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OPTIMISING RESIDENTIAL WATER EFFICIENCY – THE JOSH'S HOUSE PROJECT

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ABSTRACT

Josh's House is an innovative housing project in the suburb of Hilton, Western Australia consisting of two 10 Star NatHERS rated homes which are demonstrating a novel approach to the truly integrated design and implementation of residential urban water management supported by a uniquely high profile media campaign for the wider dissemination of knowledge to both the public and industry.

This paper describes the design intent, implementation and commissioning of the water-based components of the project and how its performance is being monitored with both building designs and performance data being made available to the wider community.

INTRODUCTION

Drought conditions experienced in recent years in the southern and eastern regions of Australia have led to the introduction of water restrictions in most capital cities as well as many towns, which in turn has led to an increase in the innovation and dissemination of water conservation technologies and practices including greywater reuse, rainwater harvesting and efficient irrigation equipment. It can be assumed that the greatest potential for water use efficiency will be achieved when there is an integrated approach to the design and operation of these technologies, however a review of the literature indicates that the effectiveness of mains water savings through such an approach is poorly quantified.

The Josh's House Project consists of two 10 Star NatHERS rated affordable homes which have been built in suburban Perth using readily available construction materials and being built to an average residential construction timeline. The homes have been designed to maximise the integration of climate sensible design, energy efficiency and water efficiency. Through this careful design process the homes are expected to meet exceptionally high energy (90% grid energy reduction) and water efficiency (60% mains water reduction) criteria, while meeting the average Australian building budget. The homes have also been designed intentionally for ease of replication by industry.

The home of Josh Byrne and his family incorporates sensors throughout the building in order to monitor and measure all aspects of the building's performance. This includes the home's thermal performance, local weather, energy and water consumption in and around the house and provides a real life living laboratory.

Josh, who is one of Australia's iconic television presenters on sustainable living, will review and communicate the data and performance of his family home over a three year period as part of a research project on high performance housing in conjunction with the CRC for Low Carbon Living. By collating these extensive data sets over three years, the daily and seasonal trends will be fully evaluated as well as the effects resulting from a growing family. The experience is currently being documented at *www.joshshouse.com.au*

The integrated water system design incorporated in the Josh's House project takes the Mains Water Neutral Gardening model explored previously by the author (Byrne, 2013), to the next level in terms of water efficiency and savings, data monitoring and analysis, and the dissemination of this information. Whilst numerous modelling exercises and projections of potential water savings have been undertaken, limited studies analysing actual quantitative savings of integrated water systems at the single residential scale exist. This work seeks to contribute to this gap in the research and build on previous research by the author which demonstrated that typical household mains water use could be reduced by around 40% simply through the incorporation of effective greywater reuse and rainwater harvesting, whilst still sustaining a healthy and productive garden (Byrne, 2012).

Western Australia's population growth is reflected in its real estate and housing construction industry with the average weekly number of housing lots sold in WA doubling from 100/week early in 2012 to approximately 200/week in late 2013 (UDIA, 2013). This represents a current annual total of 10,000 lots sold at an indicative average sale price of between \$200,000 to \$250,000. New dwellings for the two full years 2012 and 2013 were 20,190 and 24,000 respectively with 23,660 new dwellings forecast for 2014 (HIA, 2013). Total 'dwellings' on average consists of approximately 80% single residential and 20% multi-unit constructions. WA represented approximately 16% of the total 151,500 new dwellings started nationally (HIA, 2013).

From the perspective of residential scheme water consumption this rate of new dwelling construction represents a total annual increase in demand of some 5.5-6GL assuming typical annual Perth residential demand of 227kL (WCorp, 2010). This aligns with the Water Corporation's medium to long-term demand projections which show an estimated increase in demand of some 230GL between 2008 to 2060 or an annual average increase of 4.4GL (WCorp, 2009). In addition to this scheme water consumption is the estimated annual volume of groundwater currently taken up by residential bores of some 114GL (WCorp, 2009). On 2008 figures total residential scheme water consumption was 286GL/yr making a total of 400GL/yr of water from both sources.

