Job Number: *230036*
Date: *17 April 2025*

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Les Hill
3 Alexandra Crescent
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Re: Flood Impact Assessment for 3 Alexandra Crescent, Bayview

1. Introduction

A residential development is proposed at 3 Alexandra Crescent, Bayview (Lot 2, D.P.1016440 – the Site). As per the Warringah Development Control Plan (DCP, 2011) the Site is situated in the high flood risk precinct although arguably this designation significantly overestimates the issue given a mere two hectare catchment is upstream of the site. A preliminary flood assessment of the Site was undertaken by GRC Hydro in 2023 (see Appendix A) using design rainfall estimates to define flood liability for a range of design flood events from the 20% AEP up to the PMF. The study identified a continuous flowpath forming within the Site during a flooding event, which poses a constraint to future development given Council's DCP which does not allow construction over a watercourse.

Council previously provided feedback on residential development proposal at the Site. Concerns were raised regarding the impermissibility of construction over a natural watercourse. Recognising these concerns, a concept design that implements flood mitigation works is proposed by Scope Architects. The design proposes a two-storey residence and garage, plus a diversion channel that manages flows passing through the Site. The current assessment investigates the impact of such development on existing flooding behaviour at the Site. It also provides an updated advice on the compliance of the proposed development, with respect to Council's requirements, based on the finding from the conducted analyses.

This assessment has been supervised by Stephen Gray who is the Director at GRC Hydro and specialist in hydraulic engineering and floodplain management (NER 2435438). CV is attached in Appendix B.

2. Site Description

Located approx. 450m west of the Pittwater estuary foreshore at Rowland Reserve, the Site lies within a dry gully, with ground elevation ranging between approx. 27.0 and 18.3 mAHD. The upstream catchment to the Site has an area of ~ 2 ha, which in a flooding context is diminutive; hence, commensurably small flows are expected to be routed through the Site.

A 450-mm culvert which traverses Kamilaroi Road (the DN450) discharges into the upstream end of the Site. Typically, minor percentages of the total flows from the upstream catchment enters the Site via the kerbside inlet pit on Kamilaroi Road for any given rainfall event. Moreover, the steep road crossfall at this location limits the amount of runoff that overtops the crest and flows onto the Site. The remainder of the flow at this location is conveyed in the gutter along Kamilaroi Road before being discharged into the drainage easement which is located immediately downstream of the Site.

In the 2023 report, a sensitivity analysis was undertaken on the blockage factor of the DN450. It was demonstrated that the magnitude of peak flow entering the Site significantly varies depending on the applied factor. Using the 0% blockage assumption (i.e., the *unblocked* scenario) tends to contribute to conservative peak flow estimates.

3. Watercourse Realignment

A new open stormwater channel is proposed to convey flows that enter the Site via the DN450. The channel then discharges into the existing low point at the eastern boundary of the Site. The channel is aimed to divert flows entering the Site away from the footprint of the residential development without inducing inacceptable impact to the existing flooding behaviour at the Site and its vicinity.

Typical Cross-Sectional Geometry

The Manning formula was applied in the design of a typical channel cross-section.

$$Q = A * \frac{Rh^{2/3} * S^{1/2}}{n}$$

Where Q = flow rate, A = cross-sectional area, Rh = hydraulic radius, S = slope, n = roughness.

Since the proposed alignment of the stormwater channel is characterised by variations in ground elevation gradients, the typical cross-section was designed for the critical segment where the slope was minimal.

The designed cross-section features a base width of 0.54 metres and a depth of 0.4 metres, with side slopes angled at 60 degrees. The total channel width spans 1.00 metre. Using the channel bed

slope of 6% and a Manning's roughness coefficient of 0.05, the estimated flow rate for this section is approx. 0.53 m^3/s. A sketch of the typical cross-section is presented in Image 1.

Base Width	0.54
Depth	0.4
theta (degrees)	60
Total Width	1.00
Area (d^2/tan0)+wd	0.31
Perimeter (2d/sin0)+w	1.46
Hydraulic Radius (Rh)	0.21
Minimum Slope (S)	0.06
Manning Coefficient (n)	0.05
Velocity = 1/n*Rh^(2/3)*S^(1/2)	1.73
Flow = 1/n*A*Rh^2/3*S^1/2	0.53

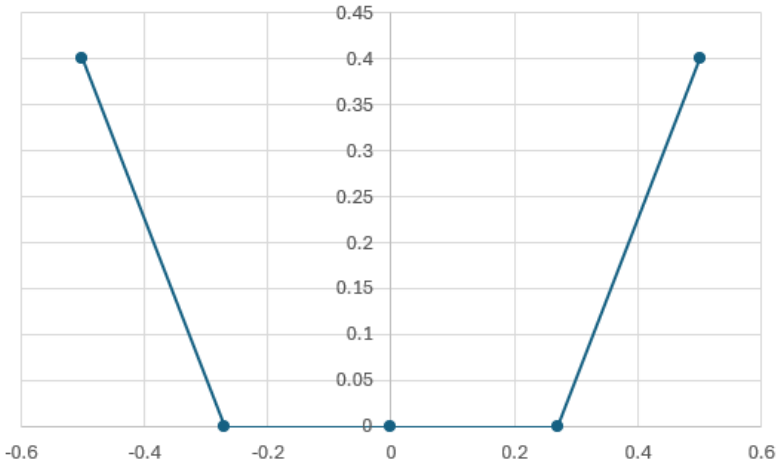


Image 1: Typical Cross-Sectional Geometry

4. Impact of Watercourse Diversion on Existing Flood Behaviour

The flood models prepared as part of the 2023 report was used as the basis of analysis. For further details of the flood modelling approach and parameters refer to the 2023 report, attached as Appendix A.

4.1. Existing Conditions Model and Results

The Existing Conditions model established in the 2023 report was used to inform baseline conditions. The *unblocked* scenario was adopted so as to conservatively determine the peak flow through the Site.

The model results for 1% AEP Existing Conditions are presented in Figures 1-3. As seen, overland flow from the upper catchment enters the Site via the DN450 and forms a continuous flowpath through the Site, whilst the remaining flow continues along the gutter of Kamilaroi Road and does not enter the Site. That is, the Site receives only a fraction of runoff from the 2-hectare catchment upstream.

Flood hazard is defined by the Australian Emergency Management Institute (2014). H1 to H3 is equivalent to low flood hazard, whilst categories H4 to H6 is equivalent to high flood hazard. For the 1% AEP event, the Site is subject to low flood hazard (H1 and H2).

4.2. Diversion Scenario Model and Results

To assess the impact of the diversion on the 1% AEP flood behaviour, the Existing Conditions model was modified to produce a Diversion scenario. The Diversion scenario results are presented alongside the Existing Conditions results in Figure 1-3.

As seen, 1% AEP flows exiting the DN450 are predominantly picked up by the channel. This consequently reduces the magnitude of flow proceeding into the gully, which is no longer a continuous flowpath (i.e., depths > 50 mm). The gully exhibits hazard Category H1 only, while the stormwater channel experiences an elevated hazard level of up to Category H5 due to the concentrated flow.

The flood level and velocity impacts of the diversion are presented in Figure 4. The maps demonstrate no adverse impacts off-site.

4.3. Peak Flow Comparison

Error! Reference source not found.provides a comparison of the distribution of 1% AEP peak flows through the Site in the Existing and Diversion scenarios. Peak flows were extracted from three reporting locations:

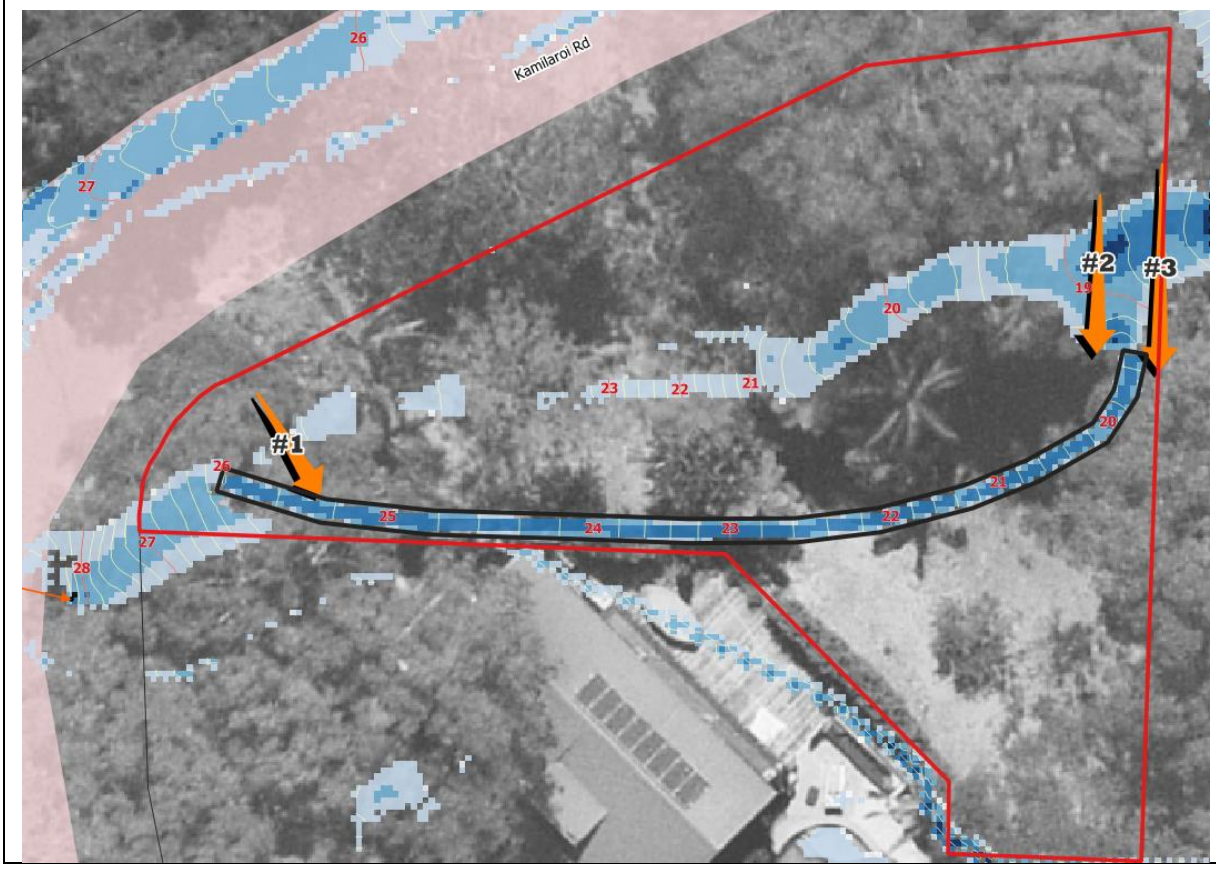
- #1: In the gully, immediately downstream of the start of the proposed channel.
- #2: In the gully, immediately upstream of the discharge location of the proposed channel.
- #3: At the downstream Site boundary.

Under Existing Conditions, peak flow increases through the Site in addition to the peak flows originating from the upper catchment (i.e., from 0.5 to 0.7 m^3/s at Locations #1 and #2/#3, respectively). This is due to intra-lot rainfall which also drains into this flowpath.

Under the Diversion scenario, the flow at Location #1 is reduced to 0.0 m^3/s as the inflows are predominantly diverted into the channel. Similarly, the flow in the gully at Location #2 is increased by 0.2 m^3/s due to intra-lot rainfall. The peak flow leaving the Site at Location #3 remains at 0.7 m^3/s. This outcome serves to demonstrate that the proposed watercourse diversion does not exacerbate the Existing flooding behaviour at the Site. It is noteworthy that GRC have made a conservative assumption in assuming that the DN450 pipe is 0% blocked in a 1% AEP event.

Table 1: Peak Flow Comparison – reporting locations are presented in the Image below.

	Existing Scenario Flow (m^3/s)	Diversion Scenario Flow (m^3/s)
Location 1	0.5	0.0
Location 2	0.7	0.2
Location 3	0.7	0.7



5. Proposed Design

A proposed design was detailed by Scope Architects (received 24 March 2025). The floor levels of the development are detailed below.

- Ground Floor and Deck: FFL = 21.20 mAHD.
- First Floor: FFL = 24.30 mAHD.
- Garage: FFL = 25.30 mAHD

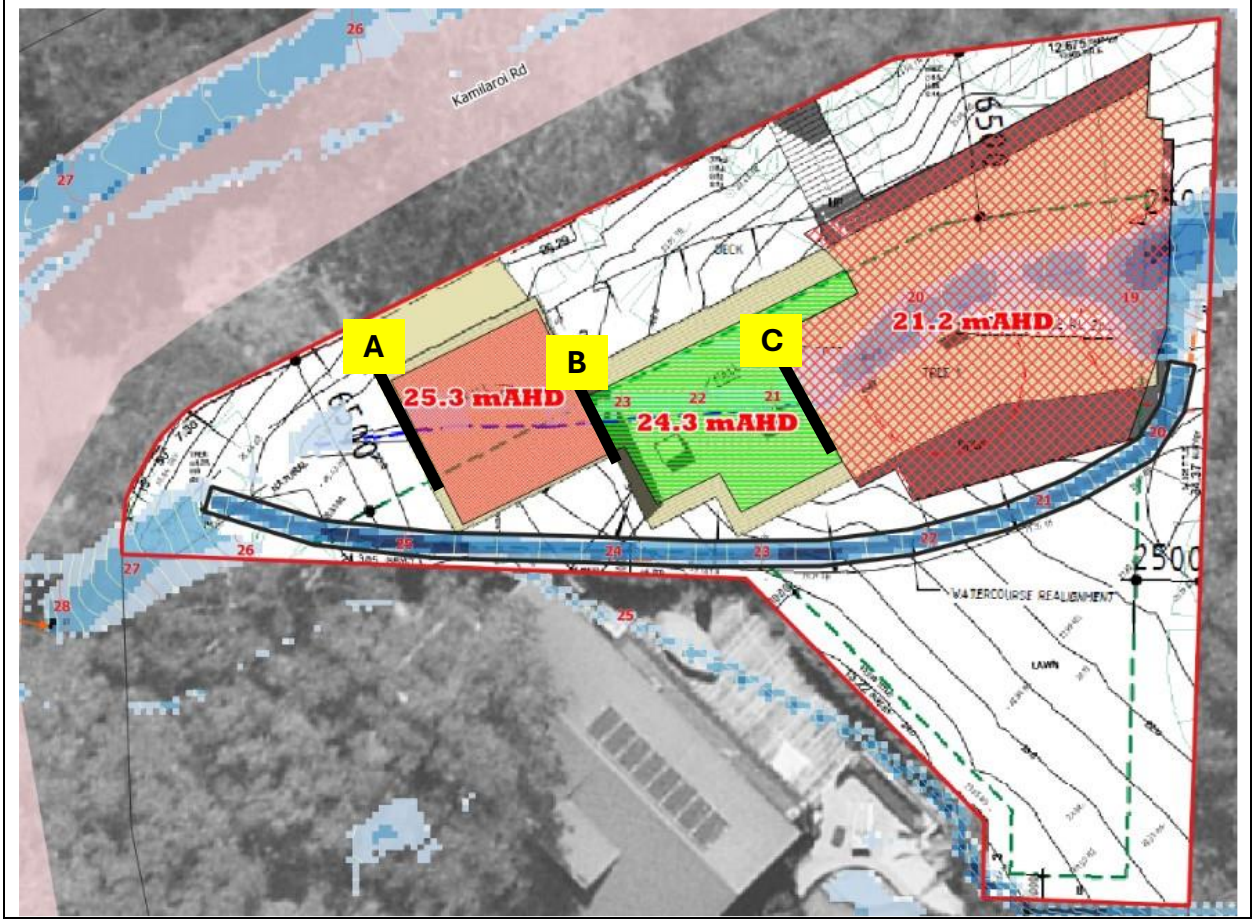
The residence is elevated above the gully floor (constructed on piers) The following sections serves to demonstrate that the proposed design does not interact with the diversion water.

Minimum Floor Level Requirements

The adopted floor levels have been assessed against minimum floor level requirements. The comparison of the adopted finished floor levels (FFL) and flood planning level (FPL) for the garage and the development is shown in Table 2.

Table 2: Comparison of Adopted FFL to FPL for the proposed development – reporting locations are presented in the Image below

	Adopted FFL (mAHD)	Freeboard (m)	1% AEP Flood Level Inspection Location	1% AEP Flood Level (mAHD)	FPL (mAHD)
Garage	25.30	0.50	A	24.8	25.3
First Floor	24.30	0.50	B	23.5	24.0
Ground Floor	21.20	0.50	C	20.7	21.2



6. Compliance with Council Requirements

A. FLOOD EFFECTS CAUSED BY DEVELOPMENT	Comments
A1) Development shall not be approved unless it can be demonstrated in a Flood Management Report that it has been designed and can be constructed so that in all events up to the 1% AEP event: (a) There are no adverse impacts on flood levels or velocities caused by alterations to the flood conveyance; and (b) There are no adverse impacts on surrounding properties; (c) It is sited to minimise exposure to flood hazard. Major developments and developments likely to have a significant impact on the PMF flood regime will need to demonstrate that there are no adverse impacts in the Probable Maximum Flood.	See Figure 4 for impact mapping. As proposed, the works do not impact flood behaviour on others. Velocity and hazard comparisons are also shown.
A2) Development shall not be approved unless it can be demonstrated in a Flood Management Report that in all events up to the 1% AEP event there is no net loss of flood storage. Consideration may be given for exempting the volume of standard piers from flood storage calculations. If Compensatory Works are proposed to balance the loss of flood storage from the development, the Flood Management Report shall include detailed calculations to demonstrate how this is achieved.	No filling is proposed and as such no loss of flood storage is proposed.
B. BUILDING COMPONENTS AND STRUCTURAL SOUNDNESS	**Comments**
B1) All buildings shall be designed and constructed with flood compatible materials in accordance with "Reducing Vulnerability of Buildings to Flood Damage: Guidance on Building in Flood Prone Areas", Hawkesbury-Nepean Floodplain Management Steering Committee (2006).	This is readily achieved and could be conditioned.
B2) All new developments must be designed and constructed to ensure structural integrity up to the Flood Planning Level, taking into account the forces of floodwater, wave action, flowing water with debris, buoyancy and immersion. Where shelter-in-place refuge is required, the structural integrity for the refuge is to be up to the Probable Maximum Flood level. Structural certification shall be provided confirming the above.	Given the diversion, the fact that the proposed dwelling is elevated above the gully and the relatively small catchment upstream and hence low flows this is readily achieved
B3) All new electrical equipment, power points, wiring, fuel lines, sewerage systems or any other service pipes and connections must be waterproofed and/or located above the Flood Planning Level. All existing electrical equipment and power points located below the Flood Planning Level within the subject structure must have residual	All are proposed to be above the FPL.

current devices installed that turn off all electricity supply to the property when flood waters are detected.	
C. FLOOR LEVELS	Comments
C1) New floor levels within the development shall be at or above the Flood Planning Level.	Section 5 demonstrates that the floor levels for the garage, first floor and ground floor are all above the FPL (defined as 1% + 0.5m freeboard).
C3) All new development must be designed and constructed so as not to impede the floodway or flood conveyance on the site, as well as ensuring no net loss of flood storage in all events up to the 1% AEP event. For suspended pier/pile footings: (a) The underfloor area of the dwelling below the 1% AEP flood level is to be designed and constructed to allow clear passage of floodwaters, taking into account the potential for small openings to block; and (b) At least 50% of the perimeter of the underfloor area is of an open design from the natural ground level up to the 1% AEP flood level; and (c) No solid areas of the perimeter of the underfloor area would be permitted in a floodway	There is sufficient clearance between the natural ground level and the floor levels for all events up to the PMF. The flood conveyance of 1% AEP flows is adequately achieved . The residence is suspended on piers as to allow the clear passage of floodwaters.
D. CAR PARKING	Comments
D1) Open carpark areas and carports shall not be located within a floodway.	Achieved
D2) The lowest floor level of open carparks and carports shall be constructed no lower than the natural ground levels, unless it can be shown that the carpark or carport is free draining with a grade greater than 1% and that flood depths are not increased.	Achieved
D3) Carports must be of open design, with at least 2 sides completely open such that flow is not obstructed up to the 1% AEP flood level. Otherwise, it will be considered to be enclosed. When undertaking a like-for-like replacement and the existing garage/carport is located on the street boundary and ramping is infeasible, consideration may be given for dry floodproofing up to the 1% AEP flood level.	The proposed car parking is not interacting with flood waters.
D4) Where there is more than 300mm depth of flooding in a car park or carport during a 1% AEP flood event, vehicle barriers or restraints are to be provided to prevent floating vehicles leaving the site. Protection must be provided for all events up to the 1% AEP flood event	Not applicable.
D5) Enclosed Garages must be located at or above the 1% AEP level	This is achieved.
D6) All enclosed car parks (including basement carparks) must be protected from inundation up to the Flood Planning Level. All access,	This is achieved.

ventilation, driveway crests and any other potential water entry points to any enclosed car parking shall be above the Flood Planning Level. Where a driveway is required to be raised it must be demonstrated that there is no net loss to available flood storage in any event up to the 1% AEP flood event and no impact on flood conveyance through the site. Council will not accept any options that rely on electrical, mechanical or manual exclusion of the floodwaters from entering the enclosed carpark	
E. EMERGENCY RESPONSE	Comments
If the property is affected by a Flood Life Hazard Category of H3 or higher, then Control E1 applies and a Flood Emergency Assessment must be included in the Flood Management Report. If the property is affected by a Flood Life Hazard Category of H6, then development is not permitted unless it can be demonstrated to the satisfaction of the consent authority that the risk level on the property is or can be reduced to a level below H6 or its equivalent. If the property is flood affected but the Flood Life Hazard Category has not been mapped by Council, then calculations for its determination must be shown in the Flood Management Report, in accordance with the "Technical Flood Risk Management Guideline: Flood Hazard", Australian Institute for Disaster Resilience (2012). Where flood-free evacuation above the Probable Maximum Flood level is not possible, new development must provide a shelter-in-place refuge where: a) The floor level is at or above the Probable Maximum Flood level; and b) The floor space provides at least 2m2 per person where the flood duration is long (6 or more hours) in the Probable Maximum Flood event, or 1m2 per person for less than 6 hours; c) It is intrinsically accessible to all people on the site, plainly evident, and self-directing, with sufficient capacity of access routes for all occupants without reliance on an elevator; and d) It must contain as a minimum: sufficient clean water for all occupants; portable radio with spare batteries; torch with spare batteries; and a first aid kit Class 10 classified buildings and structures (as defined in the Building Codes of Australia) are excluded from this control. In the case of change of use or internal alterations to an existing building, a variation to this control may be considered if justified appropriately by a suitably qualified professional.	Given the diversion, there is a small area of H5 in the 1% AEP event in the proposed diversion channel. As shown in Figure 3, in the existing case hazard is very low and this accords with the minor upstream catchment at the site. In the event of flooding, the site is perfectly safe given all floors are above PMF. Flood duration correlates to catchment size. With a 2 ha catchment, flooding will occur near simultaneously with rainfall. As such Shelter in Place is compatible with the DPHI SIP Guideline published in January of 2025.

Note that in the event of a flood, occupants would be required to evacuate if ordered by Emergency Services personnel regardless of the availability of a shelter-in-place refuge.	
F. FENCING	Comments
F1) Fencing, (including pool fencing, boundary fencing, balcony balustrades and accessway balustrades) shall be designed so as not to impede the flow of flood waters and not to increase flood affectation on surrounding land. At least 50% of the fence must be of an open design from the natural ground level up to the 1% AEP flood level. Less than 50% of the perimeter fence would be permitted to be solid. Openings should be a minimum of 75 mm x 75mm.	Can be conditioned for confirmation as design moves forward.
G. STORAGE OF GOODS	Comments
G1) Hazardous or potentially polluting materials shall not be stored below the Flood Planning Level unless adequately protected from floodwaters in accordance with industry standards.	All parts of the dwelling are at or above the FPL and there is no intent to store anything below the FPL.

