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GREEN SQUARE: PROTECTING COMMUNITIES AND ENABLING URBAN RENEWAL THROUGH EFFECTIVE FLOOD RISK MANAGEMENT

THE CULMINATION OF A STRATEGIC ALIGNMENT BETWEEN CITY OF SYDNEY AND SYDNEY WATER TO PROVIDE FLOOD PROTECTION IN THE GREEN SQUARE AREA

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ABSTRACT

The Green Square Stormwater Drain (GSSD) is the culmination of a strategic alignment between City of Sydney and Sydney Water to provide flood protection in the Green Square area. Through a complex process of optioneering and hydraulic analysis, a new 2.5 km long underground drain consisting of multiple 1800 mm diameter pipes was installed by microtunnelling. The new drain augments the existing trunk drain system and reduces flood hazard, allowing Australia's largest urban renewal project to proceed.

INTRODUCTION

Located about 3.5 km south of the Sydney CBD, the Green Square urban renewal area is Australia's largest urban renewal project, delivering significant economic benefits, including 30,000 residential dwellings housing 60,000 new residents and catering for a permanent workforce of 20,000 by 2030. The population density in Green Square will be 50% higher than Pyrmont/Ultimo in inner Sydney, which has the highest current population density in Australia.

Total urban renewal development costs are forecast to exceed $14 billion and the "total realisation value" will be around $25 billion.

The Green Square Town Centre (GSTC) is located at the heart of this urban renewal area. Prior to development, this area was part of a series of ponds, swamps and creeks that drained through to Botany Bay via the Botany Aquifer and the Cooks River.

Urbanisation changed the hydraulic character of the area, from a natural water reservoir and waterway corridor to an area of hazardous flash flooding.

Under existing catchment conditions, DRAINS and TUFLOW numerical modelling predict peak flood depths in excess of two metres at the Joynton Ave boundary of the GSTC, and up to one metre at the main transport interchange on Botany Road, for the 1% AEP (annual exceedance probability) event. These models also predict flooding of the underground Green Square Railway Station.

As old industrial land gives way to modern high density development, these existing flood hazards needed to be resolved to protect a growing community. Sydney Water and City of Sydney share stormwater management responsibilities in the Green Square area under a complex ownership arrangement.

Sydney Water is the owner and manager of the "trunk" drainage system, while City of Sydney owns and manages the "local" drainage system.

Effective flood risk management required close collaboration and strategic alignment to arrive at a trunk drainage solution that meets the key project objectives of ensuring community safety during floods and enabling urban renewal.

