proposed footway, where the footway traverses Pyrmont Street and Darling Drive;
- pedestrian and vehicular movement areas within the Darling Harbour development, on land owned by the Sydney Harbour Foreshore Authority;

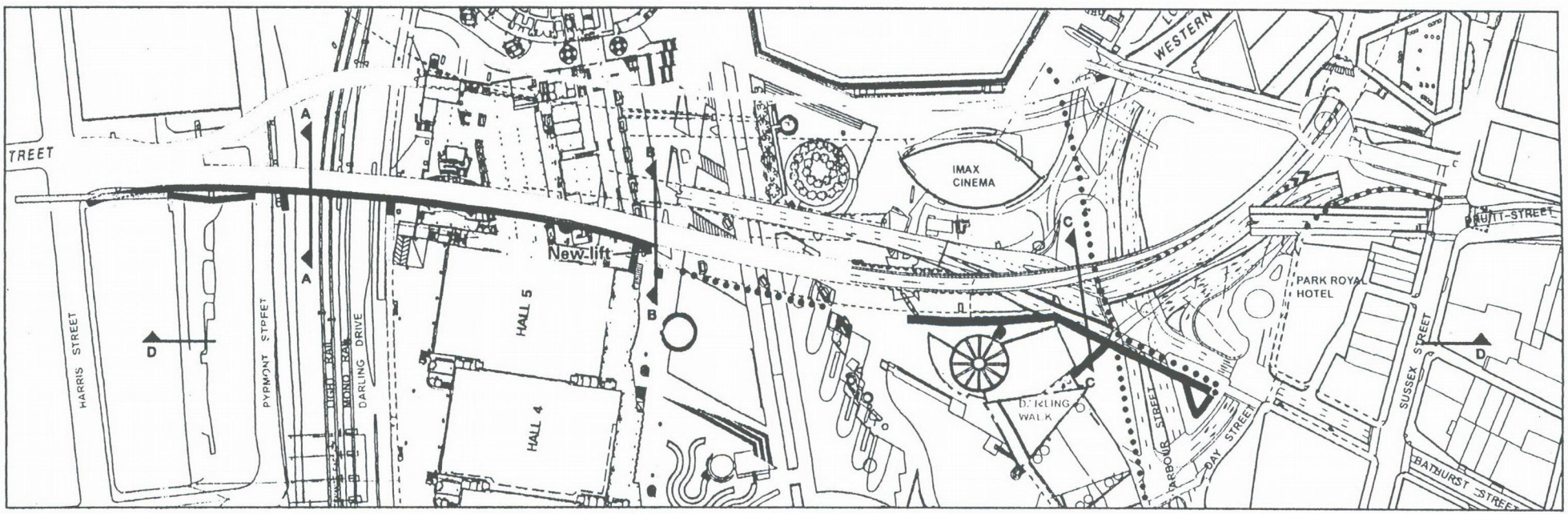


Figure 3.1 **Concept Plan of Preferred Option**

Existing footway

Existing surface level footway

New elevated footway

New surface level footway

New stair

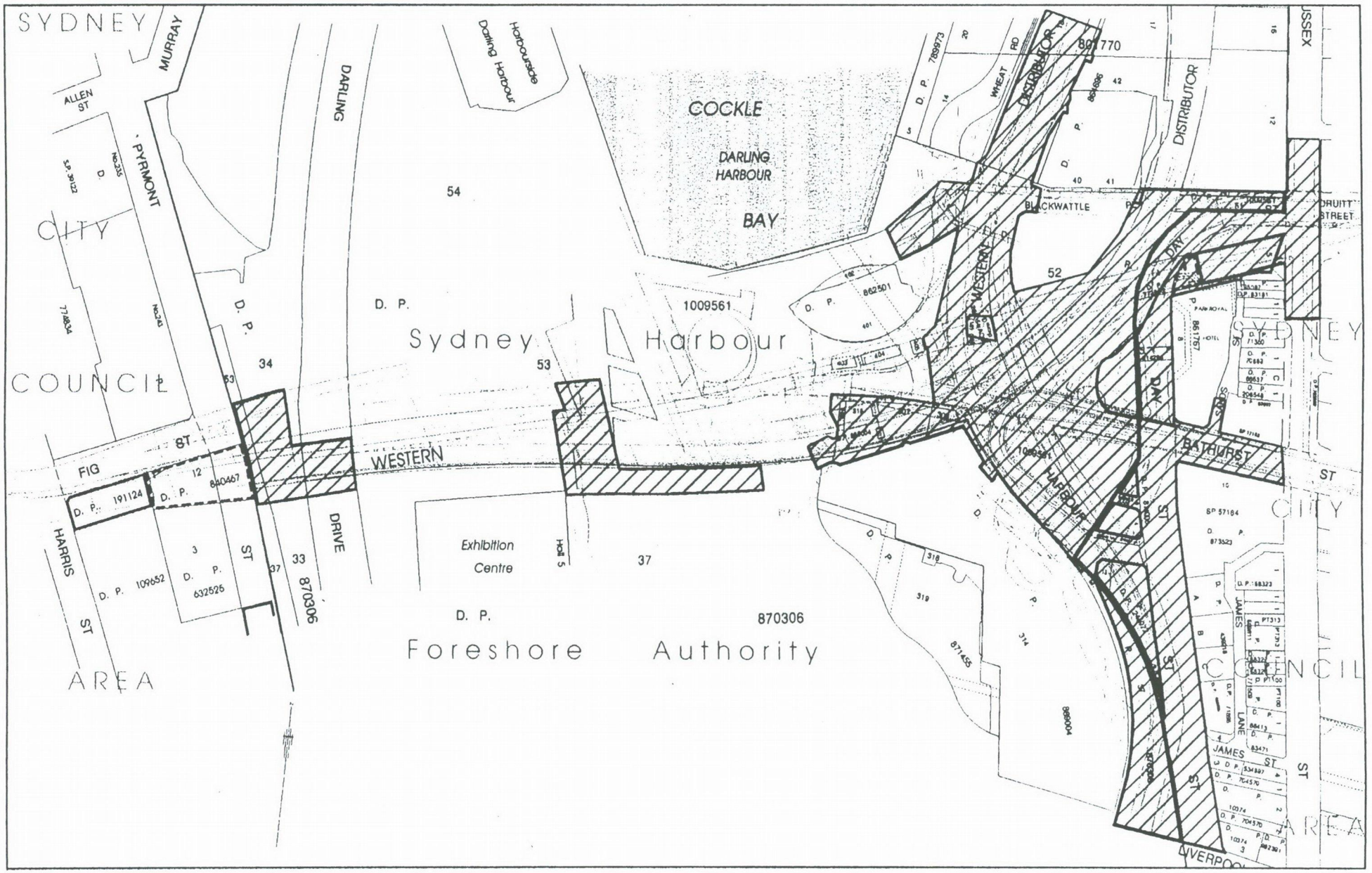


Figure 3.2 **Construction Sites**

Construction sites

- the car parking and services delivery area immediately north of the Darling Walk building, also on land owned by the Sydney Harbour Foreshores Authority; and
- road reservations in the vicinity of the Harbour Street/Bathurst Street intersections.

Partial road closures would also be required on the Harris Street exit ramp and on Harbour Street, to facilitate construction of the proposal described in this report. The car parking area immediately north of the Darling Walk building would not be available for use during the period of construction for the proposed footway above. The Contractor would be required to ensure that adequate facilities for servicing the Darling Walk building would be maintained during construction.

The main construction activities to occur would include:

- demolition activities and minor excavation works associated with connections to existing pedestrian facilities inside and outside of Darling Harbour;
- site preparation works including:
  - installing temporary security fencing and lighting for the construction areas;
  - providing temporary barriers on the Western Distributor viaducts for construction work;
  - temporary paving of parking and storage areas within the construction sites;
  - providing services to the site;
- construction of the footways, ramps, stairs and lift tower;
- fitout of the footways, ramps, stairs and lift facilities, including handrails and lighting;
- near completion of the structures, the scaffolding, barriers and/or hoardings would be dismantled and loaded out; and
- construction and restoration of landscaping footpaths, signposting, kerbs and gutters and car parking areas.

4. Statutory Planning Context

State Environmental Planning Policy No. 63 aims to facilitate four major transport projects in the Sydney region, including the Cross City Tunnel. It permits development to be undertaken without the need to obtain development consent and aims to co-ordinate the orderly and economic development of land by providing for development assessment under Part 5 of the *Environmental Planning and Assessment Act 1979*.

The proposed use of the site for the provision of pedestrian access facilities would fall under the provisions of this State Environmental Planning Policy as part of the Cross City Tunnel proposal. As such, development consent under Part 4 of the Act is not required, and environmental assessment is required to be carried out under Part 5. This report constitutes the environmental assessment of the proposal.

5. Consultation

The preferred option for the provision of pedestrian access facilities at the western end of the Cross City Tunnel project was derived following consultation with relevant agencies. This included:

- consideration of the submission prepared by the Department of Urban Affairs and Planning's Urban Design Advisory Service titled *Proposed Cross City Tunnel Pedestrian and Cycle Access to Darling Harbour Urban Design Study*, dated February 2001;
- a briefing of representatives of the Department of Urban Affairs and Planning, Sydney Harbour Foreshores Authority and the Council of the City of Sydney at the RTA's Rozelle offices on 11 May 2001;
- consideration of submissions prepared by the agencies following the briefing; and
- follow-up meetings between representatives of the Roads and Traffic Authority and each of the briefed agencies on 22 June, 3 and 5 July, 2001.

Table 5.1 provides a summary of the concerns raised by the written submissions from these agencies, together with a statement on how the concerns are addressed in, or relate to, the preferred concept. *Attachment B* contains copies of the submissions.

The general consensus arrived at during the consultations was that Option 5 would provide the best balanced solution to meeting the various access objectives of the area.

Table 5.1: Summary of Agency Submissions

Agency	Date of Submission	Key Issues/Concerns Raised	Response – How does the preferred concept relate to/address this issue.
Urban Design Advisory Service (Dept of Urban Affairs and Planning)	February 2001	Existing pedestrian and cycle access is poor, due to the physical and visual barriers, and high volumes of traffic which obstruct movement between Darling Harbour and the CBD.	Harbour Street is an existing major north-south arterial route. Together with the Western Distributor, it performs a role of taking traffic away from CBD streets such as York, Clarence, Kent and Sussex Streets. This traffic function and physical presence of the viaduct structures is not likely to change over time. The preferred concept seeks to enhance pedestrian access between the CBD, Darling Harbour and Ultimo/Pyrmont, working within these significant physical constraints. Cycle access through this general area is most appropriately catered for by utilising lower-trafficked CBD streets to access east-west routes at Pyrmont Bridge and Pier Street (see discussion in *Section 6.1.3).*
		No co-ordinated pedestrian strategy to improve pedestrian and cycle access in and around Darling Harbour and between the CBD and Ultimo/Pyrmont and beyond.	A coordinated strategy for pedestrians and cyclists, apart from the links directly affected by the Cross City Tunnel (CCT) project, are outside the scope of the proposal. Notwithstanding, it is considered that the preferred concept responds to the major pedestrian desire lines recorded in the area and meshes with regional desire lines for cyclists. It also responds to the goals of the City of Sydney and Sydney Harbour Foreshore Authority (SHFA) in facilitating greater use of at grade connections by pedestrians.
		EIS pedestrian proposal appears to prioritise vehicle movements over pedestrian access.	New vehicle movements would be created at the Bathurst Street/Harbour Street intersection, by virtue of the CCT exit ramp feeding into this intersection. Preliminary analysis of the operation of the intersection indicates that there would be capacity to provide ample green time for pedestrians to cross the southern and western at grade crossings safely at this intersection. The at grade crossings are an improvement on the current situation where no at grade crossings exist at the intersection. Additionally, pedestrians will be provided with a choice between at grade and grade separated access between Darling Harbour and the CBD.

