Chapter 6
Low Impact Design Case Studies

Introduction

The method of hydrological analysis used in this study is based on the ARC's Technical Publication 108 - "Guidelines for Stormwater Runoff Modelling in the Auckland Region" (ARC, 1999). The site case studies are for actual sites in the Auckland Region for which development has already been done using a conventional approach. Permission by the developer of each site to use the site within this study is gratefully acknowledged. However, each site has been kept anonymous for the purposes of this report.

The analysis of the three sites includes hydrological analyses of the following scenarios:

1) *Pre-development*. For all three sites the pre-development land-use is predominately pasture and reserve with areas of regenerating native bush.
2) *Standard Subdivision*. This scenario assumes that the sites are developed according to Standard Subdivision practices currently utilised within the Auckland Region.
3) *Low Impact*. This scenario implements subdivision design techniques in accordance with this guideline that are aimed to reduce runoff volumes, reduce peak discharges, and reduce erosion and sedimentation that may result from subdivision development.

The hydrological analysis of these sites includes modelling the 1 in 2 year, 1 in 10 year and 1 in 100-year peak outflows for the outlet of each stormwater system. Also calculated is the 24-hour volume of runoff for the catchment area of each stormwater system. In addition, consideration of stormwater from an annual basis rather than from an individual storm basis provides another perspective. In looking at the annual volumes, each case study has two spreadsheets which relate predevelopment runoff to both standard and low impact development.

The emphasis of the analysis is to gauge the changes in peak flow, storm volume, and annual volume related to changes in land-use.

Another key component of these case studies is the consideration of cost implications of development and sales. Consideration of cost reductions, total cost, and profit margin are important to site development. For each case study, construction costs are provided for both standard and low impact development. In addition, valuations are provided for both scenarios to provide some information on probable profit margins. If construction costs can be reduced and profit margins maintained, then low impact development should be an option considered whenever site development is intended.

The profit and risk allowance expected for a residential subdivision is often between 25% to 30 % of gross realisation before taxation. This return accounts for the general return on capital invested, income for the developer and all associated risks. Risks may include variations in the property market, variations in interest rates, variations in construction costs and resource consent complications as examples.

It should be noted that this method values the properties at the date of valuation – in this case 1 May 2000. In recent years, Auckland has experienced a rather flat property market with little variation in value and under the current economic climate it is not anticipated to have significant variations in the near future. A subdivision development, however, is spread across a number of years and prices over this period may vary. This means the estimated profit might vary from the actual profit derived by the developer.

The interpretation of the site plans provided and the site visits of the actual subdivisions have been utilised to estimate the valuation of the LID subdivisions. Confidence in the LID subdivision values is lower than the actual subdivision values as the contour and views are likely to be different due to differing earthworks. All reserve contributions are assumed to be paid in land.

Chapter Organisation

Initial components of this Chapter relate to providing site information for all three case studies and the presentation of results. The results are basically summaries of information contained in the subsequent three Appendices, which follow the initial sections. Appendix 1 relates to data and drawings on Case Study 1, while Appendix 2 and 3 relate to data and drawings for both Case Study 2 and 3. Information in these appendices relate to Model Inputs, Model Outputs, Volumes Analysis, and Site Plans.

Site Lot Yield

Arguably the major element of site design is the property yield in terms of the number of lots that the property may be subdivided in. Ideally, the number of lots should be the same for either the standard development or the low impact approach, although site restrictions will play a large part in either case. The Low Impact Development approach relies greatly on reducing individual lot sizes and increasing vegetation above that generally provided in the standard development approach and there will be concern by land developers that the lots will not provide the same financial return as larger lots. It is ARC opinion that Low Impact Development, when done correctly, will provide the same degree of profit as standard development when reduced site construction costs are considered. For the purpose of these case studies an attempt was made to increase the number of lots where possible in an effort to assuage developer concerns. The market valuation results were done to address developer concerns regarding the maintenance of overall profits.

Site 1, under a standard approach to site design, has 100 lots available for sale. Under the low impact approach, the property has 104 lots.

Site 2, under a standard approach to site design, has 297 lots. Under the low impact approach, the site yields 275 lots, which is a reduction. Consideration of site resources may, in a given site reduce the yield, if a goal of minimising impacts to site resources is to be realised. At the same time, as detailed later in this chapter, construction costs are significantly reduced.

Site 3, under a standard approach to site design, has 128 lots. Under the low impact approach, the property has 138 lots.

In all three cases, construction costs are significantly reduced.

Site Conditions

A brief description of each site is shown in Table 1 including catchment area, catchment slope, and predominant land-uses.

Table 1: SITE DESCRIPTION OVERVIEW

Site	Area (Ha)	Average Slope (m/m)	Soil Classification	Pre-development Land Use	Standard Subdivision Land Use	Low Impact Land Use
1	7.4	0.05	*All sites are Type C Waitemata Series Mudstone/ Sandstone*	Pasture	*All sites have medium density residential development*	*All sites will incorporate design principals intended to minimise rainfall runoff.*
2	27.7	0.11		Pasture, Bush		
3	14.2	0.07		Pasture		

More detailed descriptions of each site are contained within the following sections including parameters necessary for the completion of TP108's methodology.

Neighbouring the three sites are esplanade reserves. These are typically located between the sites and adjacent watercourses or tidal areas and are proposed to remain in reserve for both the Standard Subdivision and Low Impact design scenarios. Therefore, for the purpose of the present study these areas have been excluded from the analysis.

In some instances further catchments are located upstream of the case study sites and therefore discharge their stormwater runoff into the case study sites. To ensure that the present study only quantifies the effects of the difference in design principles in subdividing the three case study sites, the study does not account for the effects of stormwater runoff from these upstream catchments.

An important point needs to be made regarding proposed site conditions. The hydrologic analyses assumed that future open space areas are grassed as opposed to the placement of woody vegetation. The reason for this assumption is to provide conservative results. It may take 20 - 30 years for woody vegetation to provide a significant water quantity benefit so a worst case scenario, which still shows improvement, is to assume grass in these areas. Our intention is to see many of the open space areas vegetated with woody vegetation but from an analysis standpoint, grass is initially more accurate even though the ultimate runoff condition will be less.

Rainfall

The rainfall isohyet charts shown in Appendix A of TP108 indicate that the following rainfall depths are to be used in the hydrological model.

<u>Site 1</u>
100 Year Average Recurrence Interval = 205mm
10 Year Average Recurrence Interval = 130 mm
2 Year Average Recurrence Interval = 71 mm

<u>Site 2</u>
100 Year Average Recurrence Interval = 190 mm
10 Year Average Recurrence Interval = 135 mm
2 Year Average Recurrence Interval = 95 mm

<u>Site 3</u>
100 Year Average Recurrence Interval = 195 mm
10 Year Average Recurrence Interval = 130 mm
2 Year Average Recurrence Interval = 80 mm

Site 1

Site 1 is located adjacent to a harbour environment, it has an areal extent of 7.4 ha and has a total coast line length of approximately 800m. The harbour receives all stormwater runoff from the site.

The site's pre-developed land use consists predominantly of pasture for cattle grazing. There are minor stands of trees and bushes are located around the periphery of the site. One minor ephemeral stream drains along a boundary of the site. Due to the topography of the site most stormwater runoff will enter the receiving waters as sheet flow along the site's coastline.

In the Standard Subdivision design scenario approximately 6.9 hectares of this site was required to be earthworked with approximately 50,000 m^3 of earthworks. The Low Impact scenario yielded a reduction in the earthworks area to 5.9 hectares with an earthworks volume of 30,000 m^3. Road widths have also been slightly reduced, reducing pavement costs and impermeable surfaces.

The Standard Subdivision design had no allowance within it for stormwater quality treatment. The Low Impact design option provides for stormwater treatment via a central swale in the main access road to the subdivision as well as potential for treatment ponds on Lots 302 and 304. These Lots have been sited at the low points of the subdivision allowing drainage of the majority of the subdivision site to them. Stormwater treatment is also possible on the Lots 301, 305 and 306 by the use of one-way crossfalls on roads and vegetated filters. These areas could be either planted as landscape reserves or as grassed reserves.

The Low Impact subdivision layout comprises individual house Lot sizes generally in the 400-500 m^2 range, and it also allows for three clusters of comprehensive or village type developments around the reserves, that is, Lots 301 and 305, and adjacent to the recreation reserve, Lot 303. This arrangement should allow for a community development within these areas and enhance the amenity of these more intensely developed lots. Lot sizes in the comprehensive areas are typically in the 350-400 m^2 range.

<u>Results</u>

Storm discharge comparisons

As shown in Appendix 1 in the model outputs section, stormwater flows were calculated for the 1 in 2 (50%), 10 (10%), and 100 (1%) storm events. The results for peak rates of discharge and total storm volumes are provided along with the percentage increases and reductions that result from comparing the predevelopment condition to both standard and low impact.

	Peak Flows (m^3/sec.)			Volume (m^3)			% Increase from pre. condition				% decrease low impact from standard	
Storm Frequency	Predev.	Standard Dev.	Low Impact	Predev.	Standard Dev.	Low Impact	standard peak/volume		low impact peak/volume		peak/volume	
2	0.38	0.72	0.63	2089	3825	3348	90	66	83	60	13	13
10	1.02	1.48	1.39	5430	8025	7401	45	48	36	36	6	8
100	1.95	2.44	2.35	10297	13507	12795	25	31	20	24	4	5

Several items can be quickly seen when looking at the storm discharge results.

1. Percentage increases lessen when going from a 2 year storm to a 10 year storm to a 100 year storm. The reason for this is the greater rainfall depth causes greater soil saturation and lessens the effects of land use on runoff peaks and volumes.
2. The low impact approach reduces stormwater peaks and runoff for all three events when compared with the standard development approach.

Annual volumes of runoff

Considering stormwater runoff from an annual basis rather than from an individual storm basis provides some interesting results. Those results are displayed in the two Excel spreadsheets located in Appendix 1 where the amount of rainfall on an annual basis is used to provide an indication of the storm runoff and base flow (related to soil moisture). There are two spreadsheets provided which relate the predeveloped land use and post developed condition (conventional and low impact) to the amount of runoff generated over a year. It is felt that the annual approach may provide a better indication that land use has on stormwater runoff. As can be seen, the greater the level of imperviousness, the greater the volume of stormwater discharge.

Looking at the spreadsheet results, the conventional development increases the annual volume of stormwater runoff from the predevelopment condition from 11,311 cubic metres to 44,941 or discharges four times the amount of water. The low impact development approach discharges 37,737 cubic metres in an average year or 3.3 times as much, which is still an increase, but approximately 16 percent less runoff than does the conventional development. That is a significant difference, especially since the low impact approach provides four more lots than does the conventional approach.

Cost estimates

Cost estimates, excluding GST, have been made of the Standard Subdivision and Low Impact subdivision scenarios. These estimates are set out in Table 2 below.

Table 2: LOW IMPACT SUBDIVISION – CASE STUDIES
SITE 1 SCHEDULE OF PRICES

Item	Standard Subdivision[1]	Low Impact Subdivision[2]
Clearing and Earthworks	347,000	293,000
Pavement Construction	447,000	333,000
Sanitary Sewers	196,000	242,000
Stormwater Sewers	394,000	311,000
Water Reticulation	126,000	123,000
Trenching/Ducting/Cabling	46,000	45,000
Retaining Wall	0	57,000
Dayworks and General	288,000	186,000
Total	**$1,844,000**	**$1,590,000**

Notes: 1. Prices from actual construction costs.
2. Prices are estimates based on construction rates.

Site Valuation

The developer's profit for the actual subdivision is expected is to be $2,800,000. For the LID subdivision it is expected to be $2,500,000. Analysis of the actual subdivision indicates a developer would expect an allowance of Gross Realisation for profit and risk of 39% and the LID subdivision and allowance of 38%. From a financial perspective both scenarios appear viable.

The market for new residential lots is expanding with the development of similar subdivisions in the area. There is strong demand for new low cost housing and this is reflected in the volume of the sales over the last few years. Prices for new sections sell in the vicinity of $70,000. The size of the median lot sold is around 469 square metres. This is comparable to the actual subdivision. The median value for the LID subdivision is assessed at $65,000.

The LID subdivision raises some concerns about the minimum lot size – assuming they are permissible by the local council. Lots under 400 square metres are an unproven commodity in the market. There are few sales of land under 400 square metres, though a number of improved properties have sold in a nearby location on land from around 350 square metres. These houses are smaller, of a lower quality and certainly would not suit the current subdivision.

Site 2

Site 2 is located adjacent to a high order stream that ultimately discharges into a harbour environment. It has an areal extent of approximately 27ha.

Site 2 has a total area of 27.7 hectares. It is a steeply sloping site incised by a number of gully systems. The site drains via first and second order streams in the gully systems to a larger stream immediately adjacent to the site. There are a number of stands of bush within the gully systems comprising a mixture of exotic and native trees.

Earthworks in the Standard Subdivision scenario cover approximately 23.7 hectares of site area comprising 330,000 m^3 of earthworks. The Low Impact design scenario includes 18.8 hectares of disturbed area including 235,000 m^3 of earthworks. It is worth noting that the Standard Subdivision design scenario produces more flatter lots than the Low Impact design scenario.

Stormwater quality treatment has not been addressed or achieved within the Standard Subdivision design scenario. Stormwater quality treatment is allowed for within the extended gully areas in the Low Impact design scenario on the tributaries to the main watercourse. This has however, not been included in the pricing given below for consistency of comparison.

The Standard Subdivision design achieves 297 individual house lots for the development as opposed to the Low Impact scenario, which achieves 275. There are three areas within the Low Impact option, which could be developed on a comprehensive development basis to yield a total of 290 lots in this scenario. Each of these are neighbourhood units adjacent to bush and amenity reserve areas which could have Lots down to 250 m^2 on average each.

<u>Results</u>

Storm discharge comparisons

As shown in Appendix 1 in the model outputs section, stormwater flows were calculated for the 2 (50%), 10 (10%), and 100 (1%)year storm events. The results for peak rates of discharge and total storm volumes are provided along with the percentage increases and reductions that result from comparing the predevelopment condition to both standard and low impact.

	Peak Flows (m^3/sec.)			Volume (m^3)			% Increase from pre. condition				% decrease low impact from standard	
Storm Frequency	Predev.	Standard Dev.	Low Impact	Predev.	Standard Dev.	Low Impact	standard peak/volume		low impact peak/volume		peak/volume	
2	1.66	2.97	2.57	11080	17835	16091	79	61	55	45	14	10
10	2.95	4.65	4.16	19282	28051	25902	58	46	41	34	11	8
100	3.50	7.00	6.46	31804	42560	40062	100	34	85	26	8	6

As in case study 1, several items can be seen when looking at the storm discharge results.

1. In general, except for peak discharges for the 100 year storm, percentage increases lessen when going from a 2 year storm to a 10 year storm to a 100 year storm. The reason for this is the greater rainfall depth causes greater soil saturation and lessens the effects of land use on runoff peaks and volumes.
2. The low impact approach reduces stormwater peaks and runoff for all three events when compared with the standard development approach.

Annual volumes of runoff

Considering stormwater runoff from an annual basis rather than from an individual storm basis provides some interesting results. Those results are displayed in the following two Excel spreadsheets where the amount of rainfall on an annual basis is used to provide an indication of the storm runoff and base flow (related to soil moisture). As in case study 1, the following two spreadsheets relate the predeveloped land use and post developed condition (conventional and low impact) to the amount of runoff generated over a year.

Looking at the spreadsheet results, the conventional development increases the annual volume of stormwater runoff from the predevelopment condition from 77,202 cubic metres to 209,898 or discharges 2.7

times the amount of water. The low impact development approach discharges 170,119 cubic metres in an average year or 2.2 times as much, which is still an increase, but approximately 19 percent less runoff than does the conventional development.

Cost estimates

Cost estimates, excluding GST, have been made of the Standard Subdivision and Low Impact subdivision scenarios. These estimates are set out in Table 3 below.

Table 3: LOW IMPACT SUBDIVISION – CASE STUDIES
SITE 2 SCHEDULE OF PRICES

Item	Standard Subdivision[1]	Low Impact Subdivision[2]
Dayworks and General	162,000	160,000
Clearing and Earthworks	1,800,000	1,719,000
Pavement Construction	1,362,000	1,134,000
Concrete Works	1,036,000	574,000
Sanitary Sewers	850,000	778,000
Stormwater Sewers	1,178,000	1,050,000
Water Reticulation	492,000	455,000
Trenching/Ducting/Cabling	338,000	330,000
Total	**$7,218,000**	**$5,936,000**

Notes: 1. Prices from actual construction costs.
2. Prices are estimates based on construction rates.

Site Valuation

The actual subdivision was not complete when the site inspection was done. All lots have been valued as if they were complete at the date of valuation. The developer's profit for the actual subdivision is expected is to be $8,420,000. For the second subdivision it is expected to be $4,760,000. Analysis of the actual subdivision indicates a developer would expect an allowance of Gross Realisation for profit and risk of 26% and the LID subdivision and allowance of 18%. From a financial perspective the LID scenario does not appear to offer sufficient return to make it desirable to a developer.

Prices for new sections in the actual subdivision sell in the vicinity of $90,000 to $130,000. The median size for lots sold in this subdivision is around 589 square metres. The LID subdivision values range from $65,000 up to $125,000. The lower end is due to the introduction of smaller sites – as low as 248 square metres. There are very few sales of vacant land as small as 248 square meters in the general locality and none in new subdivisions. It is believed that people who move to the edge of the city are looking for a lifestyle away from the density of city living. Small sites are in contrast to this. The limited demand for the small sites of the LID development is reflected in the values as is the increased selling period.

Site 3

Site 3 is located adjacent to a harbour environment. The size of the site is approximately 14ha and it has a total coast line length of approximately 800 metres.

The pre-development land-use of the site primary consisted of pasture for grazing live stock. Other pre-developed site features include esplanade reserves, coastal margins, small stands of native trees around the periphery of the site, one small ephemeral stream passing through the centre of the site, and one third order perennial stream passing adjacent to the site servicing a larger catchment located upstream.

The topography of the site rises from sea level to RL 30 metres over approximately 600 metres with the site having an average slope of 5%. Slopes immediately adjacent to the coastal margins, however, are up to 30%.

Site 3 is a generally flat site, which falls steeply to a watercourse on its eastern side and harbour environments on its northern and eastern sides. An ephemeral watercourse surrounded by bush bisects the site.

The Standard Subdivision earthworks design for the site comprises earthworks on approximately 9.6 hectares of the site with approximately 7.6 hectares of earthworks area within the Low Impact subdivision design. The Standard Subdivision design comprises approximately 62,000 m^3 of earthworks with approximately 53,000 m^3 of earthworks in the Low Impact scenario. Key differences between the two development scenarios is the reduction in earthworks on the steep eastern boundary and the subsequent reduced need for retaining walls (offset by steeper sections) as well as the retention of the natural ephemeral stream bisecting the site.

The Standard Subdivision design scenario allows for stormwater treatment ponds within the ephemeral stream while the Low Impact scenario allows for stormwater treatment devices on the north-western corner of Lot the 213 recreational reserve and also on the Lot 214 recreation reserve adjacent to Lot 110. The costs for these are included in the cost estimates below.

<u>Results</u>

Storm discharge comparisons

As shown in Appendix 1 in the model outputs section, stormwater flows were calculated for the 2 (50%), 10 (10%), and 100 (1%)year storm events. The results for peak rates of discharge and total storm volumes are provided along with the percentage increases and reductions that result from comparing the predevelopment condition to both standard and low impact.