7. Conclusion

A two-storey residence is proposed at the subject site. In this assessment the following work is presented:

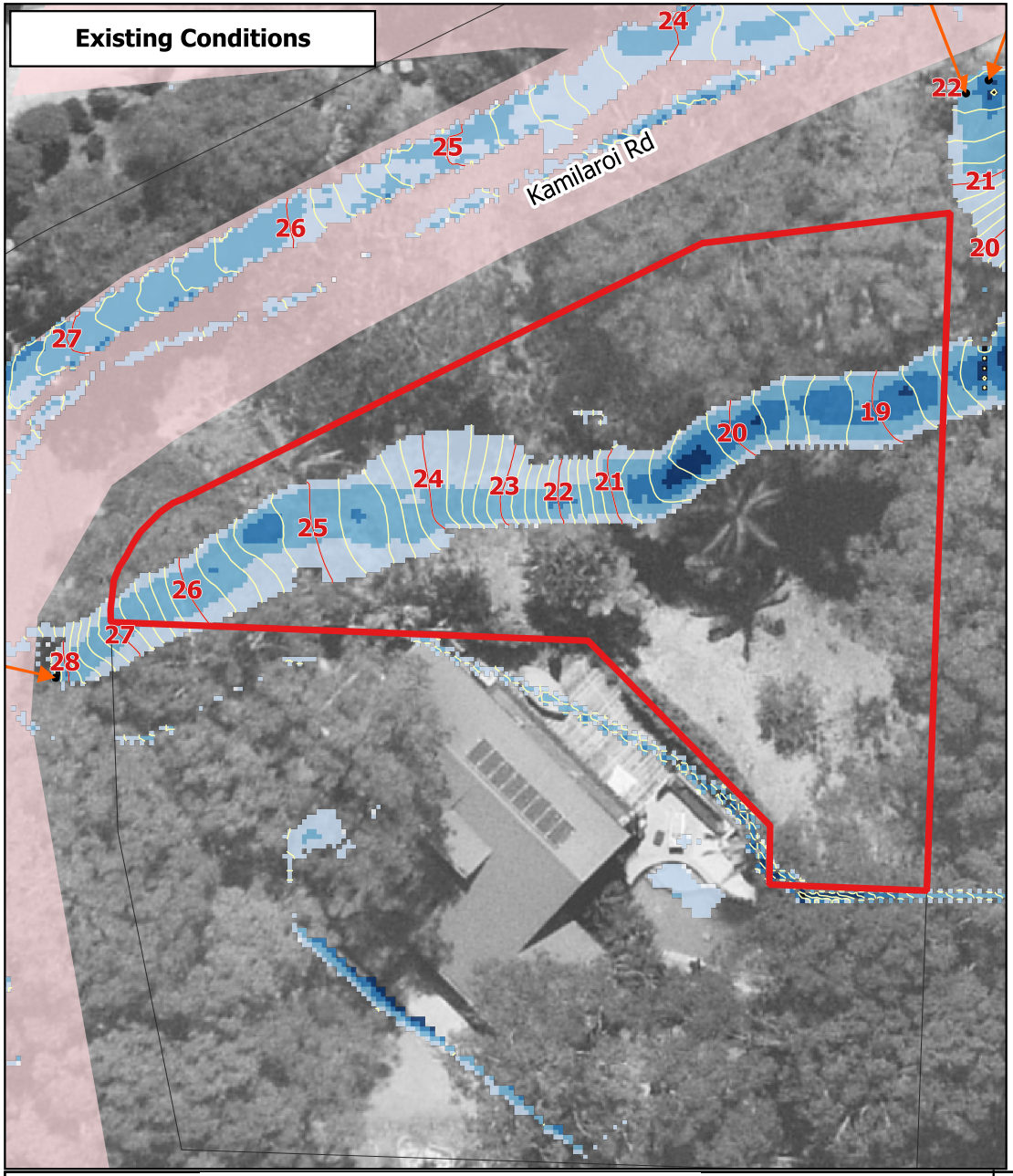
- A diversion channel design is proposed that diverts flow away from the watercourse that currently traverses the site;
- Impact modelling is shown to represent the impact (lack of in this case) the diversion and construction of proposed dwelling has on flood behaviour for adjoining property;
- Proposed floor levels are shown to be in accordance FPL requirements as per the DCP and finally
- The DCP issues pertinent to the site have been addressed individually.

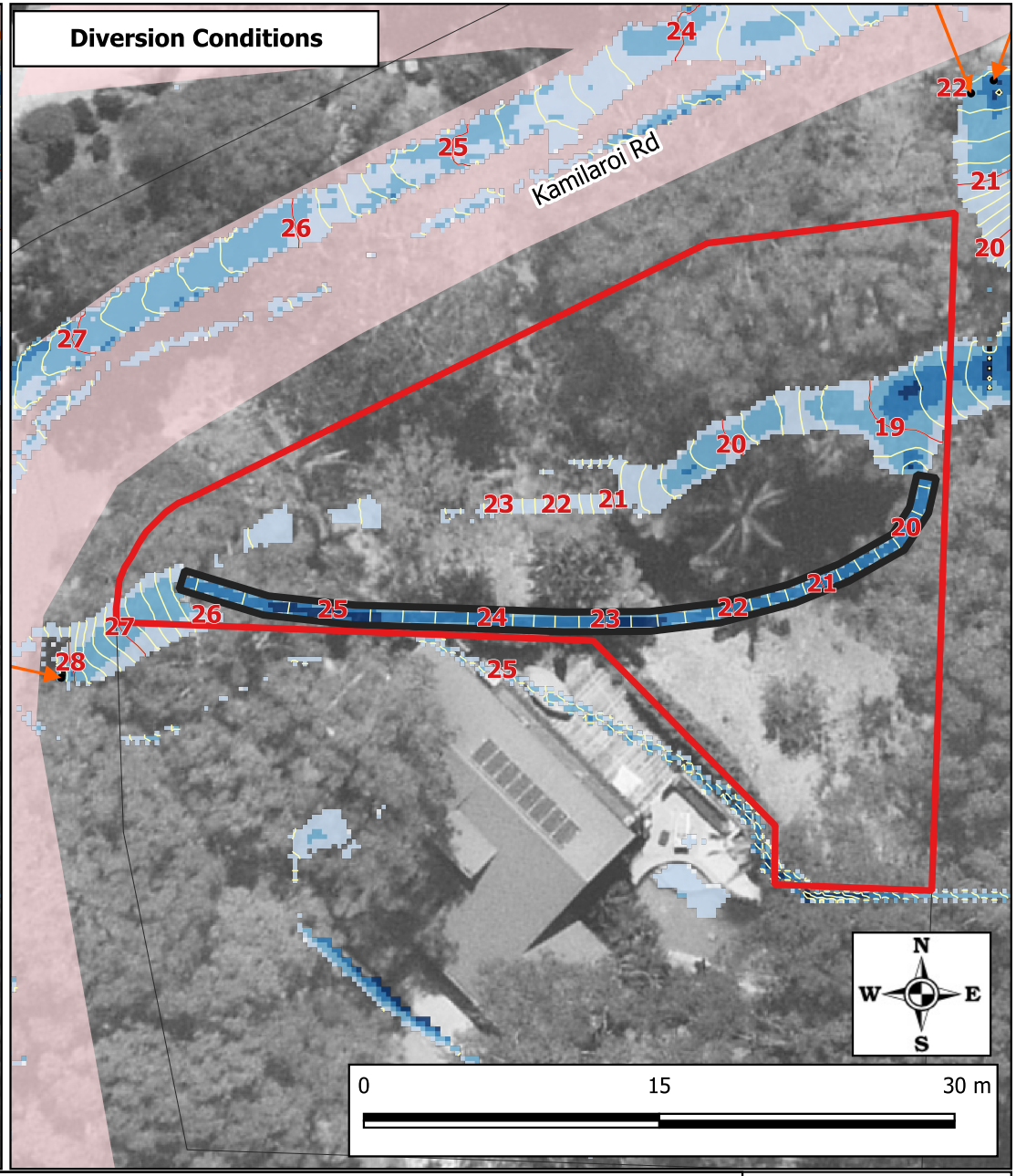
Overall, what is being proposed is a dwelling at a location which has an upstream catchment of 2 ha. By raising the dwelling above natural ground such that all floor levels exceed or meet FPL requirements, and diverting flow around the dwelling, GRC propose that relevant Council controls are addressed.

Yours Sincerely

Steve Gray
Director

FIGURES





Flood Depths (m)
- 0.00 - 0.05
- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.30
- 0.30 - 0.50
- > 0.50

Major Flood Level Contours (Spacing = 1.0m)

Minor Flood Level Contours (Spacing = 0.2m)

Subject Site

Cadastral Boundaries

Roads

Stormwater Pipes

Stormwater Pits

Proposed Channel

TITLE: **1% AEP - Flood Depths and Levels**

PROJECT: **3 Alexandra Crescent, Bayview**

PROJECT No. **230036**

DATE: **04-2025**

SCALE: 1:350

FIGURE No. **01**

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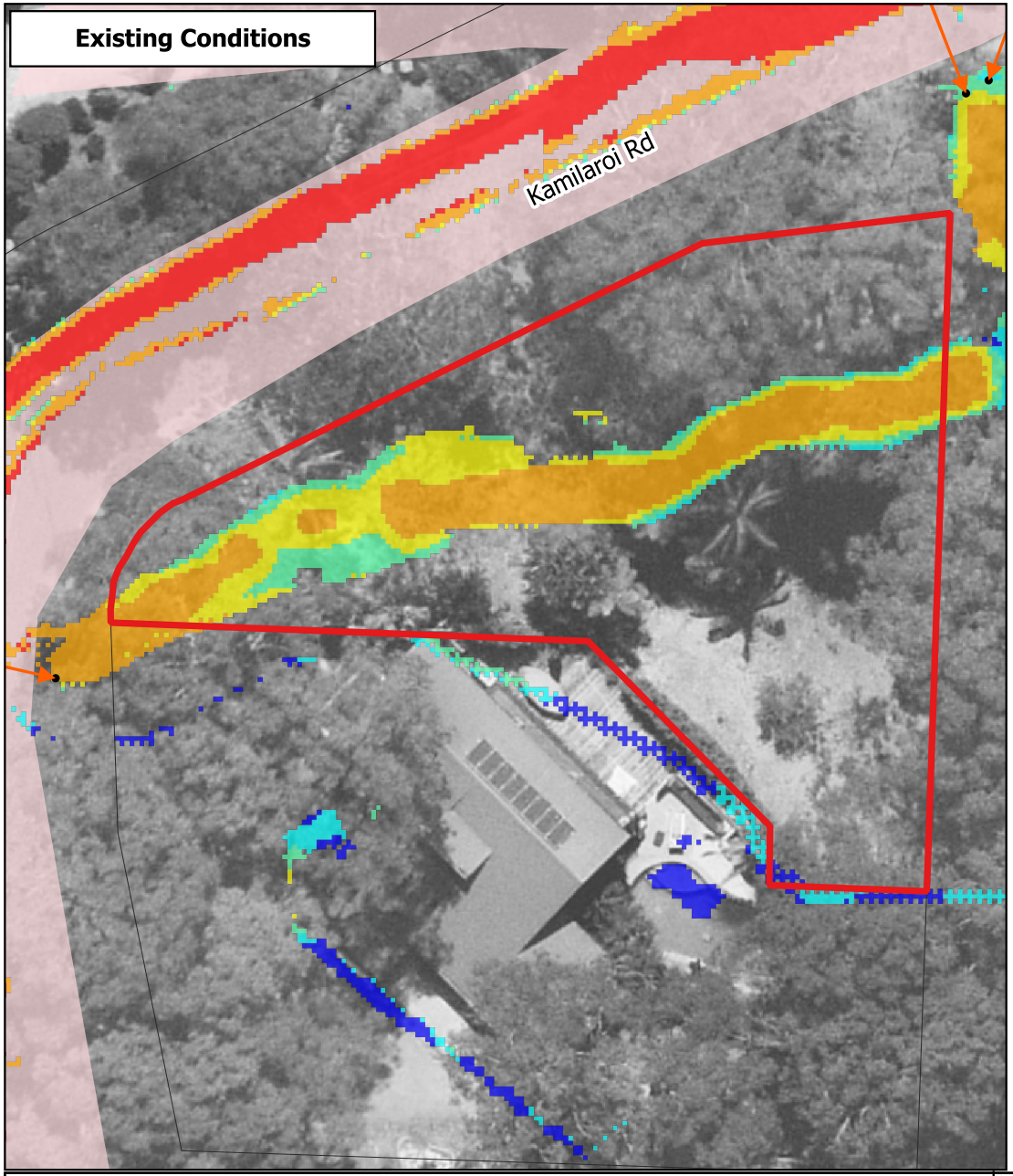

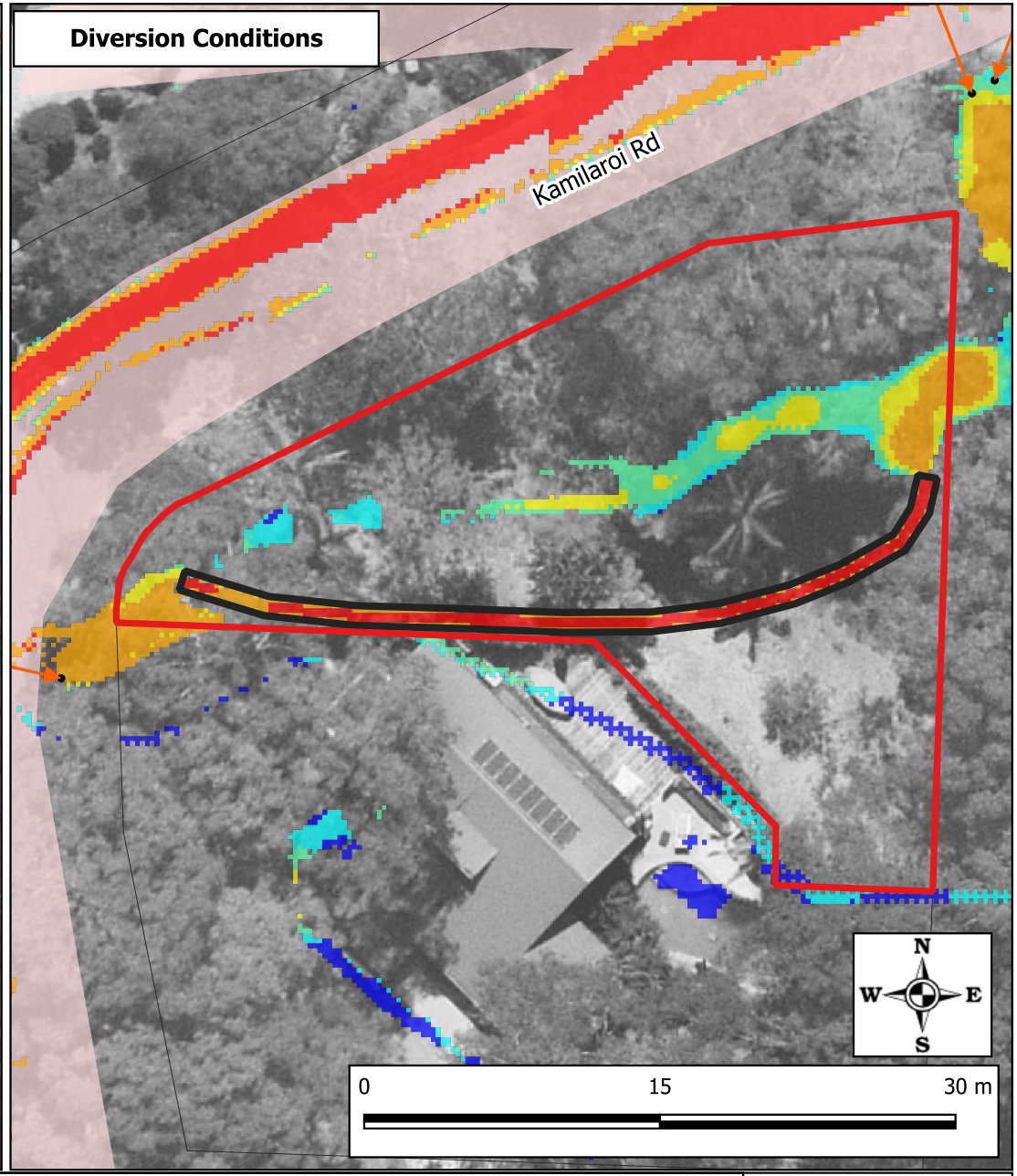

Flood Velocity (m/s)
- < 0.25
- 0.25 to 0.50
- 0.50 to 0.75
- 0.75 to 1.00
- 1.00 to 2.00
- > 2.00

- Subject Site
- Cadastral Boundaries
- Roads
- Stormwater Pipes
- Stormwater Pits
- Proposed Channel

TITLE: **1% AEP - Peak Flood Velocity**		
PROJECT: **3 Alexandra Crescent, Bayview**		
PROJECT No. **230036**		
DATE: **04-2025**	SCALE: 1:350	FIGURE No. **02**

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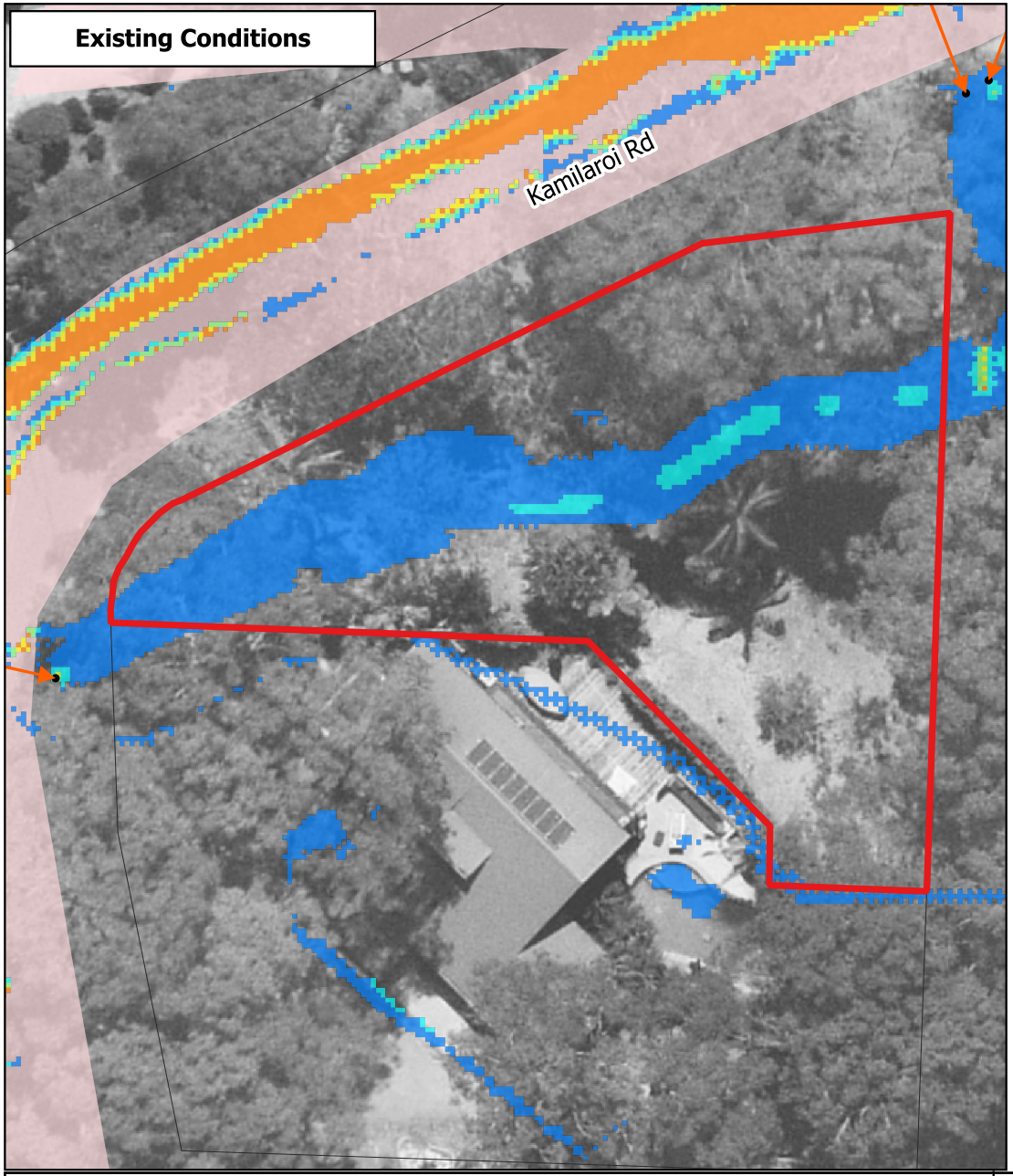

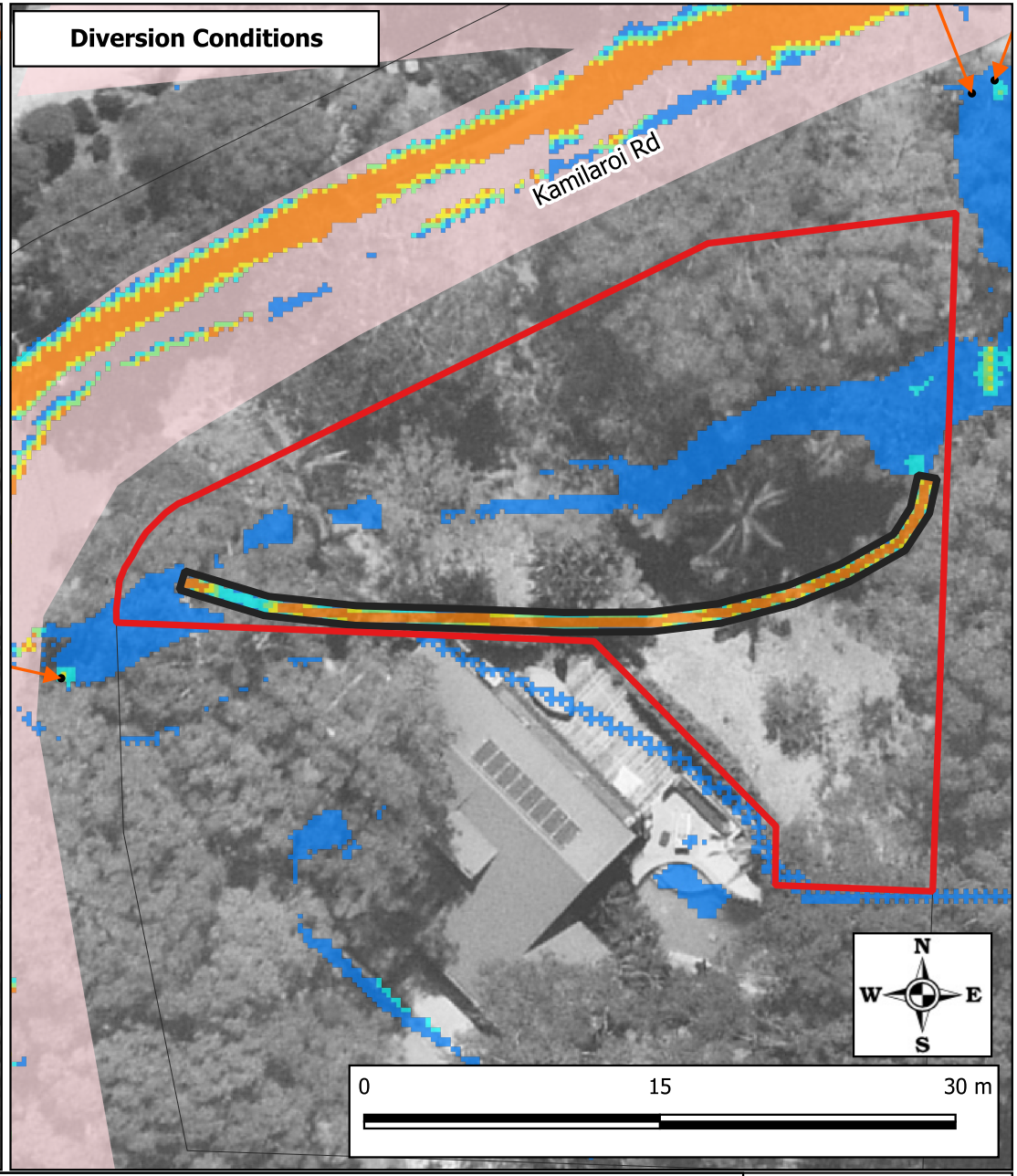

Flood Hazard
- H1
- H2
- H3
- H4
- H5
- H6

- Subject Site
- Cadastral Boundaries
- Roads
- Stormwater Pipes
- Stormwater Pits
- Proposed Channel

TITLE: **1% AEP - Peak Flood Hazard**		
PROJECT: **3 Alexandra Crescent, Bayview**		
PROJECT No. **230036**		
DATE: **04-2025**	SCALE: 1:350	FIGURE No. **03**