Agency	Date of Submission	Key Issues/Concerns Raised	Response – How does the preferred concept relate to/address this issue.
		Overall result of the Cross City Tunnel EIS proposal is a degradation of pedestrian connections in the vicinity of the Bathurst Street/Harbour Street intersection.	The proposal would improve access to Darling Harbour at ground level in the area of the Bathurst Street/Harbour Street intersection by providing a footpath on the western side of Harbour Street and a signalised pedestrian crossing. It is considered that this footpath would, in combination with the relocation of the pedestrian footbridge to the southern side of Bathurst Street (and a direct extension into the Darling Harbour central pedestrian spine on the alignment of Bathurst Street), improve the legibility and safety of this area for pedestrians and contribute to reducing the isolation of this area from Darling Harbour.
Department of Urban Affairs and Planning (Development and Infrastructure Assessment Branch)	5 June 2001	The preferred option should incorporate the following:	
		▪ A 3.6 m wide footway bridge provided to replace the existing footway between Druitt Street and Bathurst Street via the Western side of the Parkroyal Hotel.	The proposal provides a new footbridge from Bathurst Street to Darling Harbour to supplement existing bridges from Liverpool and Druitt Streets. Adequate footpath connections are available to link to these bridges.
		▪ A new signalised pedestrian crossing on the eastern side of the Liverpool Street/Harbour Street intersection. Full signalised pedestrian crossing at the same intersection to be investigated.	Pedestrian access across Liverpool Street at Harbour Street is provided at the signals. As dual pedestrian bridges are available to meet pedestrian demand and avoid traffic pedestrian conflict it is proposed not to provide at grade crossing of Harbour Street as it would have an adverse impact on traffic signal operation and increase risk for pedestrians.
		▪ Darling Walk Pedestrian Bridge should be sited at a right-angle to Harbour Street (as shown in the EIS proposal), and should be located so that it is not within the Bathurst Street view corridor.	The preferred concept includes providing a pedestrian bridge from Day Street to the Darling Walk building and to the Darling Harbour central pedestrian spine. The bridge will be positioned on the southern side of the alignment of Bathurst Street and outside of the Bathurst Street view corridor, looking west from the CBD. Provision of the most direct pedestrian access between Darling Harbour and the CBD was considered, on balance, a greater environmental benefit than providing a bridge at a right angle to Harbour Street.
		▪ At-grade pedestrian link between Bathurst Street and Darling Harbour, using the car park north of the Darling Walk building, should be part of the CCT project.	Consultations with the SHFA, owner of the carpark, confirmed the need to retain this facility. The preferred concept allows for a pedestrian footway to be erected over the carpark, thus enabling direct pedestrian access between Darling Harbour and Bathurst Street, while maintaining the car park facility.

Agency	Date of Submission	Key Issues/Concerns Raised	Response – How does the preferred concept relate to/address this issue.
		▪ Proposed footway for Druitt Street shown in Option 2 is not acceptable, as the visual and urban design impacts would be too great.	The preferred concept (Option 5) has less length of elevated footway than Option 2.
		▪ High quality pedestrian access should be undertaken during construction.	The contractor will be required to provide suitable pedestrian access during construction including provision of a temporary bridge across Harbour Street.
		▪ RTA be pro-active with City of Sydney Council in constructing high quality cycleways along Kent or Sussex Streets with safe connections to the King Street Cycleway as part of the CCT project.	Council has proposed a two-way cycle lane in King Street between Kent and Sussex Streets and the RTA will co-operate with Council in providing cycle connection along Kent and Sussex Streets to link the proposed William/Park/Druitt Street cycle facilities to King Street.
		▪ RTA to consider retaining the Market Street viaduct as an alternative cycle route, in line with cycling community wishes.	The merits of utilising the viaduct as a safe and convenient cycle route are discussed in Section 6.1.3 of this report. Taking into account urban design issues and regional cyclist movements, on balance, it is considered that the viaduct route would best serve pedestrian needs, which include Darling Harbour itself as a key pedestrian generator.
		▪ Reserve the option of Liverpool Street as a cross-city, east-west cycle route by providing a complete signalised intersection at Liverpool and Harbour Streets.	The intersection is signalised, however, it is not proposed to make specific provision at this time for cyclists as there are no connecting cycle routes.
City of Sydney	29 May 2001	Option 3 is the preferred option subject to the following:	
		▪ 'Future connection' proposed north of Darling Walk building, must be provided as part of the project. Link must be safe and convenient, segregated from vehicles, be at least 3.6 m wide and have appropriate signage and lighting.	Subsequent to the City of Sydney's written submission, Options 4 and 5 were developed, with both of these options incorporating the safe and convenient access requested. Both options proposed a minimum clear width of 3.0m for pedestrian use only.
		▪ Details of the at grade crossing of Darling Harbour water feature not provided.	The proposed at grade treatments within Darling Harbour would be determined as part of the detailed design of the preferred concept. The contractor will be required to liaise with and gain the approval of the SHFA for the proposed work.

Agency	Date of Submission	Key Issues/Concerns Raised	Response – How does the preferred concept relate to/address this issue.
		▪ Proposed relocation of northernmost crossing at the intersection of Sussex and Druitt Street is not supported, as it takes pedestrians away from the natural desire line between Druitt Street (north) and the Blackwattle Street footway.	Pedestrian crossings at this intersection will be reviewed during the detailed design phase.
Sydney Harbour Foreshore Authority	28 May 2001	Option 3 generally acceptable provided the architectural detail of the at grade connections are clarified in further discussions with the RTA.	The proposed at grade treatments within Darling Harbour would be determined as part of the detailed design of the preferred concept. The contractor will be required to liaise with and gain the approval of the SHFA for the proposed work.
		Option 2 generally acceptable, provided overhead walkway is returned to ground level at an appropriate grade near the Darling Harbour Information Centre.	The preferred concept (Option 5) incorporates this requirement. The ramp grade in this area is 1 in 10.
		SHFA prefer new pedestrian arrangements are in place at the front end of the construction program.	A pedestrian footbridge over Harbour Street, near Bathurst Street, is required to be maintained throughout the CCT project. Additionally, the existing Market Street viaduct footway would be maintained as long as possible during the project so as to limit the inconvenience to pedestrians caused by the CCT construction. Construction of the new footways, stairs and lift would likely be undertaken during the first twelve months of the outset of the CCT project to ensure that the new pedestrian amenities are in place as soon as practicable.

6. Environmental Assessment

This section assesses the impacts of the proposed modified pedestrian access facilities. *Chapter 10* of the Main Volume of the EIS contains an assessment of the Cross City Tunnel project in its entirety, for the Darling Harbour Precinct.

6.1 Access and Traffic

6.1.1 Vehicular Access

Temporary impacts on vehicle access would occur at various times during the construction period. These impacts would likely occur on the following occasions:

- during the erection of fencing, barriers, scaffolding and/or hoardings along affected streets (including the Harris Street exit viaduct and Harbour Street, Bathurst Street) and within Darling Harbour;
- delivery of concrete and materials to the construction sites;
- when cranes are required to operate in the street for construction activities which may involve partial street closures; and
- during the dismantling of hoardings, scaffolding etc near completion of the work.

For construction of the western elevated footway, it is proposed that the southernmost kerbside lane of the Harris Street exit viaduct would be closed from 9.00pm to 5.00am Monday through Sunday, subject to modification where there is conflict with special events or previously licensed proposals.

These are general times and may be changed should the proposal result in unacceptable traffic flow delays.

It is also envisaged that the works would not have any significant effect on the operational efficiency of the traffic signals at the Harris Street viaduct/Harris Street/ Fig Street intersection. Should construction work involve lane occupancies affecting the operations of the intersection times may have to be further restricted - dependent upon the type of closure / closures proposed.

For construction of the eastern elevated footway, it is also envisaged that some night work would take place, with a temporary closure of Harbour Street likely.

The contractor would ensure that construction activity on, over or adjacent to the public pathways provides a passage free of obstruction and that it has appropriate signage and ramps.

The car park on the northern side of the Darling Walk building would not be available for use during the construction period. Satisfactory arrangements for delivery vehicles to service this building during construction would need to be negotiated with the Sydney Harbour Foreshore Authority and Darling Walk tenants. When construction of the eastern footway is completed, the car park would be restored. No permanent loss of car parking would occur as a result of the proposed pedestrian facilities.

The construction contractor would be required to prepare a traffic and access management plan which would include all of the above potential impacts and nominate how they would be managed. This would be submitted to the Sydney Harbour Foreshore Authority, Council of the City of Sydney, and the Environment Protection Authority for approval prior to the commencement of construction.

For loading and unloading of construction materials required to take place on or partially on a street, the contractor would need to apply to Council for approval of an "on-street construction zone".

6.1.2 Pedestrian Access

Existing Movements

Existing pedestrian movements between Darling Harbour and the Sydney CBD, in a zone between the alignments of Druitt and Liverpool Streets, were examined to understand pedestrian behaviour and desire lines in the vicinity of the Cross City Tunnel project.

The assessments were carried out between 9.00am and 7.00pm on Sunday 8 April, Thursday 12 April and Saturday 14 April, 2001 involving the following pedestrian connections:

- from Sussex Street/Druitt Street intersection to north of IMAX Theatre, via the Darling Park/Blackwattle Place elevated footway;
- from Bathurst Street (north) to north of IMAX Theatre, via elevated footway south of Blackwattle Place;
- from Bathurst Street (north) to Market Street viaduct elevated footway;
- from Sussex Street/Druitt Street intersection to Market Street viaduct elevated walkway, via Day Street and Parkroyal Hotel entrance;
- from Darling Walk building to Market Street viaduct, Bathurst Street (north) and Day Street, via the Darling Walk elevated footway; and
- at-grade pedestrian movements at the intersection of Day Street and Harbour Street.

Results of the assessment are contained in *Attachment C*.

The assessment revealed the following findings:

- the dominant means of pedestrian access between Darling Harbour and the Sydney CBD, between Liverpool Street and Market Street, is via the two elevated footways immediately north and south of Blackwattle Place, providing access over Harbour Street between an area north of IMAX to either Sussex, Druitt, Day or Bathurst Streets. On the surveyed days an average of 5,562 pedestrians used the two footways;
- by comparison, a daily average of 1,976 persons used the Darling Walk elevated footway over Harbour Street between Bathurst Street/Day Street and Darling Harbour, and 908 persons used the at-grade signalised crossing at the intersection of Day and Harbour Streets; and
- the elevated footway on the Market Street viaduct, west of Harbour Street, constituted a relatively minor pedestrian desire line, accounting for a daily average of 213 movements. This facility provides a direct pedestrian connection between Harris Street, Ultimo and the Sydney CBD.

The following conclusions can be drawn from this assessment.

Pedestrian access facilities in the Harbour Street area near Bathurst Street mostly cater for movements between the Sydney CBD and the Darling Harbour entry near the IMAX Theatre (that is, Darling Harbour north of the road viaducts). Movements between the Darling Walk building and the Sydney CBD (that is, from Darling Harbour south of the road viaducts) are of a level less than half that experienced between the CBD and near the IMAX Theatre. Pedestrian movements between Sydney CBD and Harris Street, Ultimo, via the existing Market Street viaduct footway are very low by comparison. This indicates that Darling Harbour is the dominant origin or destination for pedestrian trips in the vicinity of the Cross City Tunnel works, with Ultimo to CBD direct trips being much less significant. As a result, proposed pedestrian facilities in the area should facilitate access to and from Darling Harbour as a priority, rather than bypassing Darling Harbour via an elevated structure.

Proposed Access

It is considered that the proposed pedestrian facilities would result in several enhancements to existing pedestrian access facilities to and from Darling Harbour:

- direct access (via ramps, stairs or lift) to the central pedestrian spine within Darling Harbour from Ultimo and from the Sydney CBD; and
- direct access from Pyrmont Street and Darling Drive into Darling Harbour (via stairs or lift) and the Sydney CBD. Currently such access is only available via a more circuitous route north or south of the Sydney Convention and Exhibition Centre.

These enhancements are in addition to enhancements which were proposed as part of the Cross City Tunnel proposal described in the EIS, namely:

- greater clarity of pedestrian access layout, avenue planting and other landscaping along Harbour Street to Darling Park;

- provision of a footpath on the western side of Harbour Street between Day Street and Wheat Road, allowing access along the Harbour Street frontage of the Darling Walk building;
- provision of at-grade signalised pedestrian crossings on the west and south sides of the Harbour Street and Bathurst Street intersection;
- a new footbridge over Harbour Street, between the Darling Walk building and Bathurst Street (south side), on an alignment outside of the Bathurst Street view corridor; and
- connection of the Blackwattle Place pedestrian bridge to the northern Western Distributor (or King Street viaduct) footway.

The western elevated footway would be able to be accessed via stairs and lift at its eastern end, and via ramps approaching Harris Street at grade and the Harris Street pedestrian bridge at its western end. Based on the relative cost of additional lifts, and the unsatisfactory visual impact of a ramp structure, only stairs are proposed to connect the footway directly to Pyrmont Street and Darling Drive.

In the west, most pedestrian trips are anticipated to involve Harris Street as an origin or destination. Developments located in Pyrmont Street (that is, Goldsbrough Mort building and future development on the former Government Printing Office site) will generate most of the need for footway users to access Pyrmont Street. Alternative access from Pyrmont Street to the proposed footway for mobility impaired persons is via the existing Harris Street viaduct underpass, located just west of Pyrmont Street.

Mobility impaired pedestrians in Darling Drive would need to use existing at grade access points north and south of the Sydney Convention and Exhibition Centre in order to approach Darling Harbour from the west. In any event, it is not considered that movements between the proposed footway and Darling Drive would be significant enough to warrant provision of a lift facility abutting Darling Drive.

The eastern elevated footway is proposed in a location similar to that identified in the EIS. Rather than only connecting Bathurst Street directly to the Darling Walk building, the footway will extend to the Darling Harbour central pedestrian spine. This will result in pedestrians having both at grade and grade separated means of accessing Darling Harbour from the Bathurst Street/Day Street area.