At 2008 the average total Perth water (scheme) use per person was 147kL (WCorp, 2009) of which residential water use averages 106kL/person/year, a figure which has been steadily decreasing due to increasing dwelling density and water efficiency measures. For example, targeted State-wide initiative such as the Water Corporation's 'HomeSmart' Community Based Social Marketing (CBSM) household water conservation program have demonstrated that savings of up to 12% in residential water consumption are possible with a concerted and sustained effort (Anda *et al.*, 2013). The latest Perth Residential Water Use Survey (WCorp, 2010) showed the average water (scheme) use per person was 106kL of which 56kL was indoor use with 46kL on outdoor use (irrigation 44kL).

The WA State Water Plan (WA Govt, 2007) has set a target of less than 100kL/person/year as the goal for on-going water efficiency measures including not more than 40-60kL/person/year of scheme water. It states that this will "require current outside watering practices and other improvements in household water use efficiency to be maintained and improved". In addition it proposed a long term (now 2030) wastewater recycling target of 30% of all wastewater.

The most recent Australian Bureau of Statistics data (ABS, 2013) indicates that in 2013 in WA rainwater was used as a source of water for only 12.1% of households, the lowest rate of all the states, for example compared to SA at 45.5%, NSW at 19.3%, Vic. at 29.5%, QLD at 33.9% and Tasmania at 22.4%. Water efficient fixtures are now well embedded in the majority of Australian homes with approximately 62% of all homes having water-efficient shower heads, 85% having dual flush toilets, although only 34% are reported as having front-loading washing machines.

WA is unique with respect to all other Australian capital cities with regards to local groundwater availability which is reflected in the number of residential bores, used exclusively for garden irrigation, estimated as over 141,000 in Perth, approximately a quarter of all Perth homes. The next highest is Sydney with approximately 11,000 in total, followed by Melbourne with 8,000 and then Brisbane with 3,400 (no data available for Adelaide, Canberra, Darwin or Hobart). Despite this high penetration of an alternative water source for garden irrigation in Perth, mains water accounts for over 70% of all other garden watering needs. Indeed approximately 40% of all Perth's mains water residential consumption is used for domestic irrigation (WCorp, 2010). The high degree of intrusion that garden/lawn irrigation makes into the overall residential demand is a unique feature of Perth's suburban landscape and this makes it difficult to compare to research undertaken on the eastern states such as by Beal and others (Beal *et al.*, 2011). This is also compounded by the distinctly Mediterranean climate that Perth enjoys and the associated rainfall pattern with respect to efficacy of rainwater tanks.

Greywater accounts for less than 3% of households in Perth which use greywater for irrigation. Nationally the average across all capital cities is 7.3% although this also includes recycled water generally (ABS, 2013). The impact that greywater reuse may make in the average total household water consumption is not straightforward (i.e. increased water efficiency means reduced greywater volumes) and is a function of the extent of in-house water efficiency appliances and occupant behaviours in addition to regulatory requirements (Byrne *et al.*, 2008).

On-site water and wastewater systems are simple decentralised systems which contrast with large scale centralised schemes. While the many potential benefits of decentralised systems are widely known "knowledge on optimal design and management practices is still developing" (Sharma et al., 2013). This project is looking to substantially add to this knowledge gap.

METHODOLOGY

Design Intent: Water Systems

The design criteria of a 60% reduction in mains water consumption is to be achieved through the integrated design of water efficiency, alternative lot-scale water sources and greywater reuse. Both homes are connected to the mains water supply and share a common bore. All surplus rainwater and stormwater is infiltrated onsite through a combination of permeable surfaces and soak wells. While water consumption is minimised, it has not been at the expense of its landscape, which includes attractive shade trees, a productive common garden in addition to private garden areas, and play spaces for children.

The principal water saving systems and the estimated per person mains water savings attributed to these are:

- Water efficient appliances, fixtures and behaviour: 32kL/year/person
- Rainwater harvesting: 24kL/year/person
- Greywater reuse: 12kL/year/person
- Borewater use: 22kL/year/person

These systems and the estimated scheme water savings are described in the following.

1.Water Efficient Appliances and Fixtures

Water efficiency inside the house consists of selected 3 star (WELS) shower heads and 4 star (WELS) kitchen and vanity basin tap ware. The main household toilet is 5 star (WELS) rated and includes an integrated hand basin for hand washing with clean water as it refills the toilet cistern. The dishwasher and washing machine have also been carefully selected to have high water efficiency. The estimated scheme water saving is 32kL/year/person based on an estimated 30% reduction compared to typical Perth per person consumption, assuming a 15% reduction will be achieved through water efficient hardware and a 15% reduction through water efficient behavioural practices.