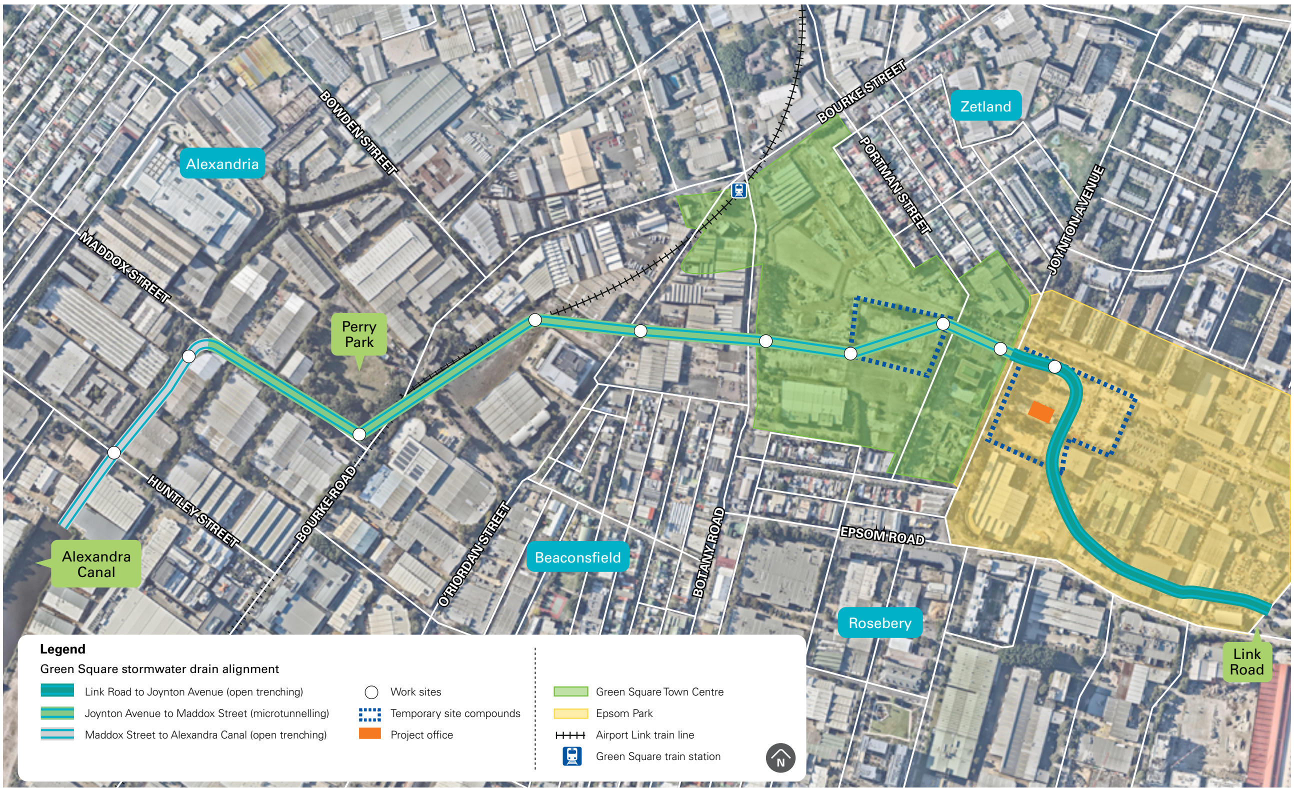

Figure 1. Overall plan of GSSD

The preferred solution involved the installation of 2.5 km of new conduits with the specific aim of reducing high hazard flooding to low hazard in the 1% AEP flood.

In addition to reducing flood risk, the project assists in realising broader benefits by incorporating stormwater treatment measures, facilitating the GSTC non-potable water recycling scheme, and implementing critical sections of the City's regional cycleway for southern Sydney.

With flow capacity of almost 30 cumecs and a capital value of $100 million, the GSSD is the largest brown-field urban drainage project in Sydney for 30 years. The City of Sydney, Sydney Water and NSW and Australian Governments are jointly funding the project. The project presented many technical, logistical and community related challenges from solving complex hydraulic issues to installing large conduits in heavily built-up areas with extensive services clashes and potential major traffic disruption.

The proposed trunk drain interacts with the local sub-surface drainage system and the ground surface so therefore required extensive 1D and 2D modelling as well as Computational Fluid Dynamics (CFD) and physical modelling of local drainage inflow structures, to ensure the finished system will meet the project objectives.

To meet the construction challenge, minimise the social impact and minimise cost the Drying Green Alliance (consisting of City of Sydney, Sydney Water, WSP Parsons Brinckerhoff, Seymour Whyte, UGL and RPS Manidis Roberts) adopted a design and construction method that uses tunnel boring machines to install 1800 mm diameter pipes in long runs (known as "micro-tunnelling") well below street level.

FLOOD RISK PLANNING

Flood risk planning for Green Square was jointly undertaken by City of Sydney and Sydney Water through a committee of State and local agencies, community members, elected representatives and specialist consultants, and guided by the NSW Government's Floodplain Development Manual. The planning process culminated in a recommendation to upgrade the existing trunk drainage system with new twin box culverts to remove high hazard flooding in and around the new Green Square Town Centre.

This recommendation followed extensive optioneering and was based on a combination of hydraulic modelling and other supporting investigations.

The alignment of the new trunk drain was mostly contained in existing or future roads or land owned by City of Sydney and Sydney Water. Design and construction of the GSSD was awarded to the Drying Green Alliance following a competitive alliance process. Two alliance consortia were short-listed on their respective concept designs and total out-turn costs based on the provided reference design and hydraulic models.

The Drying Green team developed an alternative design that used micro-tunnelling of twin and triple reinforced concrete jacking class pipes in parallel instead of open trenched box culverts.