The eastern elevated footway would incorporate both stair and one in eight ramp access at its eastern end. The western approach would incorporate one in ten ramp access. Mobility impaired pedestrians may use alternative at grade signalised crossings of Harbour and Bathurst Streets in order to travel between Darling Harbour and the CBD.

During construction, pedestrian access would be maintained within the Darling Harbour development, particularly along the central pedestrian spine. Work would be programmed in such a manner so as to not preclude access in this area, which at times experiences significant pedestrian flows.

Cumulative Impacts

The cumulative impacts on pedestrian movements arising from the preferred option (compared to the option proposed in the EIS), can be viewed in terms of 'losses' and 'gains' to the pedestrian access network.

The only major loss involves removal of direct elevated access between Ultimo and Pyrmont and the CBD, alongside the Market Street viaduct (the northern, or King Street viaduct access however remains).

Investigations have revealed (see section above on existing access) that this pedestrian desire line is not significant in terms of pedestrian numbers, when compared to the pedestrian usage of pedestrian bridges north and south of Blackwattle Place.

Gains include:

- a new east–west access connecting neighbourhoods in Ultimo and Pyrmont (Pyrmont Street and Harris Street) with Darling Drive and the Darling Harbour central pedestrian spine;
- a new east–west access connecting Darling Harbour central pedestrian spine and Bathurst Street and Day Street;
- greater opportunities for more pedestrians moving about at grade, rather than on elevated footways, contributing to enhanced casual surveillance, personal security, and general vitality of the Darling Harbour precinct; and
- a reduced length of elevated structures, compared to the EIS scheme.

6.1.3 Cycle Access

The only formal access provided for cyclists traversing Darling Harbour along an east-west axis is available north of the subject site at the Pyrmont Bridge. This is a major regional route connecting Pyrmont and suburbs to the west with the Sydney CBD.

To the south, cyclists are required to use existing road space via Pier Street and Ultimo Road for access between Ultimo and the Sydney CBD.

The provision of direct and convenient cycle links through the area affected by this proposal, is constrained by the topography of Ultimo. The steep north-south ridge which runs along the peninsula impacts upon the feasibility of providing a more permeable cycle network in the area, at least for east-west links. Figure 6.1 shows the arrangement of links in the surrounding area.

The existing Market Street viaduct footway currently does not prohibit the use of bicycles, although its width (2 metres) is insufficient to allow a safe, shared pedestrian and cycle way to be provided.

The feasibility of providing a shared, elevated facility along the alignment of the existing footway was investigated as part of this proposal. However, it was found that the required width of a shared access way (minimum 3.5 metres) would result in a cantilevered structure of significant cost which would be likely to have an



Figure 6.1 **Regional Cycle Connections**

Bicycle route marked

Proposed future bicycle route

Possible future route identified by RTA

unacceptable visual impact when viewed from below. If provided at the higher level, at the level of the existing footway, it would have the added disadvantage of not allowing a feasible direct stair and lift access to the Darling Harbour central pedestrian spine.

The preferred concept does not provide for cycle access. This is because the preferred concept has a key objective to get pedestrians to use at grade connections within Darling Harbour to the maximum extent possible. Cyclists are not permitted within Darling Harbour, apart from the Pyrmont Bridge. Given the topographic constraints of the Pyrmont peninsula, it is considered that reinforcing the use of the existing northern (Pyrmont Bridge) and southern (Pier Street and further south) routes for east–west access routes by cyclists, would provide the best balanced solution.

However, the Cross City Tunnel project in its totality, does provide for the first east–west link across the CBD, using Pyrmont Bridge, King Street, Sussex/Kent Streets, Druitt Street, Park Street and William Street.

6.2 Visual Amenity

The site is currently characterised by visually-obtrusive overhead elements associated with the viaducts of the Western Distributor road. The minimisation of new overhead structures, so as to not further adversely affect the visual amenity of the Darling Harbour precinct, was a key consideration in the development of the preferred pedestrian access option.

The proposed eastern and western elevated footways, access ramps and access stairs would generally be constructed in pre-cast concrete and delivered to the sites. Handrails and safety barriers would be of galvanised steel construction. Stairs would incorporate exposed honed aggregate treads and landings.

The lift tower would be constructed in concrete *in situ* and would be to the same specification as the existing lift at the western end of the King Street pedestrian bridge.

A new at grade pedestrian access across the Darling Harbour water feature would be provided to the east of the lift tower, to allow pedestrians to make connections between the eastern and western elevated footways. The proponent would need to prepare a detailed design, in consultation with the Sydney Harbour Foreshore Authority, prior to any construction work commencing.

Details of the specifications for the proposed pedestrian access facilities are described in *Attachment D*.

6.3 Public Safety

Construction

Construction of any significant structure in close proximity to public spaces has the potential to impact on public safety. The construction areas would be enclosed by security fencing and/or hoardings around the construction site perimeter. For guidance on the structural requirements for fencing and hoardings, the construction contractor should refer to the City of Sydney's current policy on hoardings, scaffolding, shoring and façade retention and the *Code of Practice – Overhead Protective Structures* prepared by WorkCover.

Particular attention would be paid to the existing landscaping on existing roads and within the Darling Harbour development (where such landscaping is not proposed to be permanently removed). The contractor would liaise with the Sydney Harbour Foreshore Authority regarding construction activities and temporary protection installations within Darling Harbour, to ensure pedestrian access is not unnecessarily impeded for the duration of the construction works.

Before erecting fencing/hoardings on public roads, an application would be made to the Council of the City of Sydney for a Builders Hoarding Permit (for approval under the *Roads Act 1993*). A site inspection would need to be undertaken by Council officers for assistance in determining the type of hoardings required. An application would also be made to Council for a permit to operate a mobile crane from a public road, if required.

Appropriate security lighting would also be provided around the construction sites and no public access to the construction sites would be allowed. This would mean that the car parking area north of the Darling Walk building would not be available for use during the construction period. The Contractor would need to ensure that satisfactory access for servicing activities associated with Darling Walk be maintained at all times.

Operation

The proposed pedestrian access facilities have been designed in a manner which would maximise the safety of users.

The eastern elevated footway and stairs would have a minimum clear width of three metres, allowing for easy access by the anticipated significant volumes of pedestrians travelling between Darling Harbour and the CBD.

The western elevated footway would have a minimum clear width of two metres, reflecting the relatively fewer number of pedestrians likely to use this link. Stairs to Darling Drive and Pyrmont Street would have a minimum width of 1.5 metres.

Footways and stairs would be lit in accordance with the City of Sydney's Exterior Strategy.

The proposed western elevated footway would be constructed abutting the existing road viaduct, and positioned in a manner which would allow the pedestrian areas to be viewed by passing motorists. Together with the installation of appropriate lighting, this would maximise the security and safety of pedestrians using the facility, particularly during the night.

Measures would be implemented to ensure that pedestrians could not gain access to the roof of the Sydney Convention and Exhibition Centre from the elevated footway.

The Roads and Traffic Authority, and not the Cross City Tunnel contractor, would be responsible for the maintenance of the footways and associated accesses.

With these construction and operation measures in place, public safety would not be adversely impacted as a result of the proposed pedestrian access facilities.

6.4 Noise and Vibration

Construction associated with the pedestrian access facilities would be confined to the southern side of the Market Street viaduct, between Harris and Bathurst Streets, the southern side of Bathurst Street, between Day Street and Darling Harbour, and within the Darling Walk car park and the Harris Street viaduct.

The nearest residential receptors to the proposed work would be the Goldsbrough Mort building, to the north and west of the King Street viaduct in Pyrmont and the Millennium Towers residential development situated on the south-eastern corner of Day and Bathurst Streets. It is considered that these locations would be the only residential properties with any possibility of being adversely impacted by construction-related noise.

The Goldsbrough Mort building is currently impacted upon in terms of the noise generated by traffic on the Western Distributor and on the Harris Street on and off ramps. It is not anticipated that noise generated from construction activities would be significantly greater than existing ambient noise levels adjacent to the northern side of the viaduct. Further, it is likely that the existing viaduct structures would to some extent deflect any construction-related noise, such that it would not be readily perceptible to occupiers of nearby residences.

In regard to the Millennium Towers building, the proposed modification differs only slightly from that proposed in the EIS and it is therefore considered that the noise and vibration impacts would be similar to that described in the EIS.

6.5 Air Quality

Potential air quality impacts during construction resulting from the use of the construction areas would be limited to dust and vehicle and plant emissions. Management measures would be implemented as described in *Section 7* to mitigate any adverse impacts.

The environmental management plan to be prepared for the Cross City Tunnel would include an air quality management plan addressing these impacts, including monitoring of impacts at construction sites.

6.6 Waste Minimisation and Management

General waste would be generated from the site construction areas. This waste would be actively managed and minimised where possible. Except where sewer is available, site amenities would discharge all sewerage to holding tanks for removal by tankers. Rubbish skips would be provided at all construction areas and regularly removed or emptied. Any soil contamination resulting from a chemical, fuel or oil spill would be excavated and removed to an approved disposal centre. The excavation would be backfilled with clean soil compatible with the residual materials. Waste generated from the construction areas would be recycled where practicable.

Management measures to ensure waste generated from construction activities is minimised and managed properly are included in *Section 7*.

6.7 Demand on Resources

Construction of the proposal would require the consumption of energy (in the form of electricity, fuel and water), construction materials and human resources. Additional electricity supply to that described in the EIS would be required for the construction and operation of the facilities. This would generally comprise provision of lighting (including flood lighting) for external areas and provision of a lift. The increase in supply would be negligible in the context of the total consumption of 25 gigawatt hours for the entire project and would be obtained from the existing power grid. No additional fuel would be consumed as a result of the proposed pedestrian facilities. Water would be required during construction for dust control, washing equipment and drinking water. It is estimated that any additional water consumed during construction as a result of the proposed pedestrian facilities would be minimal in the context of the 15,000 cubic metres to be used for the whole project.

A negligible increase in materials for construction would be used as a result of the proposal. This would be mainly related to the structures to be erected in conjunction with the pedestrian facilities (stairs and lift).

The workforce involved in the project would not be altered as a result of the modified pedestrian access arrangements.

7. Environmental Management

Table 7.1 outlines the environmental management measures to be implemented to minimise adverse impacts and construction activities associated with the proposed pedestrian facilities.

Table 7.1: Environmental Management Measures for Construction Areas

Issue	Environmental Management Measures Proposed
Access and Traffic	▪ contractor to develop a traffic management plan for use whenever work would impact on existing traffic arrangements. This would be submitted to Council and Environment Protection Authority for approval prior to the commencement of construction and would include the use of cranes on streets, access to the construction sites, deliveries to and from the construction sites, timetable for partial road closures and access requirements to Darling Harbour pedestrian precinct; ▪ monitor Harris Street exit viaduct during construction to ensure minimal adverse impacts on traffic flow; ▪ ensure that construction activity on, over or adjacent to the public pathways provides a passage free of obstruction and that it has appropriate signage and ramps; ▪ contractor to provide connection of Darling Park footbridge to King Street viaduct footway before existing bridge over Harbour Street is demolished; ▪ a footbridge between Bathurst Street and Darling Walk is to be provided during construction, as described in the EIS; ▪ contractor to maintain existing footway from Ultimo to CBD in service until the western elevated footway is constructed and in service; ▪ ensure that adequate access to Darling Walk building for delivery vehicles is maintained at all times; and ▪ comprehensive signposting and lighting of the new pedestrian links to be implemented in accordance with the Sydney Harbour Foreshore Authority's and the City of Sydney's requirements.
Noise and Vibration	▪ particular attention would be paid to the hours of use of noisy equipment such as angle grinders, impact drills, etc. While the general hours of work would be based on normal Environment Protection Authority's requirements, noise-intensive activities could be minimised for example during the first hour or so of the daytime period (say between 7.00 am and 8.00 am); ▪ contractor to seek approval of EPA for work to be conducted outside of normal hours; ▪ wherever possible, areas used for stockpile material handling would be covered by awnings or canopy structures providing a noise screen during handling operations; and ▪ maintenance activities for construction equipment would be restricted to the standard Environment Protection Authority daytime construction period. Wherever possible, noisy maintenance activities would be minimised during the first hour (7.00 am to 8.00 am) of the construction daytime period;

Issue	Environmental Management Measures Proposed
Waste Minimisation and Management	▪ waste recycled where practicable; ▪ if no sewer is available, site amenities would discharge all sewerage to holding tanks for removal; ▪ regularly remove or empty rubbish skips; and ▪ any other relevant measures would be implemented as described in *Chapter 8* of the Representations Report.
Utilities	▪ minimise water usage where possible and use water conservation techniques for construction areas including aerated taps, waste efficient appliances, trigger action hoses and prompt repair of leaking taps and pipes.
Amenity	▪ visual amenity of the site would be managed by keeping the site areas tidy and regularly cleaned. Other management measures to minimise impacts on public amenity are included in the noise, dust, traffic and access section; ▪ notification to nearby properties of any service (electricity, gas etc) outages during building construction. Paint any hoardings and fences to a colour scheme agreed with the RTA and Sydney Harbour Foreshore Authority, including bold and informative graphics and planned as one system with barriers and signage; ▪ keep construction areas tidy and regularly cleaned; and ▪ wheel washing and watering of dust raising activities as appropriate.
Public Safety	▪ use fencing or hoardings allowing no public access to the construction areas; ▪ the design, supply, installation and structure of hoardings are to be guided by the City of Sydney's current policy on hoardings, scaffolding, shoring and façade retention, and the *Code of Practice – Overhead Protective Structures* prepared by WorkCover, and would also allow for safety and structural adequacy in accordance with the Building Code of Australia and adopted Australian Standards; and ▪ installation of security lighting around construction areas;
Run-off and Sedimentation	▪ drainage would be installed early in the construction process to enable on-site run-off to be contained within the construction sites and directed to the existing stormwater outlets; and ▪ sedimentation control measures would be used at the boundaries of the site if these are required for storm events or during construction activities that require the use of water.