	Peak Flows (m^3/sec.)			Volume (m^3)			% Increase from pre. condition				% decrease low impact from standard	
Storm Frequency	Predev.	Standard Dev.	Low Impact	Predev.	Standard Dev.	Low Impact						
							standard peak/volume		low impact peak/volume		peak/volume	
2	0.87	1.48	1.37	4865	8316	7327	70	71	58	51	7	12
10	1.89	2.70	2.57	10358	15109	13840	43	46	36	34	5	8
100	3.36	4.29	4.12	18361	24149	22689	28	32	23	24	4	6

As in case studies 1 and 2, several items can be seen when looking at the storm discharge results.

1. Percentage increases lessen when going from a 2 year storm to a 10 year storm to a 100 year storm. The reason for this is the greater rainfall depth causes greater soil saturation and lessens the effects of land use on runoff peaks and volumes.
2. The low impact approach reduces stormwater peaks and runoff for all three events when compared with the standard development approach.

Annual volumes of runoff

Considering stormwater runoff from an annual basis rather than from an individual storm basis provides some interesting results. Those results are displayed in the following two Excel spreadsheets where the amount of rainfall on an annual basis is used to provide an indication of the storm runoff and base flow (related to soil moisture). As in case study 1, the following two spreadsheets relate the predeveloped land use and post developed condition (conventional and low impact) to the amount of runoff generated over a year.

Looking at the spreadsheet results, the conventional development increases the annual volume of stormwater runoff from the predevelopment condition from 31,449 cubic metres to 99,160 or discharges 3 times the amount of water. The low impact development approach discharges 81,945 cubic metres in an average year or 2.6 times as much, which is still an increase, but approximately 17 percent less runoff than does the conventional development. That is a significant difference, especially since the low impact approach provides ten more lots than does the conventional approach.

Cost estimates

Cost estimates, excluding GST, have been made of the Standard Subdivision and Low Impact subdivision scenarios. These estimates are set out in Table 4 below.

Table 4: LOW IMPACT SUBDIVISION – CASE STUDIES SITE 3 SCHEDULE OF PRICES

Item	Standard Subdivision[1]	Low Impact Subdivision[2]
Clearing, Earthworks and Retaining Walls	1,425,000	605,000
Pavement Construction	1,390,000	1,111,000
Sanitary Sewers/Rising Mains	500,000	498,000
Stormwater Sewers/Treatment	855,000	861,000
Water Reticulation	210,000	220,000
Trenching/Ducting/Cabling	1,123,000	1,123,000
Dayworks and General	460,000	60,000
Total	**$ 5,963,000**	**$ 4,478,000**

Note 1. Actual costs for site not available. The amounts shown are based on preliminary estimates from earlier proposals, however subdivision construction costs may vary.
2. Prices are estimates based on typical construction rates.

Site valuation

The developer's profit for the actual subdivision is expected is to be $2,640,000. For the second subdivision it is expected to be $3,960,000. Analysis of the actual subdivision indicates a developer would expect an allowance of Gross Realisation for profit and risk of 15% and the LID subdivision and allowance of 23%. The LID development appears to be a far more attractive scenario from a financial perspective.

The actual subdivision has an average lot size of 750 square metres which distinguishes it from other subdivisions. By reducing the average lot size to 655 square metres for the LID subdivision the sites will be comparable to alternative subdivisions in the area.

References

ARC, 1999, Guidelines For Stormwater Runoff Modelling in the Auckland Region, Technical Publication 108.

Chow, V. T., 1959, Open-channel Hydraulics, McGraw-Hill.

Appendix 1
Case Study 1

Appendix Components

Model Inputs
Model Outputs
Volumes Analysis
Site Plans

Model Inputs

The maximum elevation of the site is approximately RL14m and owing to its topography the hydrologic model of the pre-development scenario has been divided into four sub-catchments. These sub-catchments are shown in Figure 1-1 in Appendix 1. The sub-catchments areas; channelisation factor, C; main channel lengths, L; main channel slopes, S_c; time to peak flow, t_p (= 2/3 time of concentration, t_C); weighted initial rainfall abstraction, I_a; and weighted curve numbers, CN are shown in Table 5. Where time of concentrations, t_C, are less than 10 minutes it is assumed that t_C for the sub-catchment is 10 minutes in accordance with the procedures defined in TP108. The above parameters are required for the SCS hydrological assessment methodology used in TP108 and the HEC-HMS software.

Table 5: CASE STUDY – SITE 1 (PRE-DEVELOPMENT SCENARIO)

Sub-catchment	Area (ha)	C	L (km)	S_c (m/m)	t_P (hrs)	I_a (mm)	CN
1	1.06	1.0	0.15	0.05	0.11	5.0	74.0
2	1.13	1.0	0.09	0.04	0.11	5.0	74.0
3	3.81	1.0	0.18	0.05	0.11	5.0	74.0
4	1.47	1.0	0.21	0.04	0.12	5.0	74.0

The site layout for the proposed Standard Subdivision scenario is shown in Figure 1-2 in Appendix 1. The design of the site's stormwater reticulation system has meant that the Standard Subdivision site layout is divided into 5 sub-catchments with sub-catchment 3 of the pre-development scenario separated into 2 sub-catchments and the reticulation system of each draining to a common outlet. This layout is shown in Figure 1-3 in Appendix 1. The earthworks required for the Standard Subdivision are shown in Figure 1-4 in Appendix 1.

The hydrological model of the site for the Standard Subdivision scenario retains all reserve areas as pasture and assumes that the minimum permeable area for each developed lot is 35% of the lot area. Table 6 contains the parameters values required by TP108 and HEC-HMS.

Table 6: CASE STUDY – SITE 1 (STANDARD SUBDIVISION SCENARIO)

Sub-catchment	Area (ha)	C	L (km)	S_c (m/m)	t_P (hrs)	I_a (mm)	CN
1	0.79	0.6	0.18	0.02	0.11	1.4	91.1
2	1.39	0.6	0.18	0.02	0.11	1.1	92.6
3a	1.83	0.6	0.23	0.03	0.11	2.1	88.1
3b	1.27	0.6	0.20	0.04	0.11	1.1	92.3
4	2.12	0.6	0.21	0.05	0.11	1.3	91.6

The site layout for the proposed Low Impact scenario is shown in Figure 1-5 in Appendix 1. The stormwater network and catchment layout for the Low Impact scenario is shown in Figure 1-6 in Appendix 1. The earthworks required for the Low Impact scenario are shown in Figure 1-7 in Appendix 1. The Low Impact scenario also assumes that the minimum permeable area for each developed lot is 35% of the lot area and retains all reserve areas as pasture. Table 7 contains the parameters values required by TP108 and HEC-HMS. The Low Impact scenario contains two proposed water treatment devices. These are shown on Figure 1-5 as Recreation Reserves 302 and 304.

Table 7: CASE STUDY – SITE 1 (LOW IMPACT SCENARIO)

Sub-catchment	Area (ha)	C	L (km)	S_c (m/m)	t_P (hrs)	I_a (mm)	CN
1	1.29	0.6	0.23	0.02	0.11	2.6	85.3
2	0.69	0.6	0.13	0.02	0.11	2.1	87.8
3a	2.51	0.6	0.27	0.02	0.11	2.0	88.4
3b	2.47	0.6	0.36	0.02	0.12	2.2	87.5
4	0.48	0.6	0.06	0.02	0.11	2.3	87.0

TP 108
Modelling Results

Results

Site 1

Table 8 presents the pre development, Standard Subdivision and Low Impact changes to flow at each outlet from the site for the 2-year, 10-year and 100-year average recurrence interval events.

Graphs 6.1 to 6.3 also present the peak flow and volume runoff for the 50%, 10% and 1% ARI events respectively.

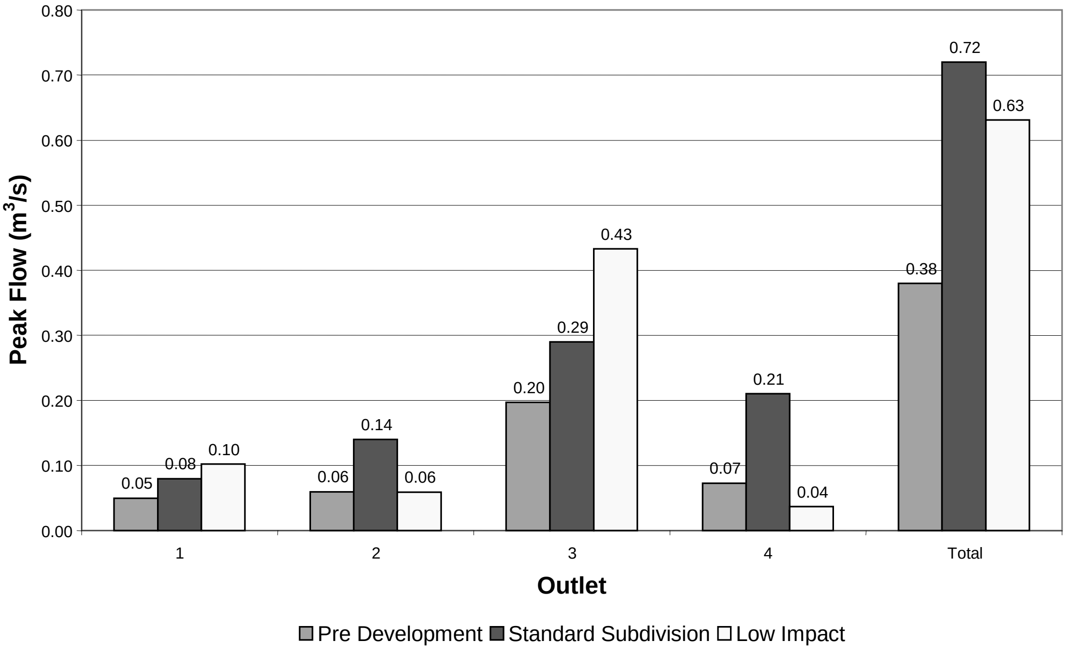
Table 8: SITE 1 RESULTS

1% ARI												
Outlet	Area (sqm)			Qp (cumecs)			Volume (cu.m)			Runoff (mm)		
no.	Pre Development	Standard Sub-division	Low Impact	Pre Development	Standard Sub-division	Low Impact	Pre Development	Standard Sub-division	Low Impact	Pre Development	Standard Sub-division	Low Impact
1	10239	7892	12919	0.27	0.26	0.40	1415	1437	2149	138	182	166
2	12240	13892	6948	0.32	0.46	0.22	1692	2575	1200	138	185	173
3	37690	31492	49864	0.99	1.02	1.59	5210	5619	8633	138	178	173
4	14323	21216	4761	0.37	0.70	0.15	1980	3876	813	138	183	171
Total	**74492**	**74492**	**74492**	**1.95**	**2.44**	**2.35**	**10297**	**13507**	**12795**	**138**	**181**	**172**

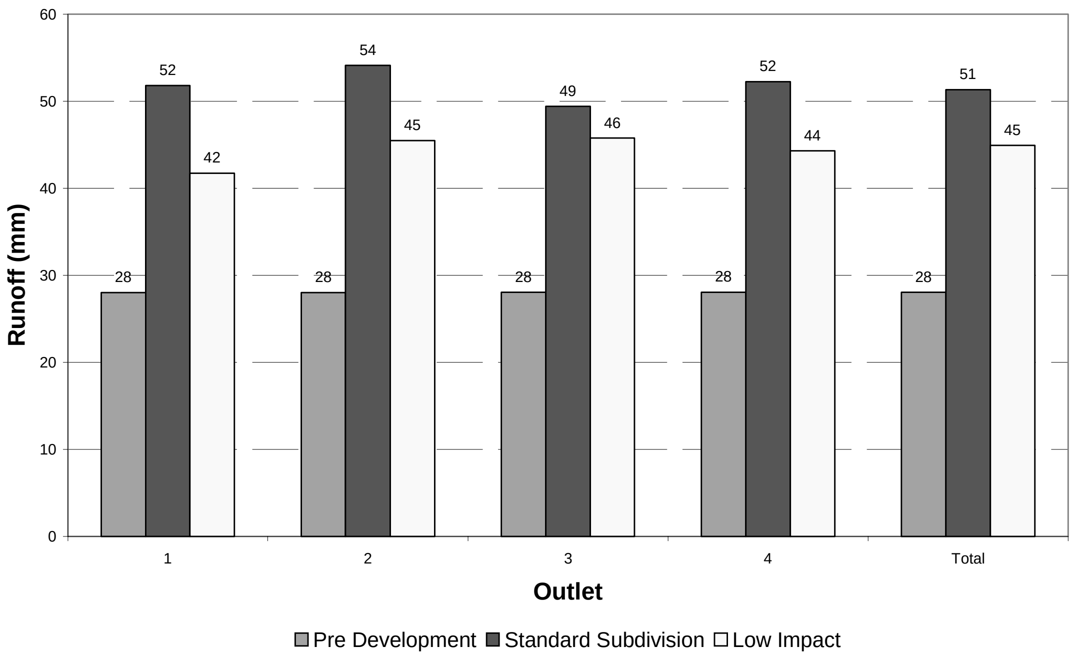
Table 8 : SITE 1 RESULTS Cont …

10% ARI												
Outlet	Area (sqm)			Qp (cumecs)			Volume (cu.m)			Runoff (mm)		
no.	Pre Development	Standard Subdivision	Low Impact	Pre Development	Standard Subdivision	Low Impact	Pre Development	Standard	Low Impact	Pre Development	Standard Subdivision	Low Impact
1	10239	7892	12919	0.14	0.16	0.23	746	855	1224	73	108	95
2	12240	13892	6948	0.17	0.28	0.13	892	1546	696	73	111	100
3	37690	31492	49864	0.52	0.61	0.94	2748	3313	5012	73	105	101
4	14323	21216	4761	0.19	0.43	0.09	1044	2311	469	73	109	99
Total	**74492**	**74492**	**74492**	**1.02**	**1.48**	**1.39**	**5430**	**8025**	**7401**	**73**	**108**	**99**

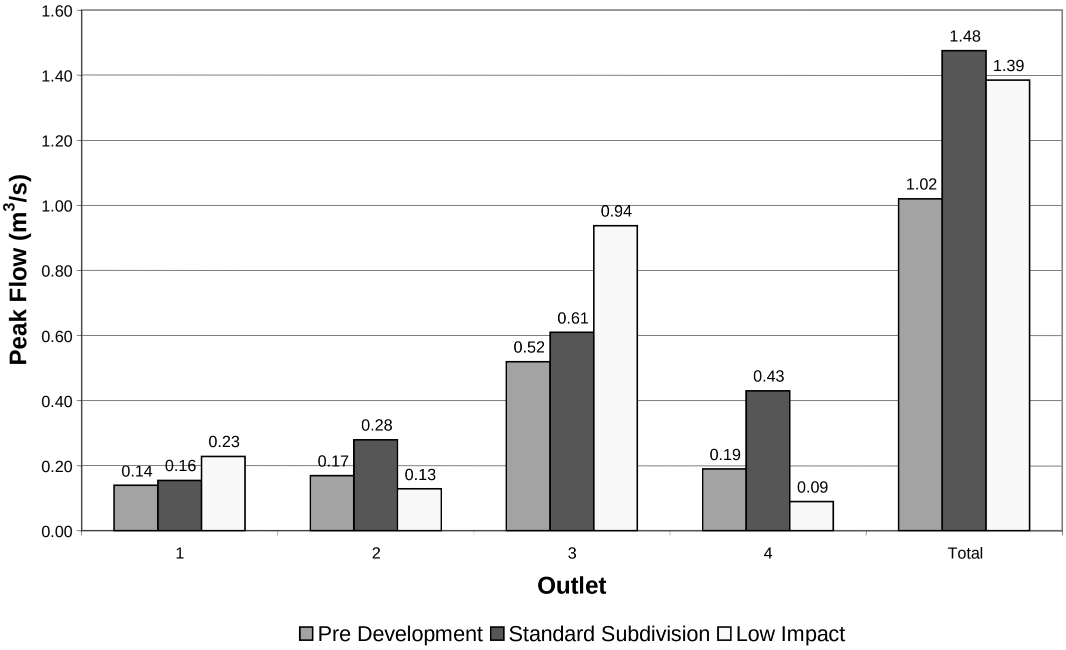
50% ARI												
Outlet	Area (sqm)			Qp (cumecs)			Volume (cu.m)			Runoff (mm)		
no.	Pre Development	Standard Subdivision	Low Impact	Pre Development	Standard Subdivision	Low Impact	Pre	Standard	Low Impact	Pre Development	Standard Subdivision	Low Impact
1	10239	7892	12919	0.05	0.08	0.10	287	409	539	28	52	42
2	12240	13892	6948	0.06	0.14	0.06	343	752	316	28	54	45
3	37690	31492	49864	0.20	0.29	0.43	1057	1556	2282	28	49	46
4	14323	21216	4761	0.07	0.21	0.04	402	1108	211	28	52	44
Total	**74492**	**74492**	**74492**	**0.38**	**0.72**	**0.63**	**2089**	**3825**	**3348**	**28**	**51**	**45**



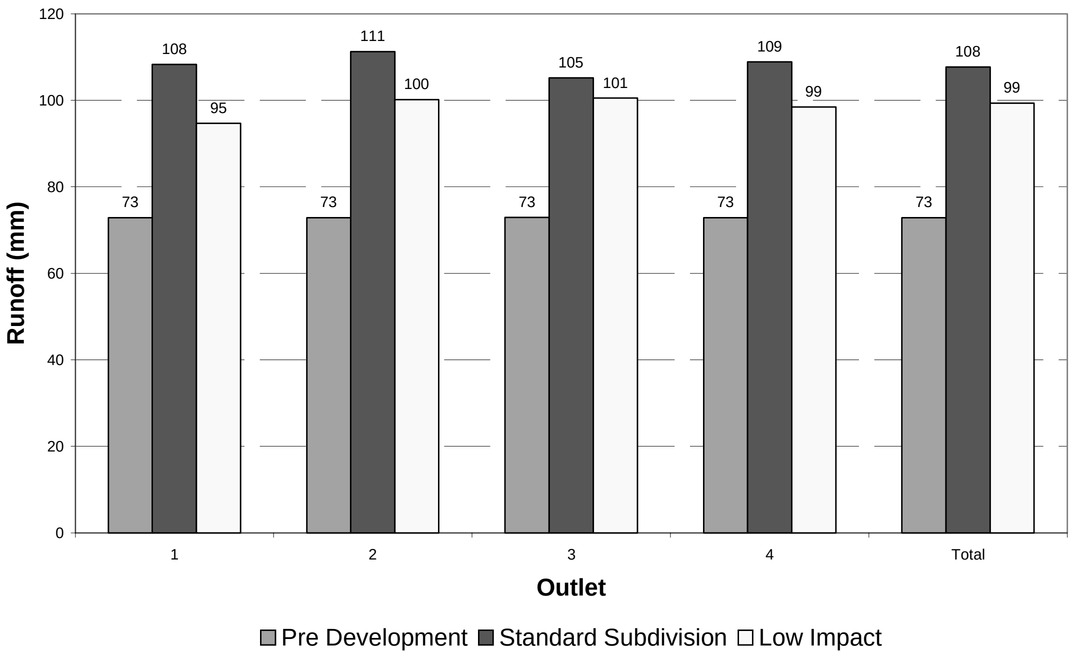
Graph 6.1a: Site 1, Peak flows at each outlet for pre-development, Standard Subdivision, and Low Impact scenario catchment conditions during a 50% ARI event.