DESIGN

The hydraulics of the proposed system differed significantly from the reference design, which assumed box culverts running not more than 80% full.

The adopted system transitions from part-full to full and pressurised depending on the flow and tail-water conditions. Areas that required special attention were:

- structures with large lateral and plunging local drain inflow
- the two to three pipe transition structure
- air transport and blow-back potential as the system transitions from part to full flow
- interaction between the trunk drain hydraulics and the local surface drains and flooding
- the confluence of the new trunk drain with the existing main open channel
- the existing twin culverts crossing Huntley Street
- the twin gross pollutant traps on the new trunk drain
- potential mobilisation of sediments in Alexandra canal where the GSSD discharges

The alliance method of delivery allowed a wider project team to be involved in identifying and evaluating options to ensure the infrastructure delivered provides the greatest benefit and value for the community. The trunk drain design relied on computer simulation of the catchment hydraulic behaviour above and below ground.

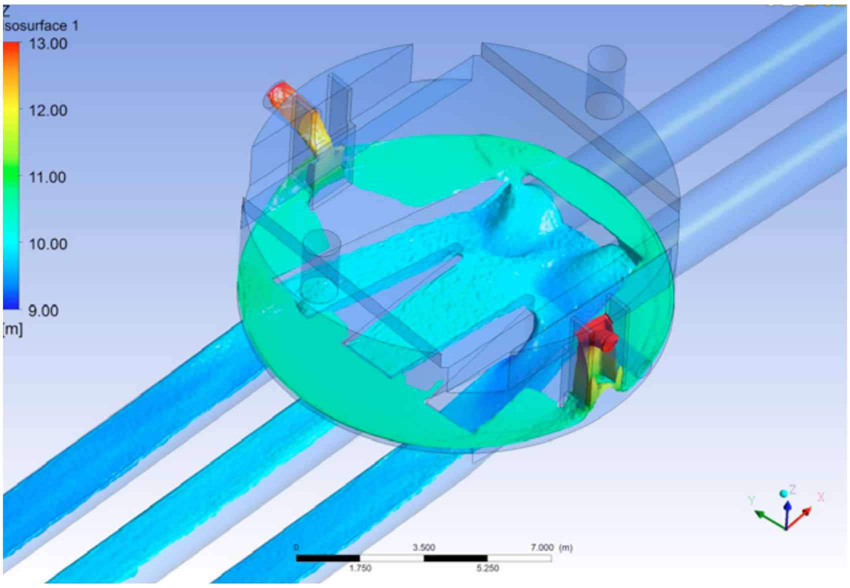

Figure 2. CFD model – three-pipe to two-pipe transition, water surface

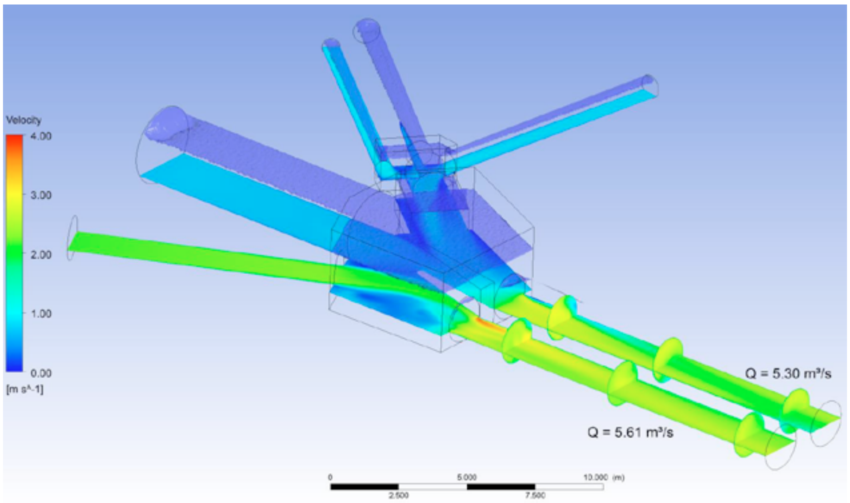

Figure 3. CFD model – upstream connection structure – velocity

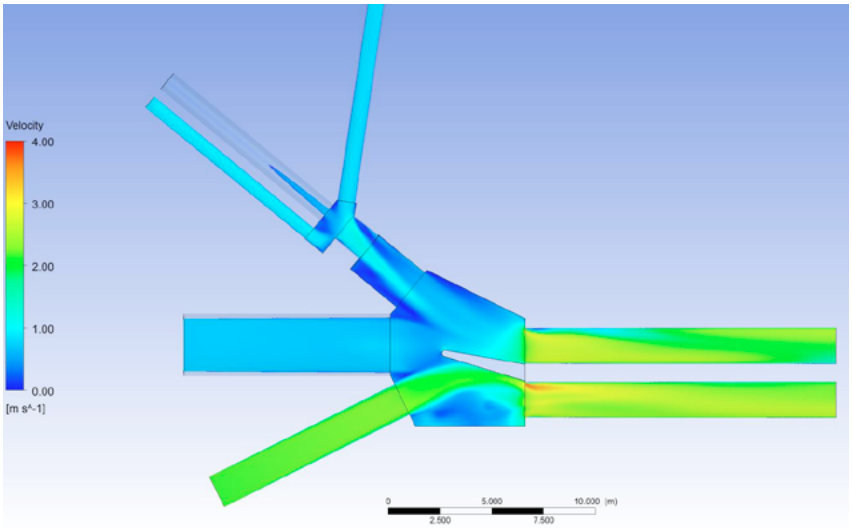

Figure 4. CFD model – upstream connection structure – velocity

As the pipe system was pressurised in the 1% AEP event, a hydraulic grade line analysis was used to assess different pipe and structure configurations during design development and confirm through surface catchment modelling that the flood hazard reductions could be achieved.

Hydraulic Modelling

The whole catchment is modelled using Tuflow with 2D surface modelling linked to a network of 1D sub-surface conduits. The model is very large and takes many hours for each run (between six and 24 depending on the time step chosen).

The long run time made testing concepts time consuming, so just the new GSSD was modelled in 1D using XPSWMM. For the concept design, the 1D unsteady flow model of the trunk drain was developed using parameters from published standard formulae. There are over 20 structures which add head loss to the system, being inflow/ junction structures, access structures and mitred bends.

The large number of structures had the potential to add significantly to the headloss in the system, raising the hydraulic grade line (HGL) to the point where it would start to choke the inflow and increase surface flooding. Therefore, accurate determination of structure losses was essential.