8. Conclusion

The RTA proposes to modify the access arrangements for pedestrians at the western end of the Cross City Tunnel project, in the vicinity of Darling Harbour. Modifications are required to better align the facilities with key pedestrian needs and urban design objectives for the Darling Harbour precinct and surrounds.

The modification includes the construction of two separate elevated pedestrian footways between Harris Street, Ultimo and Bathurst Street, Sydney CBD. Stair access from Pyrmont Street and Darling Drive would be provided to the western footway. A lift and stairs would be provided for access between the footway and the central pedestrian spine. The EIS had proposed this east–west connection at a higher level, adjacent to the Market Street viaduct but without direct access to the Darling Harbour central pedestrian spine.

The proposed provision of pedestrian access facilities would fall under the provisions of State Environmental Planning Policy No. 63 as part of the Cross City Tunnel proposal and as such, development consent under Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) is not required.

An environmental assessment of the proposed modification has therefore been carried out under Part 5 of the EP&A Act. The main environmental impacts of the proposed modification include:

- limited disruption to pedestrians, due to ground level areas being cordoned off as construction sites;
- some disruption to vehicles, due to construction and partial road closures on the Harris Street exit viaduct of the Western Distributor and due to closure of the at grade car park north of the Darling Walk building;
- little or no perceptible change in noise and air quality impacts to that which were assessed in the of the Cross City Tunnel EIS; and
- adverse effects on local visual amenity during construction, caused by plant, hoardings, scaffolding, etc.

Appropriate mitigation measures developed and implemented in consultation with the Environment Protection Authority, Sydney Harbour Foreshore Authority and the Council of the City of Sydney, as outlined in Section 7 of this report, would satisfactorily address these local environmental concerns.

The major local impact would be changes to existing pedestrian facilities. The major change involves the removal of direct elevated access between Ultimo and the CBD, alongside the Market Street viaduct (the northern, or King Street viaduct access however remains).

On the other hand, the benefits of the proposal for pedestrians include:

- less length of overhead pedestrian connections, with a corresponding lesser impact upon visual amenity in the Darling Harbour zone;

- a new pedestrian connection from the Ultimo/Pyrmont neighbourhood into the Darling Harbour central pedestrian spine, with provision for access by persons with a disability or persons who are less mobile;
- new pedestrian connections from Darling Drive and Pyrmont Street to the Darling Harbour central pedestrian spine; and
- a new pedestrian connection from Bathurst Street directly into the Darling Harbour central pedestrian spine.

On balance, the proposed modification would result in a pedestrian access network at the western end of the Cross City Tunnel project which provides the best balanced access solution, providing improved connections to where pedestrians want to go.

Attachment A

Design Options

DARLING HARBOUR ACCESS OPTIONS ANALYSIS

OPTION 1 - "UPPER LEVEL OUTRIGGER"

This is the option exhibited in the Environmental Impact Statement for the Cross City Tunnel. The Harbour Street to Harris Street footway is reinstated on the same viaduct it presently occupies. The structure of the footway is supported on cantilevered steel "outriggers". At the east it is accessed by a ramp on the southern side of Bathurst Street between Day and Harbour street and a link from Darling Walk. In the west it uses the existing ramp and bridge to Harris Street.

Disadvantages

The most obvious limitation is the absence of intermediate links to the ground between Harbour and Harris Streets some 550m.

Vertical links are difficult because the pedestrian has climbed nearly 20m above Darling Harbour. This point is about 10m higher than Harris Street.

Costly and difficult to construct. Viaduct is already Lean structure and cantilevers are an inefficient structure.

Advantages

This option replaces an existing structure as closely as possible in its present location.

Provides an excellent view from the upper deck.

It leaves the western ramps intact reconnecting at the upper deck level.

For most of the route the pedestrian path is under surveillance of passing motorists

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OPTION 2 – "UNDERSLUNG"

This option replaces the existing footway with one hanging beneath the viaduct it presently occupies. It includes an extension to the East with a ramp link up to the Druitt Street Viaduct over Day Street and down this viaduct in what is now a breakdown lane to Sussex Street. It is also accessible via stairs on the northern side of Bathurst Street between Day and Harbour Streets and a stair over the east bound Cross City Tunnel portal. It also provides an upper level link to Daring Walk. This option provides vertical links to Darling Harbour with a stair adjacent to the Kodak Kiosk and a lift and stair adjacent to the exhibition hall number 5. In the west it links to the existing Harris Street ramp and bridge.

Disadvantages

Places pedestrians in an environment of poor surveillance with limited escape for most of the route.

Provides a platform over Darling Harbour from which objects might be dropped

Represents a proliferation of elevated structures over Darling Harbour and adjacent to the Park Royal Hotel

May require modification to exhibition building to allow footway to pass

Advantages

Provides a direct elevated link to the intersection of Sussex and Druitt Streets

Minimises elevated structures in the area over Harbour Street

3 access points East of Darling Harbour and 2 in Darling Harbour

Relatively small vertical climb

Re-uses Harris Street ramps and bridge from the landing

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OPTIONS 3, 4 & 5 "AT GRADE" ACROSS DARLING HARBOUR - HARRIS STREET VIADUCT LINK

The western link between Darling Harbour and Harris Street is common between options 3, 4 & 5. Access onward to Harris Street is via a lift or stair giving access to a footway on the lower level "EH" viaduct. Stair links give access to Darling Drive and Pyrmont street. The approach to Harris Street is at the level of Harris Street. A new ramp link provides access to the Harris Street footbridge. This configuration provides access from all the eastern darling Harbour entry points such as the Darling Park footbridge and Liverpool Street Foot bridges.

Disadvantages

Requires use of lift or stair to gain access to elevated footway limiting bicycle amenity

Requires demolition of Harris Street Ramp access structure

Advantages

Places pedestrian access on ground level increasing pedestrian activity in Darling harbour

Improves internal circulation within Darling Harbour

Provides for important new surface level entry to Darling Harbour

Pedestrians climb to minimum height required

Surveillance and escape provided by proximity to viaduct

Two new vertical links west of Darling Harbour

Harris street connection is at grade

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BATHURST STREET TO DARLING HARBOUR ACCESS OPTIONS

OPTION 3 –"AT GRADE"

This option proposes a ground level entry to Darling Harbour on the alignment of Bathurst street. Taking advantage of the new level crossing of Harbour Street at this location. The route passes the northern corner of the Darling Walk Building and continues along its northern edge. Direct bridge access to the first floor of the Darling Walk building could be provided in addition if required.
It should be noted that both proposals result in the same number of parked cars so that car park surveillance is not reduced.

The proposal has the following advantages and disadvantages:

Advantages

The city footpath grid is extended by provision of access at grade into Darling Harbour.

Provides an opportunity to activate the northern wall of the Darling Walk building. Currently this wall is without windows, though it contains a bar.

Surveillence of the car park currently provided by the parking attendant will be supplemented by passing pedestrians.

Better use is made of what is now 'left over' space between the 'Darling Walk' building and Imax.

Allows pedestrians to enter Darling Harbour at grade.

There is line of sight between the stairs to the Harris Street walkway at the Exhibition Hall and the Bathurst Street. The footway follows this line of sight.

Reduces the need for elevated structures in Harbour Street and Darling Harbour

Provides direct disabled access to Darling Harbour from Bathurst Street.

Does not require construction of costly elevated structures

Disadvantages

Pedestrians walk past cars in the Darling Walk car park.

Pedestrians pass under the northern corner of the Darling Walk Building, which may require some additional signage to identify the route as a major entrance to Darling Harbour.

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BATHURST STREET TO DARLING HARBOUR ACCESS OPTIONS

OPTION 4 – "PEDESTRIAN BRIDGE AND RAMPS FROM BATHURST AND SUSSEX STREETS TO DARLING HARBOUR"

This option continues the existing high level walk to the east with a ramp link up to the Druitt Street Viaduct over Day Street and down this viaduct, in what is now a breakdown lane to Sussex Street. It is similar to options 2 and 5. It is accessible via stairs on the northern side of Bathurst Street between Day and Harbour Streets and a stair over the east bound Cross City Tunnel portal. It also provides an upper level link to Darling Walk. It includes a ramp (1:10) to the west, providing a ramped Darling Harbour entry adjacent to the Kodak Kiosk.

Disadvantages

The link between the Park Street and Druitt Streets viaducts reduces privacy in the Park Royal Hotel.

Requires pedestrians climb several metres to clear Cross City Tunnel exit road on steep gradient. (Approx 1:10).

Costly relative to surface level option

Creates 'dead space' around the ramp north of Darling Walk

Advantages

Permits access to Darling Harbour from both sides of Bathurst Street

Provides a direct elevated link from the intersection of Sussex and Druitt Streets to Darling Harbour

New elevated structures are concentrated to the North near the WD viaducts. The main street space east of Darling Walk is left uncluttered.

Does not preclude a future surface level Darling Harbour entry being provided north of Darling Walk.

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BATHURST STREET TO DARLING HARBOUR ACCESS OPTIONS

OPTION 5 –"PEDESTRIAN BRIDGE AND RAMPS "

Access from Darling Harbour to Pyrmont is the same as for option 3. This option proposes an elevated walkway on the alignment of Bathurst Street connected by ramps (1:8) and stairs at the east and a ramp (1:10) to the west. Linking Day and Bathurst Streets with the upper level entry of Darling Walk and Darling Harbour adjacent to the Kodak Kiosk.
Retains parking space north of Darling Walk for around 30 cars.

Disadvantages

Excludes disabled access on direct alignment

Does not provide the line of sight to destination that is achieved by Option 1?

Requires pedestrians climb up about 5m then descend the same distance.

Creates wasted space between ramp and Darling Walk Building.

Proliferates elevated structures in Harbour Street

Costly to construct relative to surface level entry

Reduces opportunity for landscaping on the traffic island between Day, Harbour & Bathurst Streets and in the area north of Darling Walk.

Creates 'dead space' around ramp landings

Advantages

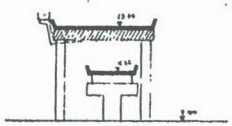
Pedestrians walk past parked cars on elevated structures without giving them access to parked cars.

Stairs, ramps and bridge provide an additional crossing of Harbour Street to the ground level crossing on the same alignment.

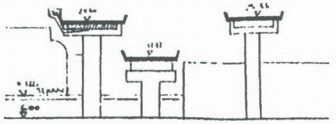
Maintains access to Darling Harbour on Bathurst Street alignment, while allowing the car park north of Darling walk to be fenced.