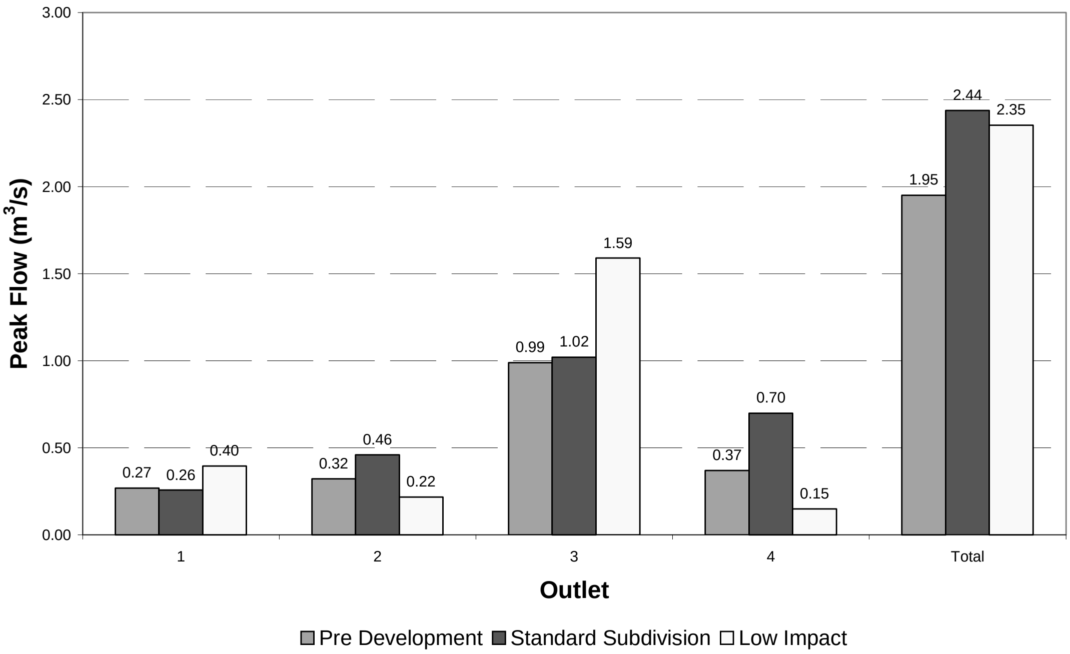
Graph 6.1b: Site 1, Volume Runoff at each outlet for pre-development, Standard Subdivision, and Low Impact scenario catchment conditions during a 50% ARI event.



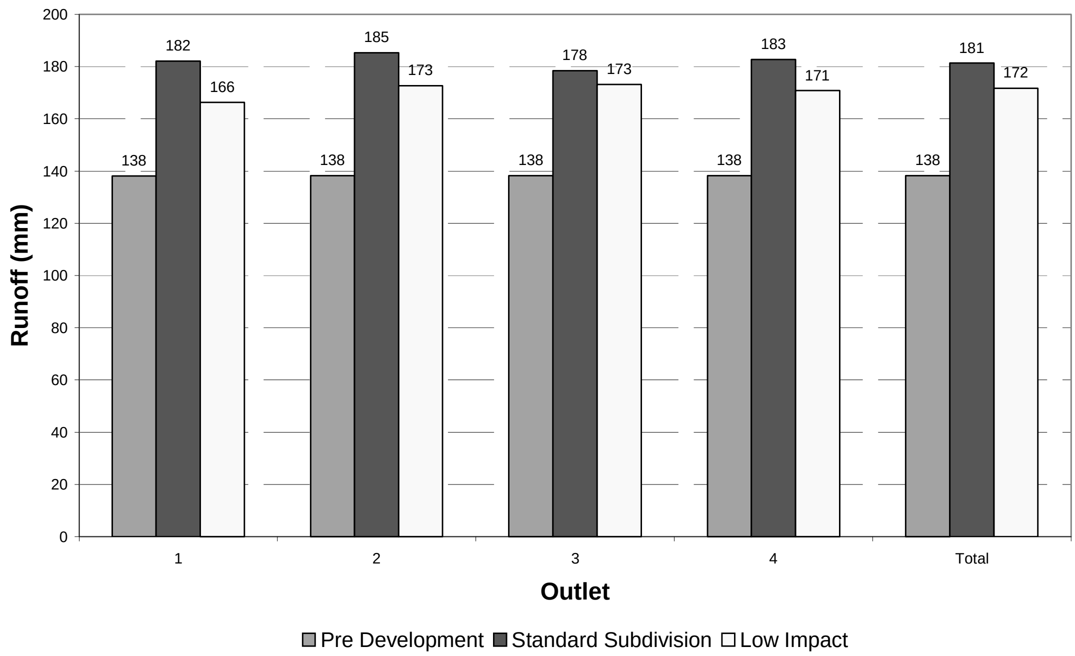
Graph 6.2a: Site 1, Peak flows at each outlet for pre-development, Standard Subdivision, and Low Impact scenario catchment conditions during a 10% ARI event.



Graph 6.2b: Site 1, Volume for pre-development, Standard Subdivision, and Low Impact scenario catchment conditions during 10%.



Graph 6.3a: Site 1, Peak flows at each outlet for pre-development, Standard Subdivision, and Low Impact scenario catchment conditions during a 1% ARI event.



Graph 6.3b: Site 1, Volume Runoff at each outlet for pre for pre-development, Standard Subdivision, and Low Impact scenario catchment conditions during a 1% ARI event.

Case Study 1
Volumes Analysis

SITE:	Case study 1	By:		Date:		Ref:	
DETAILS:	evaluation of predevelopment versus conventional development						
Rainfall Factor Kr	0.97	IA	5				

LAND USE DATA				SCENARIO 1			SCENARIO 2		
ID	Description	Soil type	Land use	CN	%Imp	Area	CN	%Imp	Area
Pervious & Unconnected Impervious									
1	Waitemata Series	C	Pasture / lawn	74	0	7.45	74	0	2.16
2									
3									
4	Impervious	-	Hardstand		100		98	100	
			Subtotal	**74.0**		**7.5**	**74.0**		**2.2**
Connected Impervious									
						0			5.29
			Subtotal			**0.0**			**5.3**
			TOTAL AREA		Scenario 1	**7.5**		Scenario 2	**7.5**

Record length:	9709 days	26.6 years	Average annual rainfall	1131 mm

RESULTS	SCENARIO 1				SCENARIO 2			
	Rainfall	Storm flow	Base flow	Total runoff	Rainfall	Storm flow	Base flow	Total runoff
99 percentile daily runoff (m3)	2,652	742	132	864	2,652	1,863	38	1,872
95 percentile daily runoff (m3)	1,178	109	126	187	1,178	676	36	697
90 percentile daily runoff (m3)	687	21	113	129	687	325	33	340
Wet year total runoff (m3)	115,118	27,433	25,207	52,640	115,118	69,760	7,308	77,068
Dry year total runoff (m3)	60,218	3,820	14,891	18,711	60,218	29,059	4,317	33,376
Average annual runoff (m3)	**84,282**	**11,311**	**17,690**	**29,000**	**84,282**	**44,941**	**5,129**	**50,070**

KEY		STATUS		
Data entry	Cells locked	This run:	FINISHED	Calculated

SITE:	Case study 1	By:		Date:		Ref:	
DETAILS:	evaluation of predevelopment versus low impact approach						
Rainfall Factor Kr	0.97	IA	5				

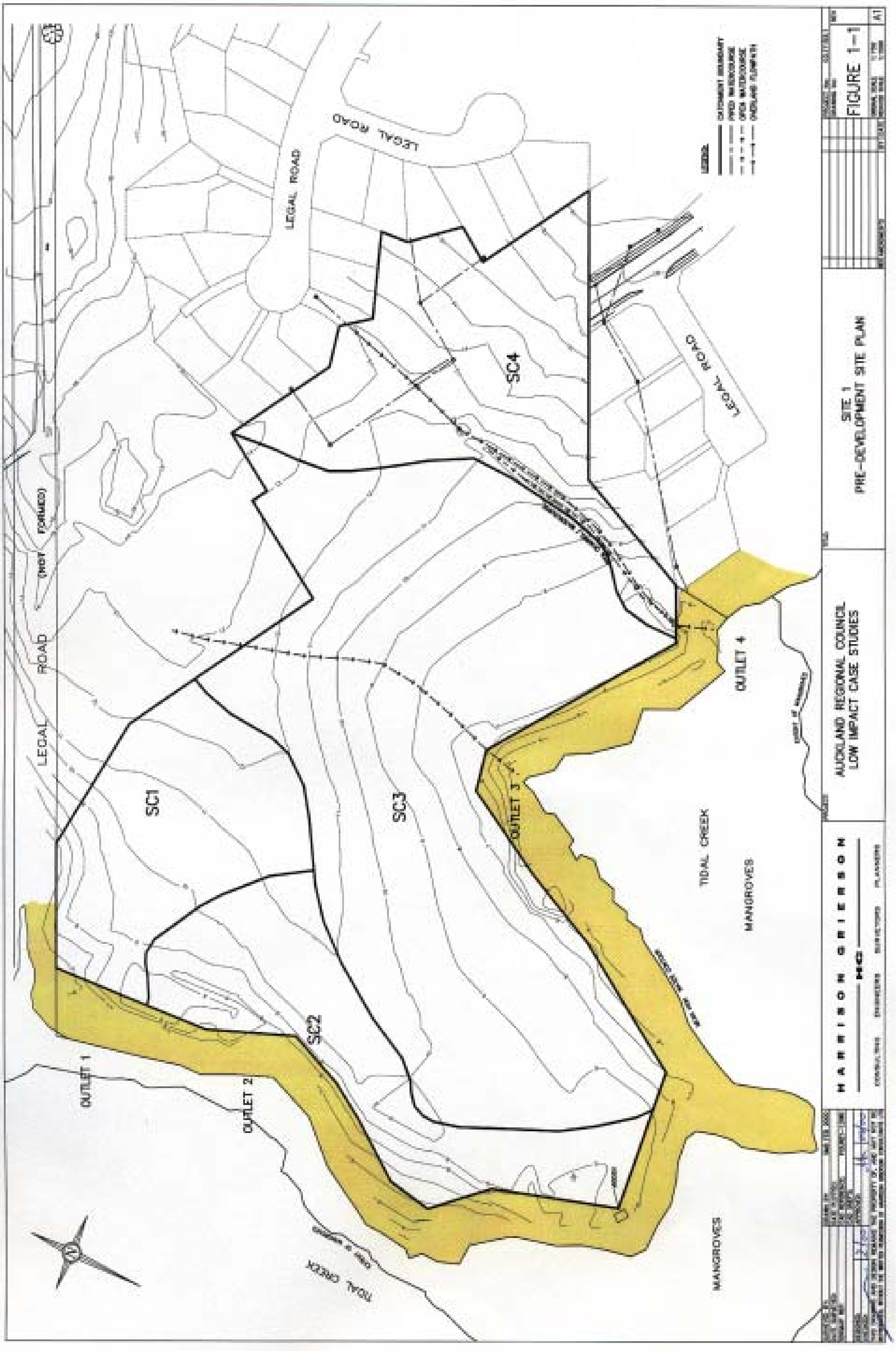
LAND USE DATA				SCENARIO 1			SCENARIO 2		
ID	Description	Soil type	Land use	CN	%Imp	Area	CN	%Imp	Area
Pervious & Unconnected Impervious									
1	Waitemata Series	C	Pasture / lawn	74	0	7.45	74	0	3.29
2									
3									
4	Impervious	-	Hardstand		100		98	100	
			Subtotal	**74.0**		**7.5**	**74.0**		**3.3**
Connected Impervious									
						0			4.16
			Subtotal			**0.0**			**4.2**
			TOTAL AREA		Scenario 1	**7.5**		Scenario 2	**7.5**

Record length:	9709 days	26.6 years	Average annual rainfall	1131 mm

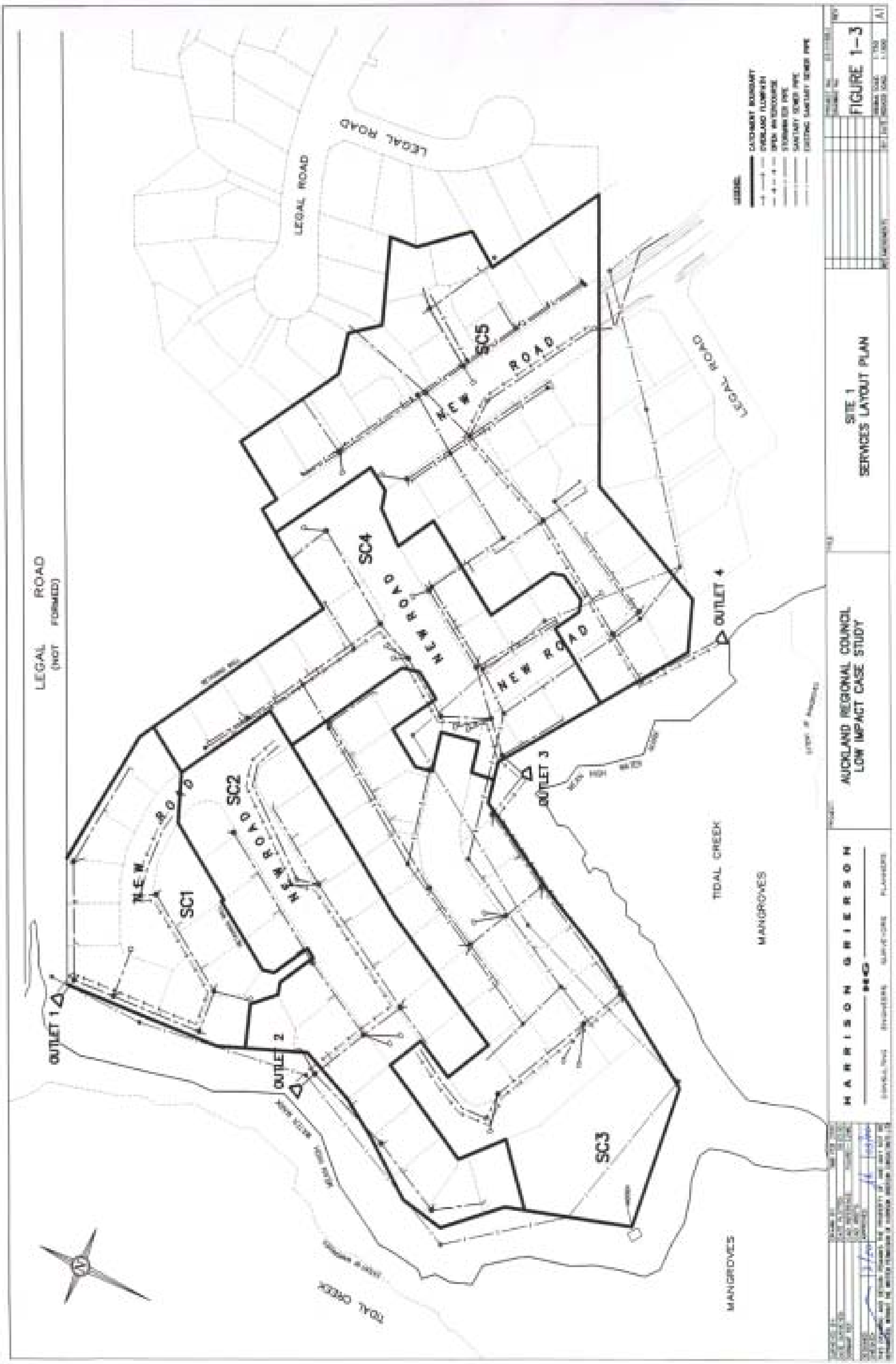
RESULTS	SCENARIO 1				SCENARIO 2			
	Rainfall	Storm flow	Base flow	Total runoff	Rainfall	Storm flow	Base flow	Total runoff
99 percentile daily runoff (m3)	2,652	742	132	864	2,652	1,622	58	1,648
95 percentile daily runoff (m3)	1,178	109	126	187	1,178	557	56	582
90 percentile daily runoff (m3)	687	21	113	129	687	262	50	289
Wet year total runoff (m3)	115,118	27,433	25,207	52,640	115,118	60,718	11,132	71,850
Dry year total runoff (m3)	60,218	3,820	14,891	18,711	60,218	23,668	6,576	30,244
Average annual runoff (m3)	**84,282**	**11,311**	**17,690**	**29,000**	**84,282**	**37,757**	**7,812**	**45,569**

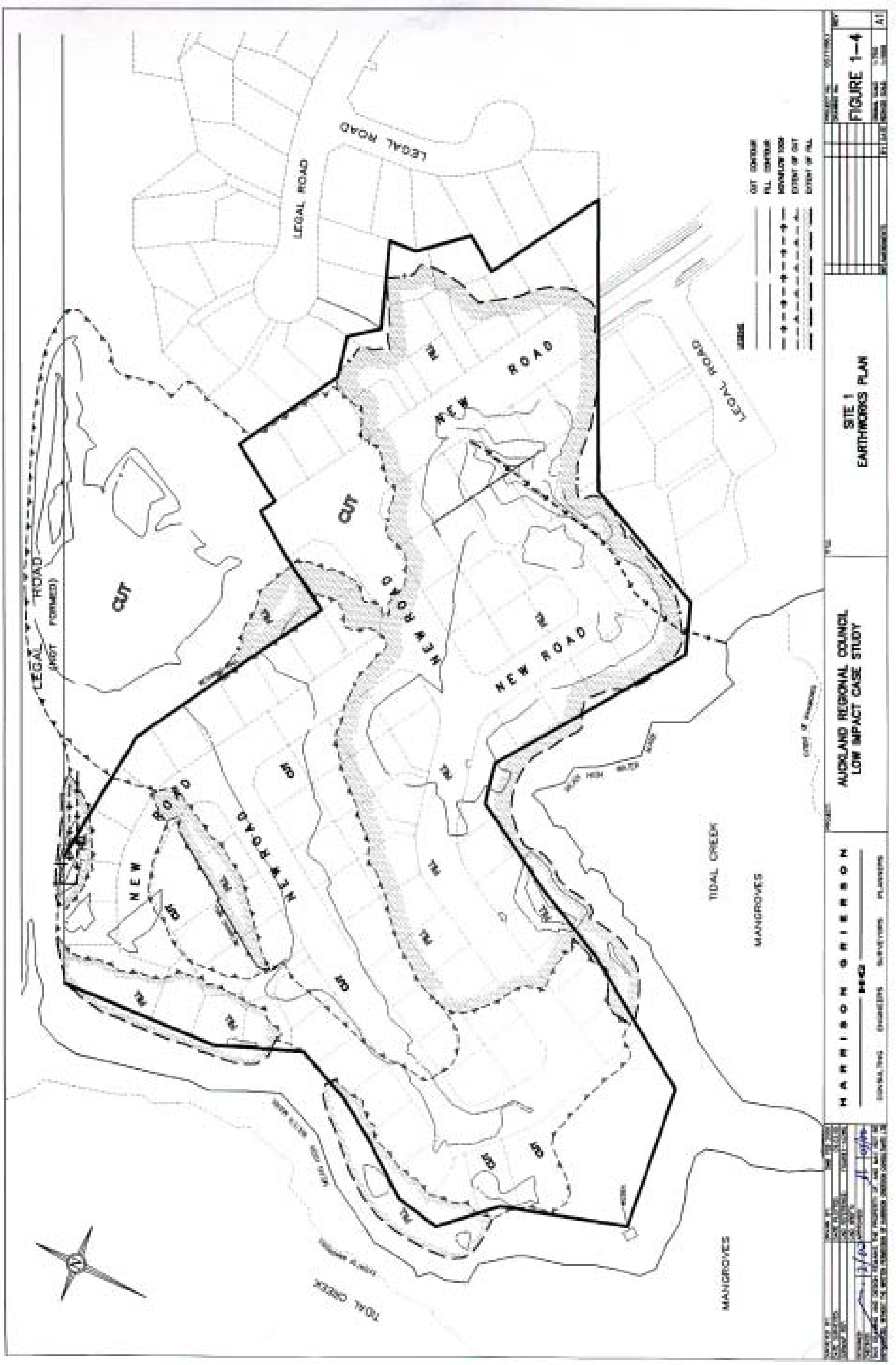
KEY		STATUS		
Data entry	Cells locked	This run:	FINISHED	Calculated