Critical structures were modelled using 3D computational fluid dynamics (CFD). This allowed the head loss and flow split between parallel conduits to be accurately determined. In all, seven structures were modelled, some because they were unique designs and some because they were representative of a number of structures within the system.

If the standard loss factors were inaccurate, the cumulative effect had the potential to be significant. However, it was found that the initial calculations were generally confirmed by the CFD modelling.

CFD modelling did not inform the air transport behaviour and, as this was considered to be a significant risk to drain capacity, physical modelling was carried out.

Physical modelling was undertaken on three of the most critical or representative structures to confirm that the CFD was providing realistic results and to assess air transport in the part-full to full flow transition.

This allowed us to further refine the hydraulic loss factors used in the hydraulic grade line analysis and provide insights into air and water movement at different headwater, tailwater and flow conditions.

The CFD and physical models also allowed optimisation of the final designs of a number of structures.

For example, the alignment of guide walls was adjusted based on modelling to yield even flow splits between conduits for optimum hydraulic performance of the system.

The CFD and physical model results provided cross checking and verification of theoretical structure losses, providing certainty in the overall modelling and confidence that the system would operate as intended.

Challenges

The hydraulic modelling was a challenge due to the large catchment and complex interaction of 1D and 2D elements. For example, there are over 1,500 pipes and pits in the overall catchment model.

This resulted in very long run times of the 2D catchment model, which necessitated decoupling of the 1D trunk model so it could be modified and re-run more readily. This 1D trunk hydraulic model needed to be updated continuously during the design phase to account for the developing design and progressive results from the CFD and physical modelling.

The site investigations, modelling, design and construction were run concurrently due to overall project time constraints, meaning that the model had to be repeatedly updated and re-run as designs developed and construction difficulties were encountered and overcome.