2.Rainwater Harvesting
Each of the homes has been fitted with a separate rainwater tank to collect the rainwater from the entire roof area, which is approximately 200m^2 per dwelling. The principal house for this study house is fitted with a 20,000L water tank and is expected to meet the demand for all internal purposes for about eight months of the year, based on Perth's rainfall. The nominated tank volume was deemed to be optimal as the result of a supply-demand modelling exercise, with increasing size bringing a diminishing return in terms of yield per increased unit of storage. During dry summer months the tank will typically be empty and the water supply will automatically switch to mains water.

Rainwater is supplied to the house via a domestic pressure pump and a Watermark approved mains water backup valve to switch between rainwater and mains water. These are located in a cabinet along with the necessary isolation valves, back flow prevention devices, cartridge filter, UV disinfection lamps and water meters for tracking both rainwater and mains water usage. A 90L pressure tank has also been fitted to reduce pump start-ups when drawing small volumes of water. The water used for drinking and cooking passes through an additional 0.2 micron cartridge and carbon filter at the point of use to remove any odours and impurities. All piping, water outlets and taps are clearly labelled as 'RAINWATER' to comply with AS/NZS 3500:1 Plumbing and Drainage Standards.

Modelling undertaken internally based on recent Perth rainfall records, as well as estimated internal water demand, an allowance for runoff losses and available storage has determined an estimated scheme water saving of 24kL/year/person.

3.Greywater Reuse
A locally supplied and nationally approved greywater diversion device with automatic backflush for reduced maintenance has been installed to each house to provide a restriction free fit-for-purpose water for garden irrigation. The systems include a top-up arrangement via bore water to a greywater drainage disconnection gully (DG) with an air gap for periods when the houses may be vacant. Greywater is applied at a maximum rate of 10mm of water per day over an of 40m^2 of garden incorporating fruit trees, shrubs and other ornamental plantings in accordance with the state health department guidelines (DoH, 2010).

An associated outcome from this project has been the development of residential greywater-ready guidelines as information regarding the plumbing requirements to enable new homes to be built greywater-ready was an identified gap in the industry. These guidelines are now publically available (JBA, 2013).

An estimated scheme water saving of 12kL/year/person has been determined based upon the displacement of a proportional amount of scheme water which may have been used according to the mandated two day per week watering saving measures and winter irrigation ban that is in place for mains water users in Perth (DoW, 2014). The volume of greywater actually applied is far greater, however for the purpose of a true assessment of the ability of alternate sources to reduce typical mains water demand, an equivalent figure to match an irrigation schedule of two day per week for nine months of the year has been used.

4.Bore Water Use
Groundwater is supplied via an onsite bore in order to provide an appropriate fit-for-purpose water source for garden irrigation (where greywater may not be appropriate) as opposed to relying on constrained scheme water. The bore has been located in a non-trafficable section of the driveway and goes down 30m to tap into the superficial aquifer. This bore water irrigates the vegetable garden, turf, and greenhouse hydrozones, as well

as native garden areas for establishment. Garden taps are also connected to the bore for hand watering and other outdoor water uses.

An estimated scheme water saving of 22kL/year/person has been determined based upon the displacement of a proportional amount of scheme water which may have been used according to the mandated water saving measures as outlined above.

5.Stormwater Use
All stormwater on site is recharged to the local shallow aquifer via directing excess rainwater into soak wells, the use of permeable surfaces and a winter dampland soak feature. The shared driveway for example consists of a lightweight recycled plastic drainage cell overlaid with a geotextile and gravel to allow infiltration with no overland flow off site.

A plan view of the overall Josh's House project site with associated surface treatment areas is provided in Figure 1.

Design Intent: Meters, Sensors and Monitoring

The performance of Josh's House will be monitored over a three year period with an integrated monitoring system that is now operational.

This includes sensors to monitor local weather conditions such as temperature, wind, humidity, rainfall and solar radiation; internal room temperatures, as well as concrete slab, ceiling, roof cavity and roof surface temperatures; metering of all water sources (mains, rainwater, greywater, and bore); as well as gas and electrical supply (grid and rood top PV system) and their respective sub metered usage. This will enable a detailed thermal and operational energy footprint to be determined for the complete site, including the energy footprint of all water supplies for example, thereby informing the performance of best practice sustainable design to be analysed and reported.

