URBIS

FORBES RESIDENCES

INTERFACE ANALYSIS

MAY 2019

CONTENTS

1.0 THE SITE

The Forbes Residences Project is located at the corner of Forbes and Kishorn Roads in Applecross. The site is located within the M10 zone of the Canning Bridge Activity Centre Plan and interfaces with the M15 zone to the south and the H4 zone to the west. Kishorn Road is a local distributor road connecting much of the Canning Bridge Precinct to the Canning Bridge Train Station and Forbes Road performs a local access street function. Both streets are well vegetated with heavy canopy coverage; like much of the Applecross locality.

2.0 METHODOLOGY

In reviewing the approach to the Forbes Residences we have identified a range of considerations that we believe are relevant to the application for additional height and interface with surrounding lower height zones. Putting aside the need for additional residential housing in well serviced and accessible locations and the desire to meeting infill targets, the approach undertaken focuses primarily on the design interface and ensuring that the proposed additional height is appropriate given its context.

Specifically, this assessment has considered:

- Visual Impact;
- Design Excellence; and
- Height Transition.

In examining the Forbes Residences project and it's interface impact, we have also examined a number of relevant Perth case studies, where similar height interfaces have developed or are developing successfully.

Forbes Active Ground Plane

Cascading Landscape Podium

Forbes Residences podium viewed from Kishorn Road

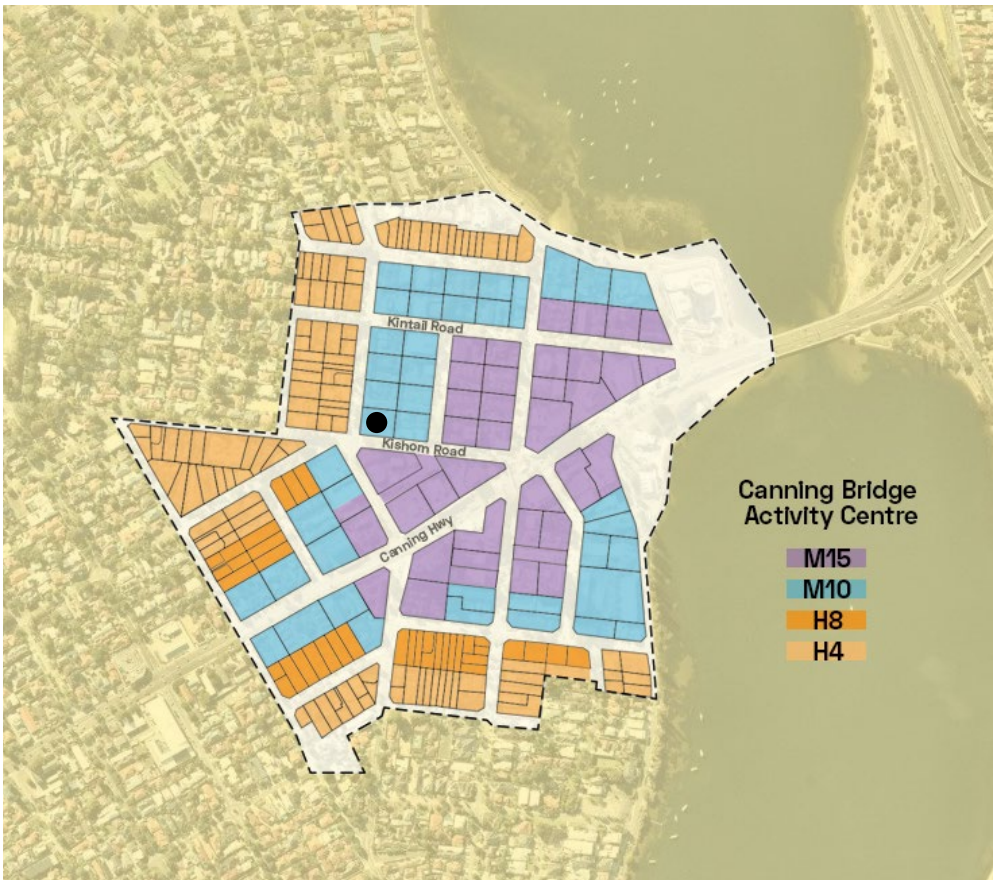
3.0 PLANNING CONTEXT

The Canning Bridge Activity Centre Plan (CBACP) is the framework which was developed to facilitate the transition of the precinct from a suburban and car based environment, into a more efficient, intensive and urban activity centre leveraging from the high amenity, transport infrastructure and proximity to the City, facilitating an additional 20,000 people in 10,000 dwellings and 6,000 jobs.

This Activity Centre plan has been prepared to provide a guide to development of the CBACP area, an area recognised as an 'activity centre' under the Western Australian Planning Commission's State Planning Policy 4.2: Activity Centres for Perth and Peel. The study area comprised the area generally considered a convenient walkable distance from the Canning Bridge bus and rail interchange which is located at the junction of the Canning Highway and Kwinana Freeway.

The CBACP represents a bold and visionary transformation within the precinct over both City of Melville and City of South Perth, with the guiding principle articulated in clause 3.1 as follows:

"The Canning Bridge area will evolve to become a unique, vibrant, creative community centres of the integrated transport node of the Canning Bridge rail station. The area will be recognised by its unique location, its integrated mix of office, retail, residential, recreational and cultural uses that create areas of excitement, the promotion of its local heritage and as a pedestrian friendly enclave that integrates with the regional transport networks while enhancing the natural attractions of the Swan and Canning Rivers. "



The subject site is located within the City of Melville portion (Kintail and Ogilvie Quarters) with a number of significant developments are approved, under construction or completed. These developments range in scale, height and design including Sabina (30 Levels), Cirque on Ogilvie (20 Levels) and The Precinct (22 Levels). The location (on the corner of Kishorn and Forbes) lies between the core mixed use precinct and residential sites with a four storey height limit. There is no height limit imposed under the planning framework, however there is guidance on the ability to provide for height above 10 storeys based on the delivery of community benefit and design excellence.

In accordance with good planning practice, consideration of the site, its context and the future intended function and environment is key. Ultimately we consider the significant contributions made by this development provide suitable justification (in comparative and real terms) for the proposed scale.