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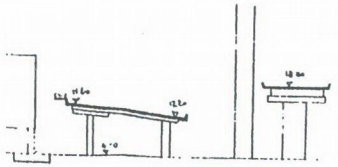
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SECTION A-A

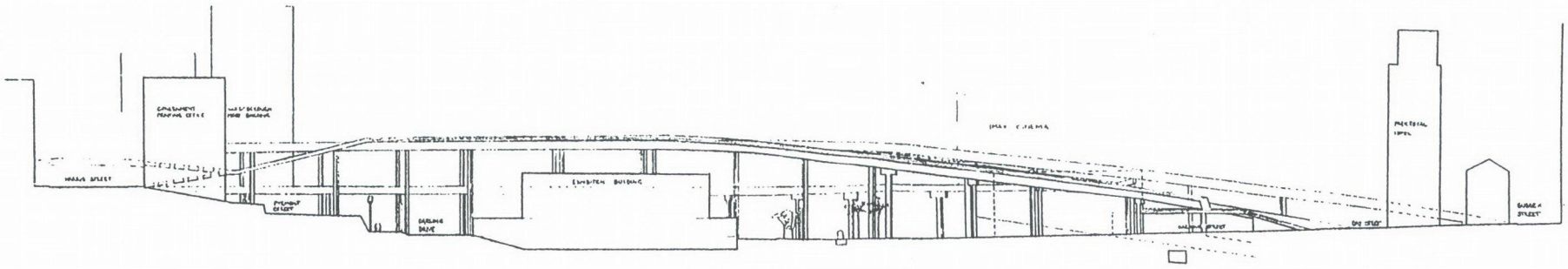


SECTION B-B



SECTION C-C

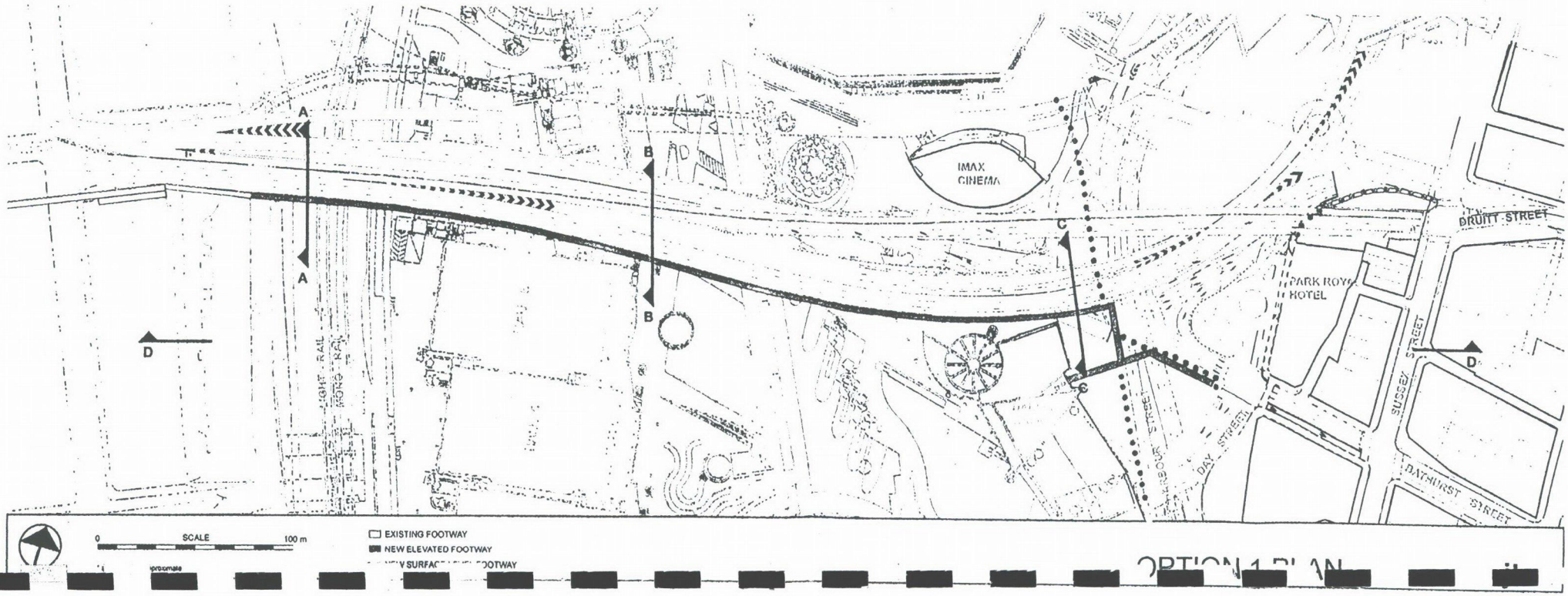
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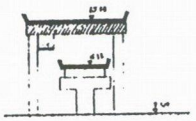
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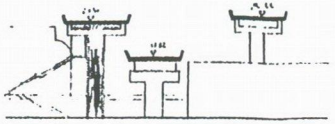
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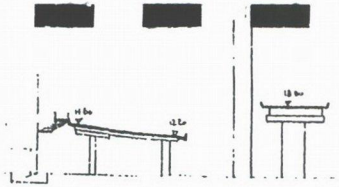
OPTION 1 PLAN



SECTION A-A

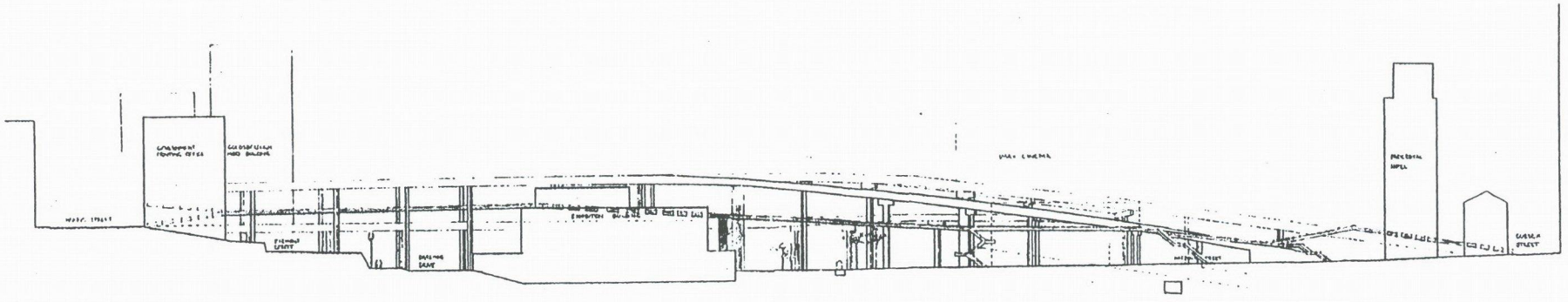


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SECTION C-C

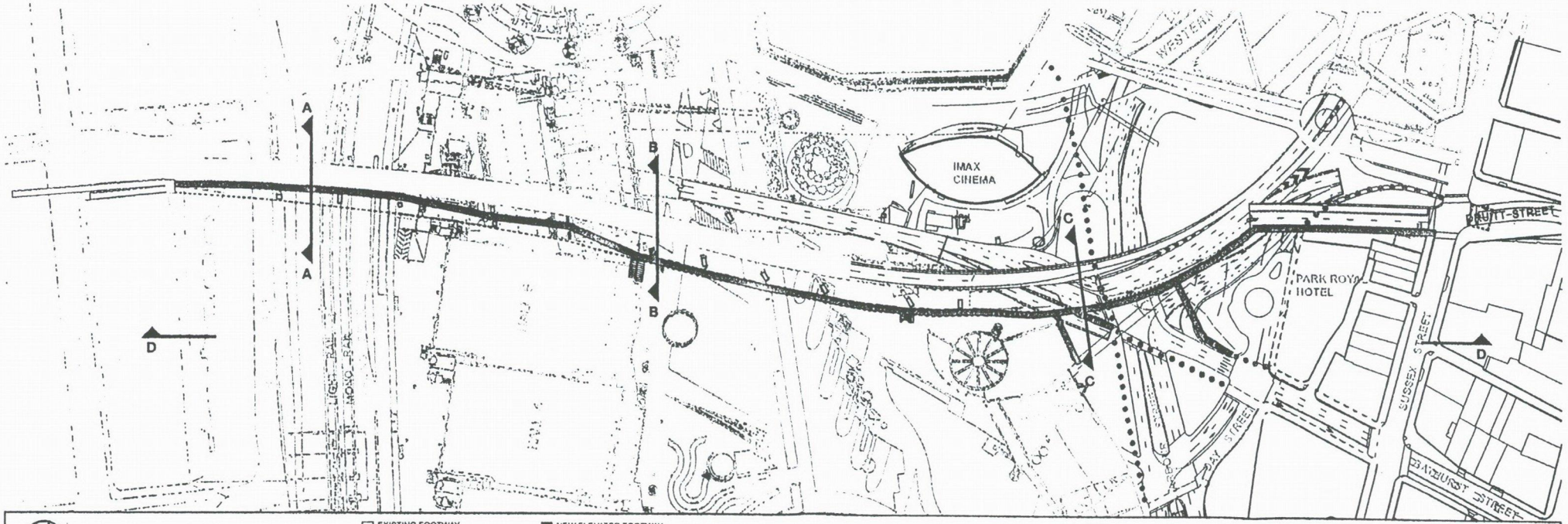
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SECTION D-D

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* all scales are approximate

EXISTING FOOTWAY

EXISTING SURFACE LEVEL FOOTWAY

NEW LIFT

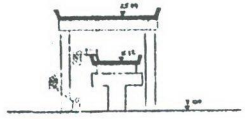
NEW ELEVATED FOOTWAY

NEW SURFACE LEVEL FOOTWAY

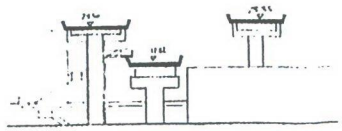
NEW STAIR

OPTION 2 PLAN

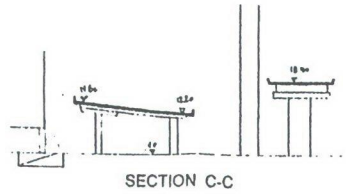
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SECTION A-A

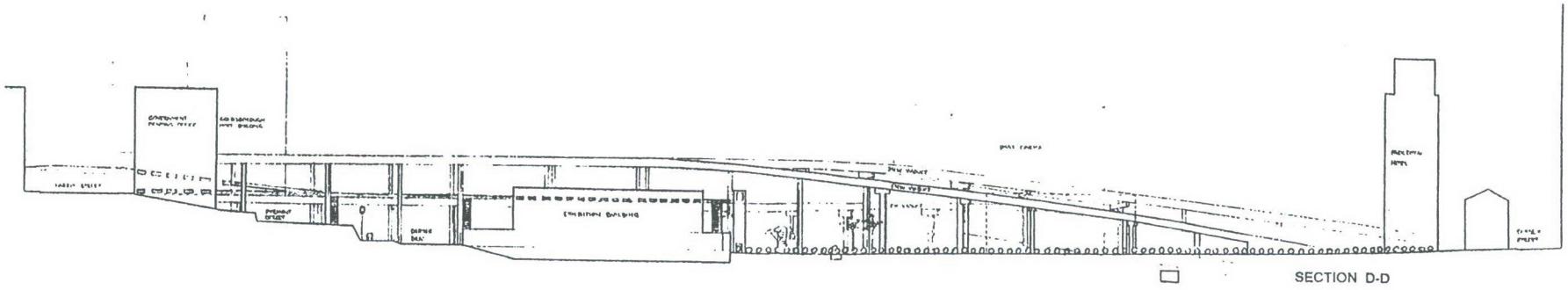


SECTION B-B



SECTION C-C

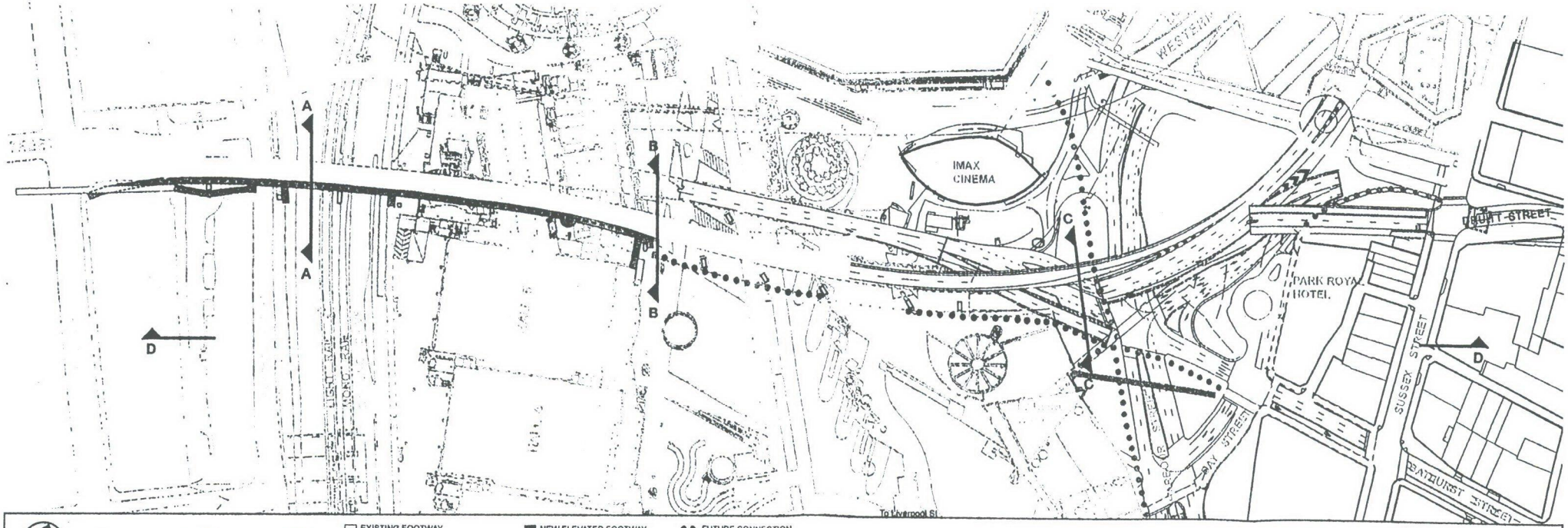
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SECTION D-D

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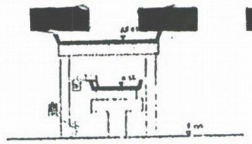
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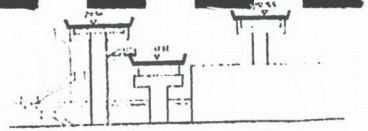
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EXISTING FOOTWAY
EXISTING SURFACE LEVEL FOOTWAY
NEW LIFT
NEW ELEVATED FOOTWAY
NEW SURFACE LEVEL FOOTWAY
NEW STAIR
FUTURE CONNECTION