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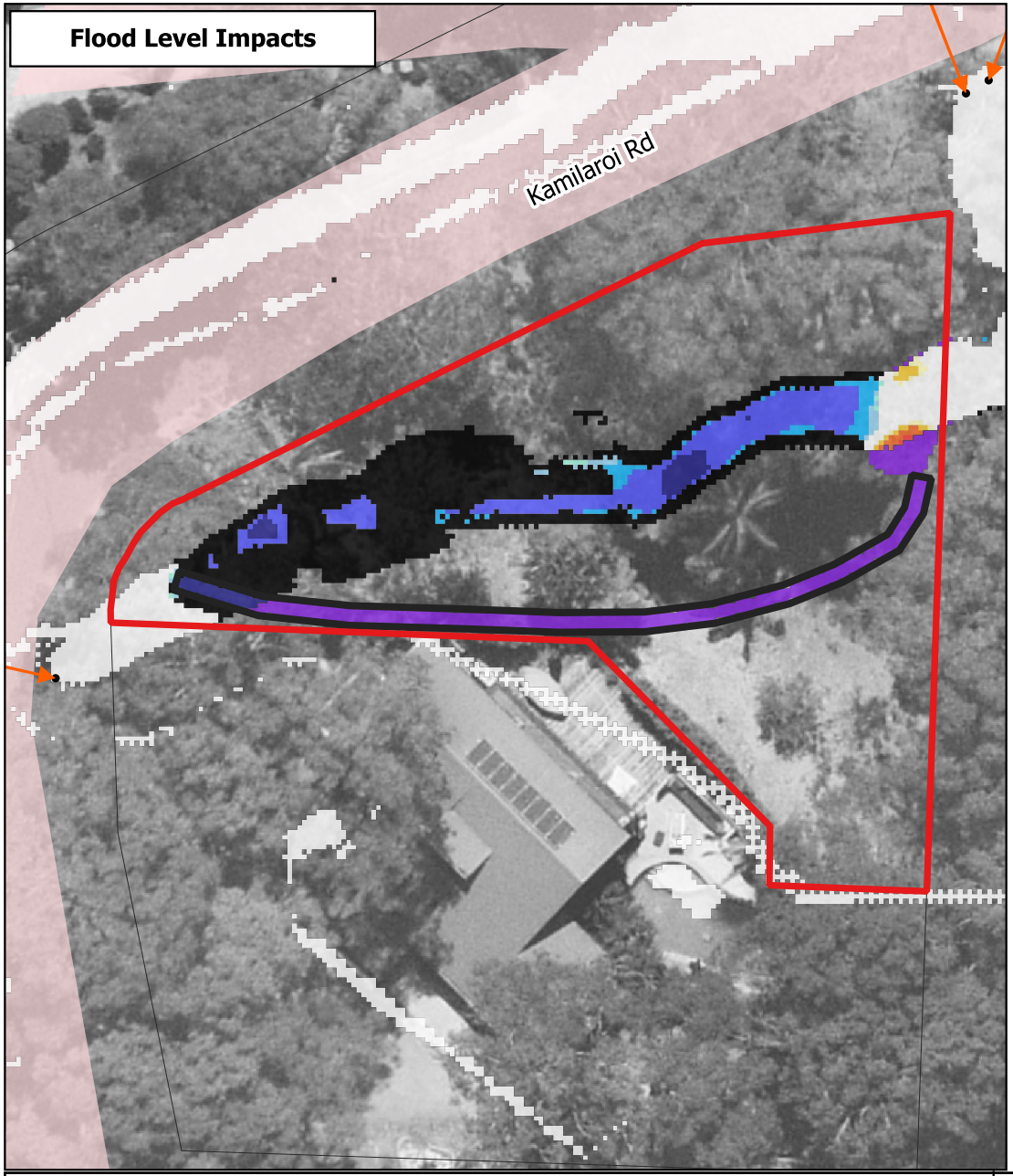

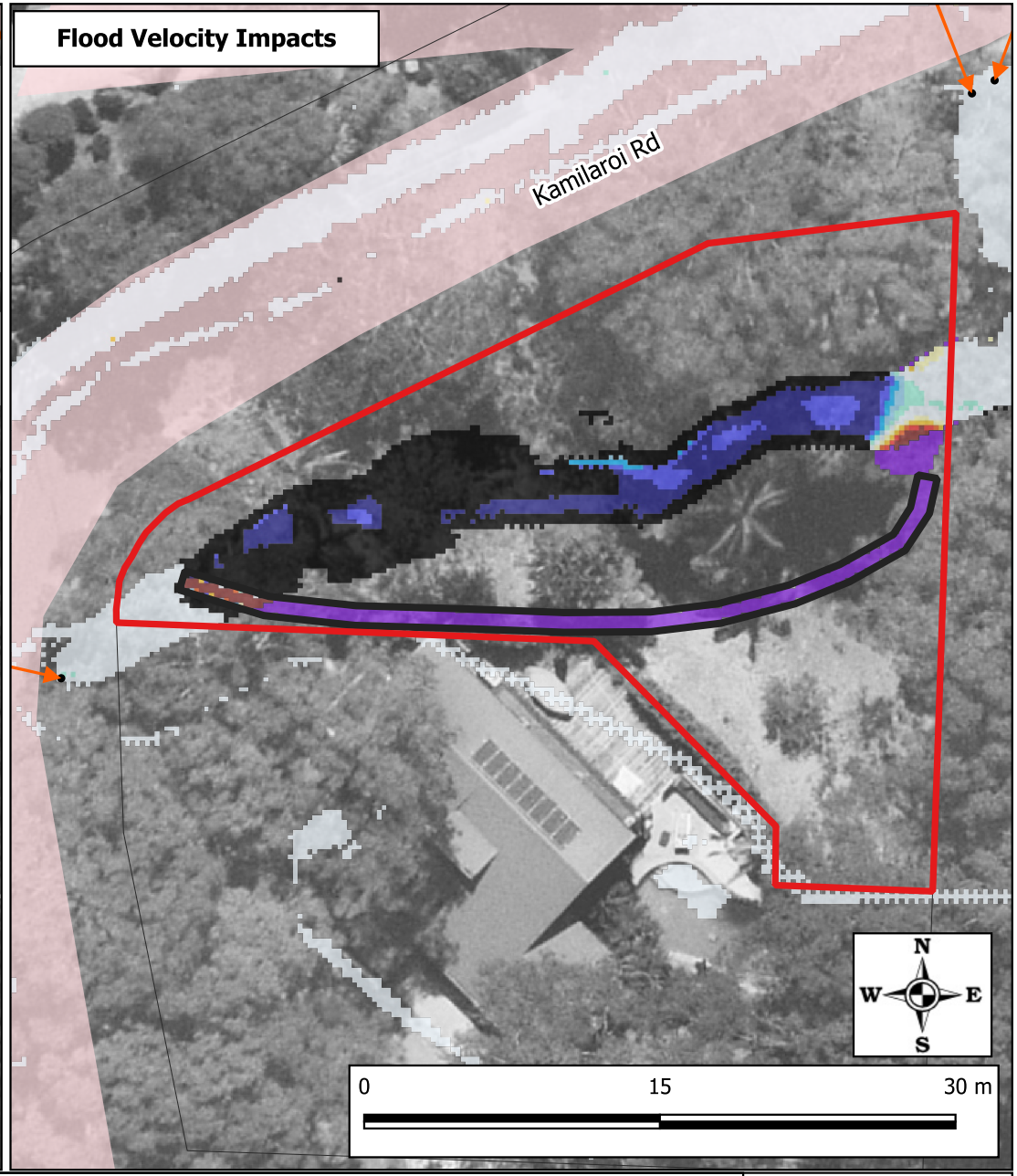

Flood Level Impacts
- Was wet - now dry
- > 0.15 m decrease
- 0.10-0.15m decrease
- 0.05-0.10 m decrease
- 0.03-0.05 m decrease
- 0.02-0.03 m decrease
- No Change (+/- 10mm)
- 0.02-0.03 m increase
- 0.03-0.05 m increase
- 0.05-0.10 m increase
- 0.10-0.15 m increase
- > 0.15 m increase
- Was dry - now wet

Flood Velocity Impacts
- Was wet - now dry
- > 0.5 decrease
- 0.5 to 0.4 decrease
- 0.4 to 0.3 decrease
- 0.3 to 0.2 decrease
- 0.2 to 0.1 decrease
- No Change (+/- 0.1)
- 0.1 to 0.2 increase
- 0.2 to 0.3 increase
- 0.3 to 0.4 increase
- 0.4 to 0.5 increase
- > 0.5 increase
- Was dry - now wet

- Subject Site
- Cadastral Boundaries
- Roads
- Stormwater Pipes
- Stormwater Pits
- Proposed Channel

TITLE: **1% AEP - Flood Impacts**

PROJECT: **3 Alexandra Crescent, Bayview**

PROJECT No. **230036**

DATE: **04-2025** | SCALE: 1:350 | FIGURE No. **04**

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APPENDIX A

Job Number: *230036*
Date: *19th June 2023*

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Overland Flooding Report for 3 Alexandra Crescent, Bayview

INTRODUCTION

A residential development is proposed at 3 Alexandra Crescent, Bayview (Lot 2, D.P.1016440 – the subject site). The subject site is situated in the high flood risk precinct (see Image 1) by definition of the Warringah Development Control Plan (DCP, 2011). This report seeks to define site flood liability.

This assessment has been undertaken by Stephen Gray who is the Director at GRC Hydro and specialist in hydraulic engineering and floodplain management (NER 2435438).

PROJECT SCOPE

The following work scope has been executed.

- Site Visit and Data Review;
- Build a rainfall-on-grid TUFLOW hydraulic model;
- Apply design rainfall using the ARR1987 methodology in order to yield conservative estimates;
- Assess site flood liability for a range of design flood events: 20%, 10%, 5%, 2%, 1% AEP and PMF.
- Develop flood maps which present flood depths, levels, velocities, and hazards.
- Review pertinent planning documentation for applicable flooding controls.

PREVIOUS STUDIES

The McCarrs Creek, Mona Vale and Bayview Flood Study (the Flood Study) was completed by Royal Haskoning DHV in 2017 on behalf of the Northern Beaches Council. The Flood Study provides information on flood conditions on a range of design floods. The Flood Study identified the subject site as a flood prone lot, with a flood hazard category of *low* and a hydraulic categorisation of *floodway*.

Council's definition of the high flood risk precinct was updated during the course of the 2017 study to include all flood prone land that is:

a) within the 1% AEP Flood Planning Area; and
b) is either subject to a high hydraulic hazard, within the floodway or subject to significant evacuation difficulties (H5 and or H6 Life Hazard Classification).

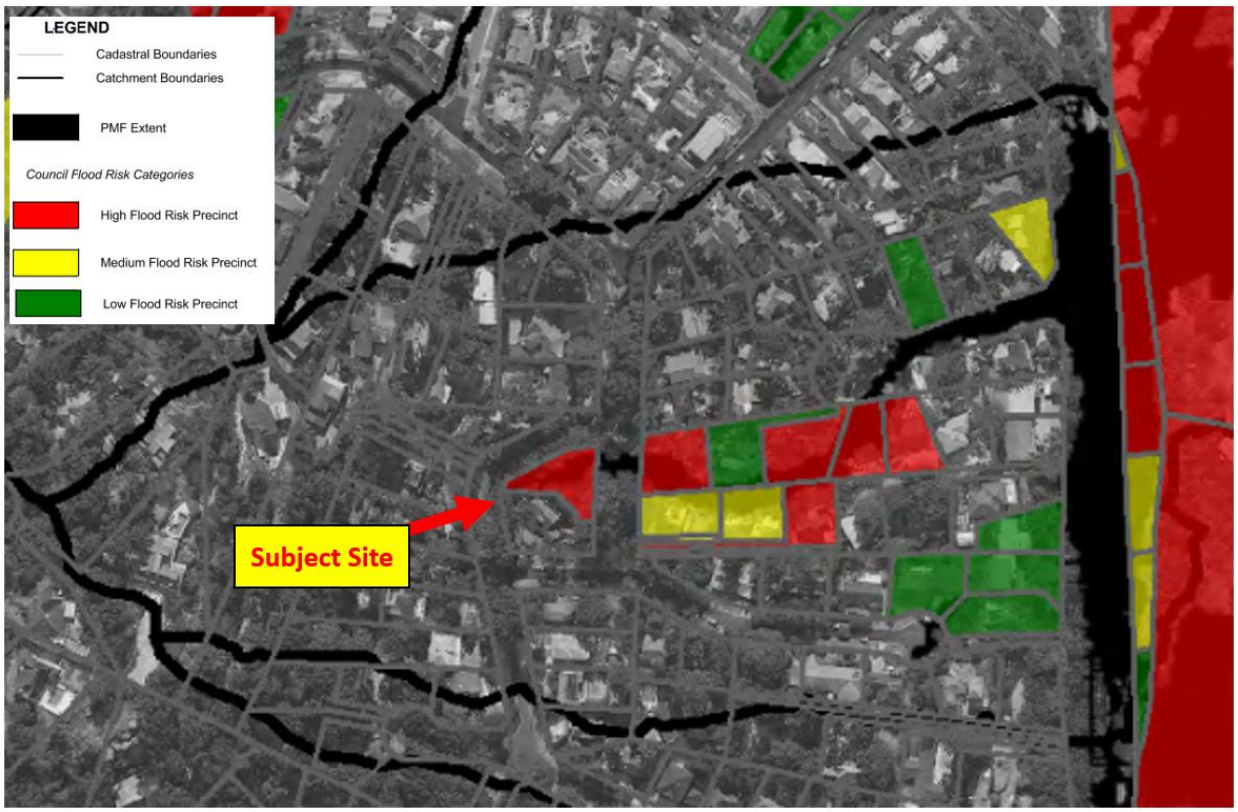


Image 1: Flood Risk Precinct Mapping (Source: McCarrs Creek, Mona Vale and Bayview Flood Study, 2017).

SITE DESCRIPTION

The subject site is located within a catchment area which drains in easterly direction towards the Pittwater estuary foreshore at Rowland Reserve. Located approx. 450m west of the foreshore, the subject site lies within a natural gully, with a maximum and minimum ground elevation of approx. 27.0 mAHD and 18.3 mAHD, respectively. The local catchment to the subject site encompasses an area of approx. 2 ha to the west of Kamilaroi Road. A 20-metre easement is situated directly east (downstream) of the subject site.

Kamilaroi Road serves as an important control for the management of flooding behaviour at the subject site. The following aspects of its design serve to limit the magnitude of runoff that enters the subject site.

- The road pavements crossfall on the upstream side is steep and this limits the amount of runoff which crests the road centreline and flows into the subject site.
- A kerbside pit situated in front of 6 Kamilaroi Road, picks up flows into a 450mm culvert which is discharged into the subject site via a headwall.
- Two kerbside pits on the corner of 5 Alexandra Crescent connected to a 450mm and a 525mm culvert convey flows beneath the road – and is discharged into the easement that lies downstream of the subject site.

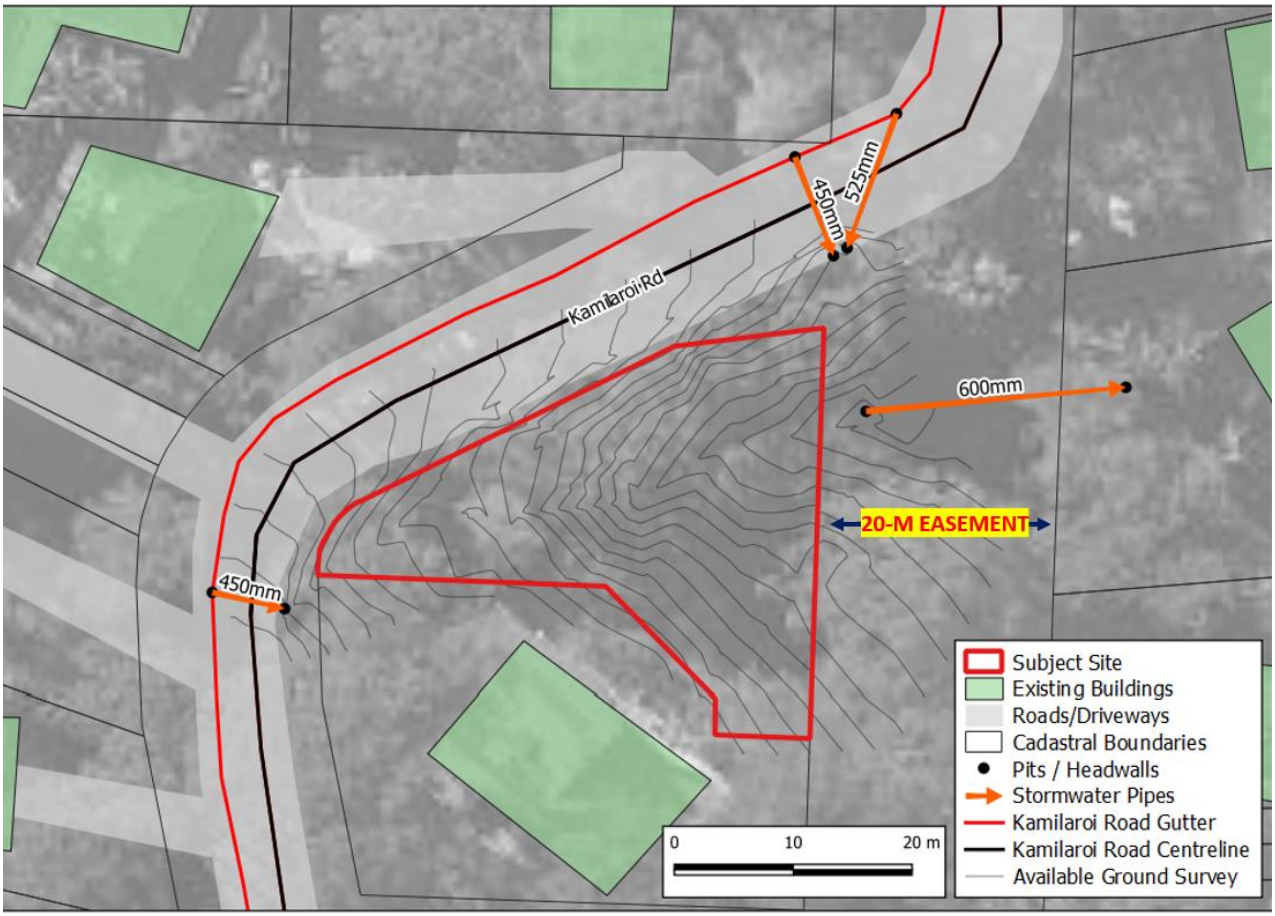


Image 2: Site Features

TUFLOW MODELLING

TUFLOW is a 2D numerical hydraulic modelling package. This software is widely used and is considered best practice under the NSW Floodplain Risk Management Program. For this study, the depths, levels, velocities, and hazard of the 20%, 10%, 5%, 2% and 1% AEP and PMF design flood events were analysed using a conservative method. This is as follows.

1. Design rainfall was applied to the TUFLOW model, with ground levels informed by publicly available LiDAR data (Date: June 2020). This data has a typical accuracy of ±0.15 m (1st confidence interval). The extent to which rainfall was applied is shown in Image 2, which also details the elements of the developed TUFLOW model as well as the overland catchment of the subject site in question. The area to which design rainfall was applied was exaggerated to ensure that no flowpaths which may impact the subject site were missed.
2. Ground levels within the subject site were informed by the Site Survey Plan (11208detail.dwg).
3. The road profile of Kamilaroi Road for the segment adjacent to the subject site was informed by the Site Survey Plan.
4. 10 mm initial loss and 2 mm/h continuing loss were applied to design rainfall.
5. Buildings can block flood paths and therefore significantly impact flood behaviour. As such, existing buildings in the vicinity of the subject site were blocked out of the TUFLOW model.
6. The sizing of key stormwater assets was informed by the Site Survey Plan.
7. Sensitivity analysis of the drainage blockage has been done with 0% and 100% blockage.
8. Drainage outside the site was not included. Broadly the absence of pits and pipes will tend to contribute to estimates being conservative.
9. A fixed tailwater was adopted at 200 m downstream of the site (approx. 15 m lower than the subject site).

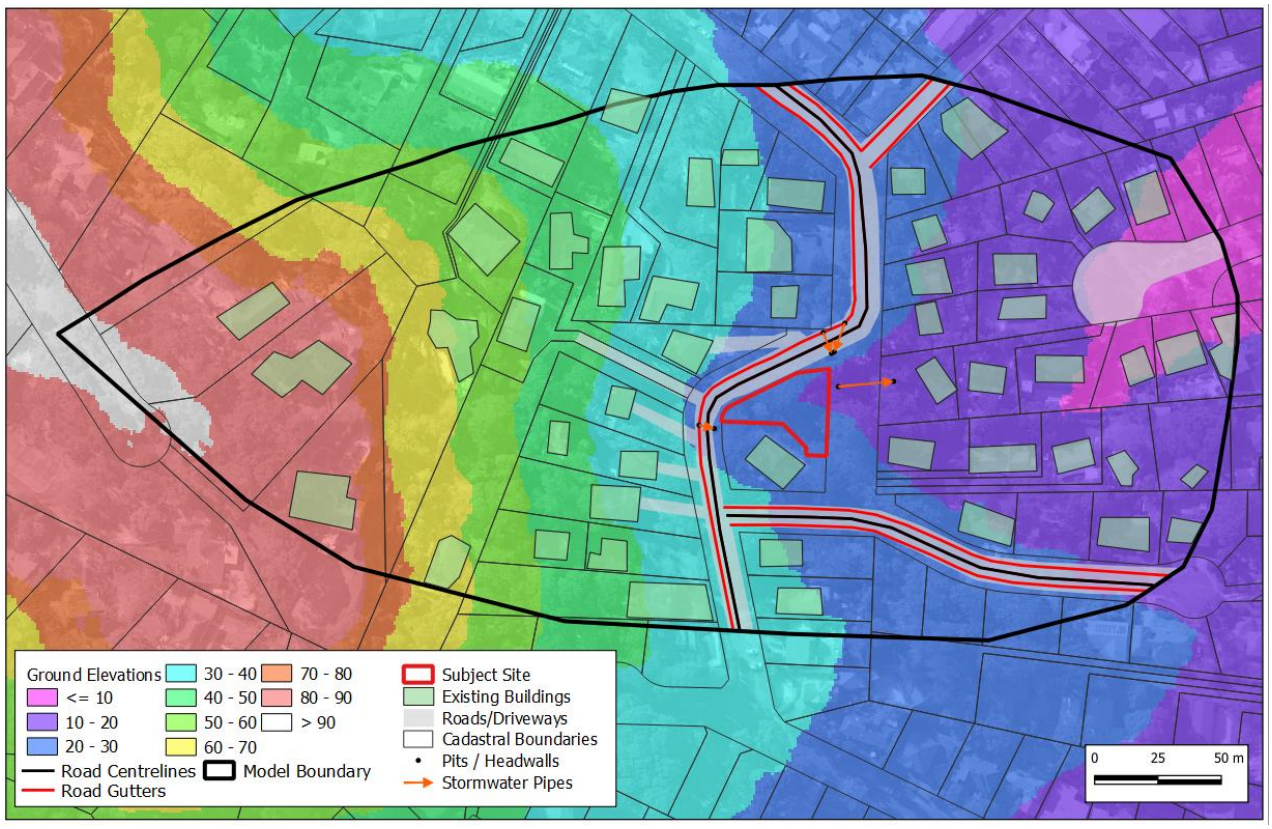


Image 3: TUFLOW Model Schematisation

Design Rainfall Procedures

Design rainfall was obtained using the ARR1987 methodology. A critical duration assessment was undertaken in TUFLOW for the location of the subject site. The 2-hour and 25-minute events were run. The 25-minute event was a good match for the 2-hour event which often is critical in SE Australia due to the temporal pattern used. The 25-minute event produced greater flood depths than the 2-hour event and was thereby deemed critical.

The PMF was run for the 15-minute event only. This run provides a result which approximates the critical PMF such that the exposure of the site can be properly assessed for its flood liability in the most extreme of storm events.

EXISTING FLOODING BEHAVIOUR

The resulting flood depths and levels, velocities and hazard across all design events are presented in Figures 1 to 18. The results demonstrate that the stormwater runoff from the upper catchment which approaches Kamilaroi Road will be distributed differently depending on assumed blockage for the *No Blockage* and *Full Blockage* scenarios. These differences are discussed below and presented in Tables 1 and 2.

No Blockage Scenario

In the 1% AEP event, a peak flow rate of 0.24 m^3/s enters the subject site from the west. The remaining runoff from the upper catchment (peak = 0.54 m^3/s) is conveyed in the north-easterly direction along the gutter of Kamilaroi Road. Of this amount, approx. 20% (peak = 0.11 m^3/s) traverses the road centreline and spills onto the subject site, while the remaining 80% are discharged into the easement east of the subject site. Combined with direct rainfall on the subject site, a peak outflow rate of 0.67 m^3/s is estimated at the eastern boundary.