4.0 VISUAL IMPACT

There is accepted wisdom on the impact of building height from a street level perspective, that once a building extends above 6 storeys the visual impact becomes less imposing. According to Alois Regel's aesthetic model, the way our eyes read our environment has a near, middle and far perspective. This theory notes that as objects move from the near scale into the middle scale our eyes reduce structures to shading and contrast. In the far perspective, simple colours and forms are the most important. From an architectural sense a streetscape is viewed primarily at the near to middle scale.

This means that the street level is very important to ensure that appropriate detail, activity and energy is applied. As the perspective moves into the middle scale, to the podium and beyond, detail become less critical and the visual perspective reads more about general massing and bulk. The difference at this point between a 6 storey and 20 storey structure becomes less relevant visually as we perceive it as a general mass. Our brains create visual shortcuts that provide a kind of spatial understanding of scale without needing to define a structure as being a specific height, just near, middle or far.

The visual impact of a structure from street level is less about height in meters and more about how we visually perceive it in terms of massing and scale.

There are a number of ways to further reduce this visual impact through the use of podiums and through the introduction of vertical and horizontal elements in the building that provide structure and relief. The purpose of a podium level is to provide an edge that fits in with the human scale at the street edge. A podium is typically at the 2-6 storey range. This establishes a pedestrian scale to the building that is readable at the street level and sits within between the 'near' and middle visual range. A high level of detail and activation is required here.

A podium approach introduces the ability to setback a tower from the street edge. Because of the setback the visual impact of the tower structure is significantly decreased. Instead of reading a 10-20 storey building, the missing middle section that is obscured by the podium bypasses our visual understanding and creates a shortcut that reads the tower as a lower scaled general mass. Through this podium mechanism we can reduce the visual impact of a structure from the street level.

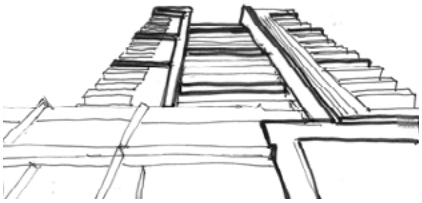
This podium approach to reduce visual scale has been a preferred approach to retain the pedestrian scale at the street level. This approach has been adopted locally by organisations such as LandCorp and the MRA and across local governments such as the City of South Perth, Scarborough, and Victoria Park.

A podium with tower setback can help to maintain the pedestrian scale and offset building heights above 2-6 storeys.

Another effective way to break massing of the structure is to provide vertical and horizontal articulation. By moving away from a solid mass and introducing some push and pull to the structure the visual impact of this articulated edge is reduced. Including depth and shadow within the structure helps to minimise the visual impact of the height of the structure as it provides relief.

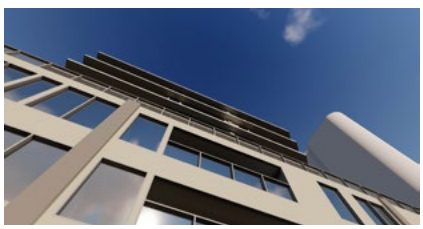
In summary, the actual height of a building differs from the perceived height of a building. **The height differential between a 10, 15 or 20 storey building is less critical than ensuring that the detail in our near perspective at the street level is done well.** When combined with a podium approach the overall massing and scale of a building can be further reduced from a visual perspective.

Figure 1 Example of 1 Harper Terrace, South Perth – View from the street – minimising impact of tower.



- Articulation of the horizontal and vertical façade collapses floors in to segments and reduces visual impact.
- Use of Podium visually reduces the number of floors
- View of tower compresses from the street level.

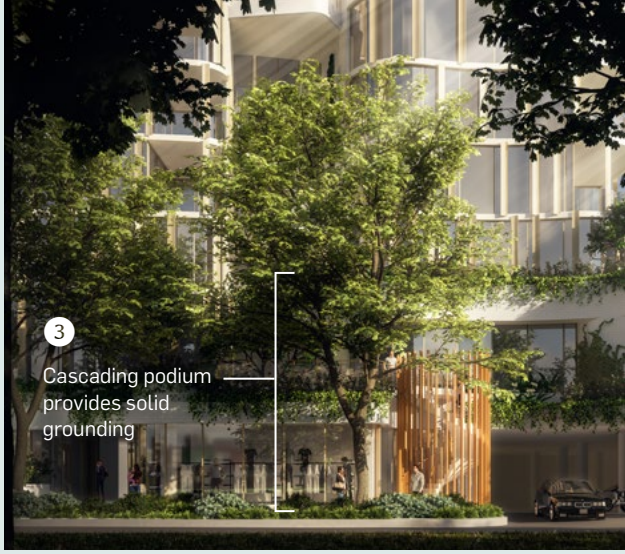
Forbes1 - Proposed building



Forbes2 - Compliant yet unarticulated 10 storey building

2

Significant void interrupts visual building massing



3

Cascading podium provides solid grounding

APPLICABILITY TO FORBES RESIDENCE

The introduction of strong horizontal bands at set intervals (every 3 storeys in this case) reduces the Forbes structure into segments. From a cursory glance, we visually collapse the structure into manageable pieces and read these as single layers, so a 20 storey building broken into seven sections is less imposing. 1

Further visual reduction of the structure has occurred with the inclusion of a significant void on the top third of the building as viewed along the northern and western elevations. 2 This helps to break the building into separate pieces where we read a top, middle and bottom. In this case, the highest levels consists of 5-6 floors that will read as the 'top'.

The bottom consists of a 'cascading' podium' that provides a solid grounding for the building and extends into the 3rd and 4th floors. The remainder of the tower reads as the middle. 3

The introduction of vegetation at the podium level also assists to break up the horizontal lines of the structure and can re-establish a new visual ground plane. The non-linear nature of a vegetated edge visually provides depth and articulation to the horizontal plane. This can now be read as a secondary ground plane. Vegetation on top of this podium edge will also help to further break up the built form of the tower and provide further visual relief against the structure. 4

Finally, the placement of a structure can assist in minimising the visual impact of a structure. In the context of Forbes, the proposed structure itself is located on the inside corner of Kishorn and Forbes Roads, meaning that there are no direct visual corridors on the north-south orientation. The building will sit off the edge of Kishorn Road, which has an extensive canopy that even in autumn and winter, provides a direct visual impediment from street level.

The building is offset from view corridors and will exist primarily in peripheral views from the public realm.

1

Reducing structure mass into manageable pieces visually.

4

Non-linear landscaping provides depth and articulation of horizontal planes to emphasise visual hierarchy of podium.