The trunk drain operates under pressure in the design 100-year storm event and the HGL analysis was critical to confirm flooding compliance. Where the HGL came close to the ground surface, the inlet capacity began to be impacted, resulting in an increase in surface flood levels.

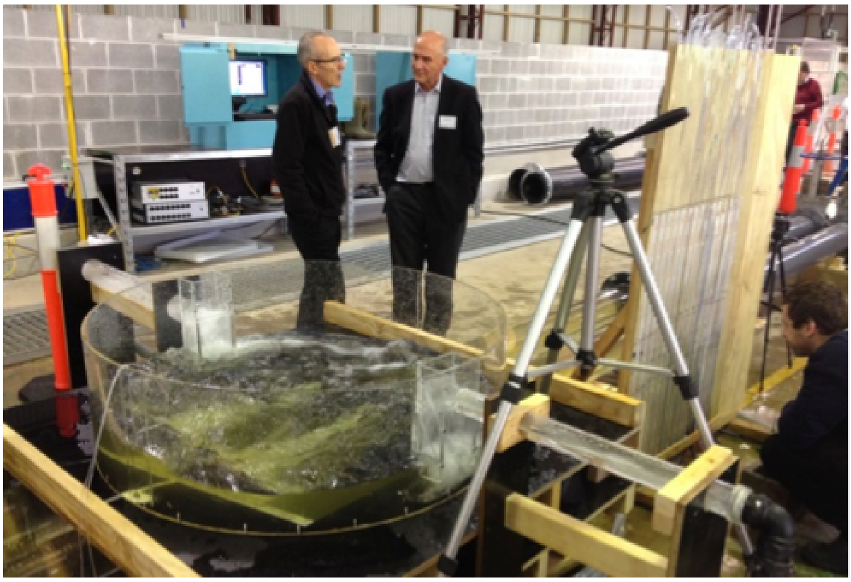

Figure 5. Physical model, three-pipe to two-pipe transition

To address this, the trunk drain size in the upstream reaches was increased to provide additional conveyance and some additional temporary storage.

This reduced the peak flow rate somewhat, due to the nature of the storm events in this catchment, which produce relatively short duration, peaky flow hydrographs.

The upstream reaches presented hydraulic challenges as the GSSD incorporates two (one per pipe) in-line gross pollutant traps (GPTs), each treating 3-month flows of 2.0 m3/s. Substantial design development in consultation with the GPT supplier resulted in a design for a streamlined diversion structure, which minimised the headloss at 1% AEP design flow. The diversion structure also has a 1.2 m drop in the floor to provide driving head for the vortex separator without compromising the streamlining of the through conduit.

The GSSD passes under Sydney's Main Southern Sewer at O'Riordan Street, requiring a significant longitudinal grade change and the potential for a hydraulic jump to form and entrain air into the flow.

Hydraulic calculations showed that the flow velocity would transport air downstream and out of the provided vent shafts, rather than trying to rise upstream or "blow-back", a potentially dangerous situation that can blow off access shaft covers.