Case Study 1
Site Plans


LEGAL ROAD
(NOT FORMED)
LEGAL ROAD
LEGAL ROAD
LEGAL ROAD
SC1
SC2
SC3
SC4
OUTLET 1
OUTLET 2
OUTLET 3
OUTLET 4
TIDAL CREEK
MANGROVES
TIDAL CREEK
MANGROVES
HARRISON GRIERSON
AUCKLAND REGIONAL COUNCIL
LOW IMPACT CASE STUDIES
SITE 1
PRE-DEVELOPMENT SITE PLAN
FIGURE 1-1

LEGAL ROAD
(NOT FORMED)
LEGAL ROAD
NEW ROAD
TIDAL CREEK
MANGROVES
FIGURE 1–2
SITE 1
SUBMISSION LOT LAYOUT
AUCKLAND REGIONAL COUNCIL
LOW IMPACT CASE STUDY
HARRISON GRIERSON


LEGAL ROAD (NOT FORMED)
LEGAL ROAD
LEGAL ROAD
LEGAL ROAD
NEW ROAD
NEW ROAD
NEW ROAD
NEW ROAD
NEW ROAD
SC1
SC2
SC3
SC4
SC5
OUTLET 1
OUTLET 2
OUTLET 3
OUTLET 4
TIDAL CREEK
MANGROVES
MANGROVES
TIDAL CREEK
HARRISON GRIERSON
AUCKLAND REGIONAL COUNCIL
LOW IMPACT CASE STUDY
SITE 1
SERVICES LAYOUT PLAN
FIGURE 1-3


LEGAL ROAD
LEGAL ROAD (NOT FORMED)
NEW ROAD
CUT
TIDAL CREEK
MANGROVES
AUCKLAND REGIONAL COUNCIL LOW IMPACT CASE STUDY
SITE 1 EARTHWORKS PLAN
FIGURE 1-4
HARRISON GRIERSON


LEGAL ROAD
(NOT FORMED)
TIDAL CREEK
MANGROVES
TIDAL CREEK
MANGROVES
HARRISON GRIERSON
CONSULTING ENGINEERS SURVEYORS PLANNERS
AUCKLAND REGIONAL COUNCIL
LOW IMPACT CASE STUDY
SITE 1 – LOW IMPACT SCENARIO
LOT LAYOUT PLAN
FIGURE 1–5

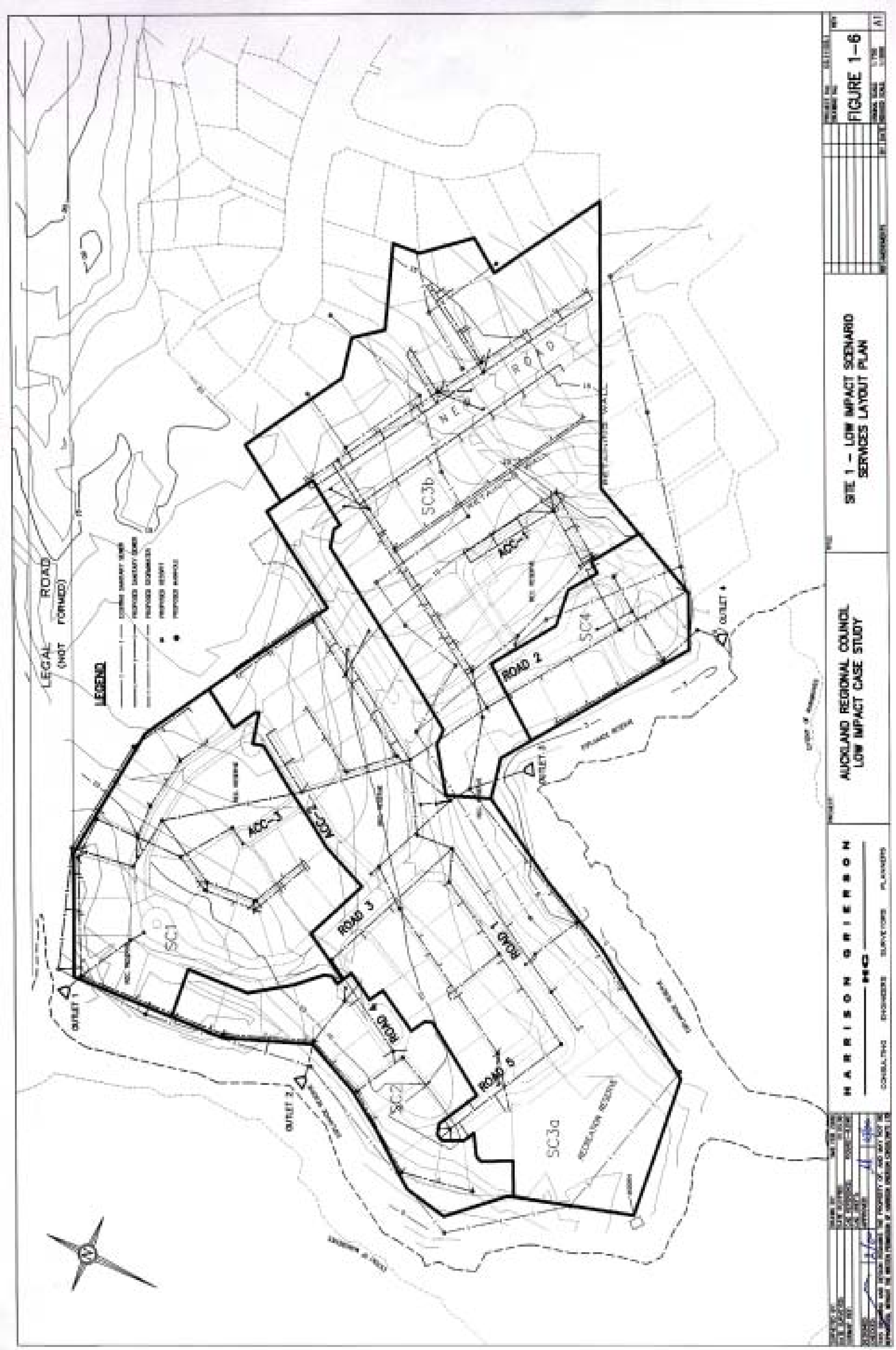
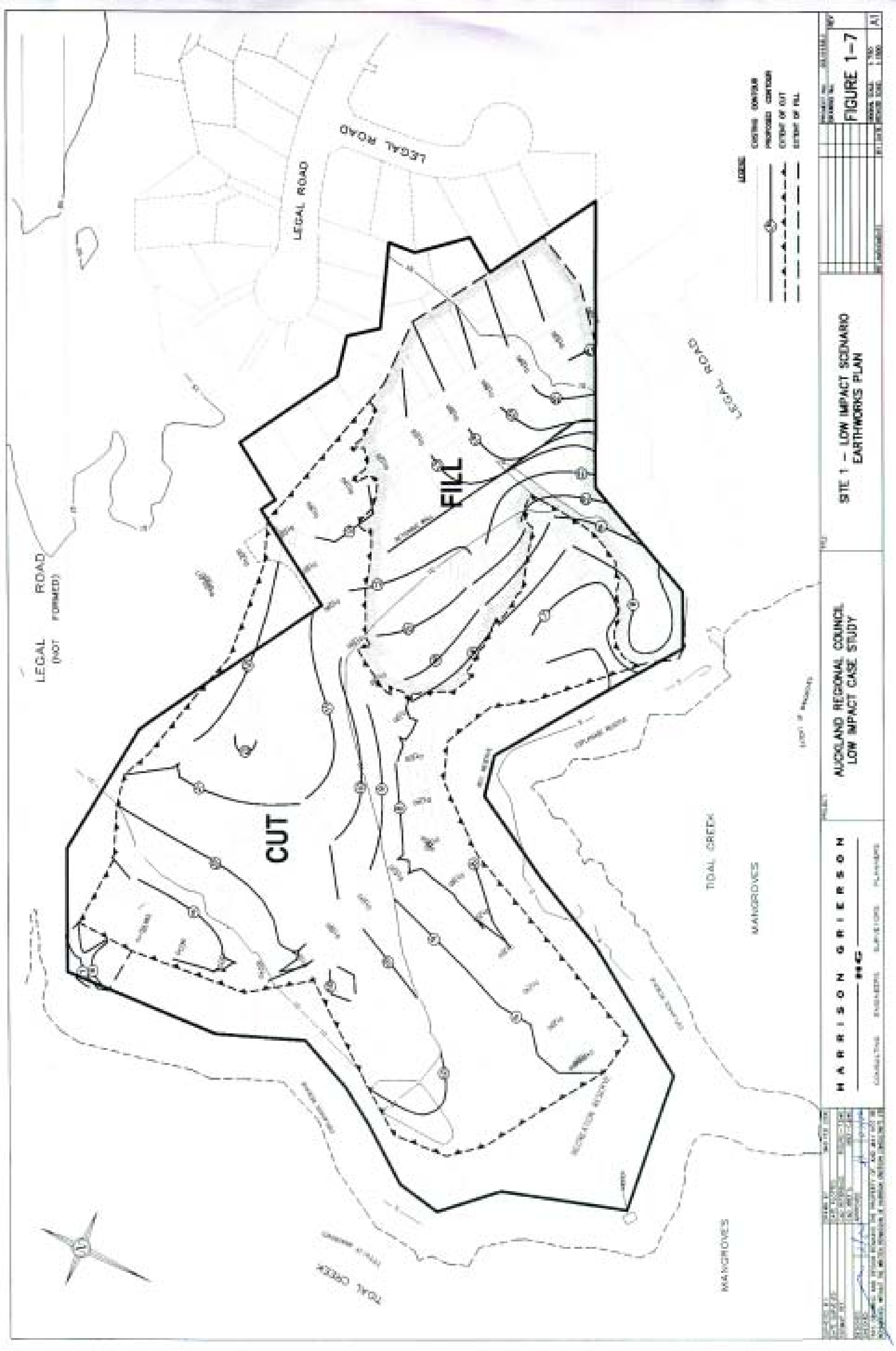


FIGURE 1–6
SITE 1 – LOW IMPACT SCENARIO
SERVICES LAYOUT PLAN
AUCKLAND REGIONAL COUNCIL
LOW IMPACT CASE STUDY
HARRISON GRIERSON
LEGAL ROAD
(NOT FORMED)
LEGEND
ROAD 1
ROAD 2
ROAD 3
ROAD 5
SC1
SC2
SC3a
SC3b
SC4
ACC-1
ACC-3
OUTLET 1
OUTLET 2
OUTLET 3
OUTLET 4


LEGAL ROAD
LEGAL ROAD (NOT FORMED)
CUT
FILL
TIDAL CREEK
MANGROVES
LEGEND
FIGURE 1–7
SITE 1 – LOW IMPACT SCENARIO EARTHWORKS PLAN
AUCKLAND REGIONAL COUNCIL LOW IMPACT CASE STUDY
HARRISON GRIERSON

Appendix 2
Case Study 2

Appendix Components

- Model Inputs
- Model Outputs
- Volumes Analysis
- Site Plans

Model Inputs

The sites pre-development features are shown in Figure 2-1 in Appendix 2 and include five first order streams and two second order streams. Extensive bush was located along the stream margins and cleared areas were used for grazing and vineyards. A minimal number of houses stood adjacent to the road that is located at the top of the site. The site covers four minor mostly self-contained catchments. The areas located outside of the case study site are not included within this hydrological assessment.

To analyse the flow in each stream the four catchments in the pre-development scenario are divided into eight sub-catchments. The sub-catchment boundaries, the topography of the site and the four outlets are shown in Figure 2-1 in Appendix 2. Table 9 presents the necessary parameters for completion of the TP108 methodology using the HEC-HMS software.

Table 9: CASE STUDY – SITE 2 (PRE-DEVELOPMENT SCENARIO)

Sub-catchment	Area (ha)	C	L (km)	S_c (m/m)	t_P (hrs)	I_a (mm)	CN
1	5.55	1.0	0.26	0.12	0.11	5.0	71.5
2	2.09	1.0	0.21	0.16	0.11	5.0	71.0
3	4.47	1.0	0.32	0.11	0.12	5.0	69.0
4	2.03	1.0	0.18	0.07	0.11	5.0	74.0
5	4.80	1.0	0.40	0.08	0.15	5.0	69.2
6	1.40	1.0	0.16	0.15	0.11	5.0	67.5
7	2.61	1.0	0.31	0.14	0.11	5.0	69.6
8	4.78	1.0	0.38	0.11	0.14	5.0	65.0

The hydrologic model of the pre-developed site also includes 3 routing reaches. These reaches were modelled in HEC-HMS using the Kinematic Wave Std option with trapezoidal channels. The lengths of the reaches named R1, R2 and R3 are 50 metres, 170 metres, and 130 metres respectively. The energy slopes of each reach are assumed to be equal to the channel slopes, which are approximately 5%. The width and the side slopes of each channel are 1 metre and 45-degrees respectively, and it is assumed that the Manning's roughness value, n, is 0.05 (Chow, 1959), which accounts for some vegetation being present within the watercourses.

The proposed development of the site includes extensive earthworking and piping of the watercourses. The five outlets from the site will remain however. To model the Standard Subdivision flows discharging from each outlet the site has been divided into five sub-catchments.

The site layout for the proposed Standard Subdivision scenario is shown in Figure 2-2 in Appendix 2. The hydrological model of the site for the Standard Subdivision scenario includes all reserve areas and models the minimum permeable area for each developed lot as 40% of the lot area in accordance with District Plan requirements. Table 10 contains the parameter values required by TP108 and HEC-HMS.

Only one reach is routed in the Standard Subdivision scenario. The length and slope of this reach is 75 metres and 10% respectively. The remaining kinematic wave parameters are kept the same as above. The earthworks required for the Standard Subdivision are shown in Figure 2-4 in Appendix 2.

The site layout for the proposed Low Impact scenario is shown in Figure 2-5 in Appendix 2. The hydrological model of the site for the Low Impact scenario also includes all reserve areas and models the minimum permeable area for each developed lot as 40% of the lot area. Table 11 contains the parameters values required by

Table 6: CASE STUDY – SITE 2 (STANDARD SUBDIVISION SCENARIO)							
Sub-catchment	**Area (ha)**	**C**	**L (km)**	**S_c (m/m)**	**t_P (hrs)**	**I_a (mm)**	**CN**
1	1.73	0.6	0.17	0.04	0.11	2.9	83.8
2	9.95	0.6	0.48	0.08	0.11	2.0	88.4
3	12.43	0.6	0.60	0.09	0.11	2.1	87.3
4	2.68	0.6	0.28	0.12	0.11	3.6	76.1
5	0.94	0.6	0.10	0.02	0.11	3.2	78.6

TP108 and HEC-HMS.

Four reaches are routed in the Low Impact scenario. The length and slope of these reaches are shown in Table

Table 11: CASE STUDY – SITE 2 (LOW IMPACT SCENARIO)							
Sub-catchment	**Area (ha)**	**C**	**L (km)**	**S_c (m/m)**	**t_P (hrs)**	**I_a (mm)**	**CN**
1	1.83	0.6	0.18	0.08	0.11	2.3	87.2
2	2.68	0.6	0.23	0.07	0.11	1.8	89.2
3	1.83	0.6	0.53	0.07	0.11	2.2	87.3
4	2.07	0.6	0.26	0.05	0.11	2.2	87.6
5	2.54	0.6	0.26	0.10	0.11	2.0	88.2
6	0.17	0.6	0.15	0.11	0.11	2.1	88.1
7	1.21	0.6	0.18	0.09	0.11	2.1	88.0
8	2.54	0.6	0.13	0.02	0.11	2.4	86.6
9	4.87	0.6	0.38	0.06	0.11	4.3	76.6
10	4.64	0.6	0.41	0.07	0.11	3.7	76.8
11	3.36	0.6	0.35	0.12	0.11	4.3	72.8

12. The remaining kinematic wave parameters are kept the same as above.

Table 12: ROUTING REACHES - CASE STUDY – SITE 2 (STANDARD SUBDIVISION SCENARIO)		
Routing Reach	**Length (m)**	**Slope (%)**
Reach 1	178	3.9
Reach 2	260	6.3
Reach 3	408	6.5
Reach 4	249	11.1

TP 108
Modelling Outputs

SITE 2

Table 13 presents the pre development, Standard Subdivision and Low Impact changes to flow at each outlet from the site for the 2-year, 10-year and 100-year average recurrence interval events.

Graphs 6.4 to 6.6 also present the peak flow and volume runoff for the 50%, 10% and 1% ARI events respectively.

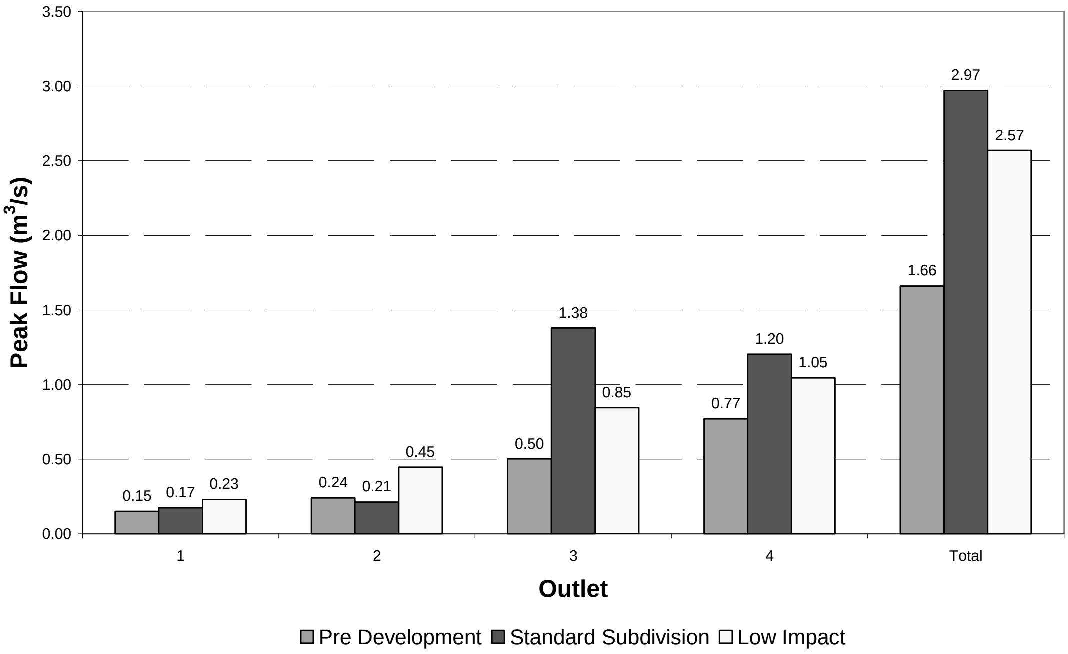
Table 13: SITE 2 RESULTS

1% ARI												
Outlet	**Area (sqm)**			**Qp (cumecs)**			**Volume (cu.m)**			**Runoff (mm)**		
no.	**Pre Development**	**Standard Sub-division**	**Low Impact**	**Pre Development**	**Standard Sub-division**	**Low Impact**	**Pre Development**	**Standard Sub-division**	**Low Impact**	**Pre Development**	**Standard Sub-division**	**Low Impact**
1	20300	17350	20990	0.42	0.43	0.54	2522	2560	3254	124	148	155
2	47800	26750	57177	0.75	0.58	1.18	5061	3476	7187	106	130	126
3	88100	124250	88450	0.82	3.20	2.13	10048	19420	13143	114	156	149
4	121100	108950	110683	1.51	2.79	2.62	14173	17104	16478	117	157	149
Total	**277300**	**277300**	**277300**	**3.50**	**7.00**	**6.46**	**31804**	**42560**	**40062**	**115**	**153**	**144**