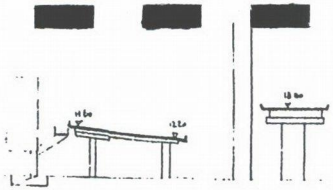
OPTION 3 PLAN



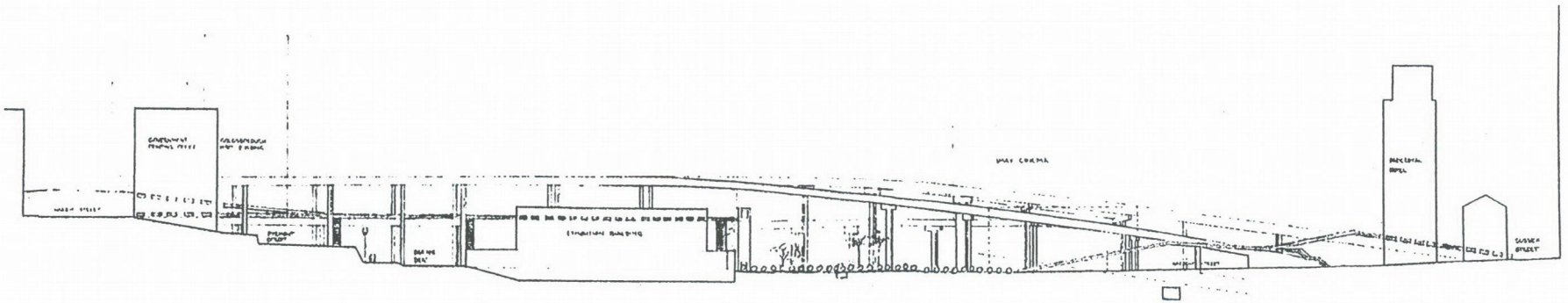
SECTION A-A



SECTION B-B



SECTION C-C

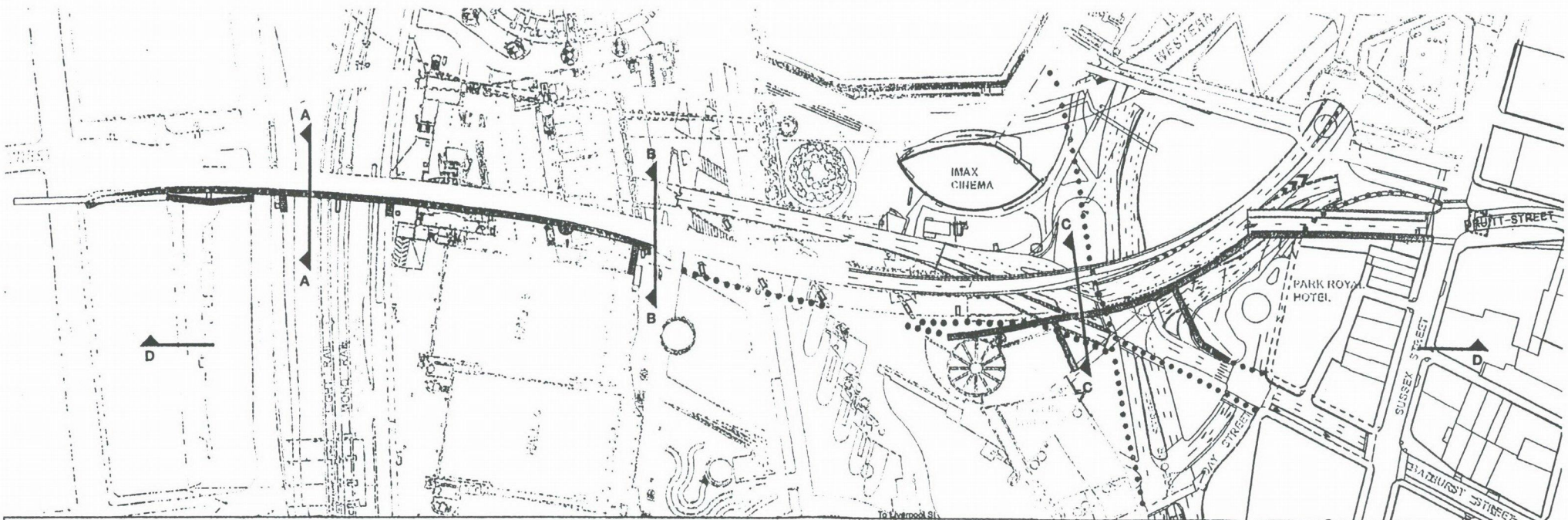


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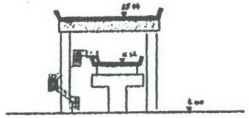


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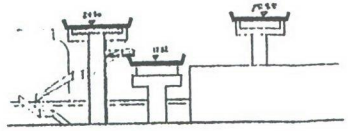
EXISTING FOOTWAY
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NEW ELEVATED FOOTWAY
NEW SURFACE LEVEL FOOTWAY
NEW STAIR
FUTURE CONNECTION

OPTION 4 PLAN

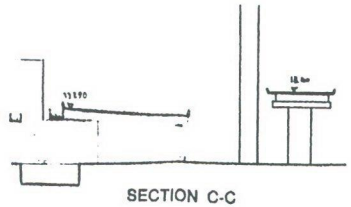
jtcw



SECTION A-A

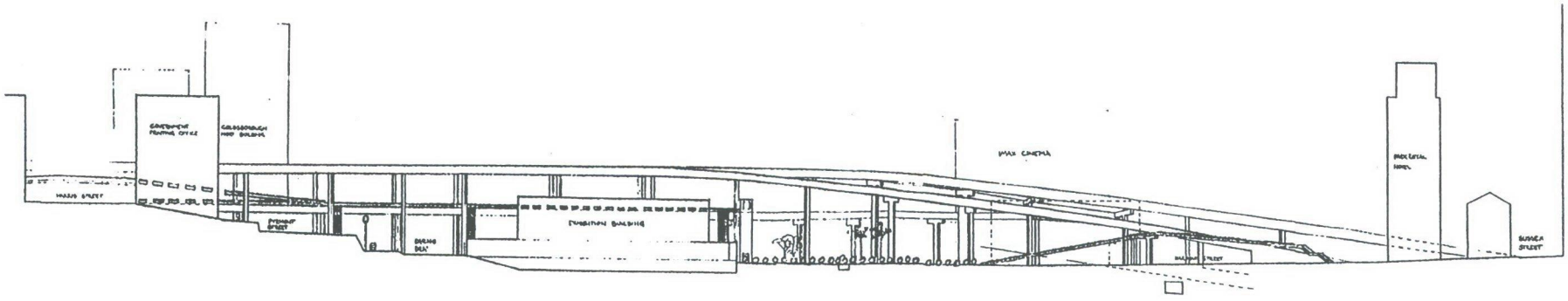


SECTION B-B



SECTION C-C

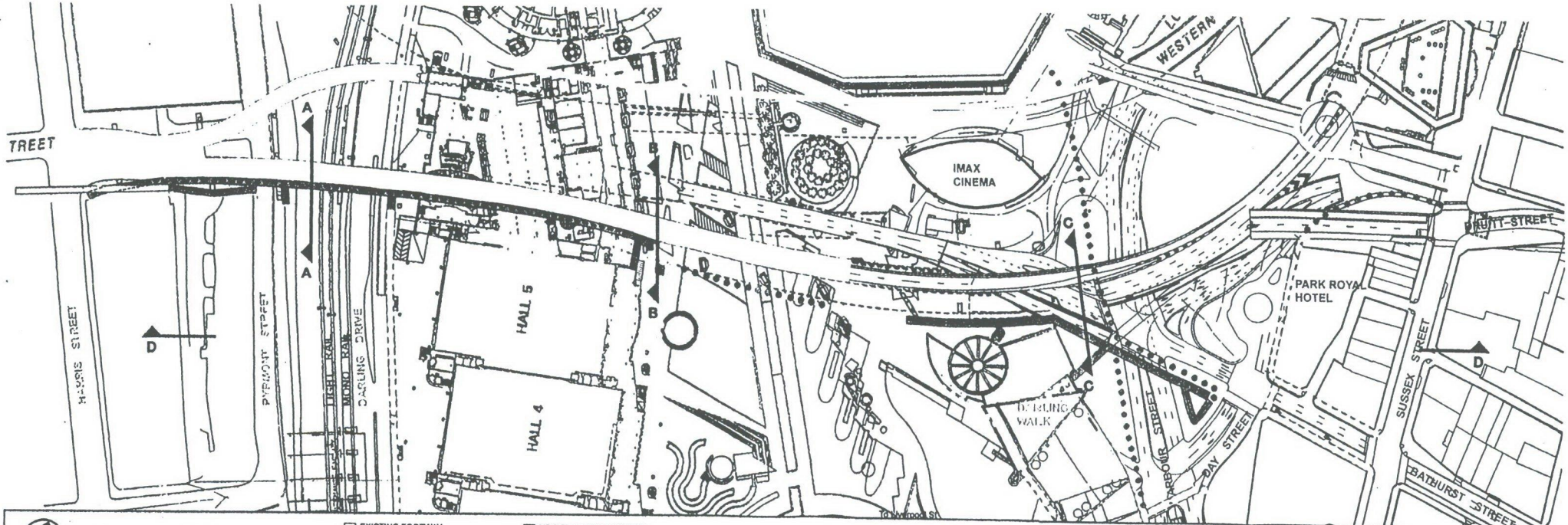
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SECTION D-D

HORIZONTAL SCALE 0 100 m

VERTICAL SCALE 0 50 m



OPTION 5 PLAN

Department of
Urban Affairs and Planning

DEVELOPMENT AND INFRASTRUCTURE
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TO:	Howard Penn Steve Arnold	**FROM:**	Chris Munro
FAX:	9352 9531 9218 6167	**PHONE:**	9391 2190
DATE:	5 June 2001	**EMAIL:**	Christopher.munro@duap.nsw.gov.au
PAGES (including cover sheet):		3	
RE:	***Cross - City Tunnel – Darling Harbour***		

☒ **Urgent** ☐ **Please reply** ☐ **For information**

Message:

Dear Howard,

Further to our meeting on 31/5/01, concerning RTA's three proposed pedestrian access options for Darling Harbour, the Department submits the following comments:

1.0 Option 3 is the preferred option with the following comments:

- RTA to provide a new continuous 3.6m wide at-grade pedestrian footpath from Druitt Street to Bathurst Street via the Park Royal Hotel. It was noted that the existing footpath along the western frontage of the Park Royal Hotel is in very poor condition, narrow and requires upgrading to the standard noted.
- RTA to provide new signalised pedestrian crossing at Liverpool Street and Harbour Street intersection connecting footpaths along the eastern side Harbour Street as part of CCT project. RTA to investigate full signalised pedestrian crossing at same intersection.
- The preferred configuration for a bridge over Harbour Street connecting to Darling Walk is that shown in option 1 where the bridge crosses Harbour Street at right angles. RTA to ensure that the bridge is located so that it is not within the Bathurst Street view corridor (looking west). DUAP/UDAS noted that the bridge is not required as a condition of consent.
- RTA to provide at-grade pedestrian link into Darling Harbour from Bathurst Street (identified in Option 3 as "future connection") as part of CCT project. Link should be of a high quality and amenity as per Sydney City Councils comments (letter from Richard West, SCC May 29 2001)
- It was agreed that the proposed footway for Druitt Street shown in option 2 is not acceptable as the visual and other urban design impacts outweigh the value of the structure as a pedestrian bridge. Furthermore, building more structures in the

area does not conform to the objective of providing more and better at-grade pedestrian links. The UDAS report (Feb. 2001) identified this Western Distributor footway link as important for both pedestrian and cycle links across Darling Harbour to Ultimo. The existing elevated route is now proposed to be replaced with option 3 where at least half the link is at grade through Darling Harbour.

2.0 Further comments:

2.1 Main east-west pedestrian link

Option 3: surface connection Bathurst Street south continuing through the Darling Walk's car park. There is an opportunity to redesign the area as a major new entry to DH in conjunction with the possible redevelopment of the Darling Walk site envisaged under the draft Harbour – City Foreshores REP strategy. **Note:** While this is the preferred option of the three presented by the RTA, it precludes the proposed reinstatement of Bathurst Street as a complete pedestrian street connecting the City's civic spaces to the harbour foreshore.

- **The full feasibility study, detailed design and commitment from the RTA for construction of the preferred option should be provided to the Department for consideration by the Assessments Branch before any decision is made. In addition, high quality pedestrian access should be guaranteed during the construction period. The Department requests further details of Pedestrian and cycle management during construction.**

2.2 Cycle movement

In relation to cycle links discussions with RTA have indicated that a cycle-only link over the Western Distributor would be expensive and cannot be connected with existing cycleways. It was noted that SCC would undertake to provide an on road cycleway along Sussex or Kent Street to link with the existing cycleway over Pyrmont bridge as part of the CCT project. The Department requests that RTA undertake a proactive role with SCC in this regard.