5.0 BENEFITS OF DESIGN EXCELLENCE

Evidence indicates that the application of a height incentive on a structure that is agreed to have met the definition of design excellence can have ongoing benefits for the site, the broader community and set a tone for future development in a precinct.

Design Excellence in Western Australia has been established by the Office of Government Architect (OGA) to define a level of building quality. This concept is based on successful guidelines from the eastern states. The principle in relational to built form and scale notes that good design ensures that the massing and height of development is appropriate to its setting and successfully negotiates between existing built form and the intended future character.

The Office of Government Architect (OGA's) senior architecture officer Carmel Van Ruth noted in her 2017 article titled *Good Design Is the Foundation of Infill* that development incentives for good design attract developers focussed on better built outcomes for the apartment market.

"Development incentives for good design are not only encouraging better developers, they are incrementally shaping expectations as our apartment market matures."

This suggests that new development in the vicinity of the Forbes site will respond to the new context established and to the design quality of an established project. There is a better chance that future projects adjacent to the site will respond appropriately with a higher quality design output. An additional benefit of the development incentive being granted for additional height includes a higher potential to establish a design quality standard and create a better design outcome in projects in the vicinity.

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The West Australian
Wednesday, November 1, 2017

Good design is the foundation of infill

Bottleyard in Northbridge was designed by MJA Studio for Handle Property Group. Picture: Dion Robeson

STREET WISE

Carmel Van Ruth

Design Review Part one of two.

Perth has witnessed an increase in high-density urban infill proposals as developers respond to a growing market appetite for housing choices in established areas.

These larger developments — typically mixed-use or multi-residential — have a significant impact on the public realm, adjacent development and the surrounding community.

It is important that these developments are well designed. Multi-residential developments accommodate a diverse range of changing occupants and must work well for longer than single houses as multiple ownership limits the ability to alter or redevelop.

More than half of Perth's metropolitan local governments have appointed multi-disciplinary Design Review Panels to offer independent expert advice on the design quality of proposals. Good design can deliver dwellings that offer good levels of amenity, are flexible in their use, cost effective to operate and maintain, and appropriate for their location.

For developers, a well-managed design review offers flexibility to depart from the R-Codes and local policies to deliver improved, site-specific outcomes. Where senior planners can participate in design reviews, solutions can be brokered collaboratively, enabling a smoother approvals phase after endorsement.

Where development incentives are offered for good design, some developers are seeking out designers who have previously earned support for exemplary projects and are granting them latitude to develop innovative solutions to deliver improved amenity. Once the positive built outcomes are realised, these developers are encouraging these approaches in other jurisdictions where the incentives don't apply — market interest and reputational benefits of good design are enough. Development incentives for good design are not only encouraging better developers, they are incrementally shaping expectations as our apartment market matures.

Skilled architects are needed for infill development. These projects are complex endeavours demanding a thoroughly considered design response.

Architects are educated — and then practise — in a culture of design review, and generally welcome the iterative process. Design teams benefit by gaining independent advice and early validation of design approach.

For local governments, having a design review signals a commitment to ensuring new developments make a positive contribution. Panel members can bring knowledge of context, community, history and future direction.

Panels can identify recurring design issues and recommend improvements to policy. Improved design outcomes can ease community concern about infill development.

In the next part of this column, we will examine how to support design review panels and assess Design WA draft policies.

Carmel Van Ruth is a senior architecture officer in the Office of the Government Architect.

Extract from The West Australian, November 1, 2017

APPLICABILITY TO FORBES RESIDENCE

Over a 6 month duration on 3 occasions WOHA and MJA Studio presented the proposal to the City of Melville Design Review Panel.

The Forums enabled consultation with Panel members and saw their inputs for improvement being adopted by WOHA and MJA Studio with a continued strengthening of support that lead to the project achieving exemplary design.

The Panel noted the project achieved an exemplary outcome through a series of design initiatives and approaches listed, but not limited to:

- A design narrative that seeks to embed the project in its cultural, historical and local context.
- An activated and engaged ground plane along with an inhabited and activated podium both of which enhance the streetscape and are arranged within required setbacks.
- A mix of uses, accessible by the public, in the podium for a co-work, commercial and community space.
- Well planned and diverse range of apartments with very high levels of cross ventilation.
- Service and vehicular entries have been minimised and car parking has been concealed underground to allow the ground plane to support and facilitate the pedestrian experience.
- Extensive landscaping at ground as well as throughout the structure, including vertical landscape has resulted in greenery equivalent to 282% of the site area.
- Provision of roof top garden and playground.
- Positive sustainable design initiatives including grey water re-use for irrigation of soft landscaping.

The project developer, Mustera Property Group valued the DRP's statement of commendation in their unabated and visionary translation of the Canning Bridge Activity Centre Plan beyond a baseline development standard.

WOHA and MJA Studio valued the recognition of DRP members who viewed this project significant in raising the bar to development standards within the Kintail Quarter and being a progenitor for future development within the Activity Centre and future development within the State.