Across all design events, the distribution of flows is similar, that is:

- Approx. 20-30% of total flows from the upper catchment enter the subject site from the west.
- Of the remaining flows which are conveyed in the gutter, approx. 15-25% spills across the road centreline and onto the subject site from the north.
- Approx. 55% of the total runoff from the upper catchment is diverted from the subject site entirely.

Table 1: Flow Distributions in the No Blockage Scenario

Design Event	Site Inflow from West	Site Inflow from North	Kamilaroi Rd Gutter	Total Site Outflow at East	Flow in Easement
20% AEP	0.12	0.06	0.40	0.40	0.45
10% AEP	0.14	0.08	0.57	0.45	0.52
5% AEP	0.14	0.11	0.41	0.51	0.63
2% AEP	0.15	0.12	0.58	0.57	0.67
1% AEP	0.24	0.11	0.54	0.67	0.79
PMF	0.85	0.43	2.25	2.93	3.48

Full Blockage Scenario

In the 1% AEP event, the blockage of the stormwater network resulted in the absence of site inflows from the west. Instead, the upper catchment runoff is solely conveyed along the gutter (peak = 0.91 m^3/s). Additionally, the magnitude of flow exceeding the road centreline was shown to increase from 0.11 to 0.17 m^3/s. All in all, the estimated peak outflow rate at the eastern boundary is reduced from 0.67 to 0.46 m^3/s. This reduction is observed across all design events, with the 20%, 10%, 5%, 2% AEP events also showing a 25-30% less site outflows, while a 10% reduction was yielded for the PMF event. In contrast, the proportion of total runoff from the upper catchment which is diverted from the subject site entirely was increased from 55% to approx. 65-75% for the 20% to 1% AEP events.

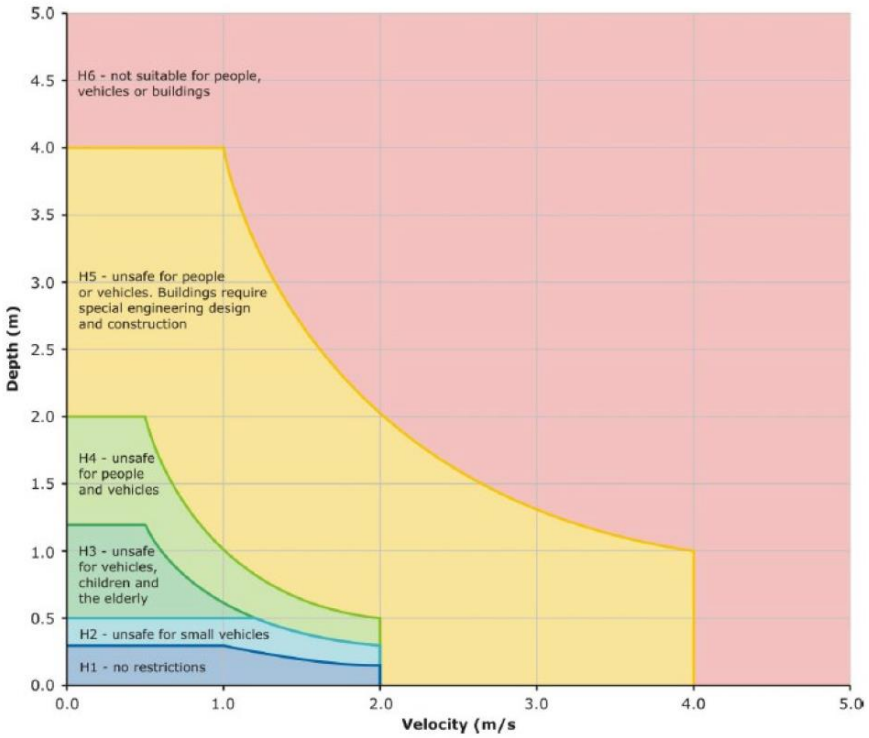
Table 2: Flow Distributions in the 100% Blockage Scenario

Design Event	Site Inflow from West	Site Inflow from North	Kamilaroi Rd Gutter	Total Site Outflow at East	Flow in Easement
20% AEP	0.01	0.09	0.58	0.30	0.74
10% AEP	0.01	0.11	0.59	0.34	0.68
5% AEP	0.01	0.10	0.58	0.39	0.72
2% AEP	0.01	0.09	0.77	0.41	1.45
1% AEP	0.01	0.17	0.91	0.46	1.07
PMF	0.49	0.35	2.55	2.65	3.56

FLOOD HAZARDS

In terms of flood hazard, the latest floodplain management practices make use of the hazard categories provided by the Australian Emergency Management Institute (2014) with its categories described in Chart 1 and results are presented from Figure 13 and 18.

Chart 1 - Hazard Categories Description



Of note is that these hazard categories are not compatible with the ones used by the 2017 Flood Study, which only categorises flood hazard as high or low. Notwithstanding, it can be said that the flood hazard categories of H1 to H3 is equivalent to "low flood hazard", whilst categories H4 to H6 is equivalent to "high flood hazard". Consistent with the 2017 Flood Study, the site is subject to low flood hazard in events up to the 1% AEP (predominantly category H1). In the PMF event however, the site is subject to categories H4 and H5 in the lower reaches.

CONCLUSIONS

The conservative ARR1987 design rainfall methodology was applied. The site flood liability has been assessed in the 2D TUFLOW model developed for the subject site. 1% AEP flows from the 2-ha catchment are in line with GRC's expectations based on our work on hundreds of sites around the Sydney metropolitan area. The sensitivity analysis undertaken on the drainage blockages reveals potential variation in flow which enters the subject site.

As per the NSW Floodplain Development Manual (NSW, 2005) it is up to Council to determine what is and what is not flood affected. Given the subject site's relatively small flows in the 1% AEP event (0.35 m^3/s enters for a no blockage scenario, 0.18 m^3/s for a 100% blockage scenario), GRC would suggest that development of the site is not hindered by flood.

COUNCIL OBJECTIONS

Further our Client has asked us to comment on what Council has written in regard to proposed development of housing at the site. Below shows Council comments in bold and italics with our response ensuing.

Construction over a Natural watercourse

Council's Comment: A natural watercourse running from west to east bisects the subject site. This watercourse forms a significant constraint to development on the site due to its location.

The watercourse such as it is, is no longer "natural". Instead the upstream catchment of 2 ha flows to Kamilaroi Road where it either flows north and away from subject site, via Kamilaroi Road gutter (majority of flow does this), or enters a 450 mm pipe to be transferred into the subject site. Note 450 mm pipes block in flow events and as such GRC's work has looked at blocked and unblocked scenarios. It is the case then that a very small percentage of the relatively small upstream catchment makes its way to the subject site for any given rainfall event. The watercourse on the subject site has been modelled using conservative best practice techniques by a firm specialising in such work. In no way does the flow thru the site in the 1% AEP event restrict development with respect to flood. Arguably the subject site, having such minor flows thru it in the modelled 1% AEP event, is not flood liable. Any development could readily occur without impacting on subject site flows such as they are. Based on the writer's experience with drainage design in the Sydney area it would be entirely normal for the flow to be placed in a culvert as it traverses the subject site.

Having such a small upstream catchment and considering the diversion in place, it is unlikely that the subject site has an ecosystem that depends on water inflows. Inflows would tend to be sporadic with many days of total dryness expected. Visual inspection indicated the same on the day of the site visit as the minor gully feature was dry and readily traversed on foot with no appearance of any water flow on the subject site.

Zone Objectives – C4 Environmental Living

Council's Comment: The proposed development does not achieve consistency with the objectives of the C4 Environmental Living zone under PLEP 2014 due to the siting of the dwelling house over the natural

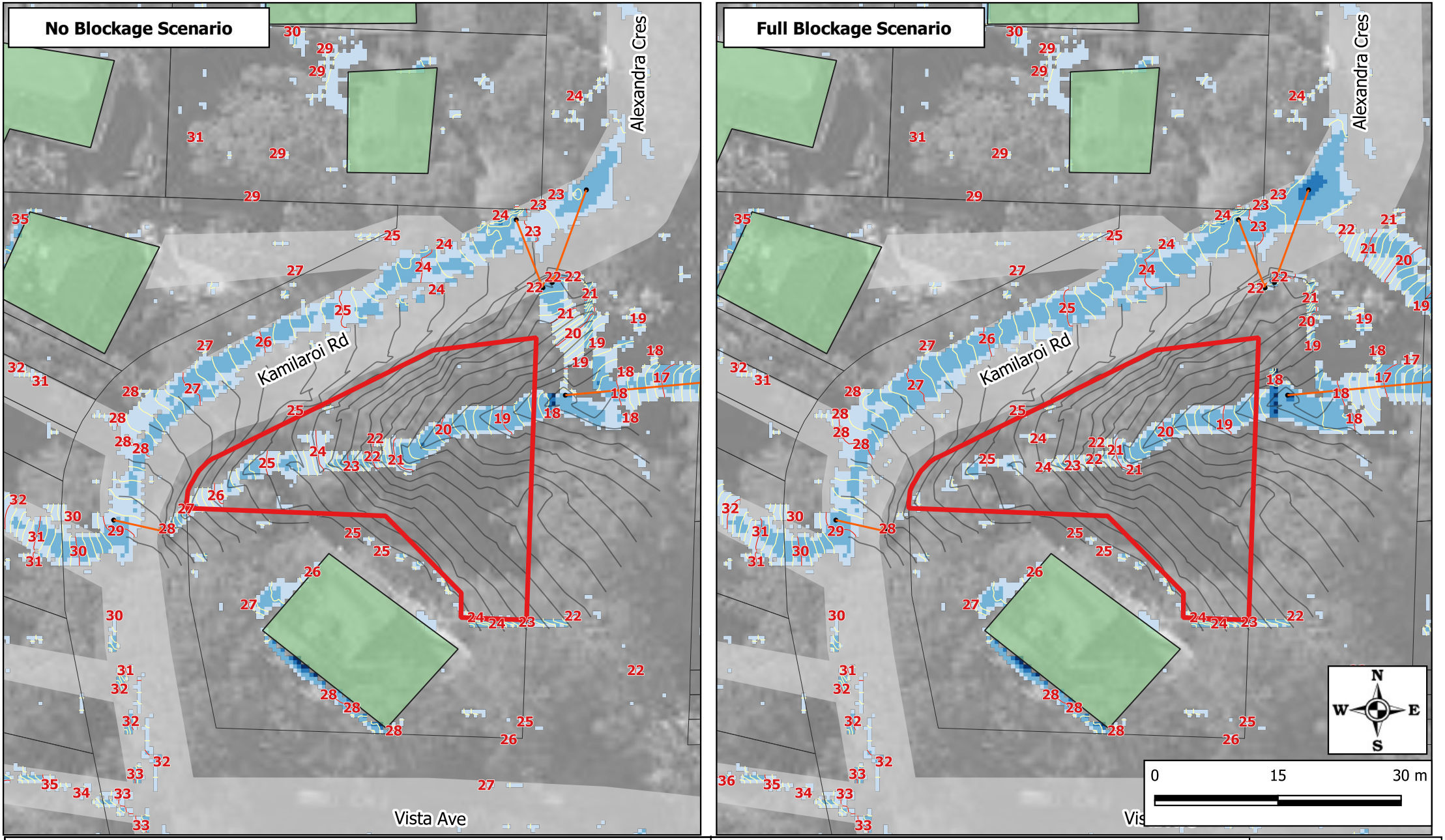
watercourse and the subsequent impacts to the ecological function of the watercourse, due to overshadowing.

As per comments above the idea that the subject site hosts a "natural watercourse" is contested. The upstream catchment is trivial at 2 ha, plus only a small fraction of upstream flow will enter the subject site as flow will diverge at the upstream Kamilaroi Road as described above (portion flows down Kamilaroi Road and away from subject site whilst some flow will enter pit and then traverse raised road via 450 mm pipe which outlets into subject site.) Being a heavily altered and relatively minor drainage path, there is not a freshwater based ecosystem on the subject site. Rather there is a dry gully which is fed by the 450 mm pipe that traverses Kamilaroi Road. Given the lack of water flow and lack of attendant ecosystem centred around same there can be no loss of ecological function of the watercourse.

Yours Sincerely

Steve Gray
Director

FIGURES



Depths (m)
- 0.05 - 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- > 1.00

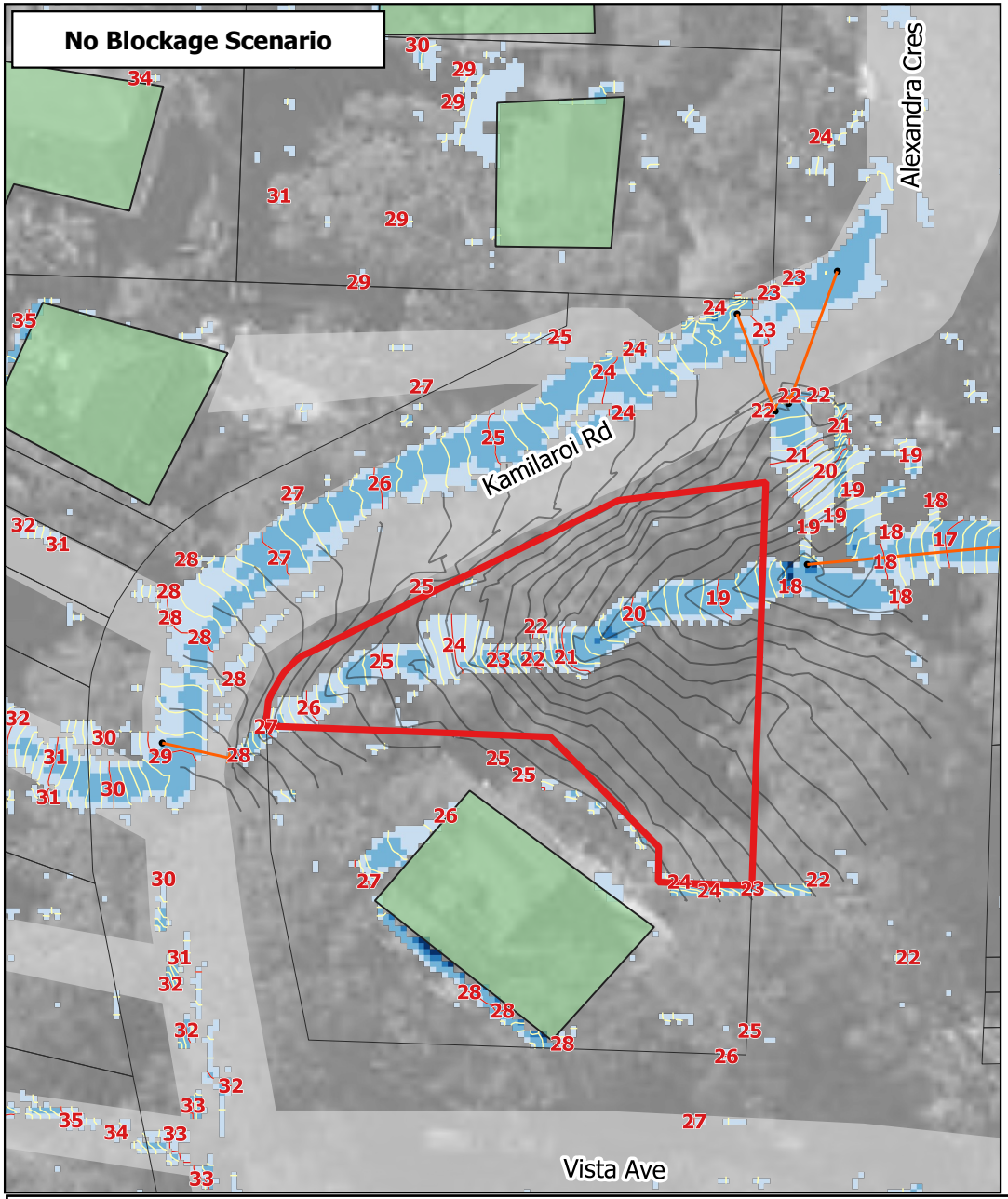
Major Contours (Spacing = 1m)

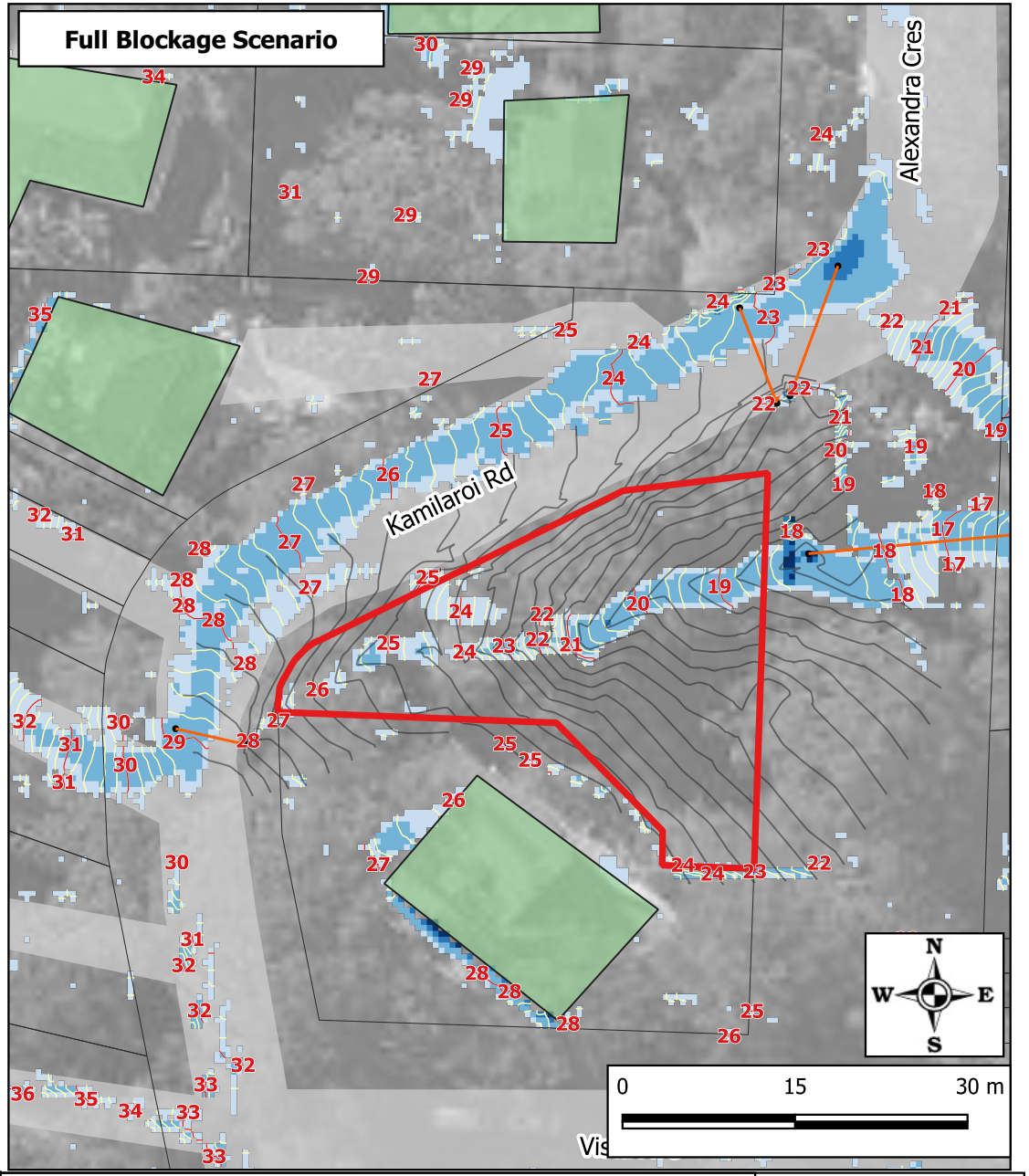
Minor Contours (Spacing = 0.2m)

- Subject Site
- Buildings
- Roads/Driveways
- Cadastral Boundaries
- Stormwater Pits / Headwalls
- Stormwater Pipes

TITLE: **20% AEP - Depths and Levels**		
PROJECT **3 Alexandra Crescent, Bayview**		
PROJECT No. **230036**		
DATE: **05-2023**	SCALE: 1:600	FIGURE No. **01**

grc HYDRO





Depths (m)
- 0.05 - 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- > 1.00

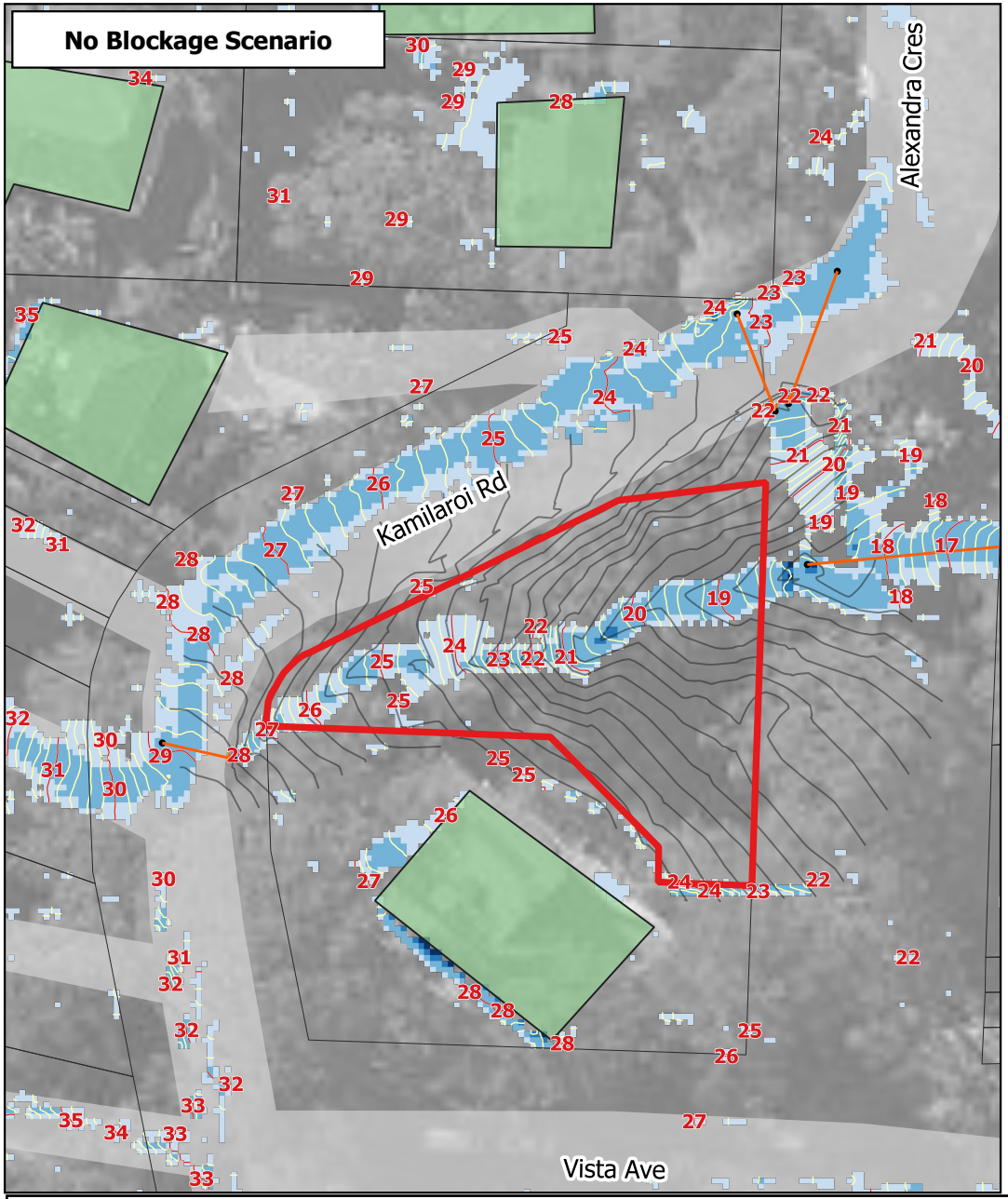
Major Contours (Spacing = 1m)