Design Intent: Knowledge Sharing Platform

A key objective of the project was to help inform both the public and building industry by providing transparent and freely available access to all building plans, designs and performance data that is obtained over the three year monitoring phase. This has entailed an on-going comprehensive media program which has documented the entire building process and has included:

- A dedicated website hosting building plans, videos and factsheets at www.joshshouse.com.au
- Regular coverage on the national ABC television Gardening Australia program
- A widely publicised industry launch held in July, 2013; and an inaugural public open day in September 2013, with further events planned
- Platform for the launch of the Residential Greywater-Ready Plumbing Guidelines which is an industry first, developed by Josh Byrne & Associates in conjunction with the Water Corporation

The success of the community and communications program has been tracked and reported from website hits and document downloads, online video views, book and DVD sales, as well as audience and attendee numbers at workshops and Open Day events.

RESULTS

Commissioning of the integrated monitoring system is currently underway with preliminary data now available. While thermal and power consumption data has been available since November 2013, commissioning issues with the data logging system has meant that water consumption data is more limited. Table 1 provides the average household (four persons) power and water consumptions over a 32 day and 12 day period respectively. Figures have been adjusted according to house occupancy where relevant. It is anticipated that the average bore water consumption will decrease as the garden becomes established and longterm monitoring will refine the accuracy of these initial consumption figures.

Table 1: Josh's House Typical Daily Water and Total Power Consumption (ranked in order of increasing power use)

Circuit	Power Use (kWhr)	Water Use (L)
Greywater pump	0.60	143
Oven	1.00	NA
Rainwater pump	1.27	248
Bore pump[#]	1.70	351
Lighting and fans	1.98	NA
Appliances	3.99	NA
TOTAL	10.54	742

Indicative daily average based on data to date when annualised

Media and Industry Engagement

The success of the community, industry and communications program has been tracked and reported from website hits and document downloads, online video views, as well as event attendance numbers. Key metrics at the time of writing this paper (March 2014) are as follows:

- Visits to the Josh's House Website totalled 213,721
- Josh's House Building Plans have been downloaded 16,047 times, Sustainability Feature Plan 9,118 times and Landscape Plans 7,200 times
- The Josh's House videos have been watched 31,309 times
- Inaugural Open Day approximately 4,000 visitors

DISCUSSION AND ANALYSIS

It is expected that above average bore-water use will be recorded in the initial six-twelve months post-construction due to garden and landscape establishment, as is the case with most new homes. After this period a return to a longer term stable, but seasonally varying, ex-house water demand is anticipated. These effects will be quantified over the full three year monitoring and reporting period.

Total electricity use is currently averaging 10.5 kWhrs a day in a four-person house, with average daily solar power generation at 20 kWhrs per day, from the 3kW roof mounted grid connected photo voltaic system, which means the house is currently producing nearly twice the amount of power it uses. Of the 3.6 kWhrs/day of power used for the supply of alternate water sources, bore water pumping represents approximately 50% (1.7kWhr/day), rainwater pumping 35% (1.27kWhr/day) and greywater 15% (0.6kWhr/day) respectively. These relative percentages of total power demand match the projected scale of magnitude of scheme water saved as illustrated in Table 1 and will be scrutinised in more detail as data comes to hand.

Research undertaken as part of the UWSRA by Tjandraatmadja *et al.,* (2012) indicated average mains water savings from plumbed rainwater tanks in the range of 40-58kL/hh/year with a specific energy consumption of approx 1.5kWhr/kL. They noted a range of important factors which can significantly impact this amount/efficiency including a mismatch between rainwater end uses and pump operating requirements and pressure storage vessels, in particular.

Monitoring of the energy usage associated with similar greywater and rainwater systems by the author (Byrne, 2012) indicated an approximate energy demand of 0.5 kilowatt hours per kilolitre (kWh/kL) of greywater supplied and 2.5 kWh/kL of rainwater supplied. It should be noted that the energy intensity of both these systems is well below that of large scale desalination plants which typically operate in the range of 3.5 – 4.5 kWh/kL of water produced (Hauber-Davidson & Shortt, 2011).