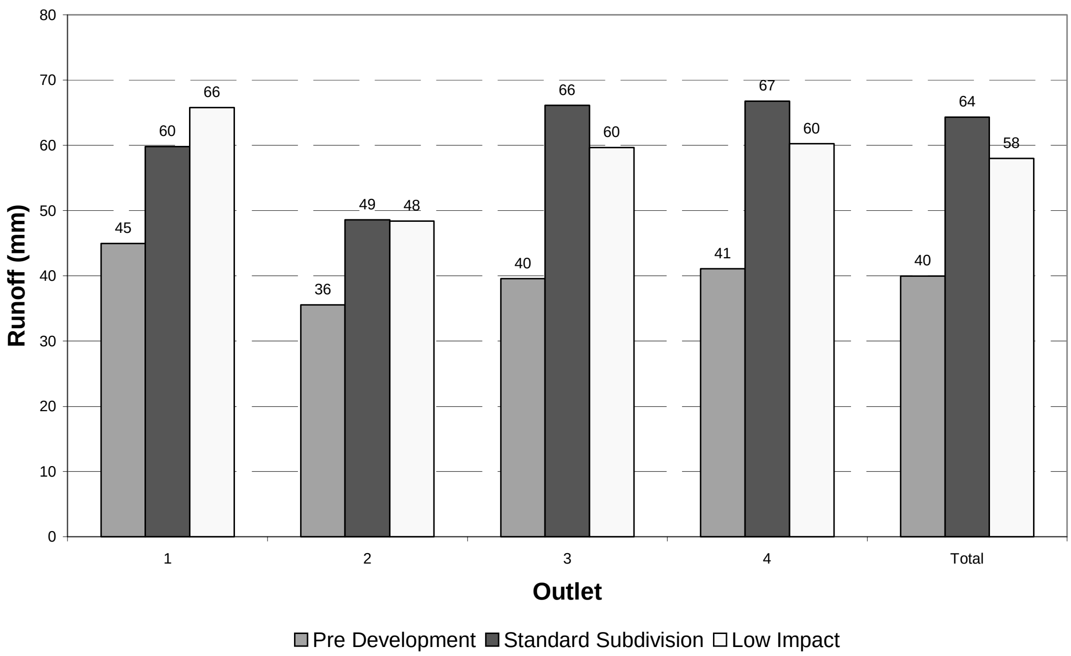
Table 13: SITE 2 RESULTS Cont …

10% ARI												
Outlet	Area (sqm)			Qp (cumecs)			Volume (cu.m)			Runoff (mm)		
no.	Pre Development	Standard Subdivision	Low Impact	Pre Development	Standard Subdivision	Low Impact	Pre Development	Standard Subdivision	Low Impact	Pre Development	Standard Subdivision	Low Impact
1	20300	17350	20990	0.26	0.28	0.36	1557	1663	2158	77	96	103
2	47800	26750	57177	0.44	0.36	0.74	3014	2177	4558	63	81	80
3	88100	124250	88450	0.90	2.14	1.37	6082	12861	8497	69	104	96
4	121100	108950	110683	1.36	1.87	1.69	8629	11350	10689	71	104	97
Total	**277300**	**277300**	**277300**	**2.95**	**4.65**	**4.16**	**19282**	**28051**	**25902**	**70**	**101**	**93**

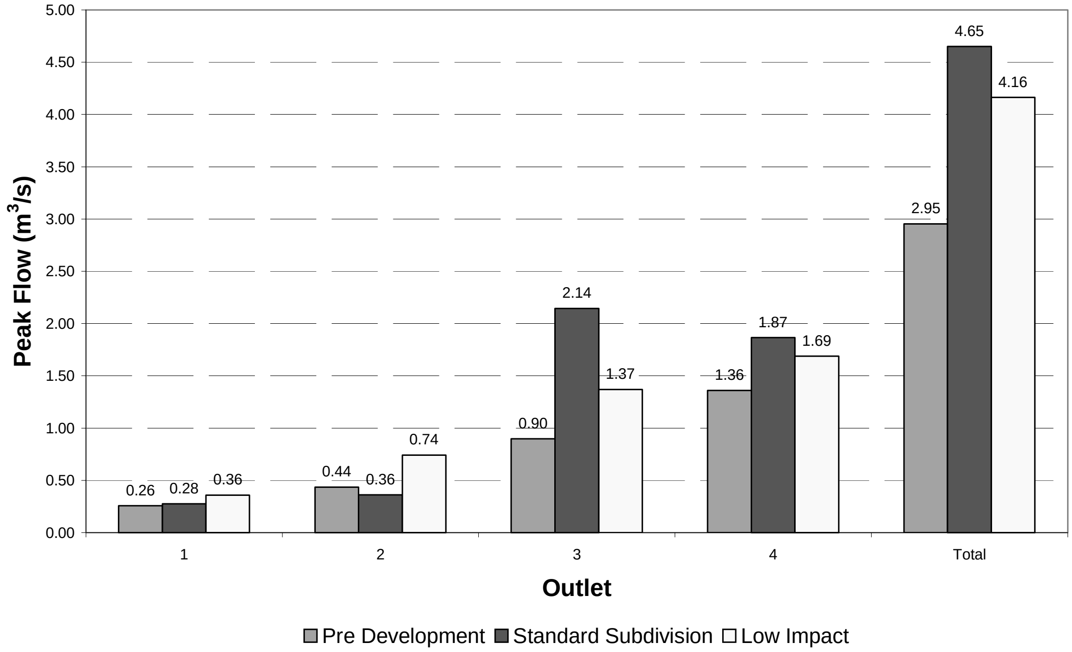
50% ARI												
Outlet	Area (sqm)			Qp (cumecs)			Volume (cu.m)			Runoff (mm)		
no.	Pre Development	Standard Subdivision	Low Impact	Pre Development	Standard Subdivision	Low Impact	Pre Development	Standard Subdivision	Low Impact	Pre Development	Standard Subdivision	Low Impact
1	20300	17350	20990	0.15	0.17	0.23	913	1038	1381	45	60	66
2	47800	26750	57177	0.24	0.21	0.45	1700	1300	2767	36	49	48
3	88100	124250	88450	0.50	1.38	0.85	3487	8220	5277	40	66	60
4	121100	108950	110683	0.77	1.20	1.05	4980	7277	6666	41	67	60
Total	**277300**	**277300**	**277300**	**1.66**	**2.97**	**2.57**	**11080**	**17835**	**16091**	**40**	**64**	**58**



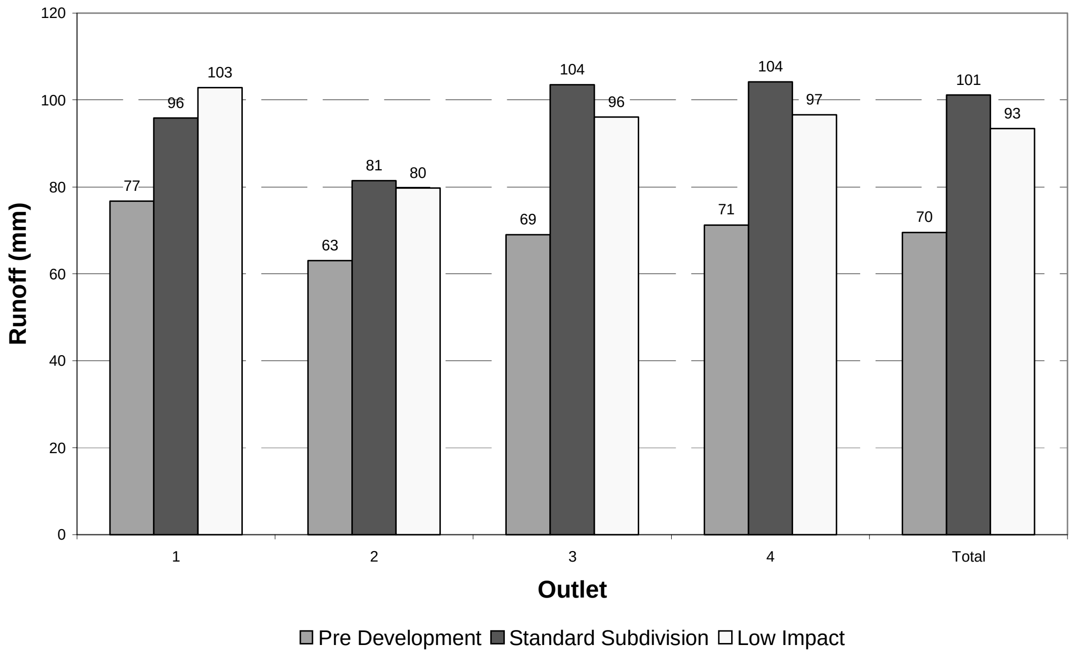
Graph 6.4a: Site 2, Peak flows at each outlet for pre-development, Standard Subdivision, and Low Impact scenario catchment conditions during a 50% ARI event.



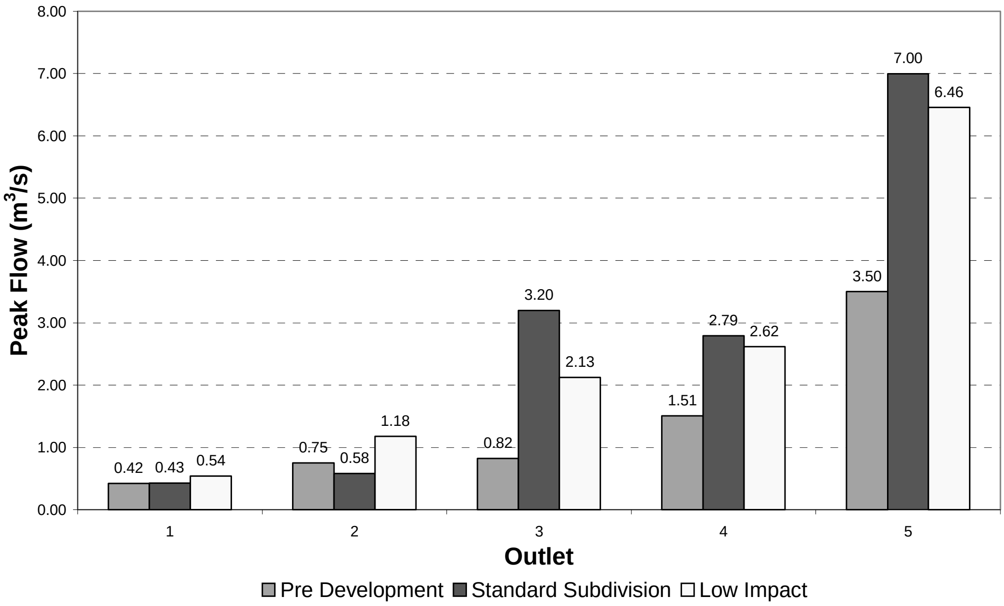
Graph 6.4b: Site 2, Volume Runoff at each outlet for pre-development, Standard Subdivision, and Low Impact scenario catchment conditions during a 50% ARI event.



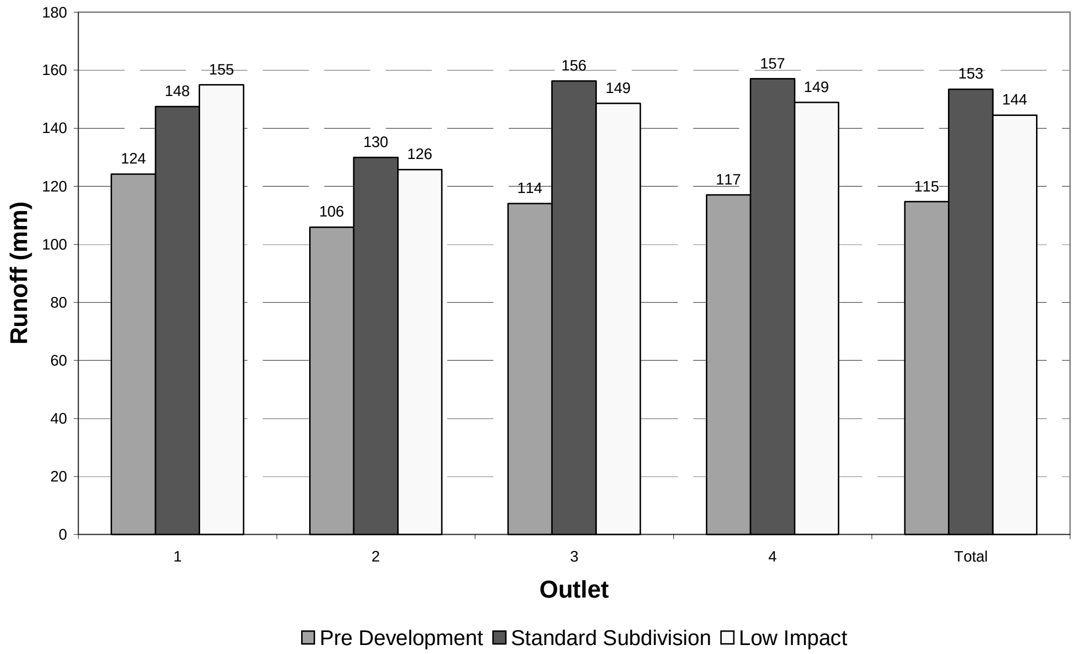
Graph 6.5a: Site 2, Peak flows at each outlet for pre-development, Standard Subdivision, and Low Impact scenario catchment conditions during a 10% ARI event.



Graph 6.5b: Site 2, Volume Runoff at each outlet for pre-development, Standard Subdivision, and Low Impact scenario catchment conditions during a 10% ARI event.



Graph 6.6a: Site 2, Peak flows at each outlet for pre-development, Standard Subdivision, and Low Impact scenario catchment conditions during a 1% ARI event.



Graph 6.6b: Site 2, Volume Runoff at each outlet for pre-development, Standard Subdivision, and Low Impact scenario catchment conditions during a 1% ARI event.

Case Study 2
Volumes Analysis

SITE:	Case study 2			By:		Date:		Ref:	
DETAILS:	evaluation of predevelopment versus conventional development								
	Rainfall Factor Kr	1.30	IA	5					
LAND USE DATA				SCENARIO 1			SCENARIO 2		
ID	Description	Soil type	Land use	CN	%Imp	Area	CN	%Imp	Area
Pervious & Unconnected Impervious									
1	Waitemata Series	C	Pasture / lawn	74	0	11.29	74	0	10.45
2	Waitemata Series	C	woods/grass	72	0	2.63	72	0	0
3	Waitemata Series	C	bush	65	0	13.78	65	0	2.4
4	Impervious	-	Hardstand		100		98	100	
			Subtotal	**69.3**		**27.7**	**72.3**		**12.9**
Connected Impervious									
						0			14.86
			Subtotal			**0.0**			**14.9**
			TOTAL AREA		**Scenario 1**	**27.7**		**Scenario 2**	**27.7**
Record length:		9709 days			26.6 years	**Average annual rainfall**		1516 mm	
RESULTS		**SCENARIO 1**				**SCENARIO 2**			
		Rainfall	**Storm flow**	**Base flow**	**Total runoff**	**Rainfall**	**Storm flow**	**Base flow**	**Total runoff**
99 percentile daily runoff (m3)		13,216	5,041	619	5,503	13,220	8,921	249	9,125
95 percentile daily runoff (m3)		5,870	896	610	1,321	5,872	3,179	247	3,348
90 percentile daily runoff (m3)		3,421	196	586	655	3,422	1,480	240	1,626
Wet year total runoff (m3)		573,640	172,722	142,830	315,552	573,847	334,263	58,910	393,173
Dry year total runoff (m3)		300,071	30,580	89,963	120,543	300,180	133,798	37,554	171,353
Average annual runoff (m3)		**419,980**	**77,202**	**106,863**	**184,064**	**420,131**	**209,898**	**44,575**	**254,473**
KEY		**STATUS**							
Data entry	**Cells locked**	**This run:**	FINISHED		**Calculated**				

SITE:	Case study 2			By:		Date:		Ref:	
DETAILS:	evaluation of predevelopment versus low impact approach								
	Rainfall Factor Kr	1.30	IA	5					
LAND USE DATA				SCENARIO 1			SCENARIO 2		
ID	Description	Soil type	Land use	CN	%Imp	Area	CN	%Imp	Area
Pervious & Unconnected Impervious									
1	Waitemata Series	C	Pasture / lawn	74	0	11.29	74	0	8.5
2	Waitemata Series	C	woods/grass	72	0	2.63	68	0	0
3	Waitemata Series	C	bush	65	0	13.78	65		8.36
4	Impervious	-	Hardstand		100		98	100	
			Subtotal	**69.3**		**27.7**	**69.5**		**16.9**
Connected Impervious									
						0			10.87
			Subtotal			**0.0**			**10.9**
			TOTAL AREA		**Scenario 1**	**27.7**		**Scenario 2**	**27.7**
Record length:		9709 days			26.6 years	**Average annual rainfall**		1516 mm	
RESULTS		**SCENARIO 1**				**SCENARIO 2**			
		Rainfall	**Storm flow**	**Base flow**	**Total runoff**	**Rainfall**	**Storm flow**	**Base flow**	**Total runoff**
99 percentile daily runoff (m3)		13,216	5,041	619	5,503	13,230	7,581	373	7,948
95 percentile daily runoff (m3)		5,870	896	610	1,321	5,876	2,514	367	2,753
90 percentile daily runoff (m3)		3,421	196	586	655	3,425	1,123	354	1,322
Wet year total runoff (m3)		573,640	172,722	142,830	315,552	574,261	285,227	86,288	371,515
Dry year total runoff (m3)		300,071	30,580	89,963	120,543	300,396	102,261	54,383	156,644
Average annual runoff (m3)		**419,980**	**77,202**	**106,863**	**184,064**	**420,434**	**170,119**	**64,606**	**234,725**
KEY		**STATUS**							
Data entry	**Cells locked**	**This run:**	FINISHED		**Calculated**				

Case Study 2
Site Plans


FIGURE 2-1
SITE 2
PRE-DEVELOPMENT SITE PLAN
AUCKLAND REGIONAL COUNCIL
LOW IMPACT CASE STUDY
HARRISON GRIERSON
SC1
SC2
SC3
SC4
SC5
SC6
SC7
SC8
EXISTING ROAD
EXISTING ROAD
OUTLET 1
LEGEND


EXISTING ROAD
EXISTING ROAD
FIELD
KAURI FOREST
HARRISON GRIERSON
CONSULTING ENGINEERS SURVEYORS PLANNERS
AUCKLAND REGIONAL COUNCIL
LOW IMPACT CASE STUDY
SITE 2
STANDARD SUBDIVISION
FIGURE 2-2