6.0 HEIGHT TRANSITION

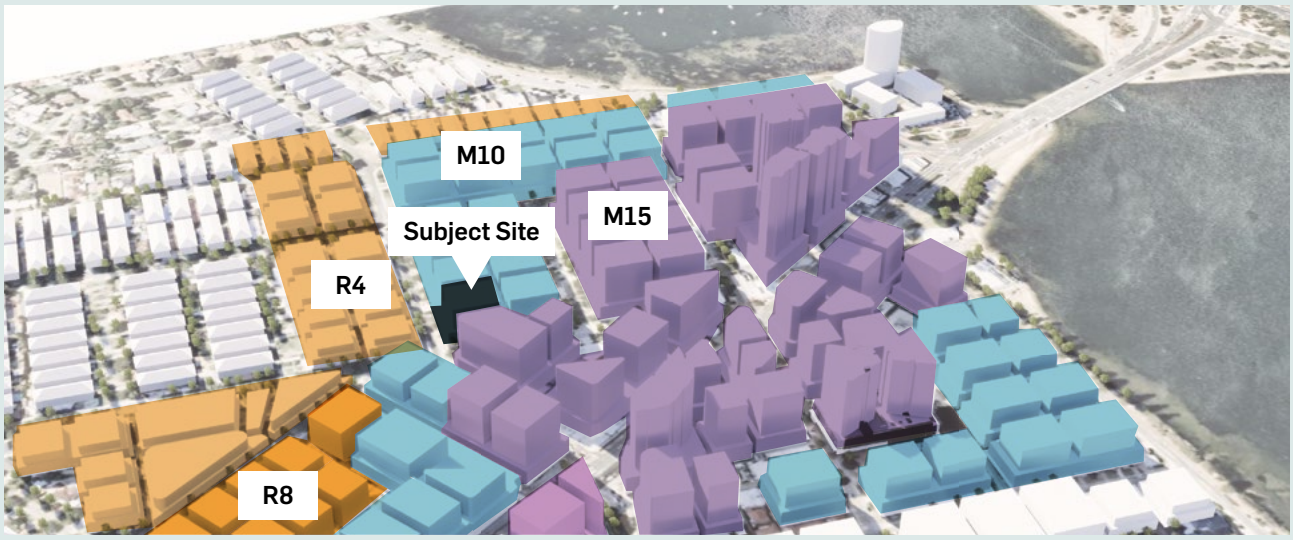
The gradation between zones is important to ensure that the transition isn't too abrupt and uncomfortable for the person on the street. However, it's worth noting that precincts tend to evolve depending on their context. Zones that transition between heights are not an unusual phenomenon in a city. There is always a point where heights of buildings move between scales to accommodate a different range of housing opportunities, dwelling types and land uses. However, the impact of the transition often has less to do with the designated code on a plan and more to do with the context of the site and the quality of the design.

APPLICABILITY TO FORBES RESIDENCE

The existing context of the subject site has a range of 1 -4 storey residential and commercial buildings. The underlying zoning has been updated to enable major redevelopment and sites along Canning Highway and properties in the vicinity are in the process of evolving; however, there are a number of legacy buildings that have not yet transitioned. Whilst there will be a period of incongruity between structures these will evolve with the property market.

The subject site itself sits in the centre of three zones and has many interfaces to address and respond to. The height allowance in the adjacent M15 zone is delivering on residential towers up to 30 storeys on the provision of certain elements required by the Canning Bridge Activity Centre Plan (i.e. community benefit). Internally to the M10 zone the height, it is possible that heights to the 20 storeys proposed by Forbes will be achieved. The transition against the R4 zone (i.e. 20 to 4 storeys) is helped by its location on the other western side of Forbes Road providing both a physical and visual separation. The street layout, vegetation and topography have all been utilised to soften this interface and reduce the visual impact. As outlined in the original Development Application, the project does not impact on the R4 zone from an overshadowing perspective and over-looking requirements of the R-Codes are not applicable within the CBACP.

The transition between these buildings can be addressed through ongoing application of high-quality design/design excellence in architecture; which is likely to occur through the provisions of the CBACP. Further, commonality in built form and material language and the use of vegetation and topography will help to tie the precinct together (a likely outcome in the context of the CBACP and Design Review Panel).



6.1 LOCAL EXAMPLES

Whilst a transition from 30 storeys to 20 storeys to 4 storeys may seem significant, such gradations in scale are not uncommon. We have identified other areas across the Perth that are dealing or have dealt successfully with similar challenges in transition zones. Through this analysis we have identified the following unifying themes that have been applied to Forbes Residence and will apply more broadly to the Canning Bridge Precinct.

Establishing Consistent Form - An example of a transition zone where the height and volume between areas has been done well can be found around Fraser Street in South Perth. In this example there is a marked height difference between the existing structures in the area sitting at around 4 to 6 storeys in the immediate vicinity and a new 38 storey tower at 1 Harper Terrace. However, this structure sits well within its context through the introduction of a 4-storey podium level. The volume of the structure has been deliberately designed to match its context. This creates a direct relationship with the other 4-6 storey structures in the immediate vicinity.

Use of Podium creates a consistent built element that ties new and old buildings together.

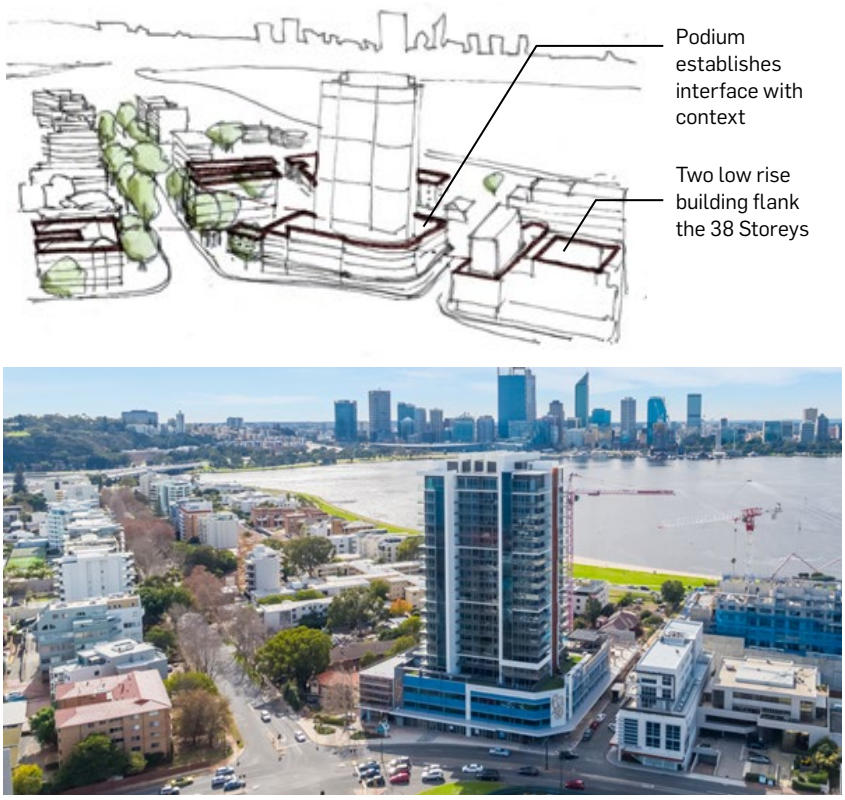


Figure 2 1 Harper Terrace, South Perth; Podium sets the tone for heights.

Nature as Transition- In this Park Street, South Perth example, there is a significant transition between high structures and lower scale buildings. The eclectic mix in this area shows these structures sitting side by side with minimal impact between them. In this case, additional vegetation and planting helps to provide a visual separation between the buildings and makes the transition in height less prominent. The trees in this instance break up the vertical scale and also work to provide elements of transition between the structures.