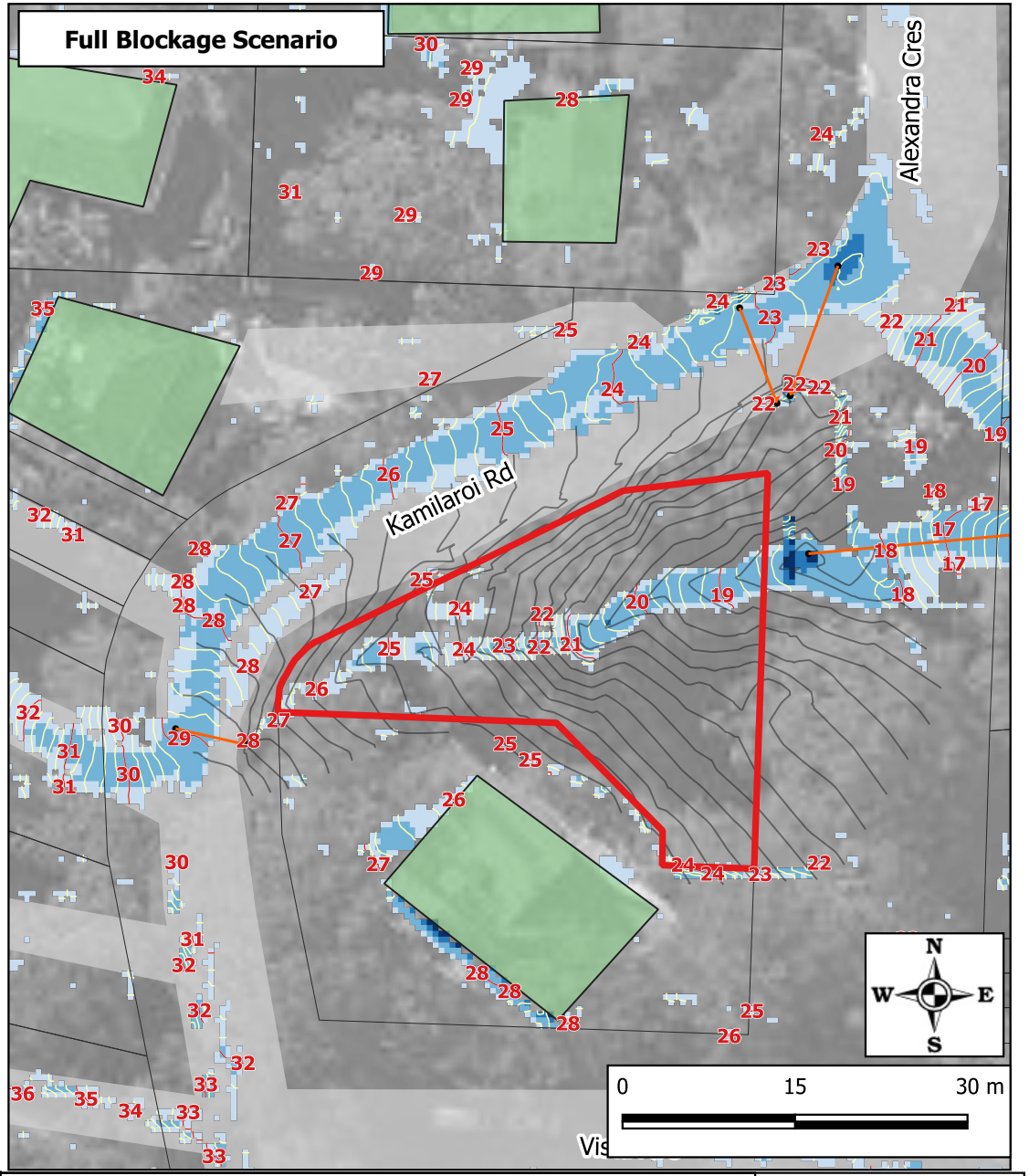
Minor Contours (Spacing = 0.2m)

- Subject Site
- Buildings
- Roads/Driveways
- Cadastral Boundaries
- Stormwater Pits / Headwalls
- Stormwater Pipes

TITLE: **10% AEP - Depths and Levels**		
PROJECT **3 Alexandra Crescent, Bayview**		
PROJECT No. **230036**		
DATE: **05-2023**	SCALE: 1:600	FIGURE No. **02**

grc HYDRO





Depths (m)
- 0.05 - 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- > 1.00

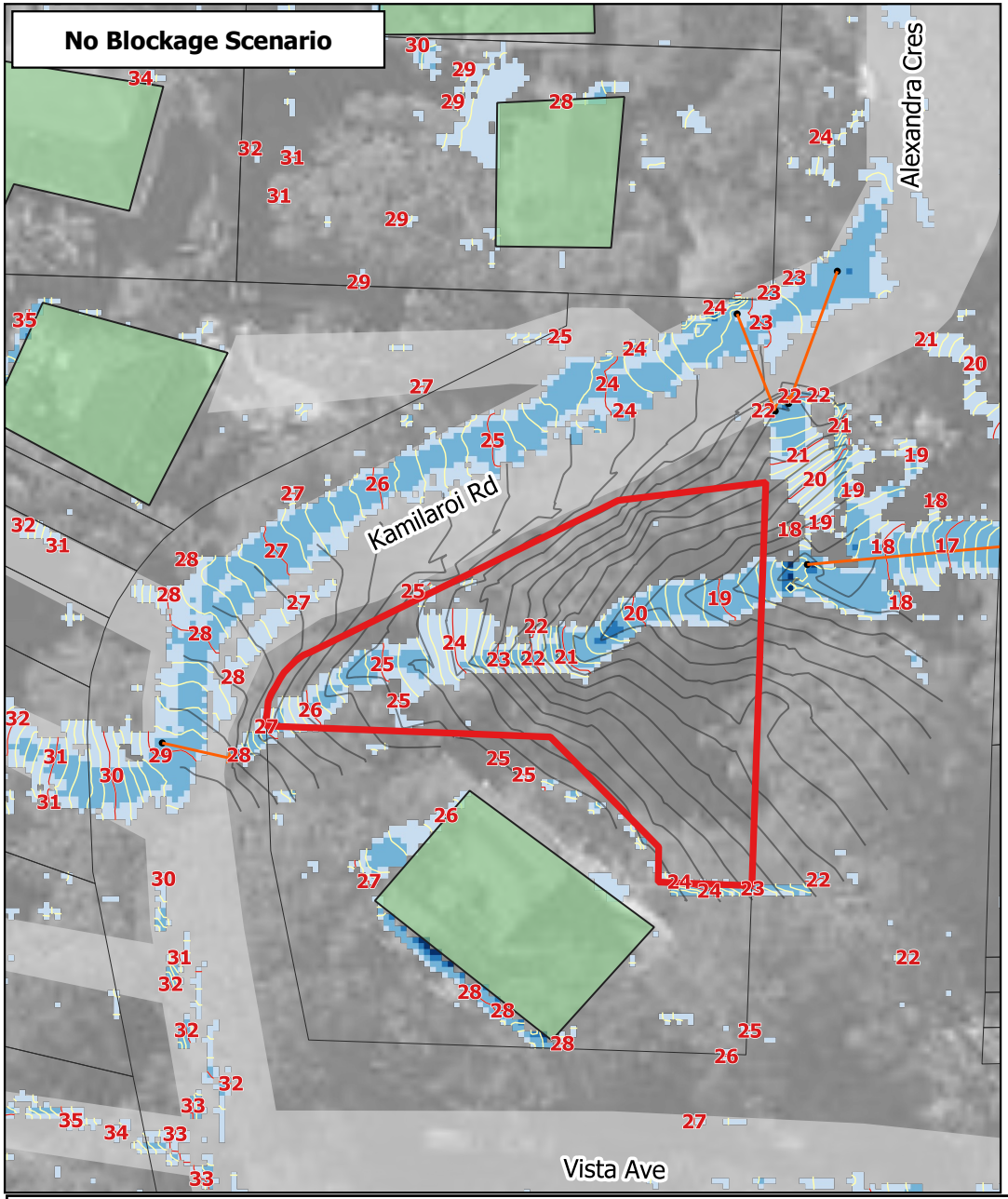
Major Contours (Spacing = 1m)

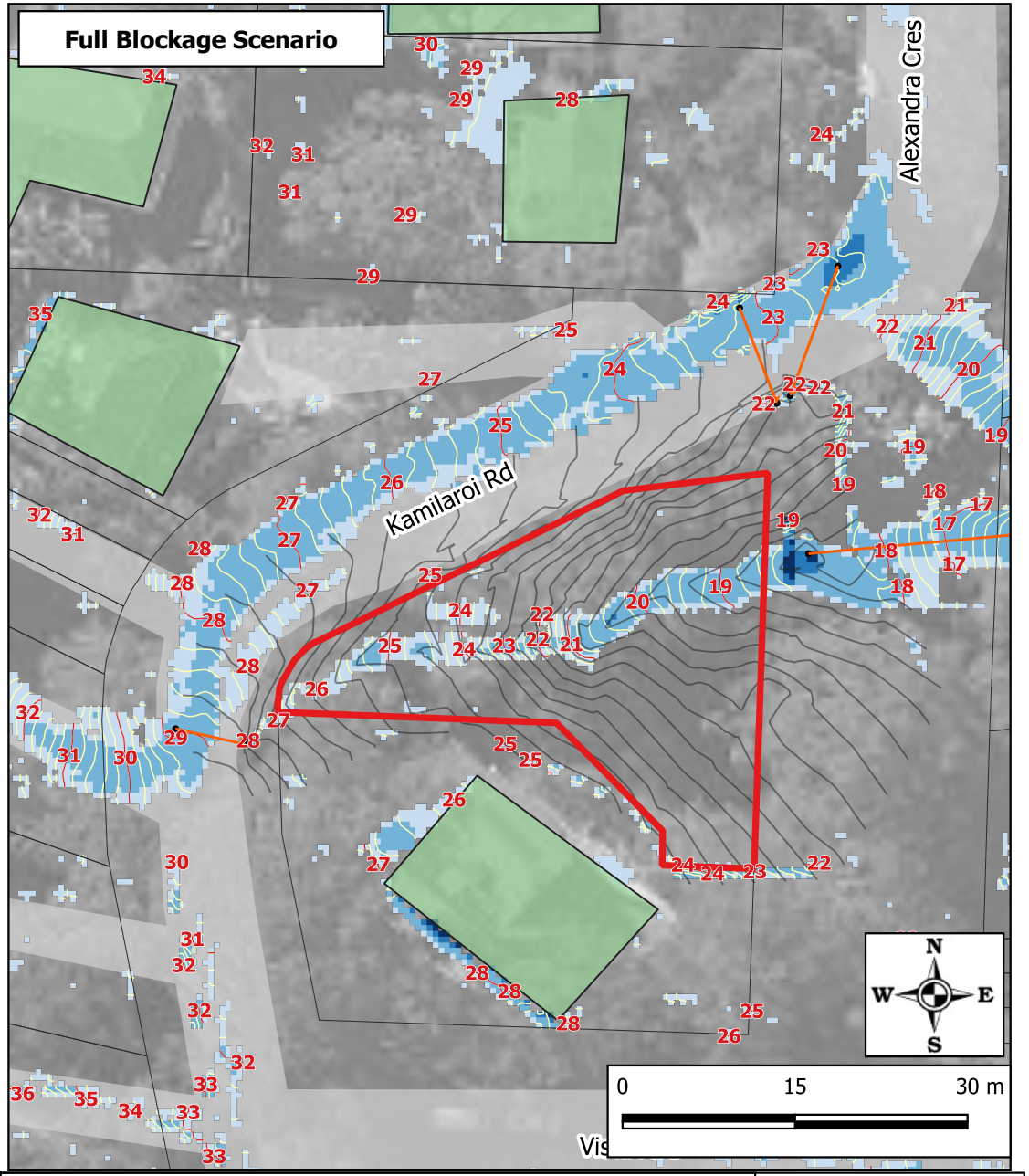
Minor Contours (Spacing = 0.2m)

- Subject Site
- Buildings
- Roads/Driveways
- Cadastral Boundaries
- Stormwater Pits / Headwalls
- Stormwater Pipes

TITLE: **5% AEP - Depths and Levels**		
PROJECT **3 Alexandra Crescent, Bayview**		
PROJECT No. **230036**		
DATE: **05-2023**	SCALE: 1:600	FIGURE No. **03**

grc HYDRO





Depths (m)
- 0.05 - 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- > 1.00

Major Contours (Spacing = 1m)

Minor Contours (Spacing = 0.2m)

- Subject Site
- Buildings
- Roads/Driveways
- Cadastral Boundaries
- Stormwater Pits / Headwalls
- Stormwater Pipes

TITLE: **2% AEP - Depths and Levels**		
PROJECT **3 Alexandra Crescent, Bayview**		
PROJECT No. **230036**		
DATE: **05-2023**	SCALE: 1:600	FIGURE No. **04**

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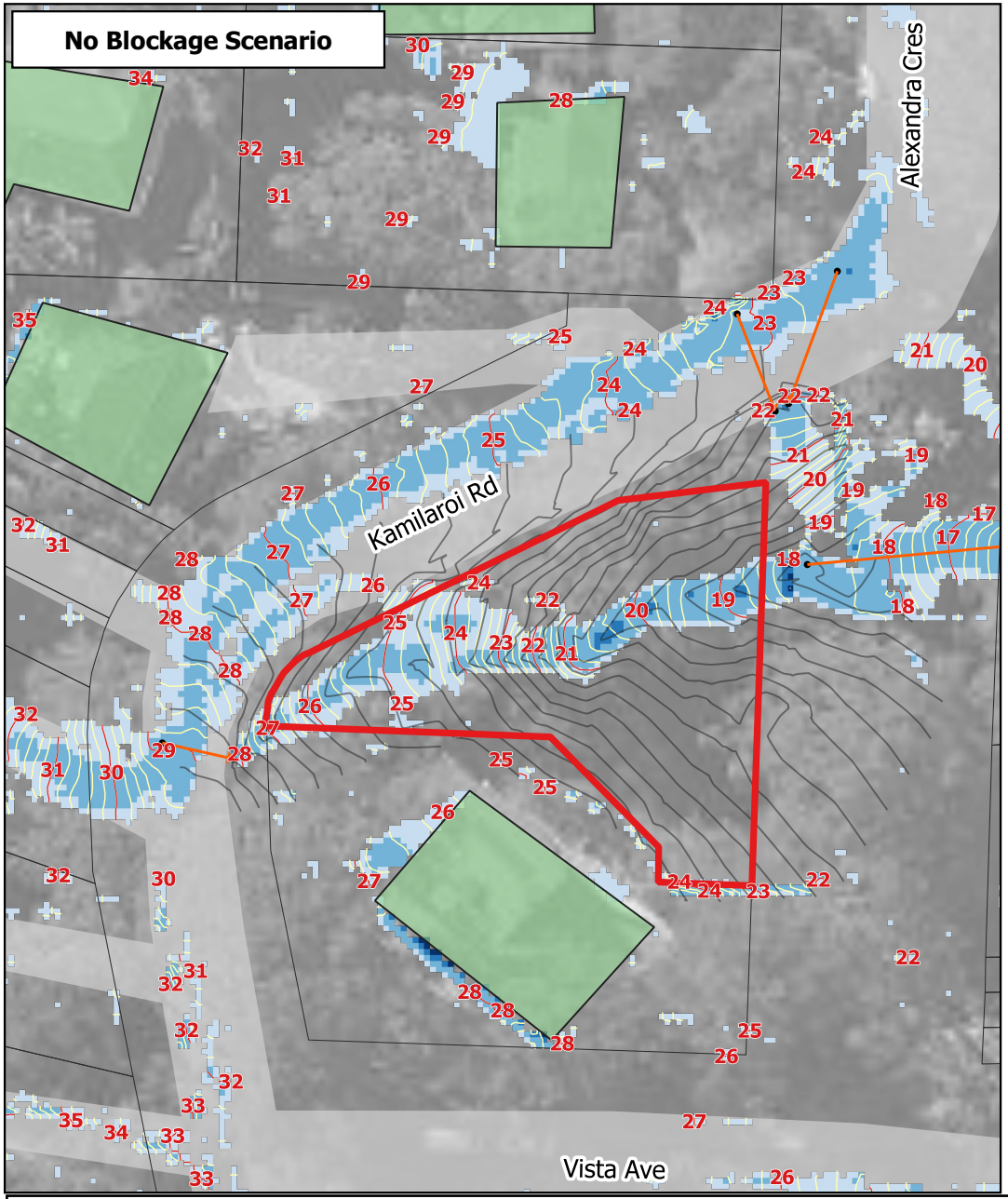
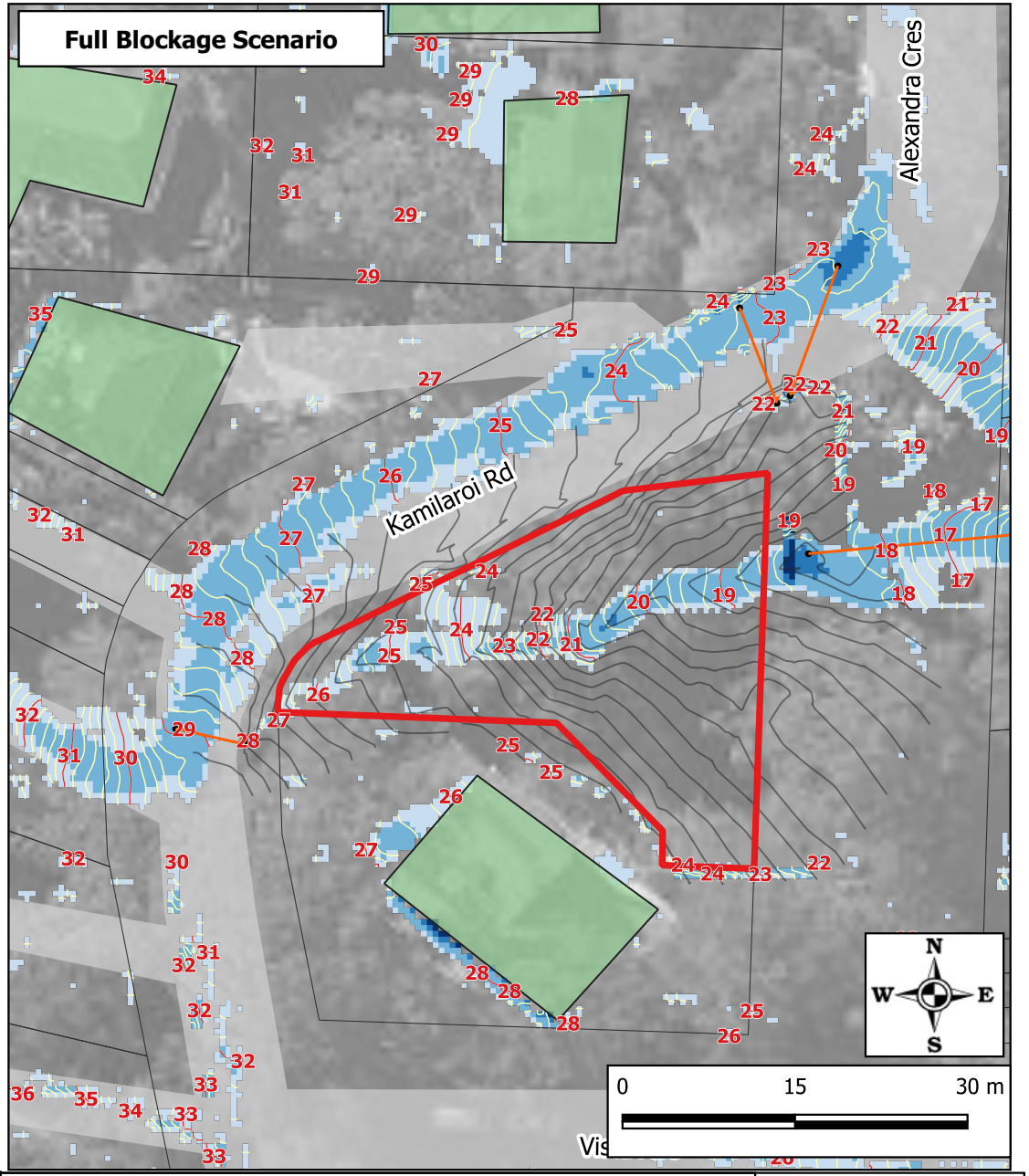




Depths (m)
- 0.05 - 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- > 1.00

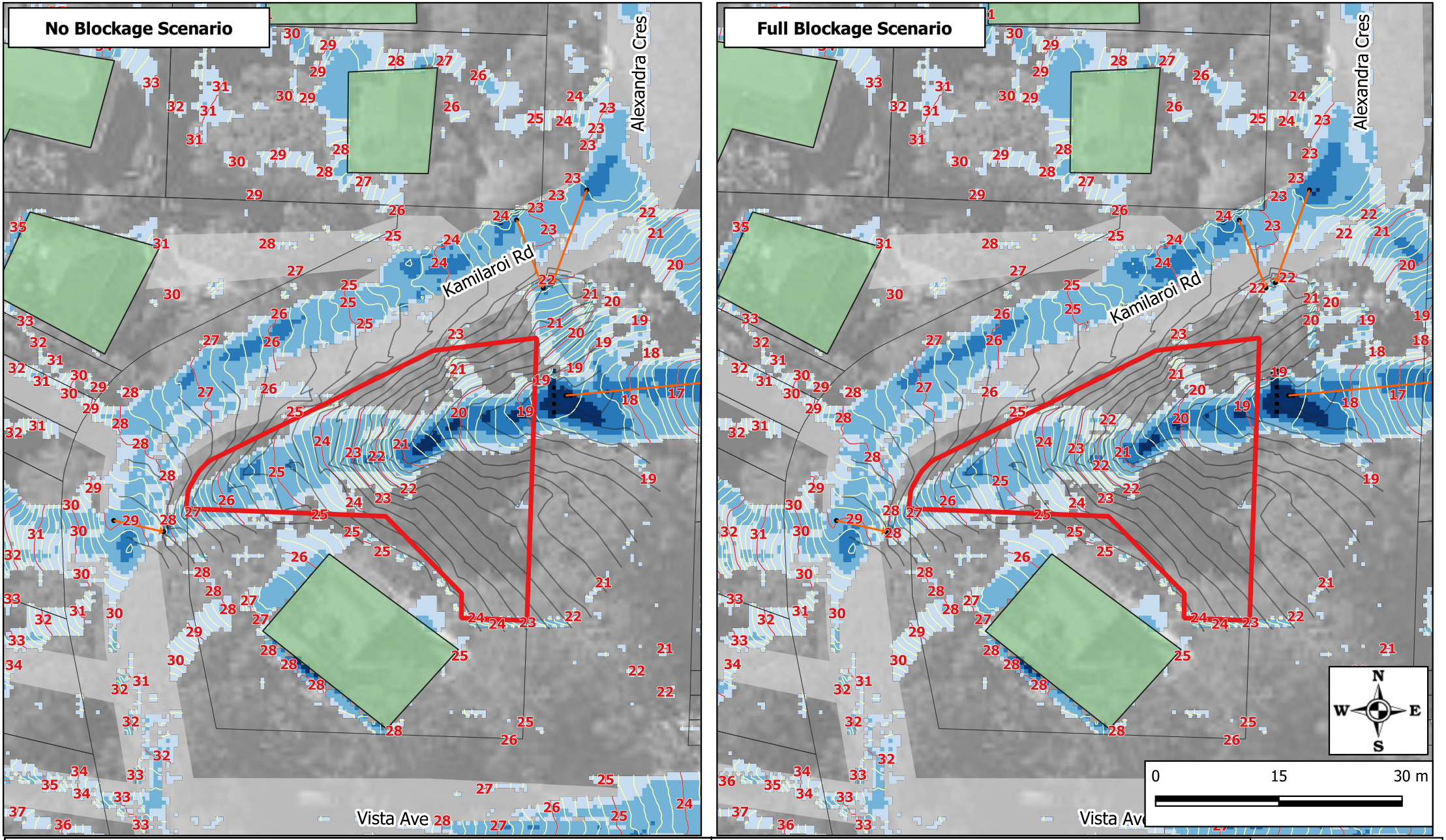
Major Contours (Spacing = 1m)

Minor Contours (Spacing = 0.2m)

Subject Site
Buildings
Roads/Driveways
Cadastral Boundaries
Stormwater Pits / Headwalls
Stormwater Pipes

TITLE: **1% AEP - Depths and Levels**		
PROJECT **3 Alexandra Crescent, Bayview**		
PROJECT No. **230036**		
DATE: **05-2023**	SCALE: 1:600	FIGURE No. **05**

grc HYDRO



Depths (m)
- 0.05 - 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- > 1.00

Major Contours (Spacing = 1m)

Minor Contours (Spacing = 0.2m)

Subject Site
Buildings
Roads/Driveways
Cadastral Boundaries
Stormwater Pits / Headwalls
Stormwater Pipes

TITLE: **PMF - Depths and Levels**		
PROJECT **3 Alexandra Crescent, Bayview**		
PROJECT No. **230036**		
DATE: **05-2023**	SCALE: 1:600	FIGURE No. **06**