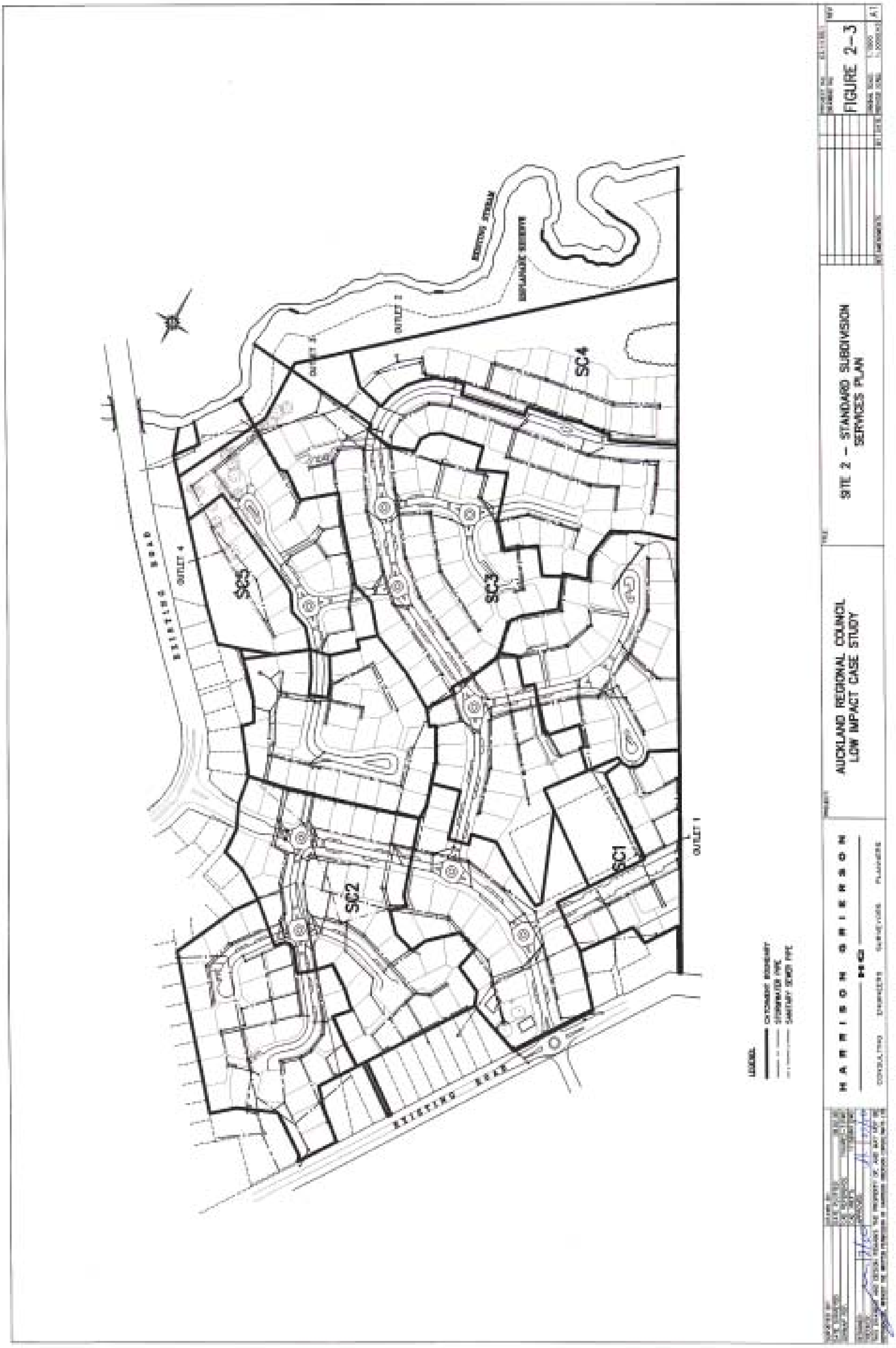
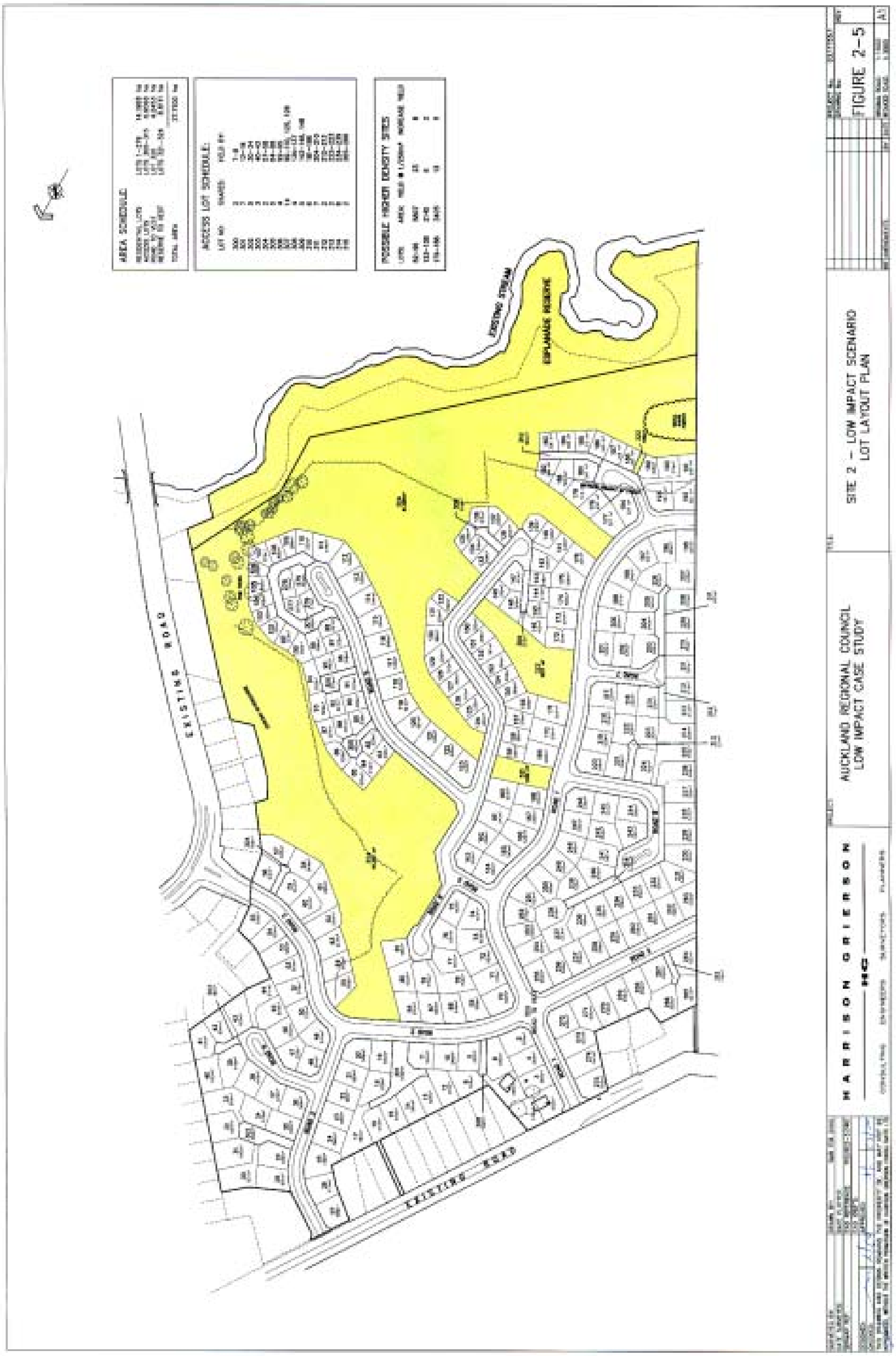
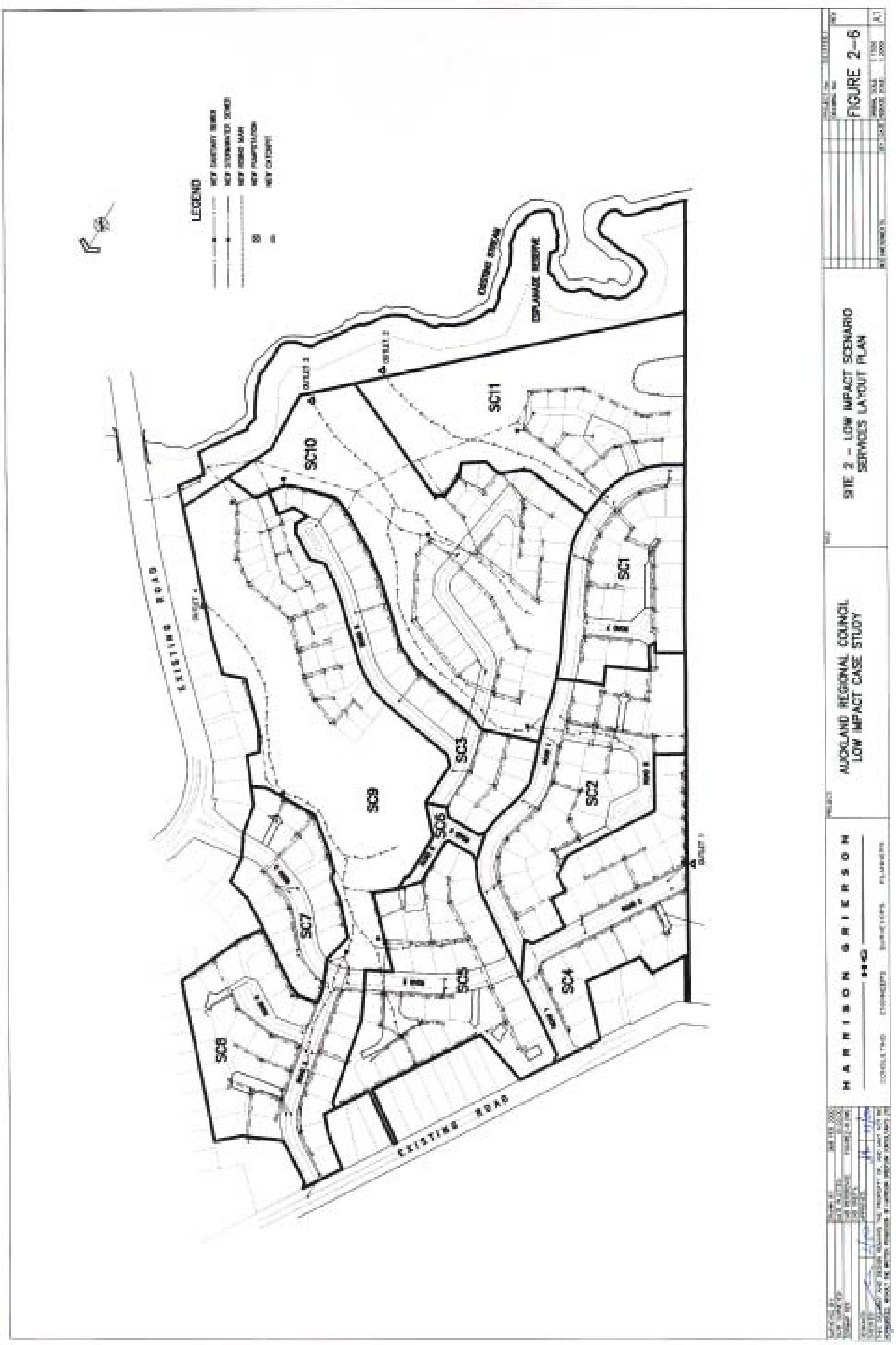


FIGURE 2-3
SITE 2 – STANDARD SUBDIVISION
SERVICES PLAN
AUCKLAND REGIONAL COUNCIL
LOW IMPACT CASE STUDY
HARRISON GRIERSON
SC1
SC2
SC3
SC4
SC5
OUTLET 1
OUTLET 4
EXISTING ROAD
EXISTING ROAD
LEGEND


FIGURE 2-4
SITE 2 - STANDARD SUBDIVISION
EARTHWORKS PLAN
AUCKLAND REGIONAL COUNCIL
LOW IMPACT CASE STUDY
HARRISON GRIERSON
CONSULTING ENGINEERS SURVEYORS PLANNERS
EXISTING ROAD
CUT
FILL



SITE 2 – LOW IMPACT SCENARIO
LOT LAYOUT PLAN
AUCKLAND REGIONAL COUNCIL
LOW IMPACT CASE STUDY
FIGURE 2–5
HARRISON GRIERSON
AREA SCHEDULE
ACCESS LOT SCHEDULE
POSSIBLE HIGHER DENSITY SITES
EXISTING ROAD
EXISTING STREAM
ESPLANADE RESERVE



LEGEND
EXISTING ROAD
EXISTING ROAD
SC1
SC2
SC3
SC4
SC5
SC6
SC7
SC8
SC9
SC10
SC11
HARRISON GRIERSON
AUCKLAND REGIONAL COUNCIL
LOW IMPACT CASE STUDY
SITE 2 – LOW IMPACT SCENARIO
SERVICES LAYOUT PLAN
FIGURE 2–6


FIGURE 2–7
SITE 2 – LOW IMPACT SCENARIO
EARTHWORKS PLAN
AUCKLAND REGIONAL COUNCIL
LOW IMPACT CASE STUDY
HARRISON GRIERSON
EXISTING ROAD
EXISTING ROAD
EXISTING STREAM
ESPLANADE RESERVE
CUT
FILL

Appendix 3
Case Study 3

Appendix Components

Model Inputs
Model Outputs
Volumes Analysis
Site Plans

Model Inputs

To model the site under pre-development conditions it is divided into 8 sub-catchments. These are based on the topography of site and proposed outlets in the Standard Subdivision scenario. Figure 3-1 in Appendix 3 shows the topography of the pre-developed site, sub-catchment boundaries and main flowpaths. Table 14 presents the parameters necessary for TP108 and HEC-HMS.

Table 14: CASE STUDY – SITE 3 (PRE-DEVELOPMENT SCENARIO)

Sub-catchment	Area (ha)	C	L (km)	S_c (m/m)	t_P (hrs)	I_a (mm)	CN
1	3.25	1.0	0.14	0.17	0.11	5.0	74.0
2	3.85	1.0	0.33	0.04	0.15	5.0	74.0
3	2.18	1.0	0.24	0.06	0.11	5.0	74.0
4	1.53	1.0	0.20	0.07	0.11	5.0	74.0
5	1.38	1.0	0.25	0.04	0.13	5.0	74.0
6	0.34	1.0	0.18	0.06	0.14	5.0	74.0
7	0.75	1.0	0.12	0.08	0.11	5.0	74.0
8	0.95	1.0	0.14	0.05	0.11	5.0	74.0

Two routing reaches were included in the pre-development model and are shown in Figure 3-1a in Appendix 3 as R1 and R2. Within the model the length and energy slope of reach R1 are 120 metres and 3% respectively, while the width of the channel is 0.5 metres and the channel side slopes are 45 degrees. The Manning's n value for reach R1 is assumed to be 0.035 (Chow, 1959) owing to clearing of the watercourse for farming purposes. Reach R2 is modelled with a length of 60 metres, an energy slope of 4%, a channel width of 10 metres, side slopes of 45 degrees and a Manning's n value of 0.035 (Chow, 1959).

The Standard Subdivision layout is shown in Figure 3-2 in Appendix 3. The development of this site includes four stormwater quality treatment facilities. Two of these facilities are the centrally located treatment marshes in-line with the original ephemeral stream (shown in Figure 3-3 in Appendix 3). These marshes treat the stormwater runoff from sub-catchments 2 and 7. The other two treatment facilities are swales that are located in sub-catchments 6 and 8 and which treat only partially the runoff from these sub-catchments (shown in Figure 3-3 in Appendix 3). The two swales will not have a significant effect on the hydrology of the catchment in terms of peak outlet discharges and catchment runoff volume. Therefore, these facilities were not modelled explicitly.

In the modelling process the two marshes were treated as wide, low water depth channels with dimensions taken from design drawings. The first marsh was modelled with a channel length of 75 metres, an energy slope of 1%, a channel width of 24 metres, channel side slopes of 25% and with a high Manning's value of 0.15 (Chow, 1959). The second marsh was modelled with a channel length of 60 metres and a channel width of 16 metres. The remaining parameters were similar to the first marsh.

As a result of earthworks and reticulation of the site, sub-catchment 3 has been assimilated into sub-catchments 2, 7 and 8 and the flow from sub-catchment 3 has been redirected from Outlet 5 into the main channel to discharge via Outlet 4. Therefore, the number of sub-catchments is reduced to seven and the number of outlets has reduced to four in the Standard Subdivision scenario.

Figure 3-3 in Appendix 3 shows the Standard Subdivision contours of the site, proposed reticulation system, sub-catchment boundaries, and site outlets. The hydrological model of the site for the Standard Subdivision scenario includes all reserve areas and models the minimum permeable area for each developed lot as 30% of the lot area in accordance with District Plan requirements.

Table 15 contains the parameters values required by TP108 and HEC-HMS.

Table 15: CASE STUDY – SITE 3 (STANDARD SUBDIVISION SCENARIO)							
Sub-catchment	**Area (ha)**	**C**	**L (km)**	**S_c (m/m)**	**t_P (hrs)**	**I_a (mm)**	**CN**
1	1.53	0.6	0.24	0.06	0.11	2.2	87.3
2	5.65	0.6	0.35	0.02	0.11	1.5	90.8
4	1.43	0.6	0.36	0.05	0.11	1.5	90.8
6	1.93	0.6	0.33	0.02	0.11	1.5	90.8
7	2.04	0.6	0.22	0.02	0.11	1.4	91.1
8	1.63	0.6	0.34	0.02	0.11	1.5	90.8

The earthworks required for the Standard Subdivision are shown in Figure 3-4 in Appendix 3.

The site layout for the proposed Low Impact scenario is shown in Figure 3-5 in Appendix 3. The hydrological model of the site for the Low Impact scenario also includes all reserve areas and models the minimum permeable area for each developed lot as 30% of the lot area in accordance with the local Proposed District Plan. Table 16 contains the parameter values required by TP108 and HEC-HMS. The catchment boundaries and stormwater network are shown in Figure 3-6 in Appendix 3.

The hydrologic model of the Low Impact scenario also includes 2 routing reaches. These reaches were modelled in HEC-HMS using the Kinematic Wave Std option with trapezoidal channels. The lengths of the reaches named Reach 1 and Reach 2 are 60 metres and 210 metres respectively. The energy slopes of each reach are assumed to be equal to the channel slopes which taken from the topographical maps are approximately 5% and 2% respectively. The width and the side slopes of each channel are 1 metre and 45-degrees respectively, and it is assumed that the Manning's roughness value, n, is 0.05 (Chow, 1959), which accounts for some vegetation being present within the watercourses. The earthworks required for the Low Impact scenario are shown in Figure 3-7 in Appendix 3.

Table 16: CASE STUDY – SITE 3 (LOW IMPACT SCENARIO)							
Sub-catchment	**Area (ha)**	**C**	**L (km)**	**S_c (m/m)**	**t_P (hrs)**	**I_a (mm)**	**CN**
1	3.15	0.6	0.18	0.12	0.11	2.8	84.4
2	4.06	0.6	0.50	0.03	0.12	2.0	88.2
3	1.55	0.6	0.34	0.03	0.11	2.0	88.4
4	1.53	0.6	0.30	0.05	0.11	1.9	88.9
5	0.54	0.6	0.13	0.05	0.11	3.5	81.1
6	0.67	0.6	0.18	0.03	0.11	2.0	88.6
7	1.03	0.6	0.32	0.04	0.11	5.0	74.0
8	1.68	0.6	0.29	0.03	0.11	1.8	89.3

TP 108
Modelling Outputs

SITE 3

Table 17 presents the pre development, Standard Subdivision and Low Impact changes to flow at each outlet from the site for the 2-year, 10-year and 100-year average recurrence interval events.

Graphs 6.7 to 6.9 present the peak flow and volume runoff for the 50%, 10% and 1% ARI events respectively.