Street trees and on-site vegetation provides common language and ease transition between sites.

Townhouses, no higher than 3 storeys are adjacent, on both sides, towers over 10 storeys

Buildings at the riverfront are 4 storeys or lowers (except 1), immediately adjacent to more than 10 storey towers

Throughout this entire area there are low rise buildings below 4 storeys, scattered between buildings of a height above 10 storeys

Topography as Transition - This example of the Crawley waterfront shows an eclectic mix of buildings of various heights sitting adjacent to each other. Topography in this area helps to provide some separation of the impacts of height. It is anticipated that when these lower scale buildings are redeveloped that these would be of a similar height and scale but in the interim they sit happily among the taller structures.

Variation in topography provides an opportunity to transition between structures of carious heights.

Common Design Language – This Burswood example illustrates an area that was designed from the outset with a transition between towers and small scale residential. Although the height differential is significant between the two typologies there is a strong design relationship between the structures through the use of materials and the orientation of the structures. Due to the planned nature of the site, when moving through these spaces on the ground the towers do not dominate and don't feel out of place.

Common design language ties structures together regardless of height.

Development surrounding the 5 Burswood towers is all below 4 storeys in height. The tallest of which, is Aurora tower, 21 storeys in height.

7.0 CONCLUSION

The extent of discretion being sought for the Forbes Residences should not be applied to every development within the Canning Bridge Precinct. It is the combination of uses, community benefit, world class architecture and the site's location within the heart of the Canning Bridge precinct that combined should give confidence to decision makers that the height of the building in its context is appropriate. In conclusion, we submit the following:

VISUAL IMPACT

- The visual impact of the 20 storeys proposed by the Forbes Residences is reduced with the introduction of strong horizontal bands that break the building mass up into a variety of segments. The building is collapsed into 7 visually manageable sections, delivering a far less visually imposing structure than a traditional 20 storey building.
- The non-linear nature of the podium landscaping provides depth and articulation of horizontal planes and establishes a new visual ground plane, reducing overall verticality of the building.
- The Forbes building itself is well setback from the Forbes/Kishorn intersection, meaning there are no direct visual corridors on the north-south orientation. The extensive canopy provided to Kishorn Road will provide a soft visual impediment from street level but still provide suitable visual access.

DESIGN EXCELLENCE

- The Forbes Residences has been lauded as "world class architecture" by City of Melville Design Review Panel members.
- It will establish a new benchmark for mixed use apartment buildings not only in the Canning Bridge Precinct but for Western Australia. The project will only encourage better design within the Caning Bridge Precinct.
- The design incorporates 5703m² of integrated landscaping which represents a 180% increase on Design WA requirements and a 282% increase on the Canning Bridge Activity Centre requirements. These soft elements (which will largely be publicly accessible) will set a benchmark in vertical greenspace provision on provide environmental, social and community benefits to both residents and the broader Canning Bridge community.

HEIGHT VARIATION

- The Canning Bridge precinct is currently undergoing a transition to a unique, vibrant and creative community centre and will include higher densities and a mix of uses.
- The Canning Bridge Activity Centre plan facilitates greater height differences elsewhere in the precinct. For example the transition between the M15 and H8 zone on Sleet Road south of the current Norup Wilson Development which equates to a 7 story differential as opposed to the 6 being contemplated here.
- As established earlier, the actual height is less important that the visual perception of the buildings and appropriateness to context. The context of the site is important in ensuring that there is a consistent form and common design language. As an early project, this context will be informed by the design excellence demonstrated in the Forbes building.
- The Forbes Road streetscape canopy consists of established vegetation that provides visual separation for existing residences to the west. The topography and existing streetscape around the site and the integration of vegetation and the stepping of the horizontal elements within the Forbes building ensures that the building is appropriate to the current conditions and will inform the future context.
- Consistency in design language and materiality through Design Review Panel and CBACP requirements will assist in softening height transitions across the precinct.

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BioSEA

Ecology & Biomimicry Design Consultants
www.biosea.sg

Forbes Residences, Perth: Ecosystem service assessment

By Dr. Anuj Jain,

1.0 Methodology

Using the Ecosystem Services Identification & Inventory (ESII) tool (http://www.esiitool.com/), we evaluated the ecosystem services provided by the greenery at Forbes Residences in Perth.

To do this, Forbes greenery was classified into 3 main vegetation types based on the vegetation density and characteristics –

i) Deep Soil plantings – at the ground level. The vegetation characteristic was medium height shrubs (~ 1m) and tall trees (new or existing ones – e.g., *Jacaranda mimosifolia*) with an estimated height of > 10 – 15 m. The total area was 91 m^2.

ii) Planting on structure – throughout the building; multi-layered/cascade plantings with small shrubs at the edges (edge cascade) to taller shrubs and small floral trees (e.g., *Bauhinia sp.*) with an estimated height of 5 – 8m. This vegetation type covered an area of 1320 m^2.

iii) Planting on balcony – We assumed that the level of plantings on the balcony would be at the discretion of the building users. With an area of 1805 m^2, we assumed that a reasonable scenario would be that 20% of the balcony area (361 m^2) would be planted with shrubs of medium height (0.5 – 2 m tall).

Note that vertical plantings contribute minimally to ecosystem services because the woody content of the climbers is low, and the rooting area of the climbers should have been included in the structure planting vegetation layer. Therefore, we a separate layer/vegetation type for vertical plantings was not needed.

In the context of ecosystem services, the total green area of Forbes (assuming the balcony area was 20% planted) = 1772 m^2.

Baseline - Built-Up Suburb

Based on WAPC (Western Australia Planning Commission) guidelines, site area > 1000m^2 should have a minimum 10% of deep soil area. This translates to 202 m^2 of deep soil area for a floor area equivalent of Forbes Residences. The deep soil area in the suburb was assumed to have the same planting typology and composition as the deep soil planting (91m^2 in area) at Forbes.