Interestingly the WA Water Corporation report a whole of utility electricity consumption per unit of water and wastewater of 1.70 and 0.8kWhr/kL respectively (WCorp, 2013 Annual Report) in what is a large scale centralised scheme. Desalination is reported as being of the order of 4kWhr/kL and will provide approximately 50% of Perth's drinking water in 2014 (WCorp, 2013).

Issues surrounding pump operation for the greywater and rainwater systems in particular will need to be further analysed in order to optimise energy savings and provide robust data on the embodied energy and carbon footprints of these techniques.

CONCLUSION

It is assumed that the greatest potential for water use efficiency will be achieved when there is an integrated approach to the design and operation of water-based technologies and systems, and the Josh's House project will provide valuable insight into the mains water savings which can be achieved over its three year intensive monitoring period.

On-going monitoring of the building and landscape's overall water performance, including energy efficiency of the homes, will confirm the water savings achievable and allow for future design improvements to be adopted by the residential building industry. The embodied energy relationships for all the water and wastewater streams will be derived enabling quantitative comparison with business-as-usual residential systems and practices.

The high profile nature of the project is raising awareness nationally as to the potential scale of water efficiency that can be achieved in the residential building industry without sacrificing building thermal performance, aesthetics or landscape amenity and productivity. It is anticipated that through the wide-reaching media campaign there will be a substantial increased demand for, and greater uptake of, best practice water efficient housing design at scale.

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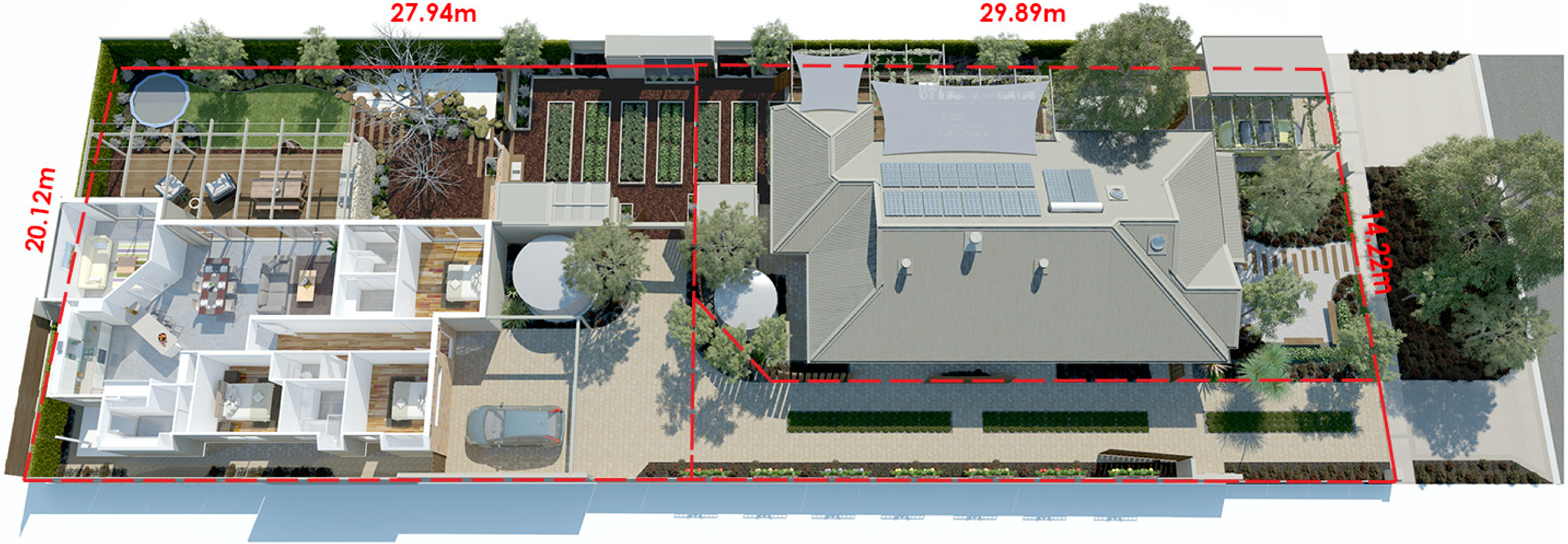

Josh's House - Rear Lot - Site Area	563 msq	100%
Rainwater harvesting Catchment	234 msq	42%
Permeable Surfaces	329 msq	58%

Figure 1: Plan of Josh's House Project Site and Surface Treatment Areas