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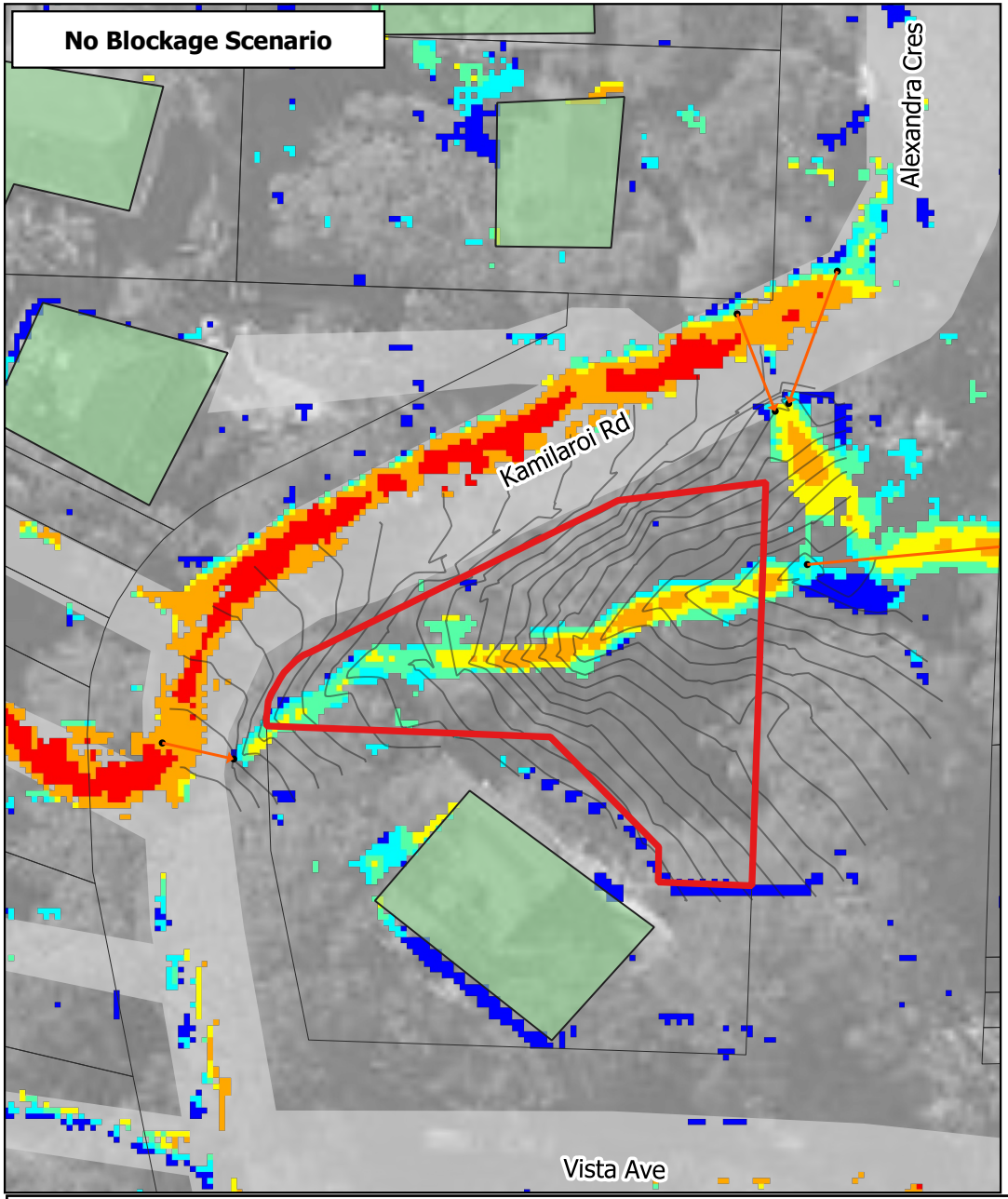
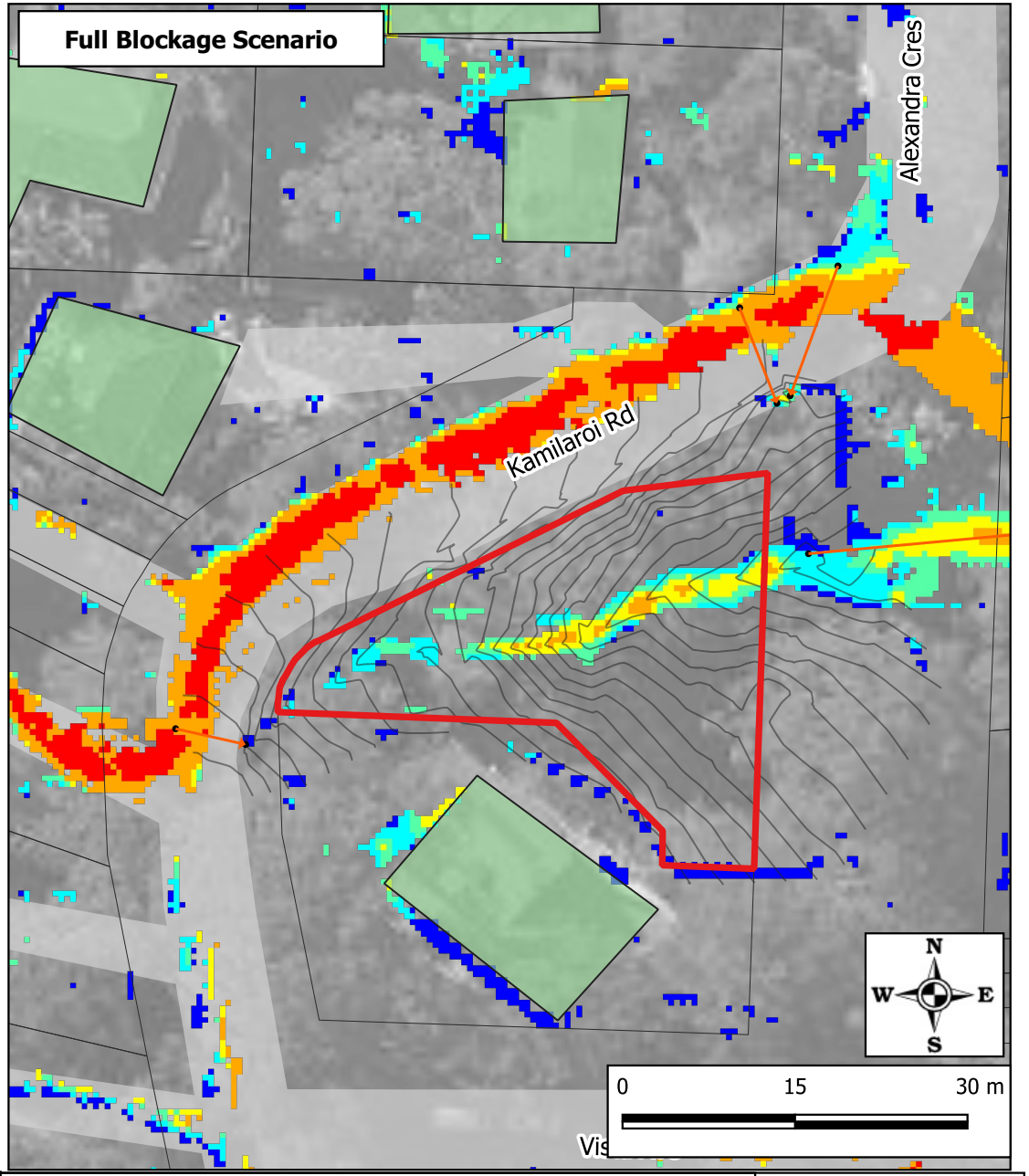


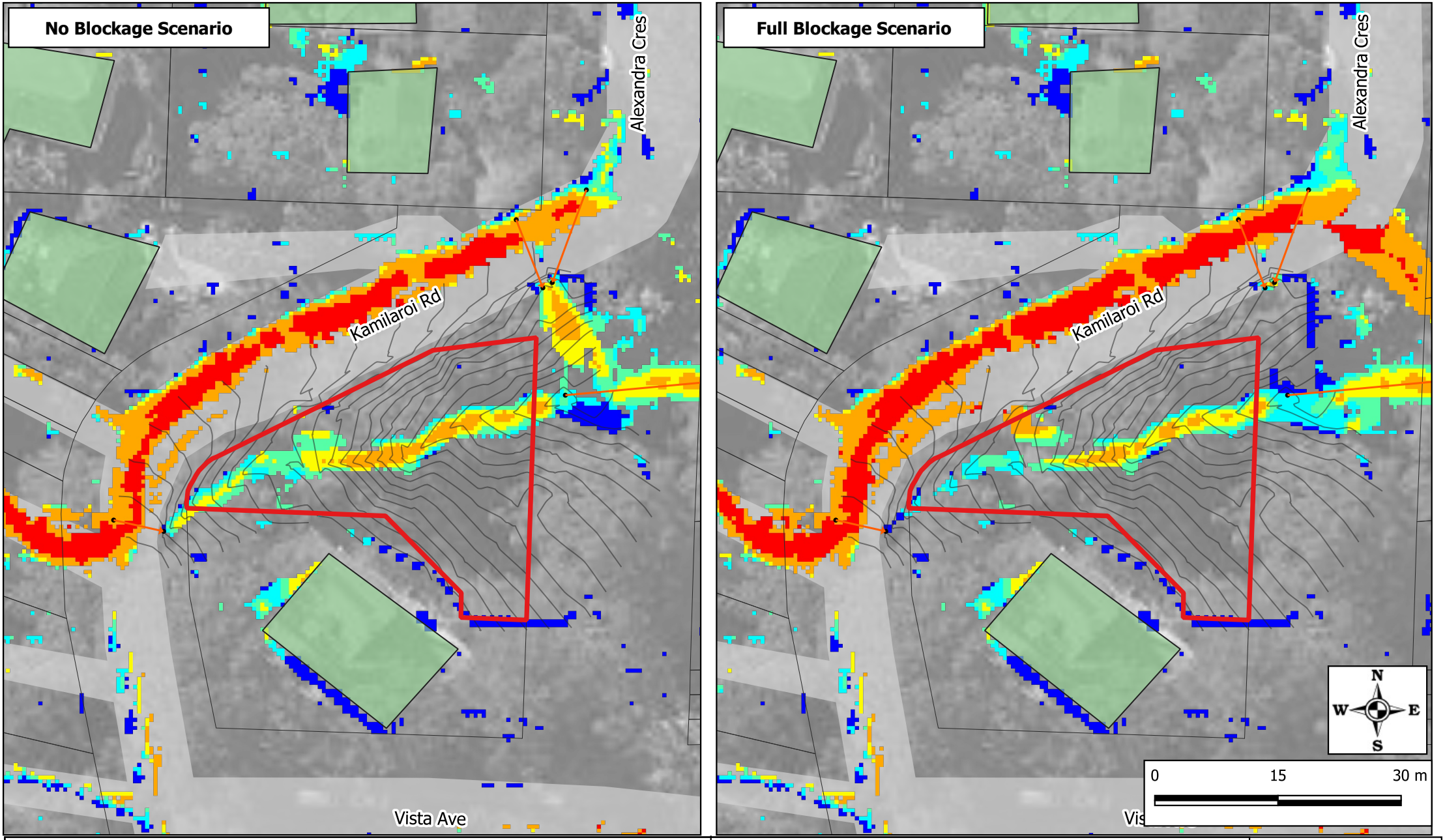


Velocity (m/s)
- < 0.25
- 0.25 to 0.50
- 0.50 to 0.75
- 0.75 to 1.00
- 1.00 to 2.00
- > 2.00

- Subject Site
- Buildings
- Roads/Driveways
- Cadastral Boundaries
- Stormwater Pits / Headwalls
- Stormwater Pipes

TITLE: **20% AEP - Peak Velocity**			
PROJECT **3 Alexandra Crescent, Bayview**			
PROJECT No. **230036**			
DATE: **05-2023**	SCALE: 1:600	FIGURE No. **07**	

grc HYDRO

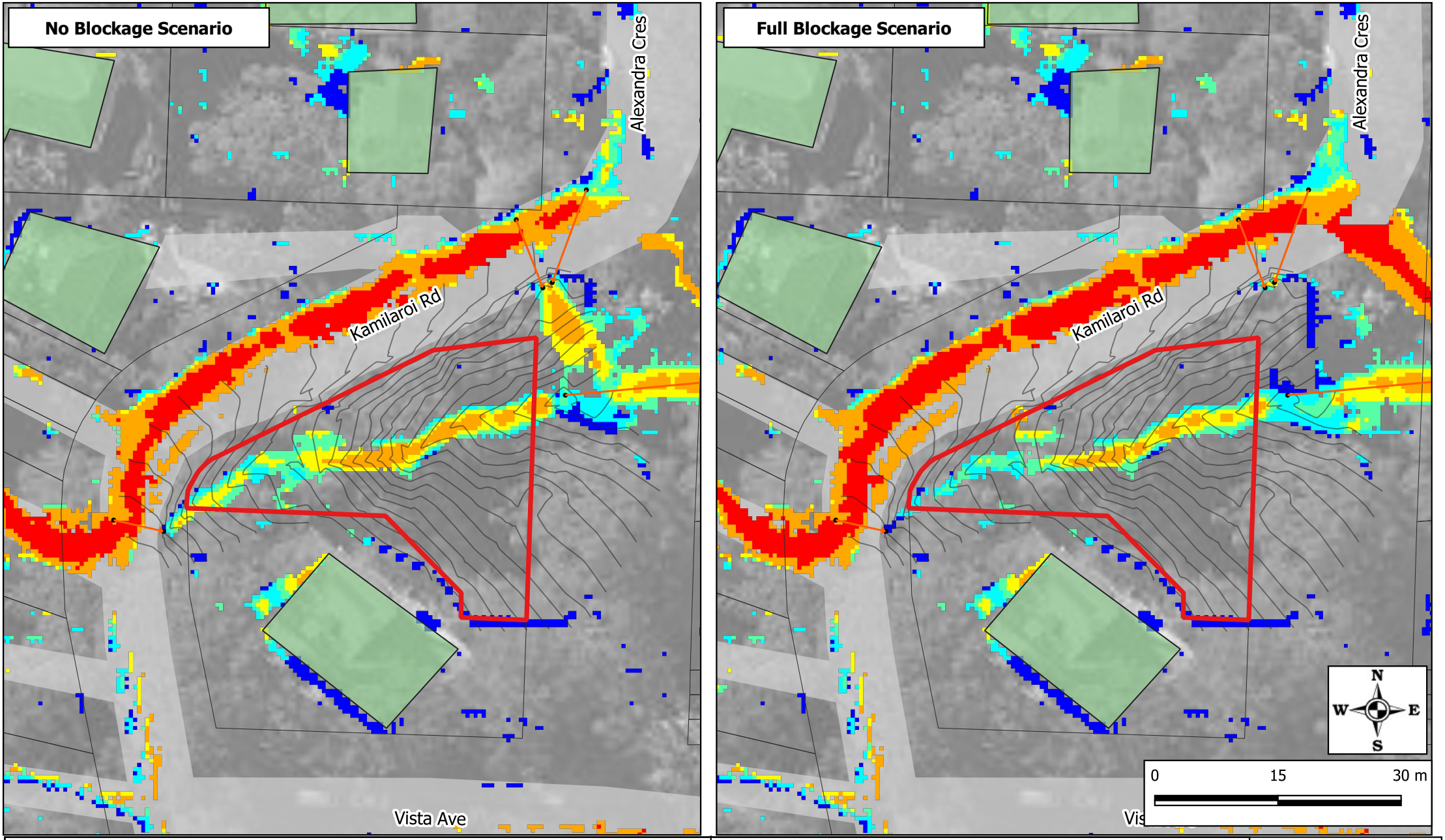


Velocity (m/s)
- < 0.25
- 0.25 to 0.50
- 0.50 to 0.75
- 0.75 to 1.00
- 1.00 to 2.00
- > 2.00

- Subject Site
- Buildings
- Roads/Driveways
- Cadastral Boundaries
- Stormwater Pits / Headwalls
- Stormwater Pipes

TITLE: **10% AEP - Peak Velocity**			
PROJECT **3 Alexandra Crescent, Bayview**			
PROJECT No. **230036**			
DATE: **05-2023**	SCALE: 1:600	FIGURE No. **08**	

grc HYDRO

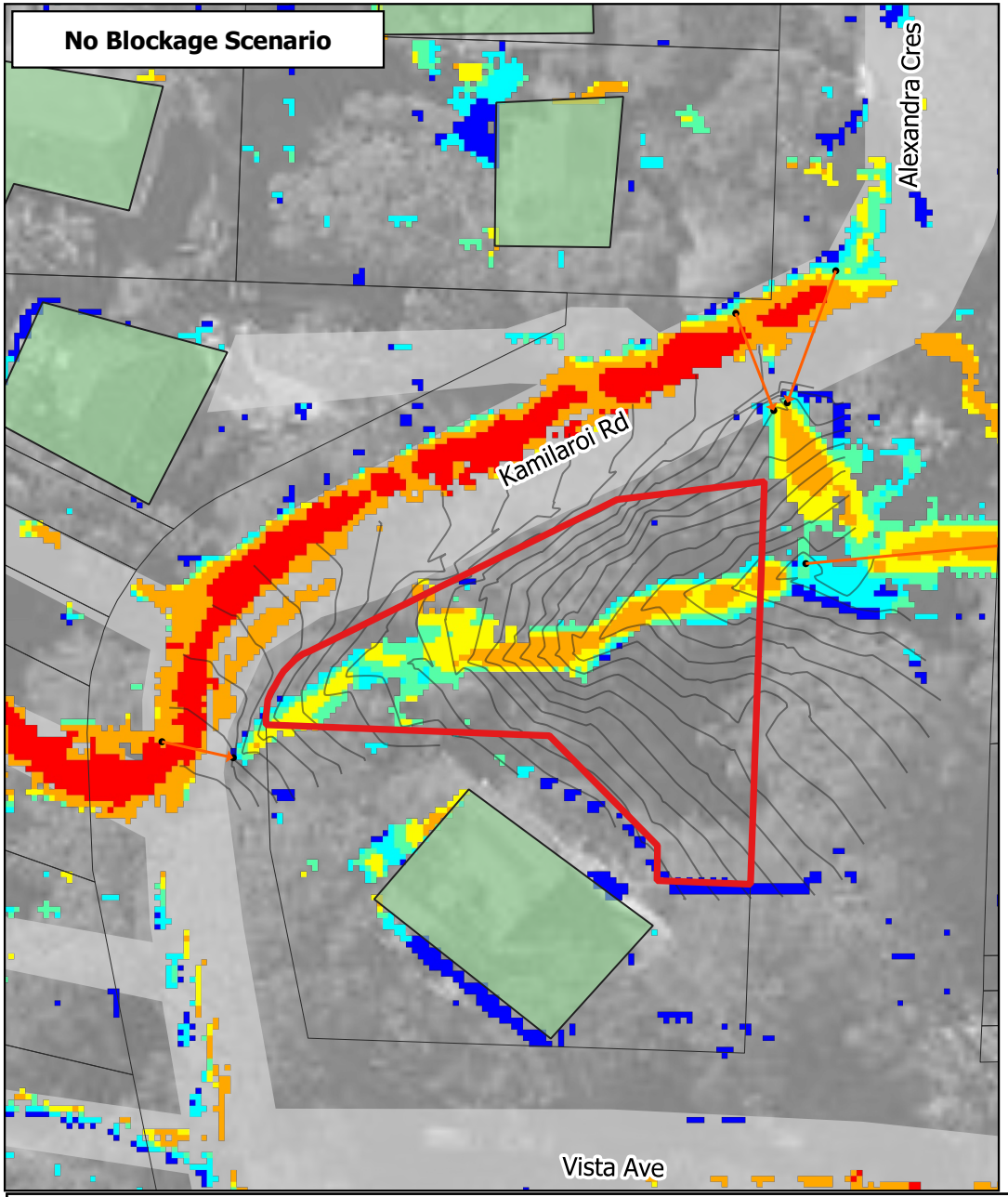


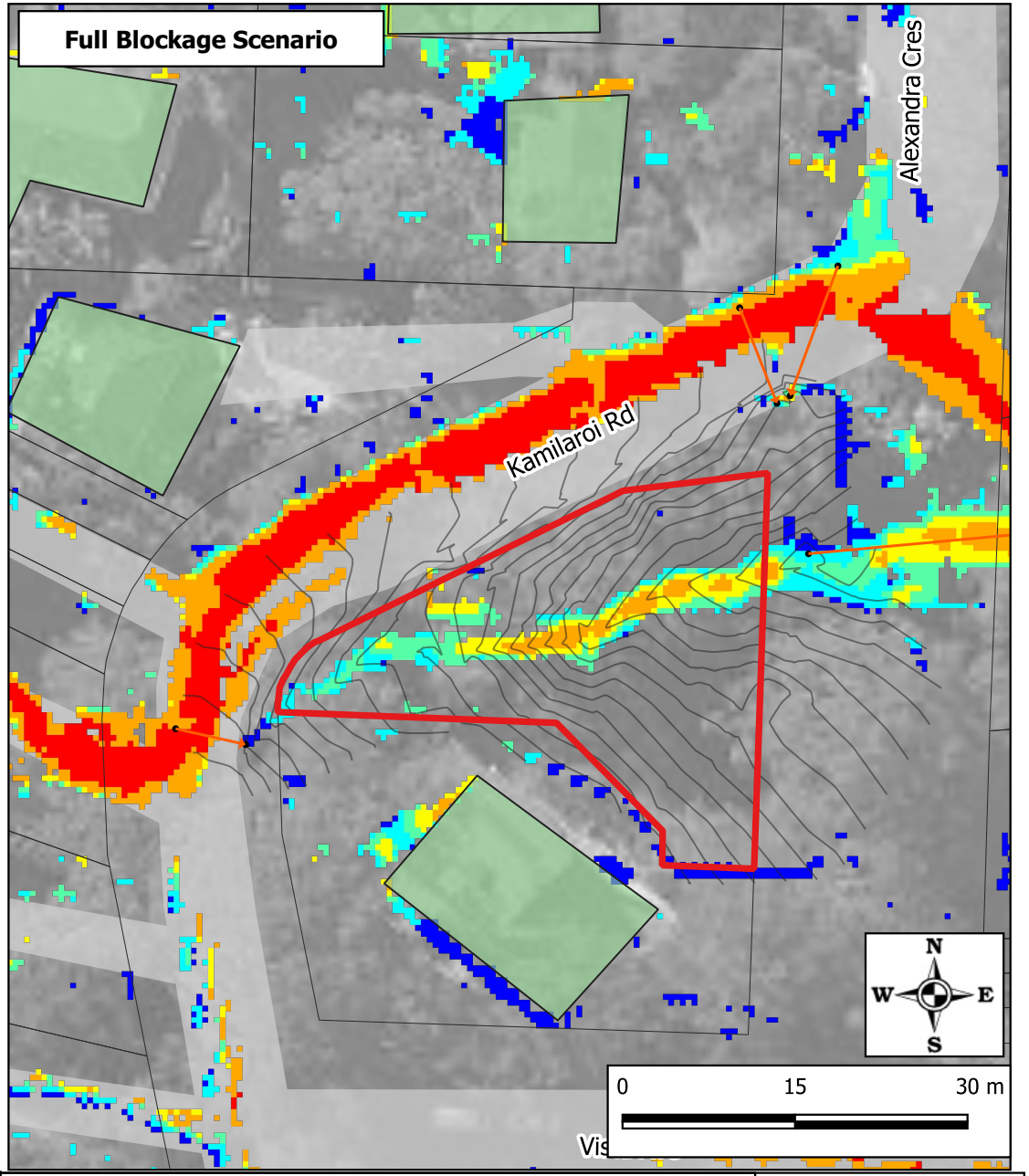
Velocity (m/s)
- < 0.25
- 0.25 to 0.50
- 0.50 to 0.75
- 0.75 to 1.00
- 1.00 to 2.00
- > 2.00

- Subject Site
- Buildings
- Roads/Driveways
- Cadastral Boundaries
- Stormwater Pits / Headwalls
- Stormwater Pipes