- **DUAP seeks that the RTA be pro-active in working with Council in constructing high quality (priority) cycleways along Kent or Sussex Streets with safe connections to the King Street cycleway as part of the CCT construction.**

The above route however does not provide for the east to west movement between Oxford Street and Surry Hills to connect the routes provided by RTA as part of the Eastern Distributor to Darling Drive cycle way for further travel to the west. Darling Drive is the preferred route for cyclists travelling west as it avoids the heavily trafficked streets of the CBD. Further, the Market Street viaduct walkway which also served as an alternative cycle route will cease to function as such because the ramped access on the eastern side will be severed by the exits from the western portal of the new tunnel. **The Department requests that the RTA consider the cycling community wishes, to retain the alternative route.**

The proposed alternative route is via Liverpool Street and the existing service road on the south of the Exhibition Centre (UDAS study, February 2001 as amended.

Note: As part of the developing the CCT proposal, the RTA carried out investigation of cycle desire lines with the aim to establish the east to west cycle link parallel with the tunnel route. *Technical Paper No.9-Bicycles* concludes that increasing numbers of cyclists are entering Sydney CBD through Ultimo from Leichhart LGA (page 3, vol 4 Tech paper 9).The cycle counts carried out as part of this investigation indicated that significant usage is already there. Liverpool Street should be considered as an optional route.

- **It is therefore important to preserve the Liverpool Street route as an option through securing a complete signalised intersection of Liverpool and Harbour Street** as per UDAS study, February 2001, Figure 10. It is also consistent with the draft Harbour REP – City Foreshores Strategy to reconnect Liverpool Street on grade to Darling Harbour.

The department requests a timeframe for consideration of these matters with SHFA comments and ultimately an expected completion date for the REF. The Department requests distribution of the REF (as a supplementary to section 7.3.1 of the PAR). to all stakeholders.

Regards

Chris Munro
Assessments Branch

9352 9566

29 May 2001

Ms K Sharman
Project Manager
PO Box 308
Rozelle Bay NSW 2039

Dear Ms Sharman

I refer to the report dated 14 May 2001 titled "Darling Harbour Access Options – Opportunities generated by the proposed Cross City Tunnel to improve access to and across Darling Harbour" which was forwarded to the City for comments.

The report outlines 3 possible options for providing pedestrian links between Central Sydney and Ultimo via Darling Harbour. Each option is relatively direct and involve a combination of at grade and elevated footways.

City Officers have reviewed the 3 options and are of the opinion that Option 3 potentially provides the best pedestrian amenity in terms of safety, comfort and convenience. Having said this, the following comments are made in relation to Option 3:-

DRAFT

- The "Future Connection" at grade footway which is proposed between the northern end of Darling Walk and the proposed Cross City Tunnel entry portal from the Western Distributor must be built as part of the project. As the area is presently "back of house" and a low use pedestrian area, the design will need to incorporate works which enhance pedestrian safety and convenience. In this regard the pathway must be segregated from vehicle activity zones, at least 3.6 metres wide, well supplemented with appropriate wayfinding signage and enhanced lighting.

- Details of the proposed footway across the Darling Harbour "Water Feature" have not been provided. In this regard the treatment must be at least 3.6m wide, wheelchair accessible and implemented concurrently with the construction of the Cross City Tunnel.

- The proposed relocation of the northern most crossing at the intersection of Sussex Street and Druitt Street is not supported. Recent surveys carried out for your organisation indicated pedestrian volumes, in excess of 1000 on weekends over a 12 hour period and more than 3000 on weekdays using the Darling Park Walkway. The relocation (southerly) of the crossing at Sussex Street and Druitt Street moves it away from the natural pedestrian desire line, and as such is not acceptable.

CITY OF SYDNEY
Town Hall House 456 Kent Street Sydney GPO Box 1591 Sydney NSW 2001 Telephone 02 9265 9333 Facsimile 02 9265 9222 www.cityofsydney.nsw.gov.au
ABN 25 [illegible]

Should you wish to discuss or require clarification to any of the issues I have raised, please do not hesitate to contact me on telephone number 9265 9391.

Yours faithfully



Richard West
Manager Transport & Access

FAXED 29/5/01

28 May 2001

Mr Howard Penn
Senior Project Manager
Roads and Traffic Authority
James Craig Road
ROZELLE NSW 2039

Dear Howard

Cross City Tunnel – DARLING HARBOUR PEDESTRIAN ACCESS

I refer to your letter dated 22 May 2001 concerning your three proposed pedestrian access options to address the loss of the Market Street viaduct walkway.

SHFA has considered the options presented, and together with our recent discussions, makes the following comments:

1. The western arrangements shown in Option 3 – 'Harris Street Viaduct Link' are generally acceptable to the Authority, including an at grade connection across the landscape area and water features. The detail of the proposal, including architectural and landscape treatments will need to be the subject of further discussions when more detailed information is available from the RTA.
2. The eastern arrangements shown in Option 2 – 'Underslung' are generally acceptable to the Authority, having the indicated connections to Darling Walk, Harbour, Bathurst and Druitt Streets, with the modification that the suspended walkway be returned to ground level at an appropriate grade beyond the existing 'at grade' car park (next to Darling Walk), ending adjacent to the existing Darling Harbour Information Office. The line and level of this walkway can be further discussed with RTA to allow maximum flexibility during the construction of the Bathurst Street entry tunnel.

Sydney Harbour Foreshore Authority
Level 6, 66 Harrington Street, The Rocks 2000
PO Box N408, Grosvenor Place NSW 1220
Telephone 02 9240 8500 Facsimile 02 9240 8899
www.shfa.nsw.gov.au ABN 51 437 725 177

These arrangements are consistent with SHFA's representations to the RTA as a result of the EIS and offer enhanced linkage between Ultimo and the CBD through Darling Harbour, together with improved flexibility in both program and method for RTA's tenderers.

SHFA would prefer these new pedestrian arrangements were in place at the front end of your construction program to minimise disruption to Darling Harbour as a result of the tunnel construction. This early separation of the pedestrians should also reduce the traffic management issues for RTA's tenderers.

I will await your further comments.

Yours sincerely

Greg Robinson
Chief Executive Officer

CC: Mr P Alward
Mr B Deacon
Mr K Hinds

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SHFA would prefer these new pedestrian arrangements were in place at the front end of your construction program to minimise disruption to Darling Harbour as a result of the tunnel construction. This early separation of the pedestrians should also reduce the traffic management issues for RTA's tenderers.

I will await your further comments.

Yours sincerely

Greg Robinson
Chief Executive Officer

CC: Mr P Alward
Mr B Deacon
Mr K Hinds

APPENDIX L

Assessment of Geotechnical Issues – Pells Sullivan Meynink

Department of Urban Affairs and Planning
September 2001

Department of Urban Affairs and Planning

PROPOSED CROSS CITY TUNNEL
ASSESSMENT OF TUNNEL CONSTRUCTION METHODS AND TECHNIQUES

Report PSM521.R1 September 2001

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1. INTRODUCTION

PSM has prepared this report at the request of the Department of Urban Affairs and Planning dated the 30th May 2001. This report addresses geotechnical and construction aspects of the proposed Cross City Tunnel.

The brief states that "The primary objective of the commission is to provide the Department with an independent assessment of the proposed construction methods to assist in the assessment process and to ensure that high environmental standards are adopted for the project in a cost effective manner."

2. SCOPE OF WORK

The main tasks to be undertaken were outlined in the brief and are:

i. Review the adequacy of construction methods proposed in the EIS and Representation Report with regard to:

- past performances of proposed construction methods and suitability to this project;
- use of best available technology, within Australia and internationally, taking into account practicalities and cost effectiveness;
- predictability of stated environmental performance;
- likelihood of meeting proposed project time frame; and
- an assessment of likely impacts.

The proposed construction methods/locations of greatest interest to the Department are the tunnelling/excavation methods in saturated alluvium and within unusual geotechnical conditions. In saturated alluvium there are likely to be particular concerns about groundwater and the predicability of settlement during construction and potential leakage during operation. When operational there may also be potential limitations on future development in the vicinity of the tunnel.

ii. Extent of identification of requirement for soil/rock anchors.

iii. Potential impacts on existing building structures and other tunnel works/utilities.

iv. Review potential contamination issues and identify whether further studies are required to adequately address contamination issues at the planning approval stage.

v. If necessary, identify possible alternate construction methods with may result in a higher environmental performance considering practicality and cost implications.

vi. Discuss effectiveness of proposed mitigation measures identified in the EIS/Representations Report or other mitigation measures/safeguards and provide further recommendations/conditions if required.

3. DOCUMENTS

We have been provided with the following documents:

- The Cross City Tunnel Environmental Impact Statement and Technical Papers, prepared for the RTA by PPK Environment & Infrastructure Pty Ltd.
- Section 19 of the Representations Report.
- Attachment 1 – Contamination Review for the Cross City Tunnel, City of Sydney.
- Attachment 2 – Final Groundwater Quality Investigation Report – Cross City Tunnel.

Our view of the proposal is based upon these documents.

4. WORK UNDERTAKEN

We have addressed the tasks listed in the Scope of Work by providing the following advice:

A. Are the proposed construction methods

- Appropriate?
- Best available practice?
- If not, can they be improved in a cost effective manner?
- What damage may be caused to third parties, during construction and operations?
- How can this be reasonably controlled?

This advice addresses tasks i, iii, v and vi of the scope of works.

B. Identify requirements for soil and rock anchors.

This addresses task ii of the above scope of works.

C. Review potential contamination issues and identify whether further studies are required.

Technical Paper 10 of the EIS contained section 10 "Preliminary Contamination Assessment". The proponent has provided additional studies (Attachments 1 and 2 in the list of documents) addressing this task. PSM assesses that these documents are adequate for the planning approval stage and that further studies are not required.

5. THE GEOTECHNICAL ENVIRONMENT

The geotechnical environment within which the proposed tunnel is to be constructed is detailed in the EIS and in Technical Paper No 10 (TP10).

Essentially the tunnel will be constructed in good geotechnical conditions within the Hawkesbury Sandstone except near the Western Portals in the Darling Harbour Precinct

and near Riley Street in the Eastern Precinct. The geology along the alignment is shown in a set of figures in TP10. Existing groundwater levels are detailed in section 4.5 of TP10.

Geotechnical conditions in and around Riley Street and Sir John Young Crescent in the Eastern Precinct are of particular note as they represent poor tunnelling conditions. In this area it is expected that the tunnel will be in laminates and shales. Also a paleovalley occurs near Riley Street, the depth of cover over the tunnel is approximately 14 m, of which 10 m consists of fill and underlying soft to stiff sandy clay alluvium.

The Woolloomooloo Fault Zone occurs near the eastern end of the tunnel.

6. THE PROPOSAL

The proposal tunnel is described in detail in the EIS. Typical cross sections are given in figure 7.4. Longitudinal sections are given on figure 7.3 and figures in section 2 of Technical Paper No 5 (TP5) show the proposal in plan.

Drainage and emergency egress are described in section 7.3.2. Sections of the tunnels to be constructed by cut and cover methods are shown on figure 7.23.

It should be noted that figure 7.3 shows the eastbound tunnel along Druitt Street and below the future Metro West rail tunnels and the westbound tunnel along Bathurst Street and above the Metro West tunnels. The rail tunnels are to be located under Kent and Sussex Streets. The figures in section 2 of TP5 show cross passages linking the east and west bound Cross City Tunnels in these same streets. This will require some considerable planning.

7. CONSTRUCTION METHODS

7.1. Description

The proposed construction methods are detailed in both the EIS and in Technical Paper No 7 (TP7). Generally there is more detail in the EIS than in TP7.

The construction is outlined in section 7.7 of the EIS, a construction program is provided in figure 7.22, areas of cut and cover on figure 7.23 and plans of site compounds on figure 7.24. Major items of plant and equipment are outlined in section 7.7.4. Construction methods are outlined in section 7.7.5 and waste management in section 7.8.

Important features of the construction in each precinct are provided in separate chapters of the EIS. The expected rate of progress for a road header excavated tunnel is provided in section 10.3.2.

Generally excavation will be undertaken by road headers. In section 11.3.2 it is stated that *"in areas of very hard rock, ripper dozers and rock breakers would also be used to assist excavation. Because of the noise they generate, rock breakers would not be operated during the night-time period from 6.00 pm to 7.00 am."* Further it is stated in TP7 that drill and blast *"is not expected to be used for this project."*

Construction of the tunnel will not produce a large volume of excavated material. It is stated in section 8 of TP7 that excavated material will be readily consumed as general fill around Sydney.

7.2. Are Construction Methods Appropriate and Best Available Practice?

The construction methods outlined in the EIS are considered to be appropriate. On the whole, the geotechnical and groundwater conditions are very favourable for tunnel construction. The tunnel alignment is complicated by numerous other underground openings. Construction, itself, is complicated by local geotechnical issues, such as the paleovalley described above.