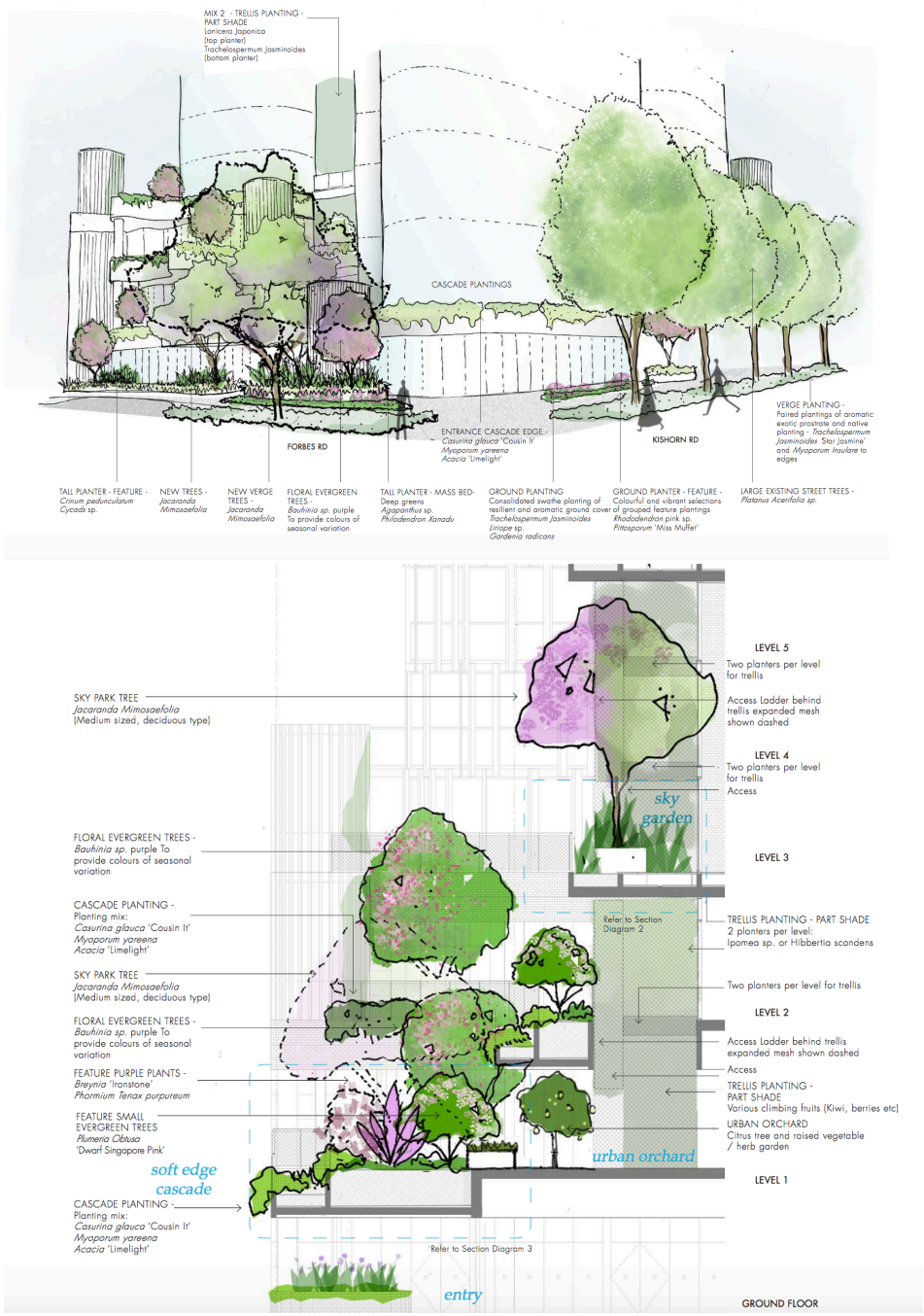

Figure 1 - The different vegetation types at Forbes - i) Deep Soil at ground level, ii) Planting on structure (taken from WOHA's landscape drawings).

ESII tool Inputs – The green areas of Forbes Residences were virtually mapped in the ESII Tool project workspace. Location specific data such as: Latitude, temperature, humidity, precipitation (annual, expected in 24 hours for a 2-year storm event), solar radiation, wind power class, incidental solar radiation etc. were entered. These were obtained from a mix of references such as http://www.bom.gov.au/climate/averages/tables/cw_009225.shtml; Global Wind Atlas (https://globalwindatlas.info/); Global Solar Atlas (https://globalsolaratlas.info/); World air Pollution (https://aqicn.org/search/#q=perth); Global Solar Radiation Data (https://power.larc.nasa.gov/data-access-viewer/) etc.

Natural soil type and conditions were obtained from https://www.agric.wa.gov.au/mysoil and http://www.soilquality.org.au.

The physical site conditions such as vegetation type and height, density, percentage coverage of standing live/dead stems, trunks, aerial cover, soil type/composition, etc. were estimated from landscape drawings and planting list.

Outputs – The tool provided 26 different outputs which relate to 4 types of ecosystem services – provisioning, regulating, supporting and recreational. The most relevant output parameters were provided as percentage performance which were referenced to the ecosystem services of an undisturbed pristine site at Perth's latitude and abiotic (weather, wind etc.) conditions.

The definitions of some of the terms is provided here –

Aesthetics

- *Visual Screening* = amount/percentage of area in which the observers will not be able to see onsite man-made structures due to natural screening (trees, shrubs etc.)
- *Noise Screening* = amount/percentage of area in which the observers will not be able to hear onsite man-made structures due to natural screening (trees, shrubs etc.)

Rainfall

- *Transpiration* = amount/percentage of evaporation of water from leaves
- *Interception* = amount/percentage of precipitation that does not reach the soil
- *Infiltration* = amount/percentage of precipitation that reaches the soil

Heat reduction

- *Reduction Shade* = Reduce the amount of incoming solar radiation due to shading by vegetation

Air Quality

- *Air NOx Removal* = Sequester airborne nitrogen-oxygen compounds through interaction with vegetation
- *Air PM Removal* = Sequester airborne particulate matter in the PM_{10} range through interaction with vegetation

Water Quality

- *Water Nitrogen Removal* = removal of nitrogen-oxygen compounds from water flowing over a site through vegetative and soil filtration processes
- *Water TSS Removal* = removal of TSS (Total Suspended Solids) from water flowing over a site through vegetative and soil filtration processes

Water Runoff

- Total number of litres/cm of runoff that would be expected to come from a site (after interception and infiltration) as the result of a 25-year precipitation event

Amount of Oxygen released

The net oxygen released by vegetation (in kg) is a function of the net carbon sequestered. The ESII tool provided the relative carbon sequestration contributions of the vegetation types (in comparison with a reference forest). The carbon sequestration contributions for the reference habitat, was calculated based on the above and below ground biomass calculations (Wijedasa L., Jain A., et al., unpublished data).