TITLE: **5% AEP - Peak Velocity**			
PROJECT **3 Alexandra Crescent, Bayview**			
PROJECT No. **230036**			
DATE: **05-2023**	SCALE: 1:600	FIGURE No. **09**	

grc HYDRO



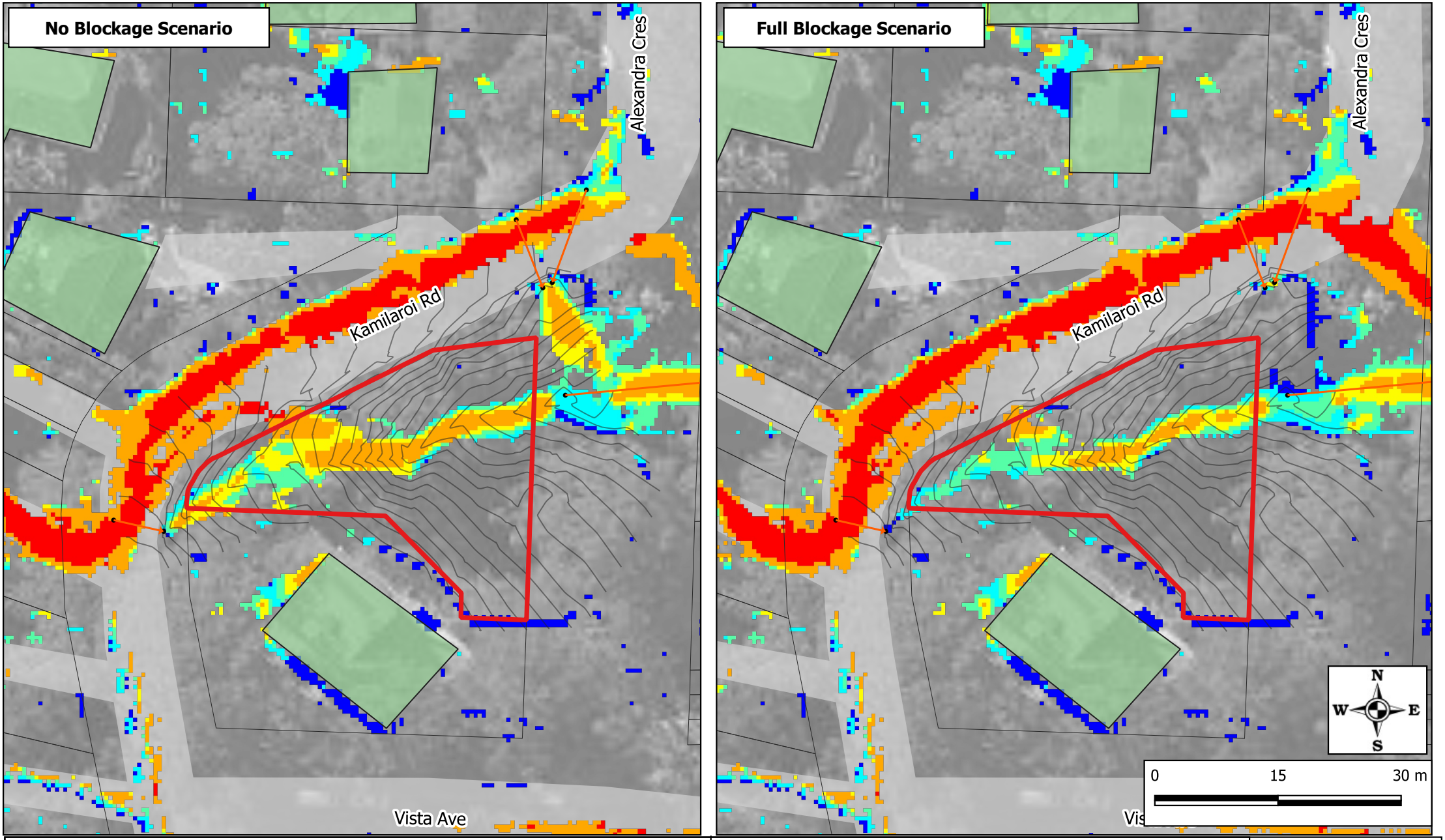


Velocity (m/s)
- < 0.25
- 0.25 to 0.50
- 0.50 to 0.75
- 0.75 to 1.00
- 1.00 to 2.00
- > 2.00

- Subject Site
- Buildings
- Roads/Driveways
- Cadastral Boundaries
- Stormwater Pits / Headwalls
- Stormwater Pipes

TITLE: **2% AEP - Peak Velocity**			
PROJECT **3 Alexandra Crescent, Bayview**			
PROJECT No. **230036**			
DATE: **05-2023**	SCALE: 1:600	FIGURE No. **10**	

grc HYDRO

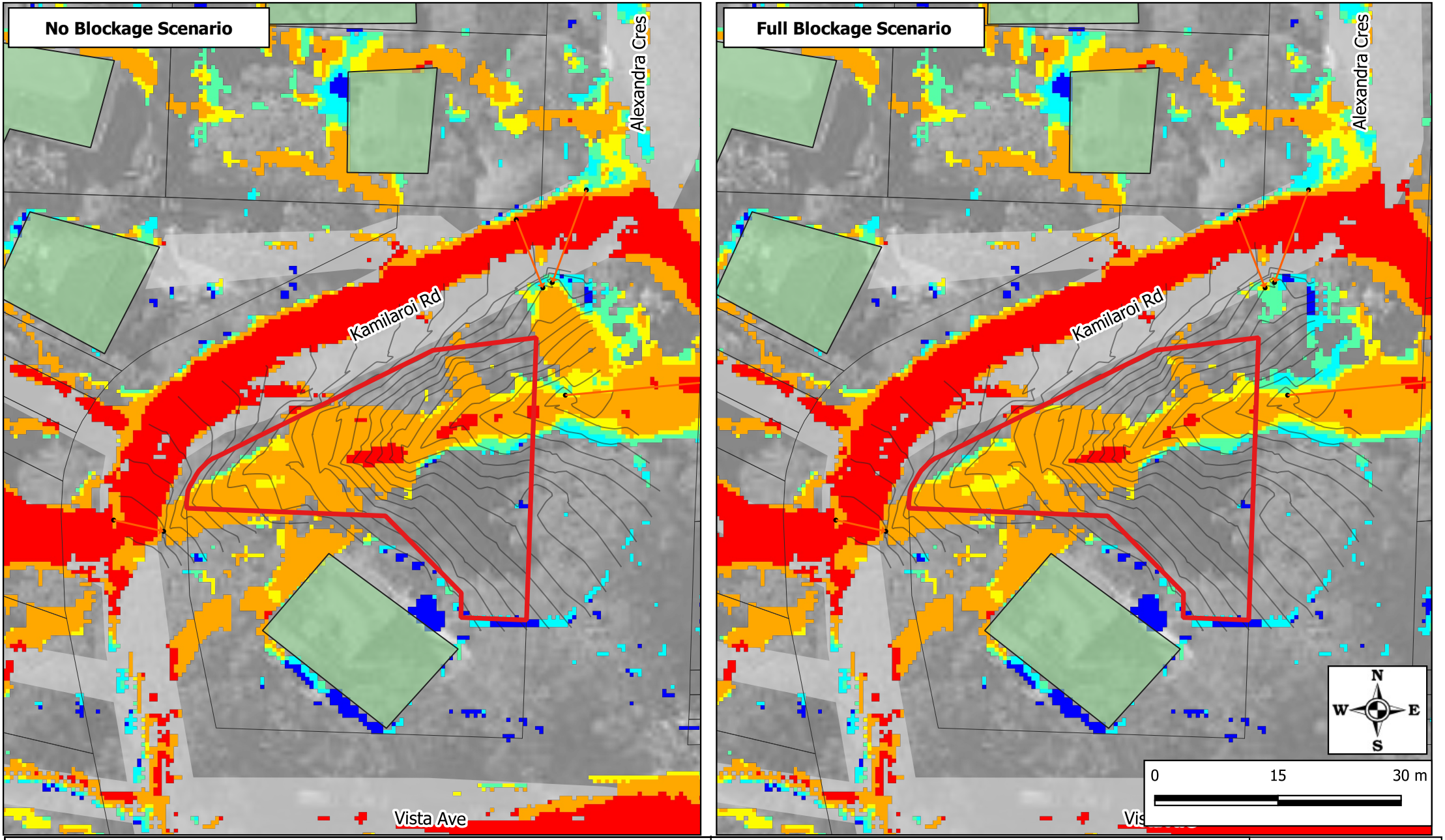


Velocity (m/s)
- < 0.25
- 0.25 to 0.50
- 0.50 to 0.75
- 0.75 to 1.00
- 1.00 to 2.00
- > 2.00

- Subject Site
- Buildings
- Roads/Driveways
- Cadastral Boundaries
- Stormwater Pits / Headwalls
- Stormwater Pipes

TITLE: **1% AEP - Peak Velocity**			
PROJECT **3 Alexandra Crescent, Bayview**			
PROJECT No. **230036**			
DATE: **05-2023**	SCALE: 1:600	FIGURE No. **11**	

grc HYDRO

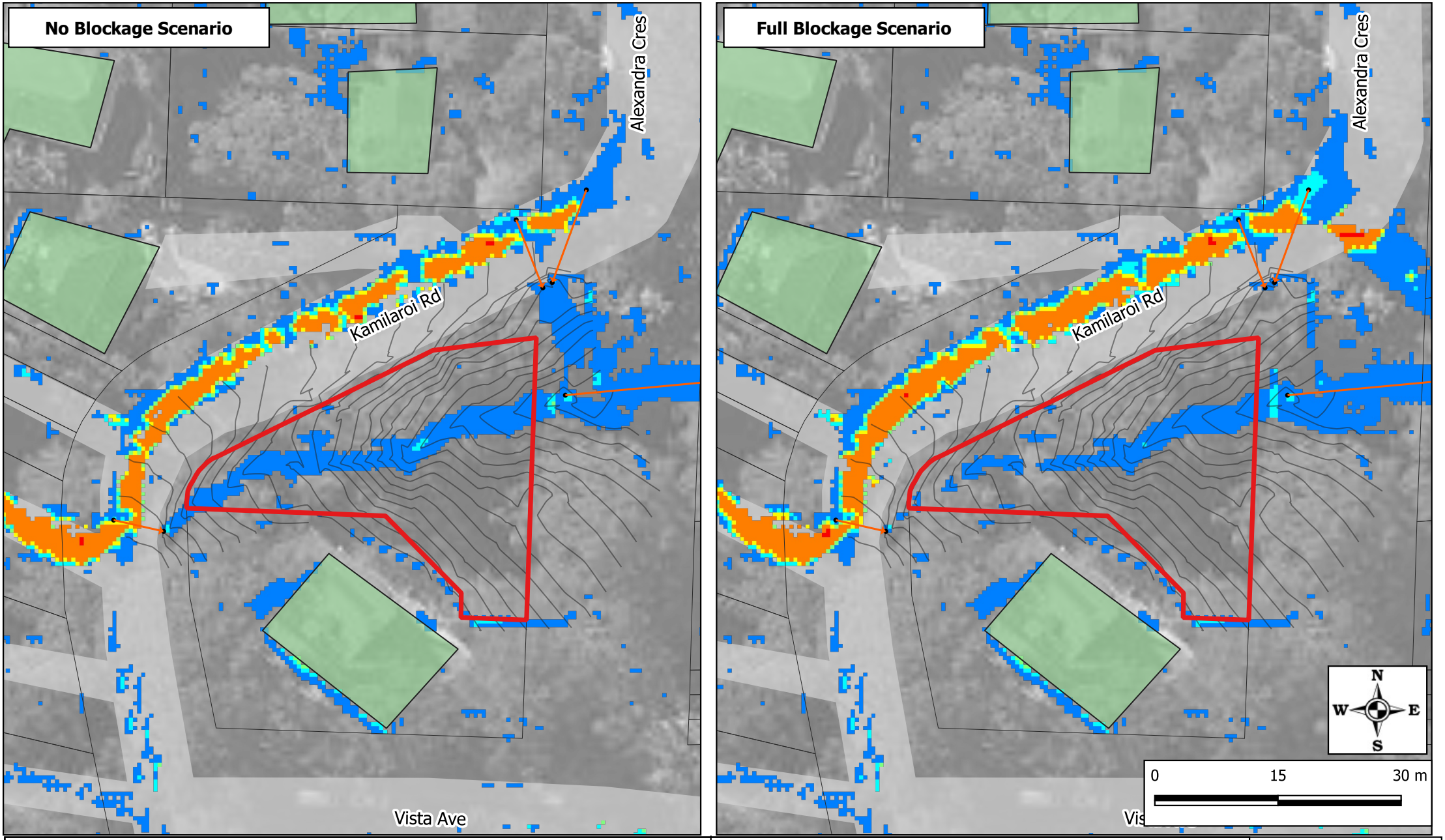


Velocity (m/s)
- < 0.25
- 0.25 to 0.50
- 0.50 to 0.75
- 0.75 to 1.00
- 1.00 to 2.00
- > 2.00

- Subject Site
- Buildings
- Roads/Driveways
- Cadastral Boundaries
- Stormwater Pits / Headwalls
- Stormwater Pipes

TITLE: **PMF - Peak Velocity**			
PROJECT **3 Alexandra Crescent, Bayview**			
PROJECT No. **230036**			
DATE: **05-2023**	SCALE: 1:600	FIGURE No. **12**	

grc HYDRO

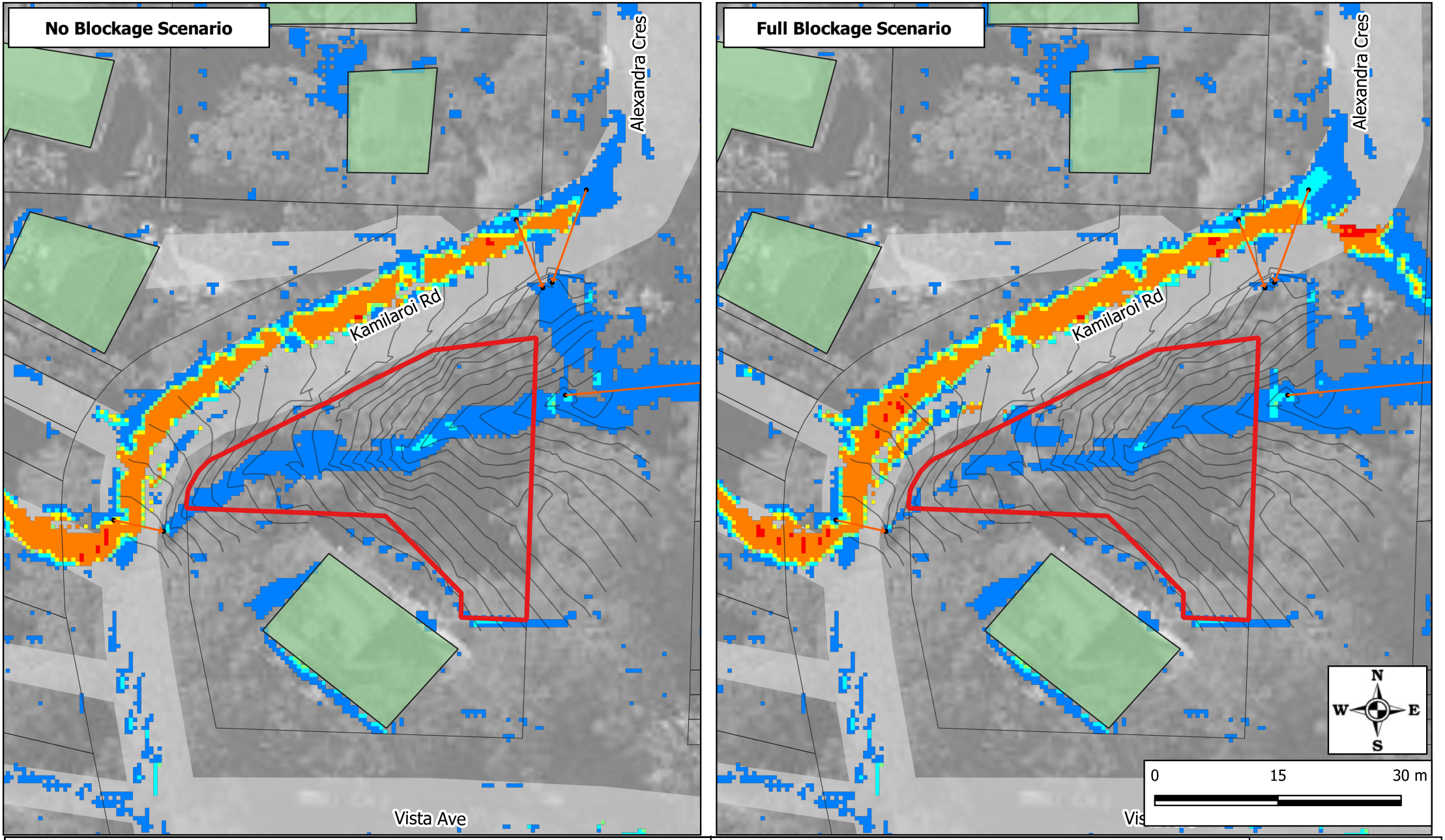


Hazard
- H1
- H2
- H3
- H4
- H5
- H6

- Subject Site
- Buildings
- Roads/Driveways
- Cadastral Boundaries
- Stormwater Pits / Headwalls
- Stormwater Pipes

TITLE:	**20% AEP - Peak Hazard**		
PROJECT	**3 Alexandra Crescent, Bayview**		
PROJECT No.	**230036**		
DATE:	**05-2023**	SCALE: 1:600	FIGURE No. **13**

grc HYDRO

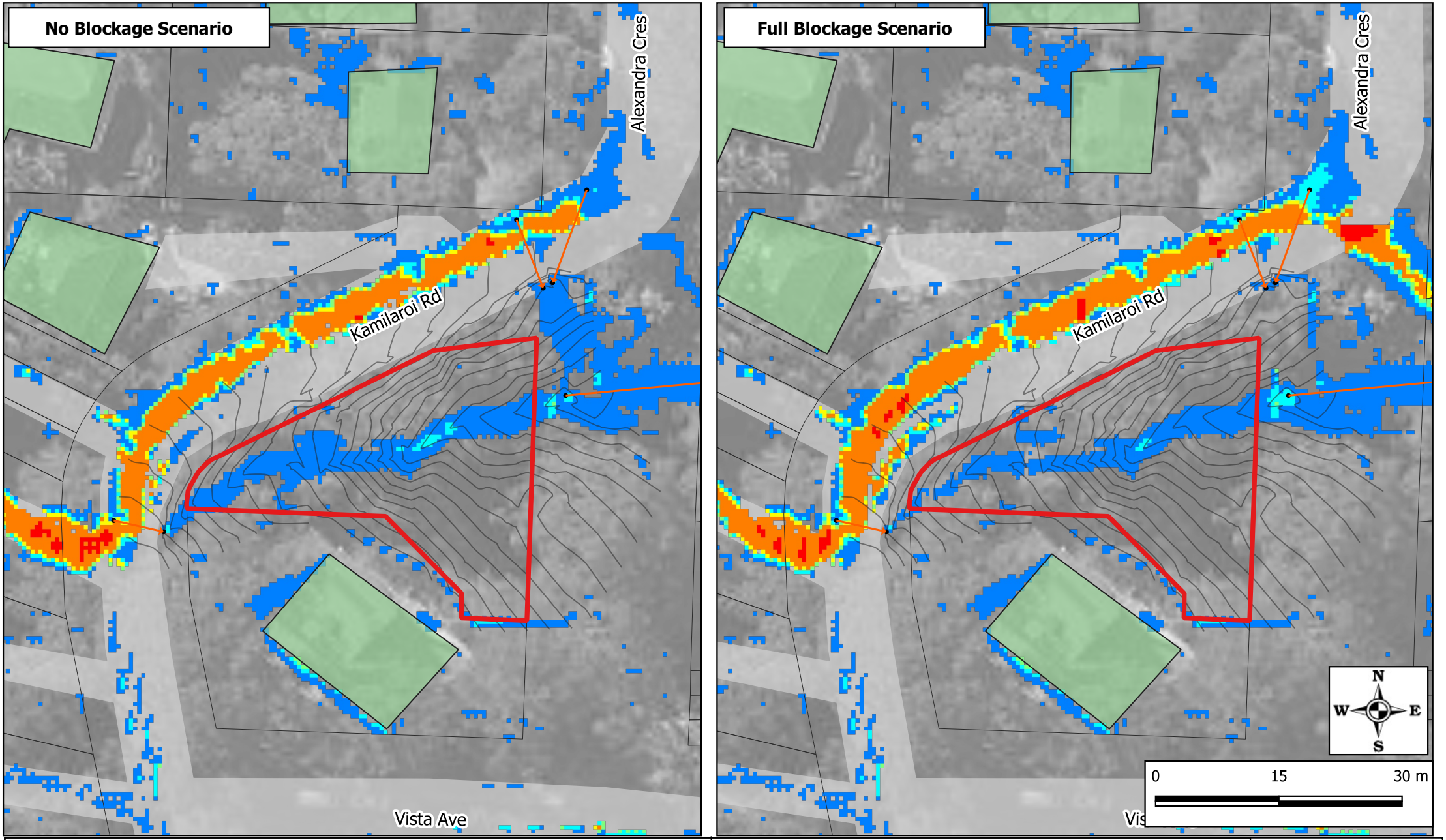


Hazard
- H1
- H2
- H3
- H4
- H5
- H6

- Subject Site
- Buildings
- Roads/Driveways
- Cadastral Boundaries
- Stormwater Pits / Headwalls
- Stormwater Pipes

TITLE: **10% AEP - Peak Hazard**			
PROJECT **3 Alexandra Crescent, Bayview**			
PROJECT No. **230036**			
DATE: **05-2023**	SCALE: 1:600	FIGURE No. **14**	