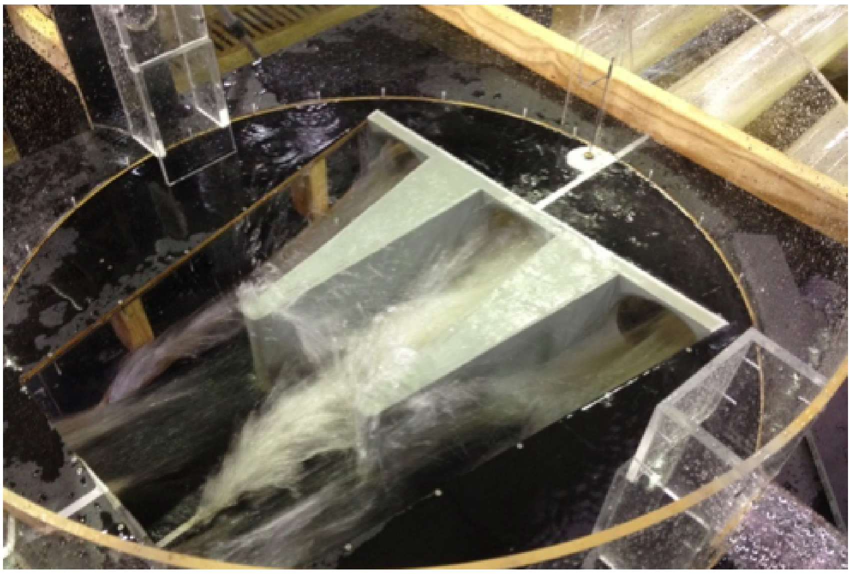

Figure 6. Physical model – three-pipe to two-pipe transition – low tailwate

In the transition from part to full flow the resulting air movements were catered for by providing fully vented access shafts at the structures immediately upstream and downstream of the grade change, allowing free movement of air along the pipes.

Further downstream, the GSSD merges with the existing open channel trunk drain near Maddox Street. The confluence of flows (30 m3/s and 80 m3/s respectively) at this location was complex, with unpredictable hydraulic interaction. Different models yielded differing results so the uncertainty was addressed by adopting the higher of the modelled water levels.

IMPLEMENTATION

Microtunnelling

The deep drains were installed by microtunnelling using earth pressure balance tunnel boring. This suited the geotechnical conditions of low strength clays and silts and high groundwater tables. Microtunnelling was also often in uncontrolled fill that is contaminated with building waste, requiring careful monitoring and control of pump pressures to minimise the risk of settlement.

In one section of the project, a diversion of the existing trunk drain required microtunnelling under an existing 100 year old DN840 steel lead-jointed water main with 200 mm clearance.

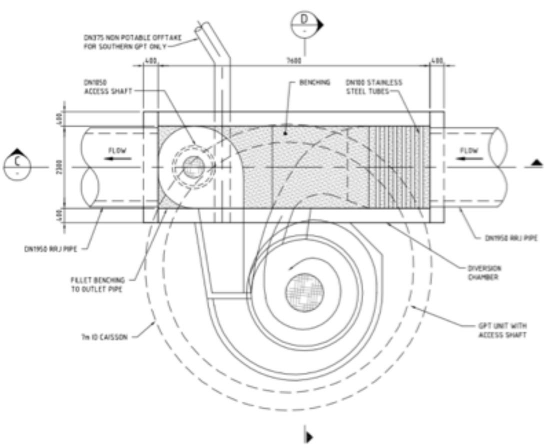

Figure 7. GPT plan

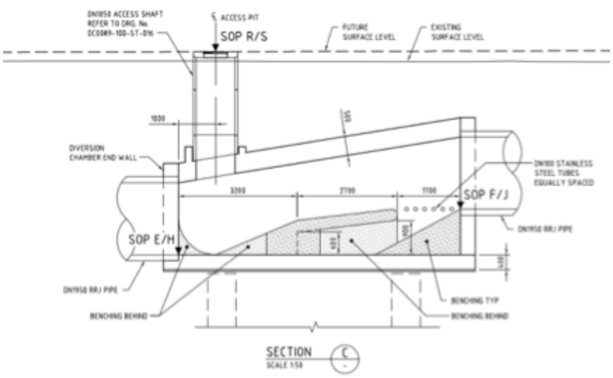

Figure 8. GPT section

In consultation with Sydney Water operators, the water main joints were strengthened as insurance against damage and the microtunnel was successfully completed with no impact to the strategically important water main.

Microtunnelling construction benefits include:

- minimum impact on the more than 120 underground utilities that cross the GSSD alignment
- minimum impact on existing roads and developments (no open cut)
- minimum environmental impact (spoil and dewatering)
- mimimum community impact (no open cut)
- cost effective hydraulic solution