Table 17: SITE 3 RESULTS

1% ARI												
Outlet	**Area (sqm)**			**Qp (cumecs)**			**Volume (cu.m)**			**Runoff (mm)**		
no.	**Pre Development**	**Standard Subdivision**	**Low Impact**	**Pre Development**	**Standard Subdivision**	**Low Impact**	**Pre Development**	**Standard Subdivision**	**Low Impact**	**Pre Development**	**Standard Subdivision**	**Low Impact**
1	32474	15317	31533	0.80	0.46	0.90	4197	2477	4882	129	162	155
2	15198	14274	20713	0.37	0.44	0.61	1964	2437	3342	129	171	161
3	13638		6602	0.32		0.20	1762		1104	129		167
4	58872	112489	83232	1.33	3.39	2.41	7608	19235	13361	129	171	161
5	21898			0.54			2830			129		
Total	**142080**	**142080**	**142080**	**3.36**	**4.29**	**4.12**	**18361**	**24149**	**22689**	**129**	**170**	**160**

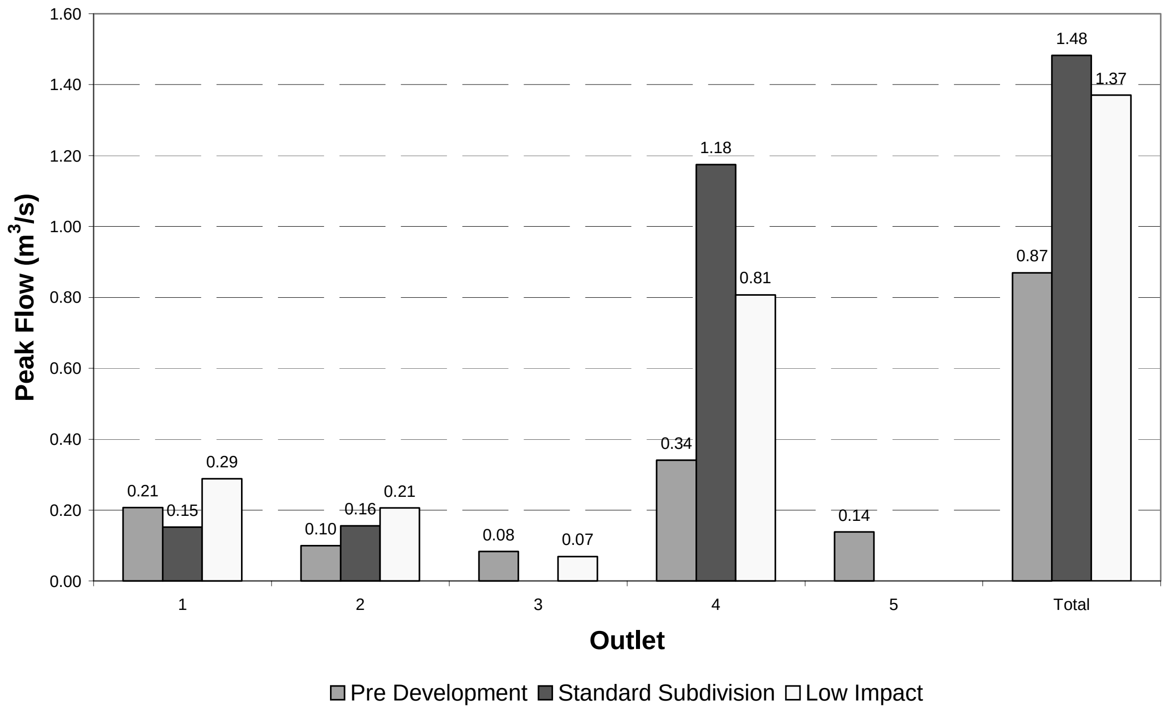
Table 18: SITE 3 RESULTS Cont …

10% ARI

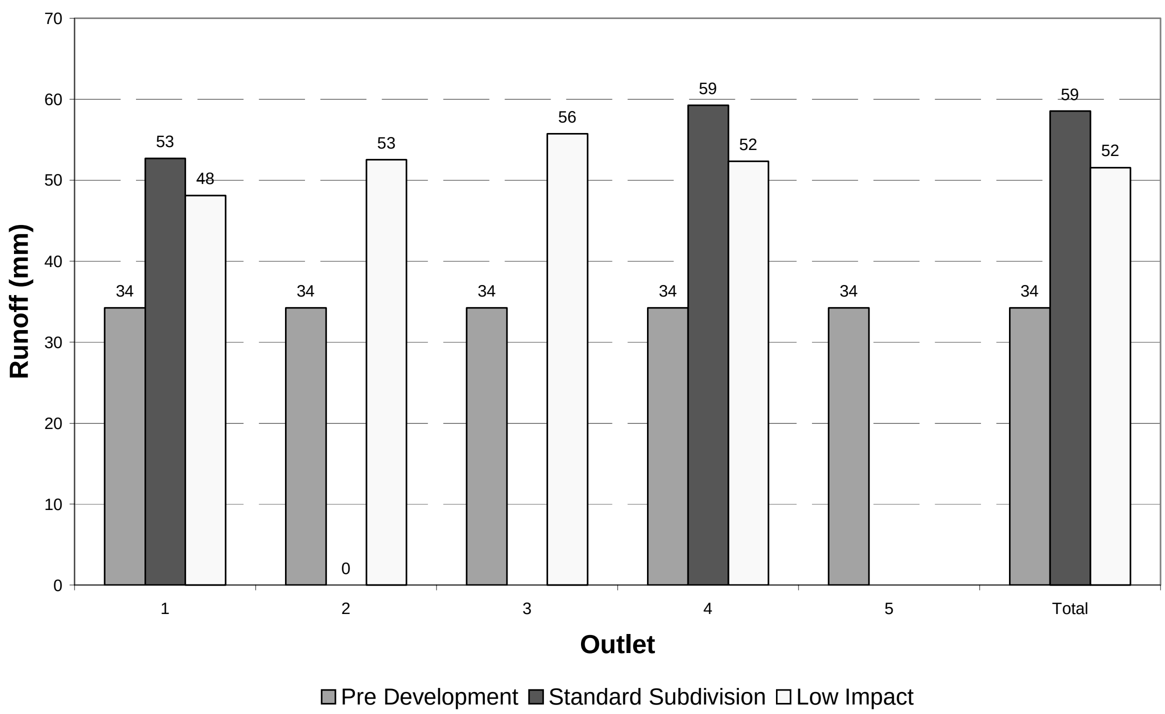
Outlet	Area (sqm)			Qp (cumecs)			Volume (cu.m)			Runoff (mm)		
no.	Pre Development	Standard Subdivision	Low Impact	Pre Development	Standard Subdivision	Low Impact	Pre Development	Standard Subdivision	Low Impact	Pre Development	Standard Subdivision	Low Impact
1	32474	15317	31533	0.45	0.28	0.56	2368	1518	2934	73	99	93
2	15198	14274	20713	0.21	0.28	0.38	1108	1527	2045	73	107	99
3	13638		6602	0.18		0.13	994		682	73		103
4	58872	112489	83232	0.75	2.14	1.50	4292	12064	8179	73	107	98
5	21898			0.30			1596			73		
Total	**142080**	**142080**	**142080**	**1.89**	**2.70**	**2.57**	**10358**	**15109**	**13840**	**73**	**106**	**97**

50% ARI

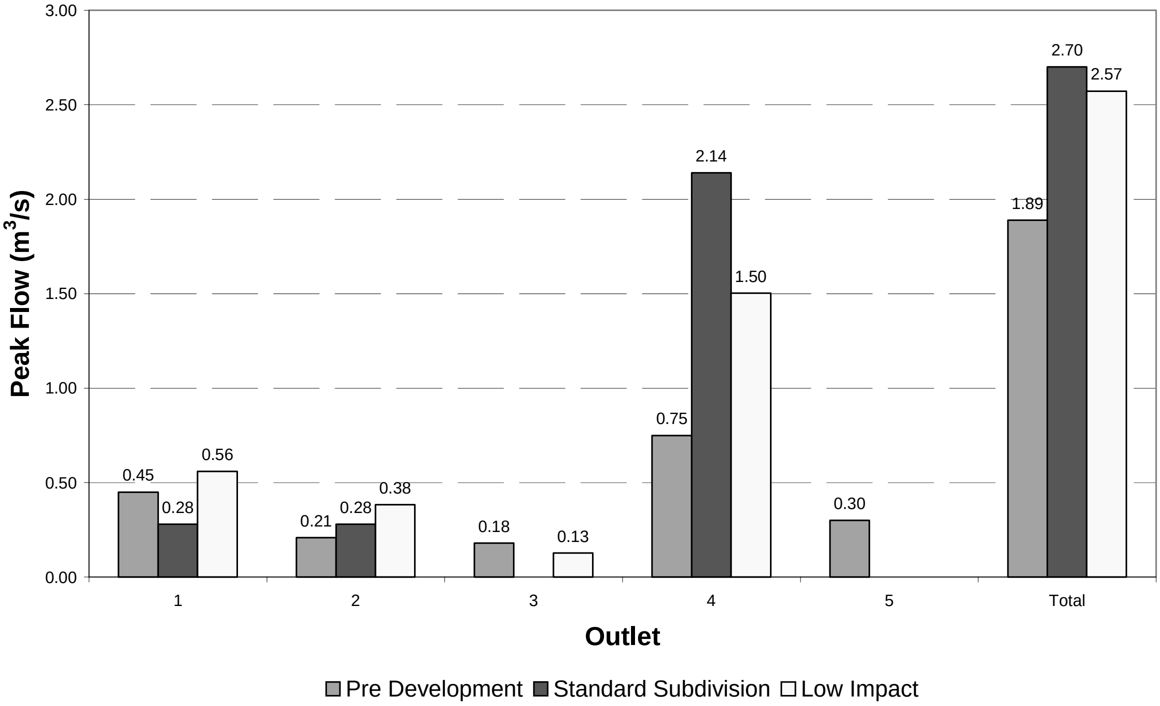
Outlet	Area (sqm)			Qp (cumecs)			Volume (cu.m)			Runoff (mm)		
no.	Pre Development	Standard Subdivision	Low Impact	Pre Development	Standard Subdivision	Low Impact	Pre Development	Standard Subdivision	Low Impact	Pre Development	Standard Subdivision	Low Impact
1	32474	15317	31533	0.21	0.15	0.29	1112	807	1517	34	53	48
2	15198	14274	20713	0.10	0.16	0.21	520	843	1088	34	59	53
3	13638		6602	0.08		0.07	467		368	34		56
4	58872	112489	83232	0.34	1.18	0.81	2016	6666	4354	34	59	52
5	21898			0.14			750			34		
Total	**142080**	**142080**	**142080**	**0.87**	**1.48**	**1.37**	**4865**	**8316**	**7327**	**34**	**59**	**52**



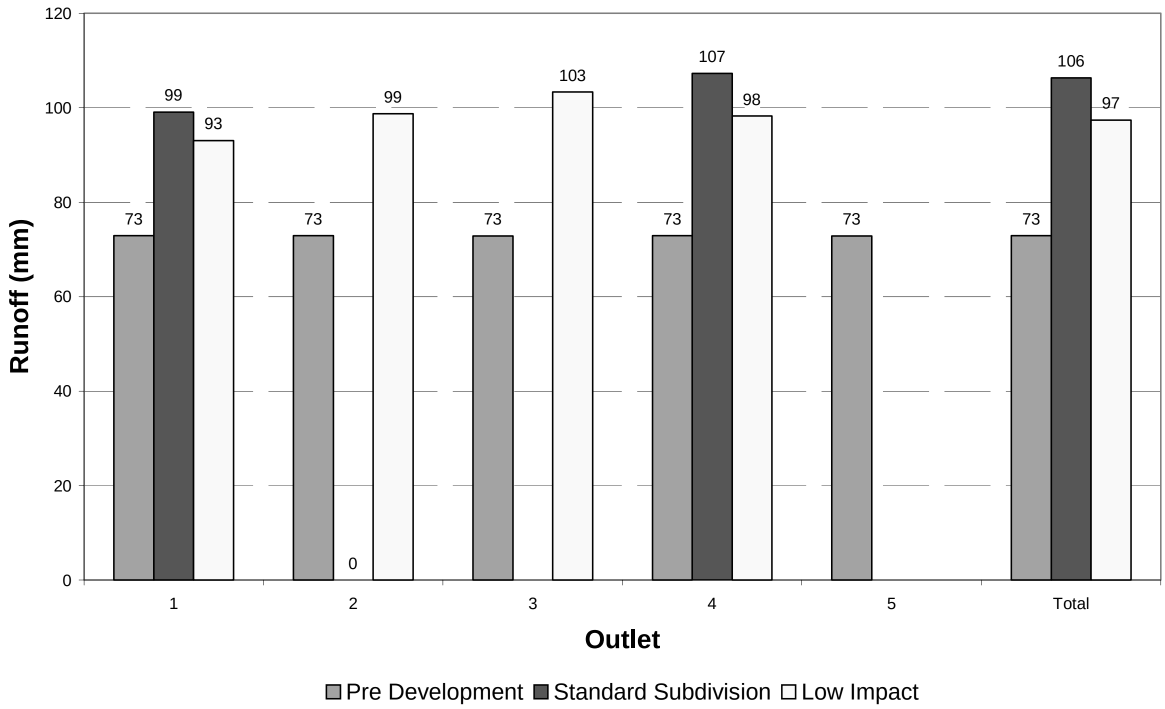
Graph 6.7a: Site 3, Peak flows at each outlet for pre-development, Standard Subdivision, and Low Impact scenario catchment conditions during a 50% ARI event.



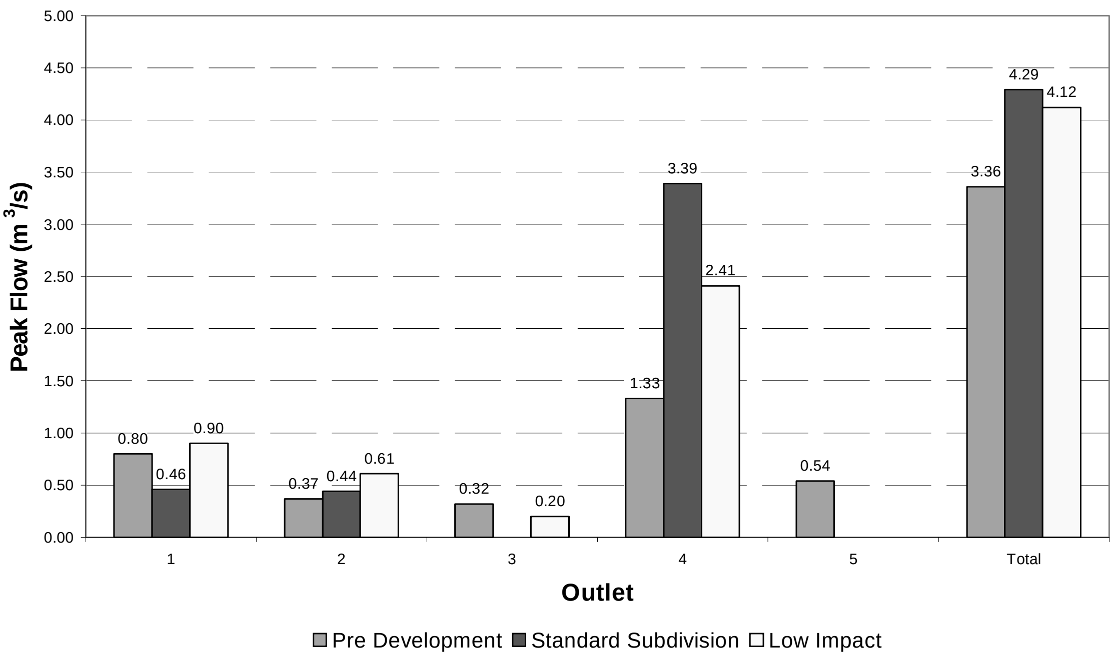
Graph 6.7b: Site 3, Volume Runoff at each outlet for pre-development, Standard Subdivision, and Low Impact scenario catchment conditions during a 50% ARI event.



Graph 6.8a: Site 3, Peak flows at each outlet for pre-development, Standard Subdivision, and Low Impact scenario catchment conditions during a 10% ARI event.



Graph 6.8b: Site 3, Volume Runoff at each outlet for pre-development, Standard Subdivision, and Low Impact scenario catchment conditions during a 10% ARI event.



Graph 6.9a: Site 3, Peak flows at each outlet for pre-development, Standard Subdivision, and Low Impact scenario catchment conditions during a 1% ARI event.

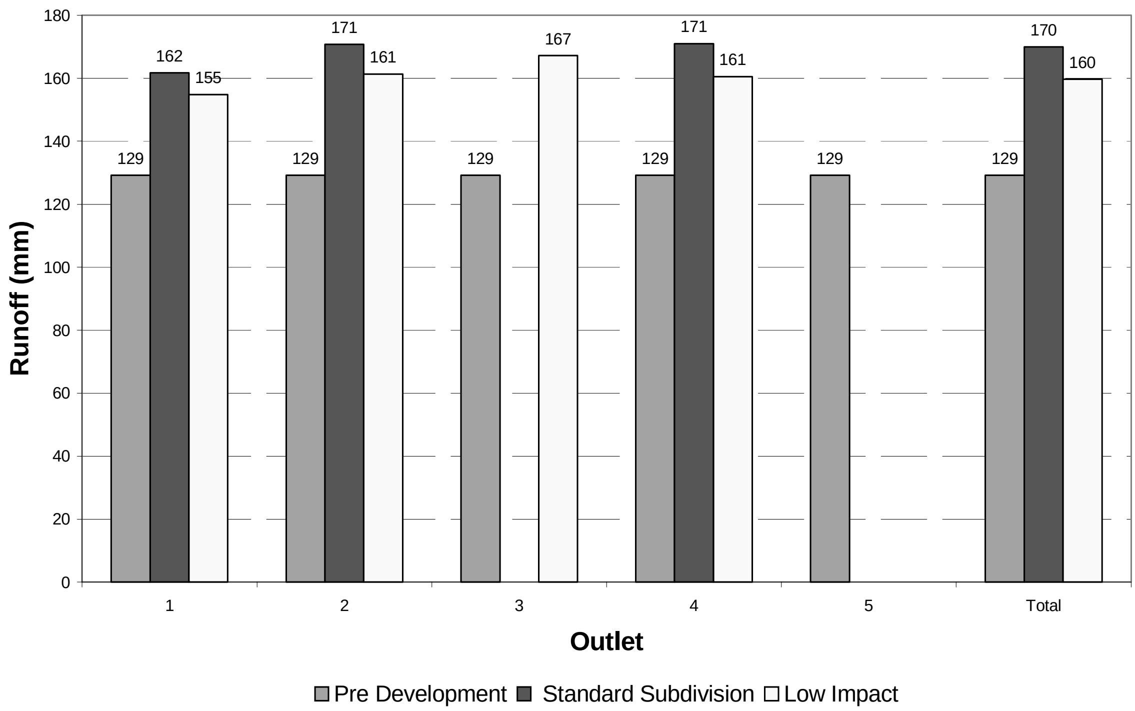


Figure 6.9b: Volume Runoff at each outlet for pre-development, Standard Subdivision, and Low Impact scenario catchment conditions during a 1% ARI event.