grc HYDRO

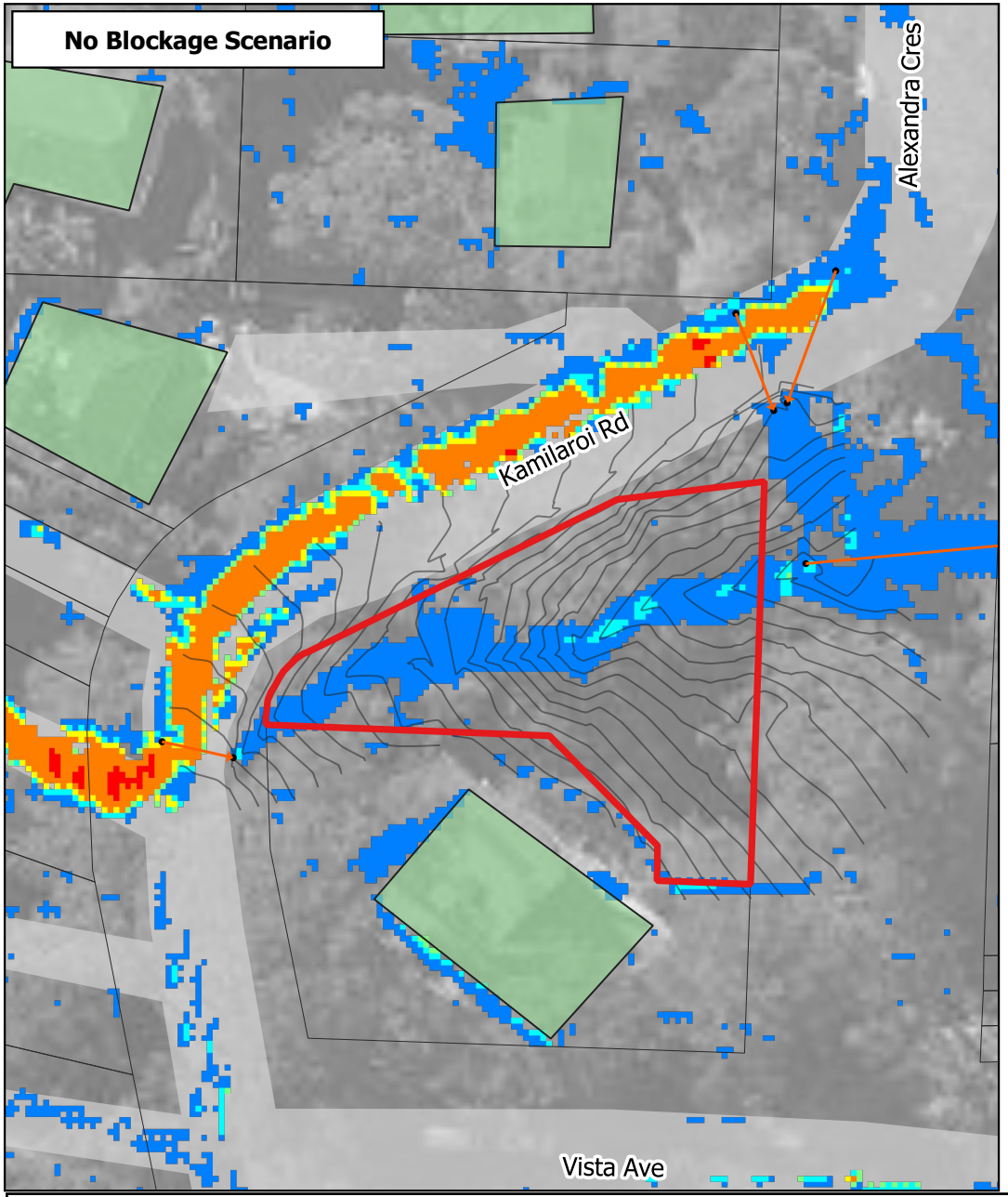


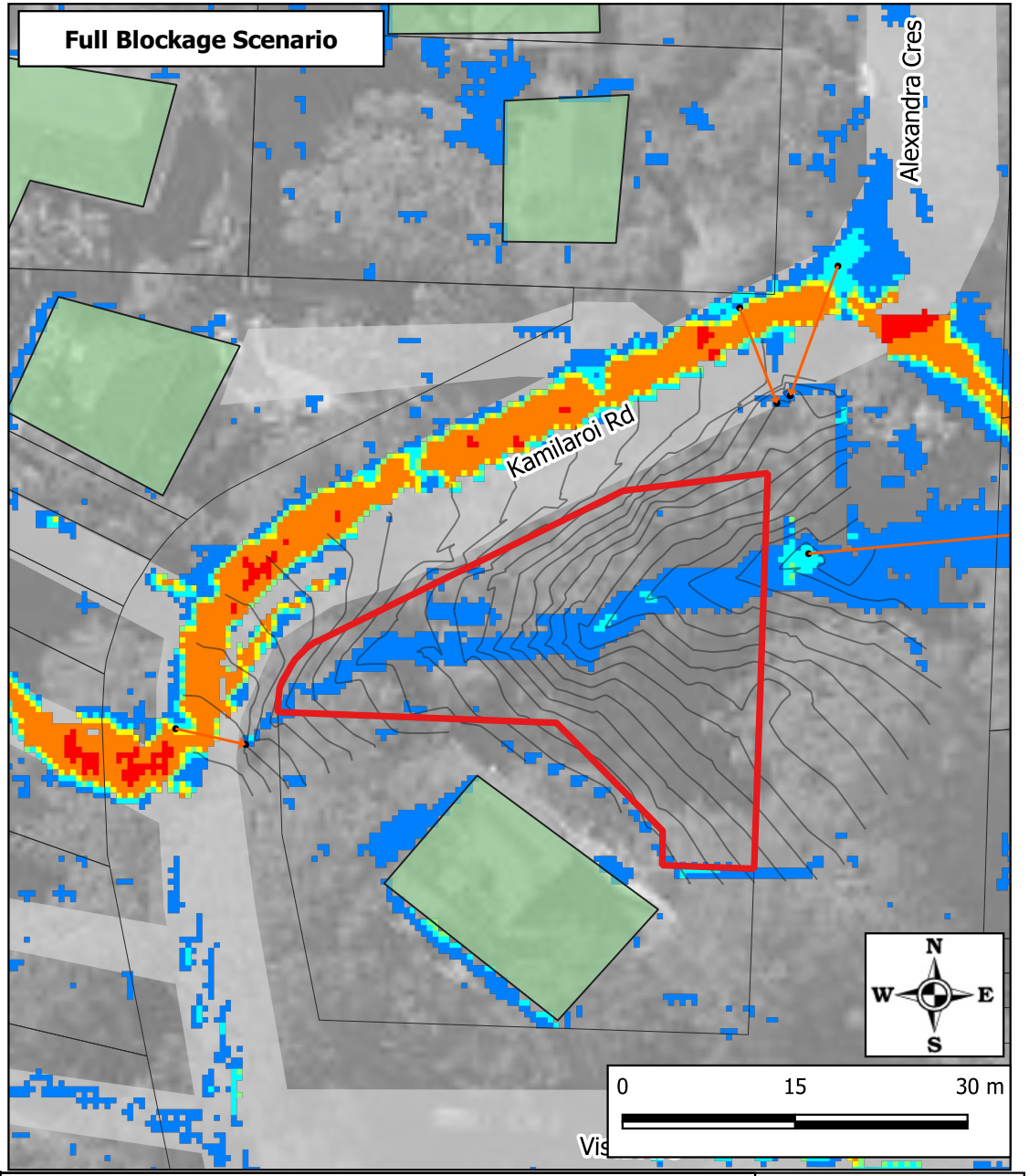
Hazard
- H1
- H2
- H3
- H4
- H5
- H6

- Subject Site
- Buildings
- Roads/Driveways
- Cadastral Boundaries
- Stormwater Pits / Headwalls
- Stormwater Pipes

TITLE: **5% AEP - Peak Hazard**			
PROJECT **3 Alexandra Crescent, Bayview**			
PROJECT No. **230036**			
DATE: **05-2023**	SCALE: 1:600	FIGURE No. **15**	

grc HYDRO



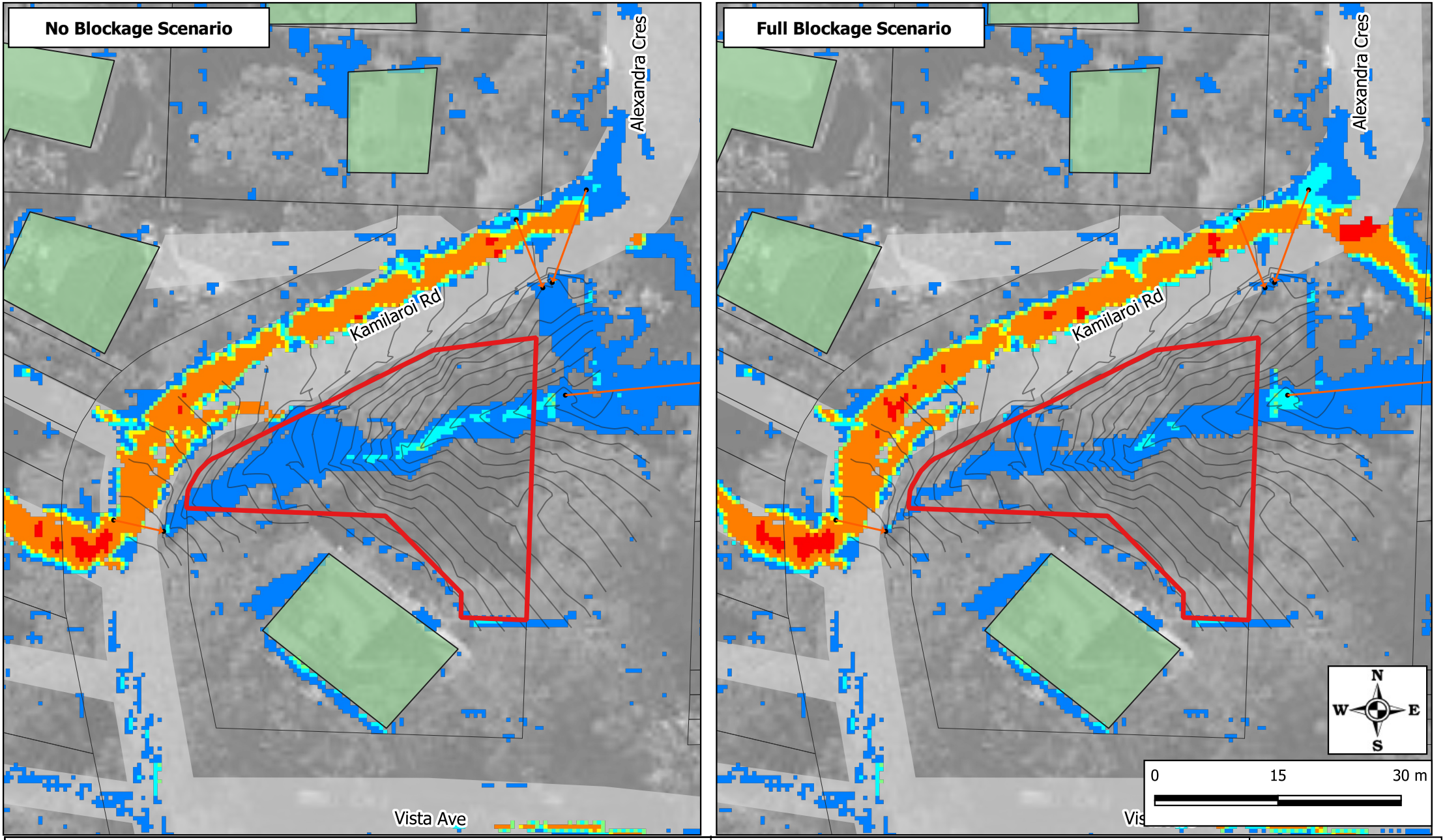


Hazard
- H1
- H2
- H3
- H4
- H5
- H6

- Subject Site
- Buildings
- Roads/Driveways
- Cadastral Boundaries
- Stormwater Pits / Headwalls
- Stormwater Pipes

TITLE: **2% AEP - Peak Hazard**			
PROJECT **3 Alexandra Crescent, Bayview**			
PROJECT No. **230036**			
DATE: **05-2023**	SCALE: 1:600	FIGURE No. **16**	

grc HYDRO

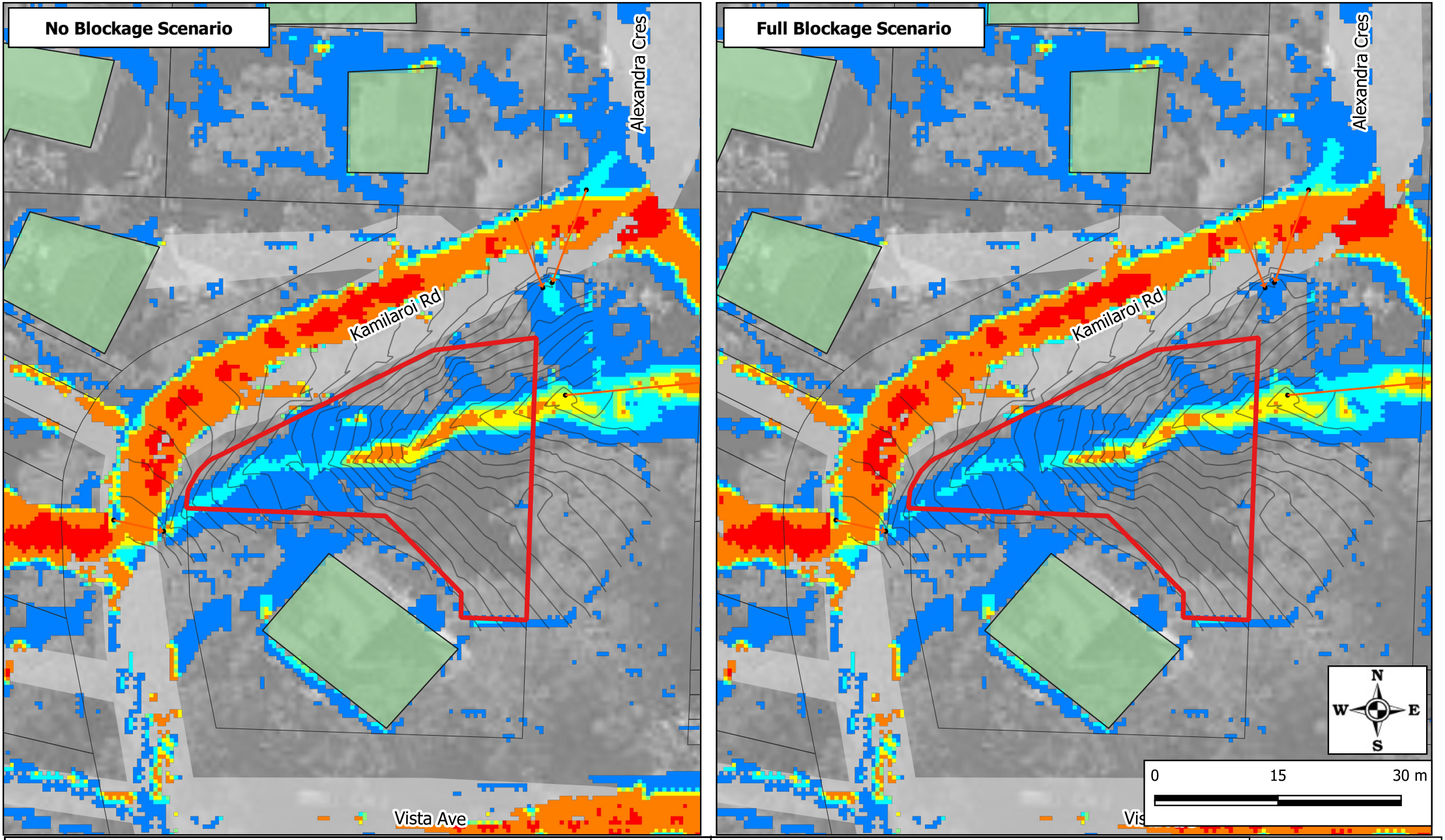


Hazard
- H1
- H2
- H3
- H4
- H5
- H6

- Subject Site
- Buildings
- Roads/Driveways
- Cadastral Boundaries
- Stormwater Pits / Headwalls
- Stormwater Pipes

TITLE: **1% AEP - Peak Hazard**			
PROJECT **3 Alexandra Crescent, Bayview**			
PROJECT No. **230036**			
DATE: **05-2023**	SCALE: 1:600	FIGURE No. **17**	

grc HYDRO



Hazard
- H1
- H2
- H3
- H4
- H5
- H6

- Subject Site
- Buildings
- Roads/Driveways
- Cadastral Boundaries
- Stormwater Pits / Headwalls
- Stormwater Pipes

TITLE: **PMF - Peak Hazard**			
PROJECT **3 Alexandra Crescent, Bayview**			
PROJECT No. **230036**			
DATE: **05-2023**	SCALE: 1:600	FIGURE No. **18**	

grc HYDRO

APPENDIX B

Stephen Gray
Director

Date of Birth:
13 July 1974

Nationality:
Australian

Profession:
Water Resources Engineer (hydrologist)

Qualifications:
Bachelor of Engineering (Res. Eng) University of New England, 1997

Masters of Engineering (Research) University of Technology Sydney, 2009

PROFILE

Steve has twenty five years' experience working in the field of hydrology and hydraulics with a principle focus on flooding. Steve's has worked in the Supreme Court of NSW and the NSW Land and Environment Court as a modelling expert. Steve would reasonably be considered an expert in the fields of: flood hydrology; flood modelling (1D and 2D models); stormwater, riverine and urban modelling; floodplain management works design; GIS integration into flooding work and floodplain management as it integrates with council planning. Steve also has a variety of experience in other water resource related fields including yield analysis, water balance and water quality related studies.

PROFESSIONAL EXPERIENCE

GRC Hydro (Director) - 2017 and ongoing

- Various Planning Proposal Reports - NSW
- L&E Expert for Nelligen Residential
- L&E Expert for Lindfield Residential
- Design Competition – 110 George St Parramatta
- Work for Valuer General NSW - Review of Flood Reports
- Rutherglen Insurance Review
- Exile Bay FRMSP (ongoing)
- Cooks Creek Overland Flow Flood Study - ongoing
- A'Becketts Creek Flood and Floodplain Risk Management Study and Plan (ongoing)
- Brisbane Insurance Review
- Dozens of Sydney Metropolitan Development Application Flood Reports
- L&E Expert for Rosehill Development
- L&E Expert for MLC Development in North Sydney
- L&E Expert for Proposed Development at Chifley St Smithfield
- Insurer Reports for Lismore March 2022 Event
- Wollongong Brooks Creek FRMSP (ongoing)
- L&E Court Expert for 10 Raceway Place Eastern Creek v 50 Peter Brock Drive
- Inner West Council Developer Contributions Plan Assessment
- Insurer Reports for March 2021 Event – Port Macquarie, North Haven and North Shore
- Wollongong CBD FRMSP Review (ongoing)
- Yarralumla Creek flood study review and mitigation works development
- ACT Light Rail Flood Impact Design and Assessment
- Rich Street Marrickville – Flood Management Report
- Barangaroo Reference Design and flooding Technical Advisor for INSW
- Snowy 2.0 Main Works SEARs Assessment - flooding
- Sydney Metro City and Southwest, Marrickville – Flood analysis for Detailed Design
- Yarralumla Creek flood study review and mitigation works development
- Canberra Light Rail Project – Flood analysis for Detailed Design
- Hickson Road Flood Modelling and Drainage Design
- Lismore/Murwillumbah 2017 Flood Event, Event Analysis for Overland Flow Damages
- Delhi Road Upgrade REF
- Private Hospital Site Flood Risk Assessment – Johnstons Creek
- Austral Flood Risk Management Report
- Erskine Park Sub-surface Flow Report
- Yallah Road OSD Review – Expert Opinion

- Chatswood Freemans Road Stormwater Impact Assessment
- Wallacia Golf Course Flood Study
- North Bexley Stormwater Assessment
- Austral Flood Risk Management Report
- Appian Way L&E Court Report
- Appian Way Supreme Court Expert Report
- Gladesville – Hillcrest Avenue Supreme Court Expert Court
- Kingsgrove – L&E Court – Flood Expert
- Snowy Mountains Flood and FRMS&P Studies
- University of Sydney – Health Precinct Project – Reviewer
- University of Sydney – Engineering Precinct Project – Reviewer
- North Sydney - LGA FRMS&P
- Hunters Hill - LGA Flood Study
- Burwood Council – Expert Advice re: 149(2) and FPA for Overland Flow Catchments
-

WMAwater (Director) - 2009 to 2017

- Hawthorne and Dobroyd Canal FRMS&P
- Alexandria and Johnstons Creek Flood Studies
- Tuggerah Lake Overland Flow Studies
- Ourimbah Creek FRMS&P
- Wagga FRMS&P Revision
- Exile Bay and Powell's Creek Flood Studies
- Culcairn, Holbrook and Henty Flood and FRMS&P Studies
- Rushcutters Bay, Centennial Park and Woolloomooloo Flood and FRMS&P Studies
- Gundagai Flood Study
- Currambene and Moona Moona Creeks FRMS&P
- Milperra Riverside Development Modelling
- CBD and Darling Harbour FRMS&P
- L&E Court – Ashfield Council
- North Sydney Overland Flow Flood Study
- Detailed Model Review – Wagga Wagga
- Lockhart and The Rock – Flood and FRMS&P Studies
- Blackwattle Bay and Johnstons Creek FRMS&P
- Medowie FRMS&P
- Harold Park Flooding, Stormwater and WSUD Review
- Commission into Brisbane River Floods of January 2011
- SES – Griffith 2012 Flood Review
- Griffith CBD FRMS&P
- Griffith CBD Flood Study
- Dobroyd Canal Flood Study
- Hawthorne Canal Flood Study
- Astrolabe Park Flood Impact Study and Design Project
- Middle Bays Floodplain Risk Management Study and Plan
- Woolaware Bay Flood Study
- Eastern Creek Hydrological Assessment – RAFTS Model Build
- Parken Pregan Road Improvement Impact Assessment
- SES - Murrumbidgee River December 2010 Flood Data Collection
- Wagga LGA Murrumbidgee River 2D Modelling
- Griffith Aerodrome Floodplain Risk Management Study and Plan
- RTA Narara to Lisarow Flood Impact Analysis and Review of Modelling
- Wagga Wagga Caravan Park Flood Impact Assessment
- Marrickville Valley Flood Study
- Jugiong Floodplain Risk Management Study and Plan
- Oura to Braehour Flood Mapping, WWCC

- Holbrook Road Development Impact Assessment – Wagga
- ANU Flood Study – ACT
- Flower Power Flood Impact Study and Floodplain Management Advice
- Medowie Drainage Study
- Upper South Creek Flood Study
- Wagga Wagga Major Overland Flow Study
- Box Hill Impact Assessment, LPMA – Sydney
- L&E Court - Timbumburi Creek Flood Study
- Boral Moorebank Impact Assessment and Floodplain Management Advice
- Murray Area 2D Modelling Review
- Hay Overland Flow Study
- Cotter MIKE She Post Bushfire Yield Review
- Young Street Residential Development – Surface Water Study
- Wagga Wagga 1D to 2D Model Conversion Project
- Griffith Airport Overland Flow Study
- Sandy Beach Development Proposal Environmental Assessment – Review of Findings

DHI Malaysia SDN. BHD, KL (Water Resources Manager)

Flooding and Floodplain Management

- Thurgoona Dam Break Study
- Tanoui NZ MIKE Flood Modelling
- Chowilla Velocity Impact Analysis
- Chowilla Water Use Analysis
- Wyong Economic Zone Hydrologic and Hydraulic Study
- Haslams Ck Tooheys Site MIKE Flood Investigation
- Thurgoona and Airport Flood Study
- Bungambrawatha Dam Break Study
- MIKE Flood Model Review – Greater Wellington Regional Council
- Bankstown Airport MIKE Flood Impact Study
- Chowilla Wetlands 2D Modelling Project
- MIKE Flood Development – Denmark
- Phulbari Open Cut Coal Mines Levee Design – Bangladesh
- East Lavington Drainage Study
- Benalla Model Conversion – MIKE21/MIKE11
- ACT Yield Modelling – MIKESHE/MIKE11
- Poulton Park 2D Drainage Study
- Huon valley Dam Break
- Iberia Street 2D Drainage Study
- Elanora 2D Drainage Study
- SMEC Laos 2D/1D Flood Diversion Project
- Bulimba Creek 2D Preliminary Flood Study
- Buttonderry Creek Development Impact Study
- Hume Dam Catchment Hydrology
- Tenterfield Flood Study
- Orange Flood Study
- RTA Tamworth Road Works
- Brisbane City Council Sewer Study
- Townsville Flood Study

Training Carried Out

- Software Support
- MIKE Product Training – Gui and Partners Sdn Bhd Training
- Papakura Council SHE/MIKE STORM Training
- MIKE Flood Advanced Training – Auckland NZ
- MIKE21 Training – Auckland NZ
- Greater Wellington Regional Council – MIKE21/Mike11 Training

- University of Canberra CRC for Freshwater Ecology – MIKE21/MIKE11 Training
- HydroTasmania MIKE21/MIKE11
- MIKE FLOOD (2D/1D) Training Course

ERM Australia PTY LTD (Senior Engineer)

- Canungra Army Base Re-development Water Strategy Study
- Parramatta Rail Link Soil and Water Sub-plans
- Hoxton Park Flood Impact Assessment
- Rolleston Coal Mine Environmental Impact Assessment
- Rhodes Peninsula Soil Rehabilitation Project EIS
- AUSTEEL Steel Mill and Harbour Facilities EIS

WBM Oceanics Australia (Water Resources Engineer)

- Hexham Swamp Tide Gate Re-Opening Impact Analysis (inclusive of TUFLOW beta testing)
- East Hills Flood Mitigation Work Analysis
- Singleton Stormwater Management Plan and Infrastructure Design Report
- Cudgera Creek, Yelgun NSW
- Riverlink Canal Estate Development Impact Study
- Steel St, Newcastle NSW
- Cottage Creek Flood Study
- Ulmarra Floodplain Management Study, Ulmarra NSW
- Newcastle Flood Data Collection Study

Ecowise Envirnmental LTD (Water Resources Engineer)

- Flood Inundation Mapping, Benalla VIC
- ACT Flood Plan
- Flood Forecasting Operations
- Flood Study for the Ginninderra Catchment, ACT

Water Resource Related Civil Works

- Installation of Discharge Monitoring Sites, Dampier WA
- Design of Sedimentation Ponds and Pipe Network, Dampier WA

Water Yield Analysis

- Proposed Lake Jerrambombera Aquatic Facility
- Cotter Dam – SHE Modelling Assessment
- Gold Creek Golf Club – Water Balance Assessment
- Department of Social Services – Basin Leak Assessment
- Preliminary Water Balance Investigation, Tuggeranong
- Water Supply Study for ACTEW

Water Quality Modelling

- Proposed Lake Jerrambombera Aquatic Facility
- GIS Land Capability Mapping and CMSS Modelling

Dam Break Modelling

- Kenyir Dam Break Assessment
- Thurgoona Dam Break Study
- Bungambrawatha Dam Break Study
- Huon Valley Dam Break Modelling
- Hume Dam Hydrology and Failures Scenarios

PUBLICATIONS

- Gray, S.D, Ball, J.E. and M.K. Babister (2011). The Direct Rainfall Method – A Critical Discussion of Current Practice. Proceedings 51st Floodplain Management Association Floodplain Managers Conference Tamworth , February 2011

- Gray, S.D and Ball, J.E. (2010). Coupled One and Two Dimensional Modelling in Urban Catchments – Reducing Uncertainty in Flood Estimation. Proceedings 32nd Hydrology and Water Resources Symposium, December 2009

- Beavis, S. G., A. J. Jakeman, L. Zhang and S. D. Gray (1997). Erosional History of Selected Upland Subcatchments in the Liverpool Plains, New South Wales. Proceedings International Congress on Modelling and Simulation, MODSIM97, University of Tasmania, 8-11 December 1997. A. D. McDonald. (Eds). Vol. 1 pp. 277