Oxygen released = constant * Carbon uptake % performance (by each habitat type) * Area * (1+ Below ground biomass/Above ground biomass) * Plot-level biomass for forests in Perth.

As a rule of thumb in forestry, the amount of CO_2 released by the vegetation in its lifetime = 3.67 * carbon stored.

2.0 Ecosystem Service Results

Table 1 – Key ecosystem services of Forbes Residences & a Built-Up Suburb in terms of % performance when compared with a pristine forest habitat in Perth of the same size.

Ecosystem Services	Built-Up Suburb	Forbes Residences	Gain (Forbes/Built-Up Suburb)
Air Filtration	8.60 %	45.60 %	530 %
Air Temperature Regulation	11.80 %	34.70 %	290 %
Evaporation	19.70 %	29.10 %	150 %
Transpiration	15.90 %	38 %	240 %
Infiltration	10.10 %	11 %	110 %
Interception	24.20 %	72.50 %	300 %
Visual Screening	4 %	37.10 %	930 %
Noise Screening	4 %	36.90 %	920 %

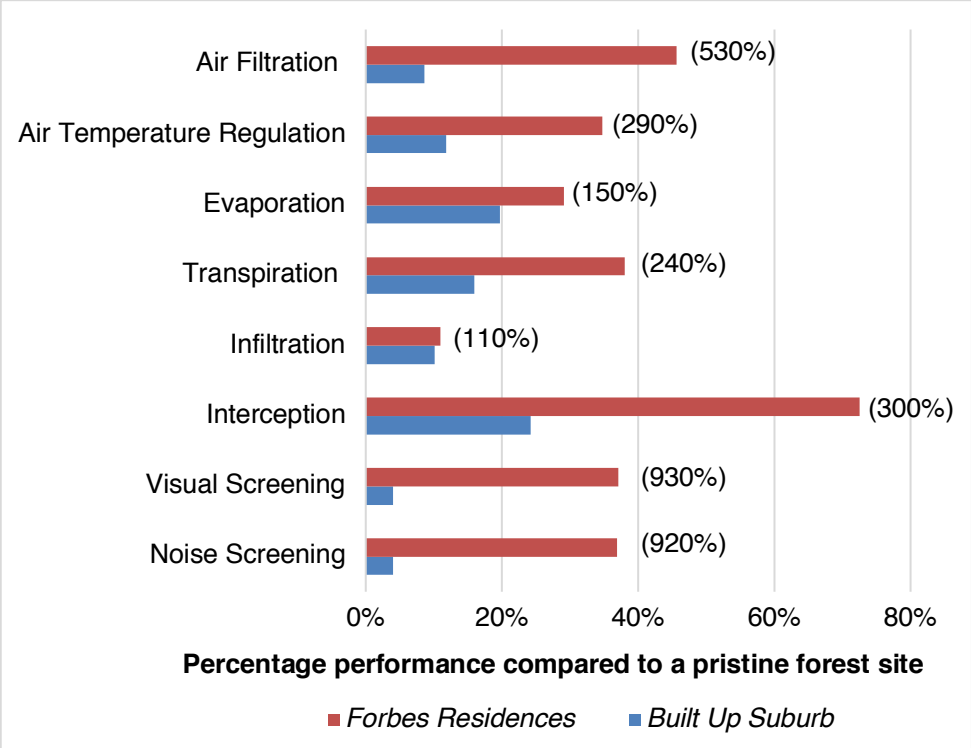

Figure 1 – Key ecosystem services of Forbes Residences & a Built-Up Suburb presented in terms of % performance when compared with a pristine forest habitat in Perth of the same size (derived from Table 1). The percentages in parentheses represent the gain in performance between Forbes Residence and Built-Up Suburb.

By way of example, the values in Table 1 and Figure 1 should be interpreted such that the built-up suburb provides only 4% visual screening as a pristine forest whereas Forbes Residences provides 37.1% visual screening as a pristine forest.

Table 2 - Key ecosystem services of Forbes Residences & a Built-Up Suburb in terms of absolute values

Ecosystem Services (units)	Built-Up Suburb	Forbes Residences	Gain (Forbes/Built-Up Suburb)
Reduction Shade (kW)	58.3	258.9	440 %
Carbon stored (tons)	2.9	17.1	590 %
CO_2 sequestered (tons)	10.6	62.8	590 %
O_2 released (tons)	7.6	45.5	590 %
Air NOx Removal (gm/year)	160	1047	650 %
Air PM Removal (gm/year)	135	886	660 %
Water TSS Removal (mg/litre)	10.5	14.67	140 %
Water Runoff (cm)	8	1.7	20 %
Water Runoff (litre)	161,492	68,669	40 %

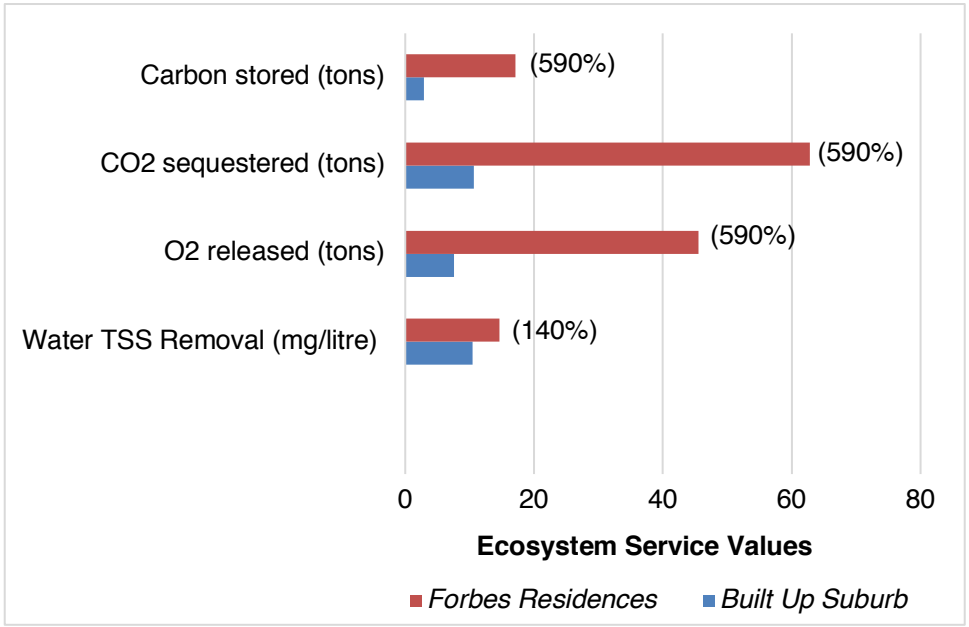

Figure 2 – Key ecosystem services of Forbes Residences & a Built-Up Suburb presented in absolute values (derived from Table 2)**.** The percentages in parentheses represent the gain in performance between Forbes Residence and Built-Up Suburb.