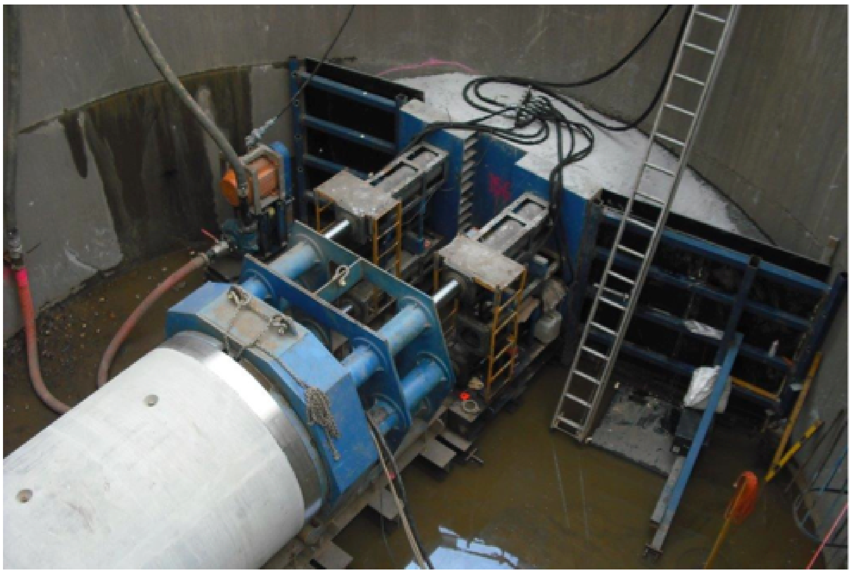

Figure 9. Microtunnel installation DN1800 pipe

Huntley Street Bridge – Win Win

The GSSD design was originally intended to transition from three 1800 mm diameter pipes into a single large box culvert for the final 300 m from Maddox St to Alexandra Canal.

The box culvert was to be constructed into the bank of the existing open channel. This channel passes under Huntley Street via twin box culverts where there are more than 15 services up to 750 mm diameter.

Some of the services pass through the walls of the twin box culverts (refer to Figure 10), reducing the waterway area, resulting in afflux and exacerbating local flooding.

A constructability assessment for the installation of the box culvert within the narrow corridor between the existing open channel and adjacent buildings indicated that open trench box culvert construction would not be cost effective.

An innovative solution was identified by the alliance, where the existing channel was widened and a new bridge constructed at Huntley Street, replacing the existing under-capacity box culverts.

The hydraulic conveyance required by the GSSD was maintained via the widened channel, while the congested utilities at Huntley Street were rationalised and better managed with the bridge. An added benefit is that the local flooding will be reduced due to lower afflux at Huntley Street.

A landscape architect designed a shared path for cyclists and pedestrians which was also incorporated into the overall design, providing a transport linkage and future community benefits.

This win-win solution was made possible by the ongoing consultation with the Project Owner that an alliance of this type provides.

Figure 10. Existing Huntley St culverts showing the many intruding services

Figure 11. Channel widening near Alexandra Canal outfall (artist's impression)

CONCLUSION

The GSSD is a complex project that is essential to eliminate high-hazard flooding from the area to deliver a liveable urban renewal of this inner-city area. It is being delivered through the cooperation of local and state government, construction contractors and designers in an alliance framework.

The most beneficial and cost effective infrastructure is being built because of the thorough planning process and rigorous hydraulic modelling that has been undertaken, both as part of developing the reference design and by the alliance designers in optimising the final design.

This work, together with the willingness of all to adopt innovative construction methods, will result in wide-ranging community and economic benefits.

ACKNOWLEDGMENT

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Nick has 32 years' experience in all areas of civil engineering from feasibility, planning, concept and detailed design, construction phase services and commissioning.

His expertise includes water, wastewater and storm water planning and design, airport and road infrastructure, flood and traffic studies and subdivisions and industrial, environmental and remote community engineering works.

Nick has recently been technical lead on a number of large water, wastewater and storm water projects and programs involving multi-disciplinary management.

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David is a principal engineer with over 30 years' experience in many facets of civil engineering.

He has extensive experience in hydrology and hydraulics (both open channel and pipe flow), site construction supervision and contract management.

David has designed a number of major pipelines and pumping stations, as well as water supply dams, weirs and irrigation or flood channels. He also has experience in structural design and general civil engineering.