The primary determinants of construction impact are the proportion of cut and cover tunnel and the method of excavation of the driven tunnels. Cut and cover construction is more disruptive than driven tunnel construction. We have assessed the sections of tunnel for which cut and cover is the proposed method of construction. These sections are appropriate in the circumstances.

The EIS advises that the primary mode of rock excavation in the driven tunnels will be by road header. The statements referenced in section 7.1 of this report are taken to indicate that the proponent is willing to exclude blasting from the works. We consider that this is appropriate in the circumstances.

7.3. Identify Requirements for Soil and Rock Anchors

The EIS and associated documents do not provide much information regarding the likely use of rock bolts or soil/rock anchors. We assess that these will be required as roof support in most of the tunnel and, occasionally, as wall support.

In addition, there will be locations at which the wall of the tunnel forms a pillar of rock with a basement excavation on the other side; these locations are identified in the EIS. Throughgoing anchors may be required in these locations. There will be some flexibility in locating these anchors and, therefore, it is unlikely that they would interfere with other services.

8. DAMAGE

8.1. What Damage May Be Caused During Construction?

Tunnelling in the geotechnical conditions in Sydney can cause damage to buildings, services (telecommunications, water/sewerage works, road pavements, etc) and other underground openings (basements or other tunnels). The dominant north south striking near vertical joint sets, means that often damage is localised to the east and west of north-south oriented excavations.

We consider that potential damage due to the Cross City Tunnel could be caused by vertical and/or horizontal strains in the ground due to:

- The excavation and associated stress relief and changes.

- Excavation leading to depressurisation of groundwater and increase in effective stress in soils.

- Construction vibrations.

We consider that all three of these effects could occur in the alluvium/fill in the paleovalley near Riley Street. The second effect is unlikely to be an issue at other locations.

The EIS comments at several places on the settlement and associated potential for damage. Section 6 of TP10 provides opinion that settlement from tunnelling (i.e. the first of the above effects) is predicted to be between 0 and 15 mm. It should be noted that this comment related only to vertical not horizontal settlement.

Settlement from drawdown (the second effect) is estimated to be between 10 and 30 mm in areas that will be affected and that this effect may extend to 100 m from the tunnel alignment. The section concludes that differential settlements are expected to be small. If these settlements are a problem, the EIS states that the settlements might be mitigated by groundwater reinjection or by grouting the sandstone.

TP10 states *"it is anticipated that generally the magnitudes of strain in the rock surrounding the tunnel will be small and are unlikely to impact significantly on adjacent underground structures."*

Most structures in the CBD are expected to be of high sensitivity to damage due to settlement

Further details of predicted settlement and consequences are given in the chapters of the EIS dealing with each precinct.

Darling Harbour Precinct

In section 10.3 it is stated that the cut and cover is generally above the water table and thus settlements will not be effected by drawdown. This section presents an edited set of allowable settlement criteria and compares them with estimates of actual settlements.

Central Precinct

The Central Precinct is the most congested and is discussed at length in the EIS. As for the project as a whole there are good ground conditions. Depressurisation due to drawdown is not expected to be a problem and settlements will be related to stress relief due to excavation of the tunnel. The EIS states that the settlements could be up to 15 mm and should not extend more than 10 to 20 m from the tunnel alignment within competent Hawkesbury Sandstone. The majority of buildings in this precinct would be classified as highly sensitive. The predicted settlements satisfy the criteria for specific structures established for the Airport Rail Link and the Eastern Distributor.

The EIS states that "Such movements are most unlikely to cause structural problems in modern buildings in fair to good condition. However, buildings in a poor condition or heritage buildings that are extremely sensitive to small movements may be affected by ground settlement from the tunnel construction." and *"The detailed assessment of the*

magnitude of stress change and ground movements requires computer modelling. ..... Movements would be expected to be small..."

The tunnels pass very close to building basements; these locations require specific assessment of tunnelling impacts.

In assessing the effect of stress relief due to tunnel excavation on adjacent buildings the EIS and TP10 state *"Experience of basement excavations and tunnels in Central Sydney suggests that about 0.5 and two millimetres of inward side movement typically occurs for every one metre of excavation depth. Typical sidewall inward movement for a nominally six metre high tunnel could therefore be between three and 12 millimetres."* We consider that this is based entirely on monitoring of city basement excavations and may not be true for tunnels.

The EIS suggests that predictions will be made for excavations induced strains in this precinct.

Hyde Park Precinct

The EIS does not envisage any settlement induced damage in this precinct.

Eastern Precinct

Sections of the driven tunnels in the Eastern Precinct are over or within alluvium and fill. The EIS estimates that surface settlement of 10 to 15 mm could occur as a result of ground water drawdown in these areas.

The EIS predicts that settlements in the cut and cover section at Sir John Young Crescent could be between 10 and 30 mm.

Overall the EIS concludes that *"movements would be expected to be small"*.

8.2. What Damage May Be Caused During Operations?

We consider that during operation the primary source of potential damage to third parties is by depressurisation of an aquifer within alluvium or fill. This risk is to existing developments and will be most acute in the period immediately following construction. This risk is isolated to the paleovalley near Riley Street.

Other sources of risk to third parties would be the combined impact of stress relief from the then existing tunnel excavation and new excavations for either basements or other tunnels/services. It is not possible to evaluate this risk without some information on the geometry and location of likely future excavations. The cumulative effect of unknown future excavations is best left to the approval process for those excavations.

We understand that SRA have provided details for the Metro West tunnels and these are shown on the sections in TP5. The proponent will have to take these into account to the satisfaction of the SRA.

We note that sections 4 of chapters 10 to 13 of the EIS – Changes relating to the operation of the proposal – do not address the issues raised above, particularly with

respect to post construction depressurisation or the cumulative effects of subsequent excavations. The conditions proposed later in this report do allow for these matters.

8.3. How Might Damage Be Reasonably Controlled?

8.3.1. The EIS

The EIS appears to make a number of commitments to control the potential for damage from construction and operation of the proposal. These are summarised in general form in sections 5 of chapters 10 to 13 and include, inter alia:

- mitigating impacts of construction vibrations; and
- monitoring settlement and ground strain.

It is important to understand that monitoring something does not amount to controlling it. In fact, some effects can be monitored but not controlled.

There is no clear statement in the EIS setting out the approach to controlling damage from construction or operation of the tunnel. We have endeavoured to third party discern the intent from the documents and summarise it in chronological order as follows:

- **Set criteria**

The settlement criteria to be adopted are the same as have been adopted for the Airport Rail Link and the Eastern Distributor. Those in the EIS are broader than those in section 6 of TP10 which includes angular distortion limits as well. Thus for buildings of high sensitivity the maximum settlement is 20 mm and maximum angular distortion is 1 in 500.

In addition, the EIS states *"Settlement criteria for critical utilities would be determined by the relevant authorities."* In particular, section 6.2.3 of TP10 suggests that the SRA/RAC will set limits of 5 mm maximum subsidence and a strain of 0.25 mm/m for rail assets. We are of the opinion that these limits could be difficult to achieve.

- **Precondition surveys**

Section 4.3 of TP7 states *"Precondition building surveys would be undertaken prior to commencing construction as part of the EMP. The building surveys would document the condition of the buildings adjacent to the construction areas. The building surveys would be used as a reference in the event that vibration from excavation activities causes damage to the adjacent structures.*

The EMP would also identify those tasks that are likely to cause vibration. The EMP would outline how the contractor would monitor vibration levels to ensure no adverse impacts are generated from the construction."

These two paragraphs are contradictory if adverse impacts are considered to include damage to adjacent structures. Notwithstanding this we consider that precondition surveys are beneficial.

- **Further field information**

Section 4.4 of TP10 recommends *"However, for the detailed design stage, further field stress measurements should be carried out along the alignment, particularly adjacent to certain nearby underground structures, so that predictions on ground movement as a result of tunnelling can be carried out."*

- **Analysis**

Section 6.1.4 of TP10 recommends *"Detailed assessment of structures that are considered to be critical or vulnerable should be undertaken during the detailed design phase."*

- **Expected outcome of analysis**

Section 4.6 of TP7 states *"Ground settlement due to either of the above possible causes* (ie stress relief due to excavation or increased stress due to dewatering) *is expected to be minimal."*

- **Install support**

The approach in the EIS appears to be based on the view that it is practical to install support that inhibits the elastic strains associated with stress relief due to excavation of the tunnel.

In section 11 of the EIS it is suggested that appropriate support can be installed to ensure that stress effects do not affect Town Hall Station.

Section 13 of the EIS states *"There is a considerable base of experience concerning the effects of tunnelling in Sydney and the design measures necessary to ensure that ground movements remain within the limits required to ensure that damage does not occur."*

Section 6 of TP10 states *"Where movements are to be minimised, the general approach could be to install a stiff support system immediately on each stage of excavation, ensuring that there is suitable contact between the rock face and support to restrain rock movements"* and *"Appropriate tunnel support methods will then need to be imposed to reduce tunnel movements to acceptable levels."*

It is possible to limit settlements and lateral movements due to dewatering (more accurately depressurisation) by limiting depressurisation. It is possible to limit vertical and horizontal movements due to stress relief cased by excavation of soil. It is not practical, and is practically impossible, to limit the ground strains due to large tunnel excavations in moderately stressed rock. The pressures required are beyond those that can be applied in practice and, even if that were not the case, could not be applied at the appropriate place and time.

- **Monitor**

Section 4.6 of TP7 states *"The contractor would determine the predicted ground settlement, if any, on areas adjacent to the work sites in its detailed design. These predictions would be confirmed, or otherwise, through the monitoring regime in the EMP.*

The EMP would include a plan to monitor the potential for ground settlement. This could utilise ground and building surveys as well as monitoring ground water levels and seepage inflow within the work sites and the excavated tunnel."

- **Vibration**

Vibration limits from blasting to avoid damage to structures are provided in Technical Paper No 18. These are discussed in detail and claimed to be conservative. We are not convinced that the limits are, in fact, conservative. This should not be an issue as rock excavation is to be by mechanical means.

- **Water flows**

Section 4.5 of TP10 states *"It is anticipated that long-term base inflows for the project are likely to be similar to those experienced for the Eastern Distributor tunnel."* These flows are stated to be about 1 litre/second/kilometre of tunnel.

8.3.2. Recommendations

We have considered the EIS and proposed tunnel construction and operation; we recommend the following conditions be placed on the proponent. We have addressed those conditions relating to geotechnical issues; we understand that DUAP has its own advice regarding environmental matters. Almost all the conditions are aimed at limiting third party damage, where foreseeable, to the minimum practical extent. It is impossible to avoid stress relief and associated strains around the tunnel and so our recommendations aim at ensuring the proponent has considered these matters well and undertakes the works diligently.

1. Limit groundwater inflows during operations to 1 l/s/km of tunnel.

2. Undertake a condition survey of buildings (including basements). The buildings surveyed should include at least:

   - All buildings within a plan distance equal to twice the invert depth from the edge of the tunnel.
   - Heritage and sensitive buildings to a distance of 100 m from the edge of the tunnel.
   - Buildings on shallow or unknown footings to 150 m from the edge of the tunnel near the Sir John Young Crescent exit or the western portal.

3. Protect identified utilities to the owner's requirements. The proponent to identify those utilities that it considers "critical".

4. Develop a detailed geotechnical model for the entire route and its environs, this is to identify and include significant geological structures. This model is to include full details of existing and currently proposed excavations near the western portal.

5. Use the above model to assess, preferably by analysis, the predicted settlement and horizontal strain profiles caused by tunnelling. Particular, but not exclusive, regard to be given to the western portal and Sir John Young Crescent.

6. Assess the impact of these predicted settlements and strains on buildings and basements.

7. Monitor the ground vibrations at those structures assessed to be most at risk of damage due to construction activities.

8. Establish and monitor inclinometers and settlement monuments along the tunnel route.

9. MISCELLANEOUS

There are a few miscellaneous matters in the EIS upon which we make comment.

Section 8 of TP10 states *"it will be necessary to impose restrictions on future building and subsurface developments in the zone of influence of the tunnel ... It will also be necessary to establish a corridor on either side of the tunnel in which any further development will need to be approved by the RTA."*

Table 3.1 of Technical Paper No 19 presents a hazard assessment matrix that appears somewhat risk tolerant when compared with that given in Appendix D of the Australian/New Zealand Standard AS/NZS 4360:1995 "Risk Management". Further the high priority risks presented in Section 5 of TP19 appear to be focused entirely on assets with no apparent risk to persons.

10. SUMMARY

The proposed tunnel passes through reasonably well known ground conditions, which, in the main, are expected to be good. Particular attention will need to be given to existing basements, tunnels and services. The area around the paleovalley near Riley Street will present particular problems.

We recommend conditions to be placed on the proponent in section 8.3.2 of this report.

For and on behalf of
PELLS SULLIVAN MEYNINK PTY LTD

G. MOSTYN

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