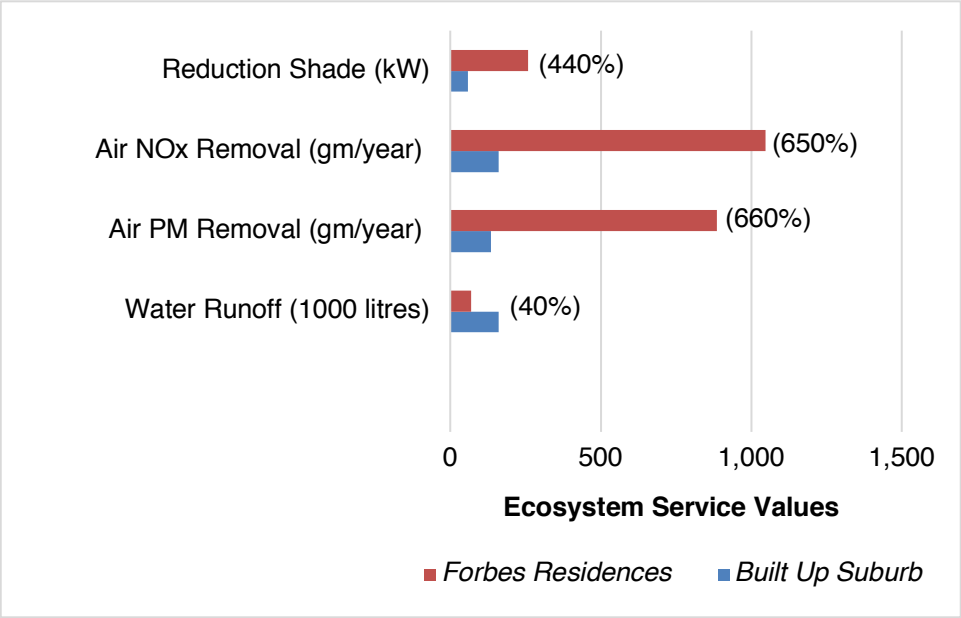

Figure 3 – Key ecosystem services of Forbes Residences & a Built-Up Suburb presented in absolute values (derived from Table 2). The percentages in parentheses represent the gain in performance between Forbes Residence and Built-Up Suburb.

Heat reduction - Impact of shading on temperature

The amount of heat energy reduced by Forbes greenery per unit time as obtained from the ESII tool is –

a) Deep soil plantings = 26.3 kW
b) Structure plantings = 214.2 kW
c) Balcony plantings (20% planted) = 18.4 kW

Total heat energy reduced by Forbes vegetation = 258.9 kW.

A 1-ton air-conditioner (5-star rating) consumes power of 1.1345 kWh. Forbes greenery saves power equivalent of a **228 air-conditioners (1-ton each)** per hour. In contrast, built-up suburb provides for 51 air-conditioners (1 ton each) per hour.

Oxygen released

The amount of Oxygen released by the 3 vegetation types at Forbes over their lifetime are -

a) Deep soil plantings = 3.4 tons
b) Structure plantings = 39.9 tons
c) Balcony plantings (20% planted) = 2.2 tons

The total amount of oxygen released by Forbes greenery (a + b + c) = 45.5 tons.

The amount of oxygen released by the greenery at the Built-Up Suburb = 7.6 tons.

When comparing this with an average adult human oxygen consumption rate which is ~ 306 kg/year or 25.29 tons over its lifetime (given that the life expectancy of a human in Australia in 2016 was 82.5 years; https://www.aihw.gov.au/reports/australias-health/australias-health-2018/contents/indicators-of-australias-health/life-expectancy).

The amount of oxygen released by Forbes greenery (over its lifetime) is equivalent to providing oxygen for **149 adults for a year** or **1.8 adults over their lifetime**. The built-up suburb (over its lifetime) provides oxygen for 25 adults for a year or 0.3 adults over their lifetime.

However, importance of a patch of greenery is far beyond the literal amount of oxygen humans need. A bigger contribution of greenery and the atmosphere for that matter, in terms of oxygen production, is in terms of regulating micro- and macro- climate cycles.

Carbon dioxide sequestered

A Sydney to Perth economy class flight consumes 0.54 tons of CO_2.
(https://www.clevel.co.uk/flight-carbon-calculator/)

This translates to a CO2 sequestered equivalent of **116 Sydney-Perth flights** for Forbes greenery whereas ~ 20 flights for the built-up suburb.

Air PM10 removal
To provide a comparison, the maximum allowed concentration of PM10 in Australia = 25 $\mu g/m^3$ (annual mean). For an air volume the size of Forbes Residences (floor area * height = 2023 m^2 * 91.2 m = 184,902 m^3), 4.623 gm of PM10. PM10 (annual mean) in Delhi, one of the most polluted city in the world, in 2010 was 286 $\mu g/m^3$.

Water runoff
Higher amounts of greenery at Forbes Residences reduces water runoff for Forbes, in comparison with a built-up suburb. Forbes greenery saves runoff equivalent of 92,823 litres (= 161,492 – 68,669 litres) or **~ 4,641 buckets of water** (20 litres each) when compared with the Built-Up Suburb.

Discussion

There were significant differences between the ecosystem service performance of Forbes Residences and the built-up suburb. The latter had comparable performance to Forbes only for infiltration, evaporation and water TSS removal. For the majority of other ecosystem services ranging from heat reduction, carbon sequestration, oxygen released, air filtration etc., the gains ranged from 440% to 660%. The biggest gains (900%) of Forbes vs. built-up suburb were in terms of Aesthetics – Visual and Noise screening. Finally, for water runoffs, the aim is to achieve a smaller runoff value. Forbes runoff is only 40% compared to the built-up suburb.