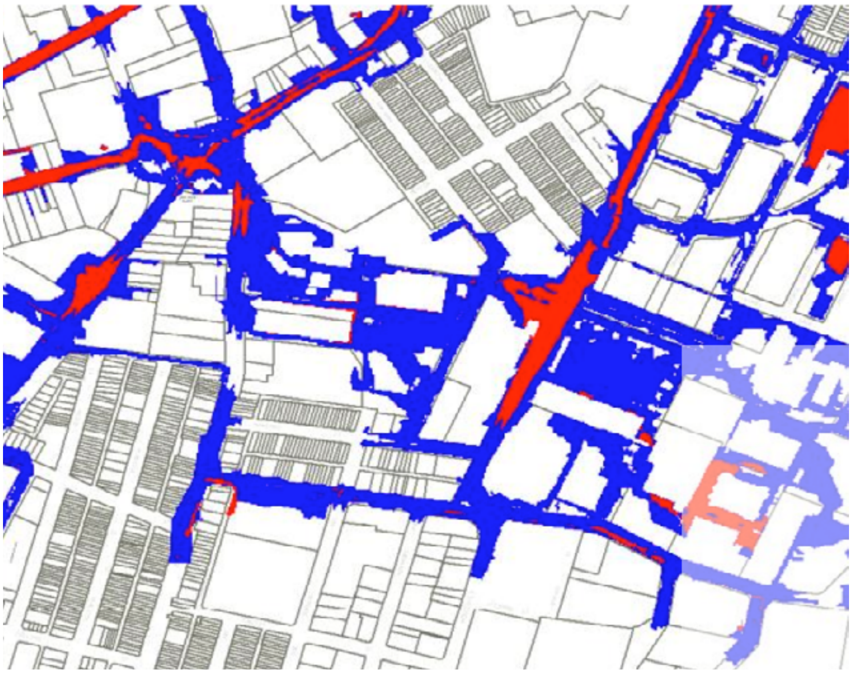

Figure 12. Flood hazard before GSSD

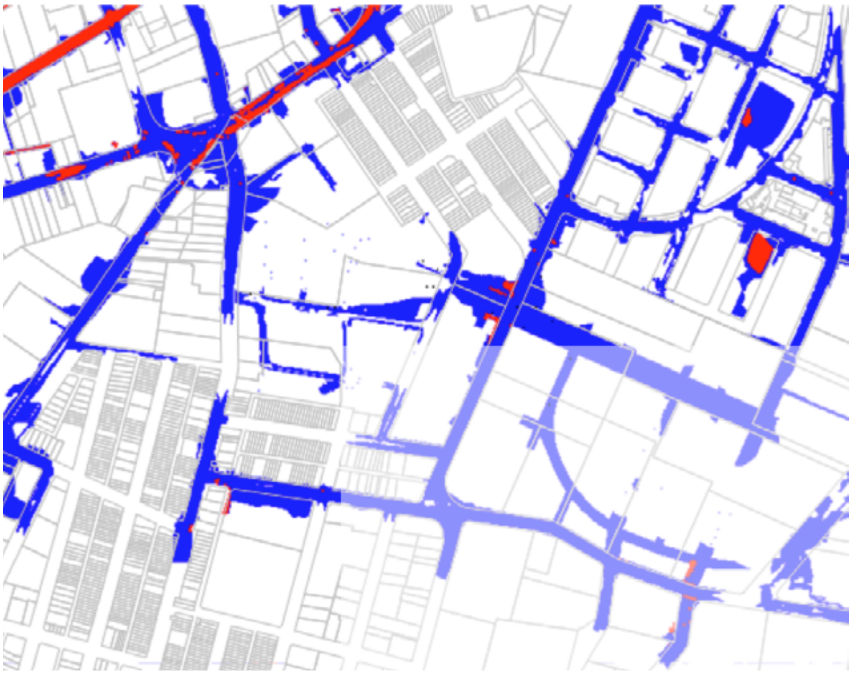

Figure 13. Flood hazard after GSSD

REFERENCES

Anderson, D.J., Smith, G.P., Drummond, C.D., Deiber, M. 2016. Green Square Trunk Drain Physical Modelling. Water Research Laboratory, University of NSW, Sydney, NSW, Australia.

Scaturro, S. 2015. CFD modelling for Green Square Trunk Stormwater Project. Expert Water CFD, Sydney, NSW, Australia.