Case Study 3
Volumes Analysis

SITE:	Case study 3			By:		Date:		Ref:	
DETAILS:	evaluation of predevelopment versus conventional approach								
		Rainfall Factor Kr	1.10	IA	5				
LAND USE DATA				SCENARIO 1			SCENARIO 2		
ID	Description	Soil type	Land use	CN	%Imp	Area	CN	%Imp	Area
Pervious & Unconnected Impervious									
1	Waitemata Series	C	Pasture / lawn	74	0	14.21	74	0	4.455
2					0				
3					0				
4	Impervious	-	Hardstand		100		98	100	
			Subtotal	**74.0**		**14.2**	**74.0**		**4.5**
Connected Impervious									
						0			9.75
			Subtotal			**0.0**			**9.8**
			TOTAL AREA		Scenario 1	**14.2**		Scenario 2	**14.2**
Record length:	9709 days		26.6 years			Average annual rainfall		1278 mm	

RESULTS	SCENARIO 1 Rainfall	SCENARIO 1 Storm flow	SCENARIO 1 Base flow	SCENARIO 1 Total runoff	SCENARIO 2 Rainfall	SCENARIO 2 Storm flow	SCENARIO 2 Base flow	SCENARIO 2 Total runoff
99 percentile daily runoff (m3)	5,716	2,089	252	2,320	5,714	4,034	79	4,065
95 percentile daily runoff (m3)	2,539	347	248	505	2,538	1,497	78	1,526
90 percentile daily runoff (m3)	1,480	72	234	256	1,479	716	73	760
Wet year total runoff (m3)	248,096	71,025	53,536	124,561	248,009	153,952	16,784	170,736
Dry year total runoff (m3)	129,779	11,761	34,192	45,953	129,734	63,878	10,720	74,597
Average annual runoff (m3)	**181,638**	**31,449**	**39,088**	**70,537**	**181,574**	**99,160**	**12,254**	**111,414**
KEY	**STATUS**							
Data entry **Cells locked**	**This run:**	FINISHED		**Calculated**				

SITE:	Case study 3			By:		Date:		Ref:	
DETAILS:	evaluation of predevelopment versus low impact approach								
		Rainfall Factor Kr	1.10	IA	5				
LAND USE DATA				SCENARIO 1			SCENARIO 2		
ID	Description	Soil type	Land use	CN	%Imp	Area	CN	%Imp	Area
Pervious & Unconnected Impervious									
1	Waitemata Series	C	Pasture / lawn	74	0	14.2	74	0	6.94
2					0				
3					0				
4	Impervious	-	Hardstand		100		98	100	
			Subtotal	**74.0**		**14.2**	**74.0**		**6.9**
Connected Impervious									
						0			7.27
			Subtotal			**0.0**			**7.3**
			TOTAL AREA		Scenario 1	**14.2**		Scenario 2	**14.2**
Record length:	9709 days		26.6 years			Average annual rainfall		1278 mm	

RESULTS	SCENARIO 1 Rainfall	SCENARIO 1 Storm flow	SCENARIO 1 Base flow	SCENARIO 1 Total runoff	SCENARIO 2 Rainfall	SCENARIO 2 Storm flow	SCENARIO 2 Base flow	SCENARIO 2 Total runoff
99 percentile daily runoff (m3)	5,712	2,088	252	2,319	5,716	3,500	123	3,564
95 percentile daily runoff (m3)	2,537	347	247	504	2,539	1,218	121	1,302
90 percentile daily runoff (m3)	1,479	72	234	256	1,480	562	114	625
Wet year total runoff (m3)	247,922	70,975	53,498	124,473	248,096	132,877	26,146	159,024
Dry year total runoff (m3)	129,688	11,753	34,168	45,921	129,779	50,625	16,699	67,324
Average annual runoff (m3)	**181,510**	**31,427**	**39,060**	**70,487**	**181,638**	**81,945**	**19,090**	**101,035**
KEY	**STATUS**							
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Case Study 3
Site Plans

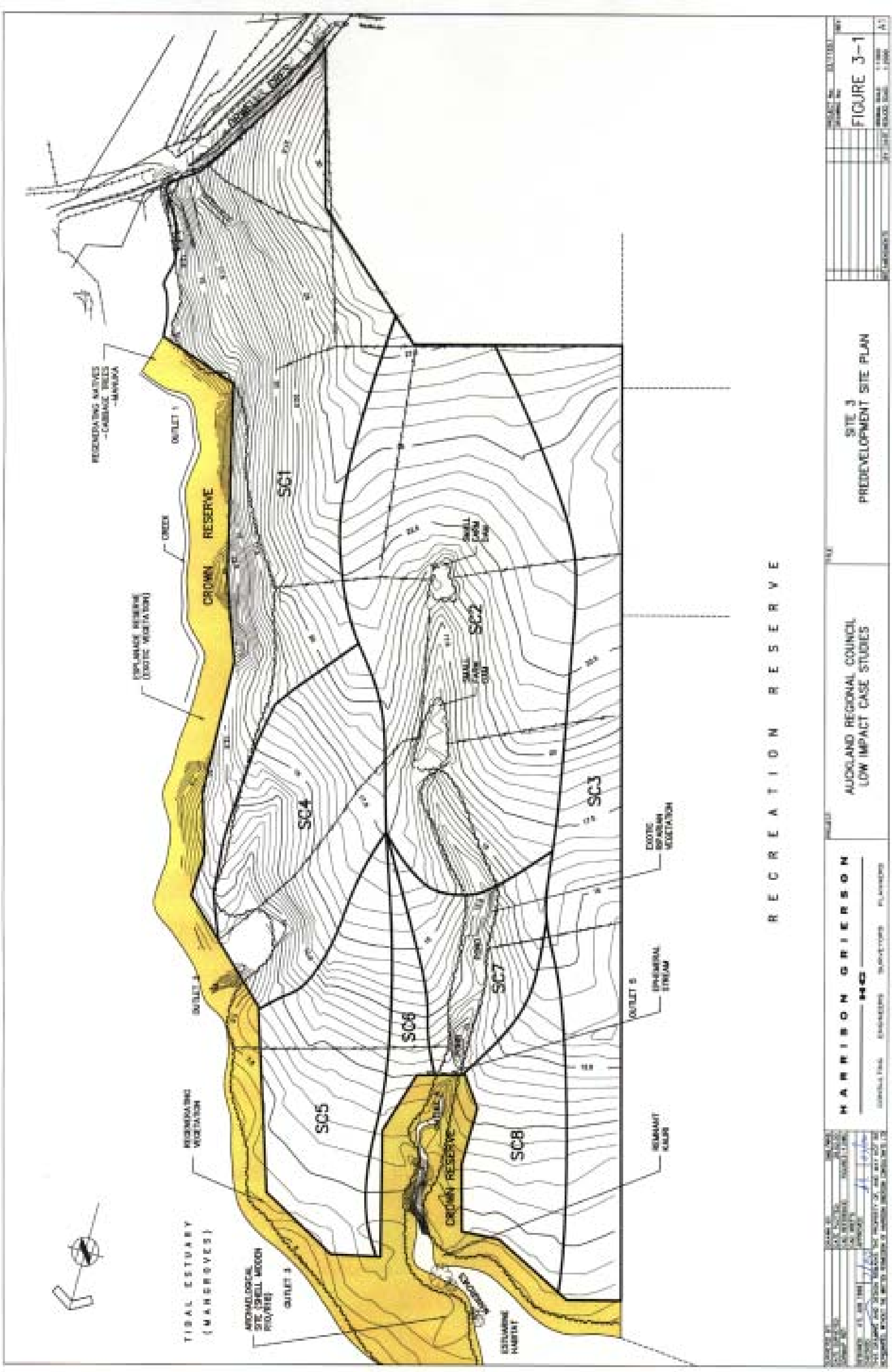
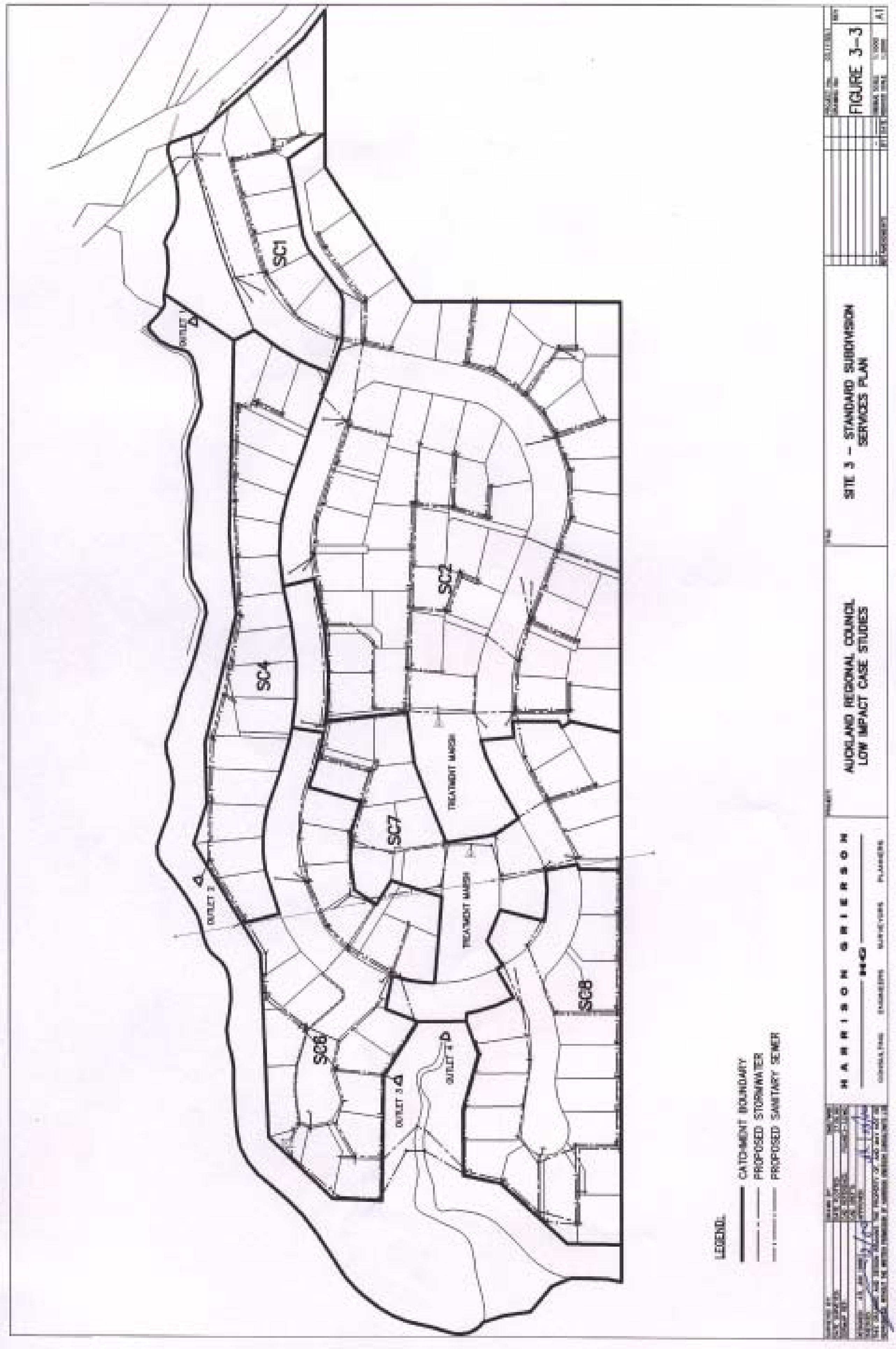


FIGURE 3-1
AUCKLAND REGIONAL COUNCIL
LOW IMPACT CASE STUDIES
SITE 3
PREDEVELOPMENT SITE PLAN
HARRISON GRIERSON
RECREATION RESERVE
CROWN RESERVE
CROWN RESERVE
TIDAL ESTUARY
(MANGROVES)
SC1
SC2
SC3
SC4
SC5
SC6
SC7
SC8

CROWN RESERVE
CROWN RESERVE
TIDAL ESTUARY
(MANGROVES)
SITE 3 - STANDARD SUBDIVISION
LOT LAYOUT
AUCKLAND REGIONAL COUNCIL
LOW IMPACT CASE STUDIES
HARRISON GRIERSON
FIGURE 3-2


SC1
SC2
SC4
SC7
SC8
TREATMENT MARSH
TREATMENT MARSH
OUTLET 2
OUTLET 3
OUTLET 4
LEGEND:
CATCHMENT BOUNDARY
PROPOSED STORMWATER
PROPOSED SANITARY SEWER
HARRISON GRIERSON
AUCKLAND REGIONAL COUNCIL
LOW IMPACT CASE STUDIES
SITE 3 – STANDARD SUBDIVISION
SERVICES PLAN
FIGURE 3-3

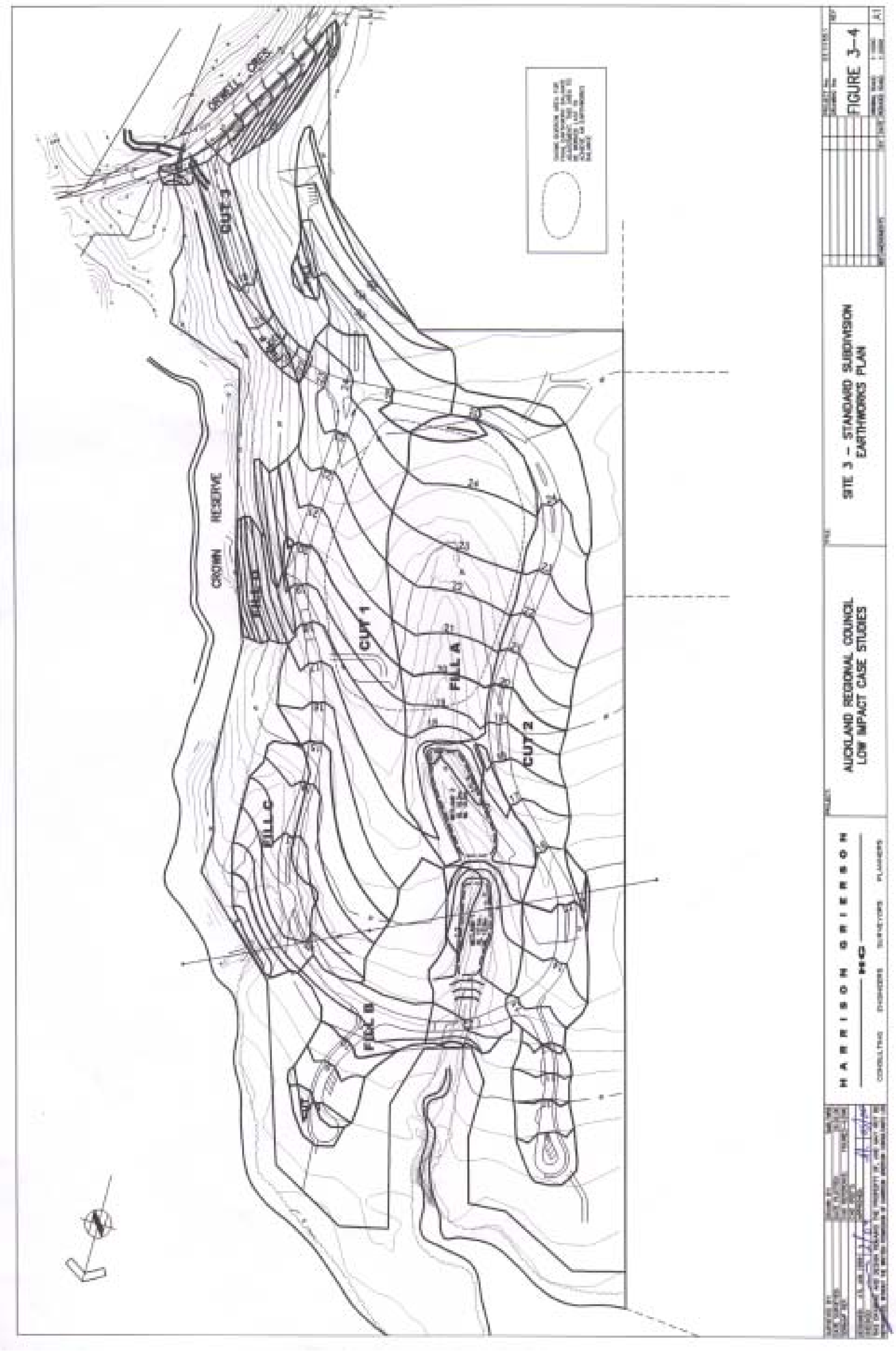
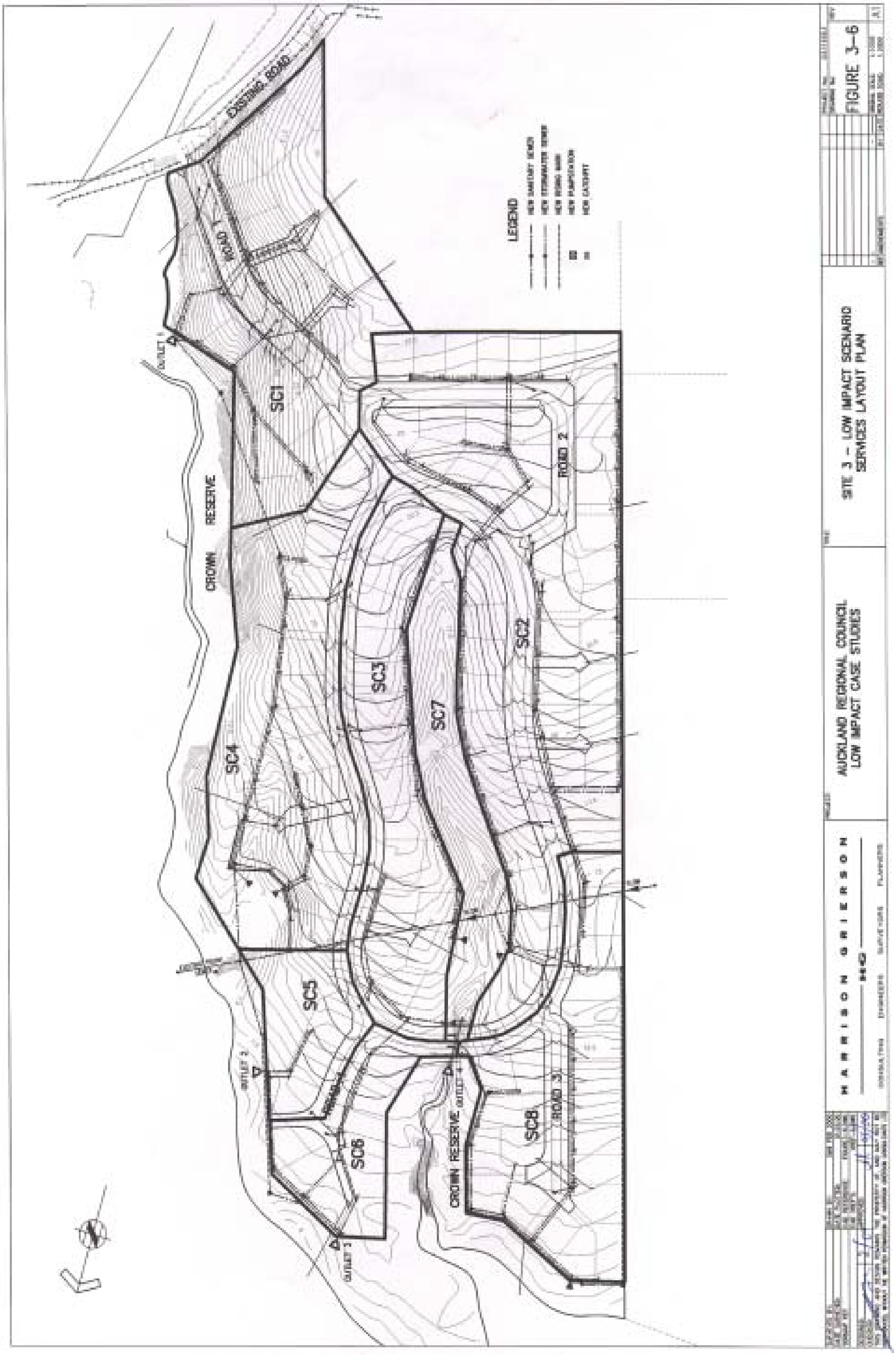

CROWN RESERVE
CUT 1
FILL A
CUT 2
FILL B
FILL C
CUT 3
HARRISON GRIERSON
AUCKLAND REGIONAL COUNCIL
LOW IMPACT CASE STUDIES
SITE 3 – STANDARD SUBDIVISION
EARTHWORKS PLAN
FIGURE 3-4


FIGURE 3–5
SITE 3 – LOW IMPACT SCENARIO
LOT LAYOUT PLAN
AUCKLAND REGIONAL COUNCIL
LOW IMPACT CASE STUDIES
HARRISON GRIERSON
AREA SCHEDULE
ACCESS LOT SCHEDULE
EXISTING ROAD
ROAD 1
ROAD 2
ROAD 3
ROAD 4
CROWN RESERVE
TIDAL ESTUARY
(MANGROVES)


EXISTING ROAD
ROAD 1
ROAD 2
ROAD 3
CROWN RESERVE
CROWN RESERVE
SC1
SC2
SC3
SC4
SC5
SC6
SC7
SC8
LEGEND
SITE 3 – LOW IMPACT SCENARIO
SERVICES LAYOUT PLAN
AUCKLAND REGIONAL COUNCIL
LOW IMPACT CASE STUDIES
HARRISON GRIERSON
FIGURE 3–6

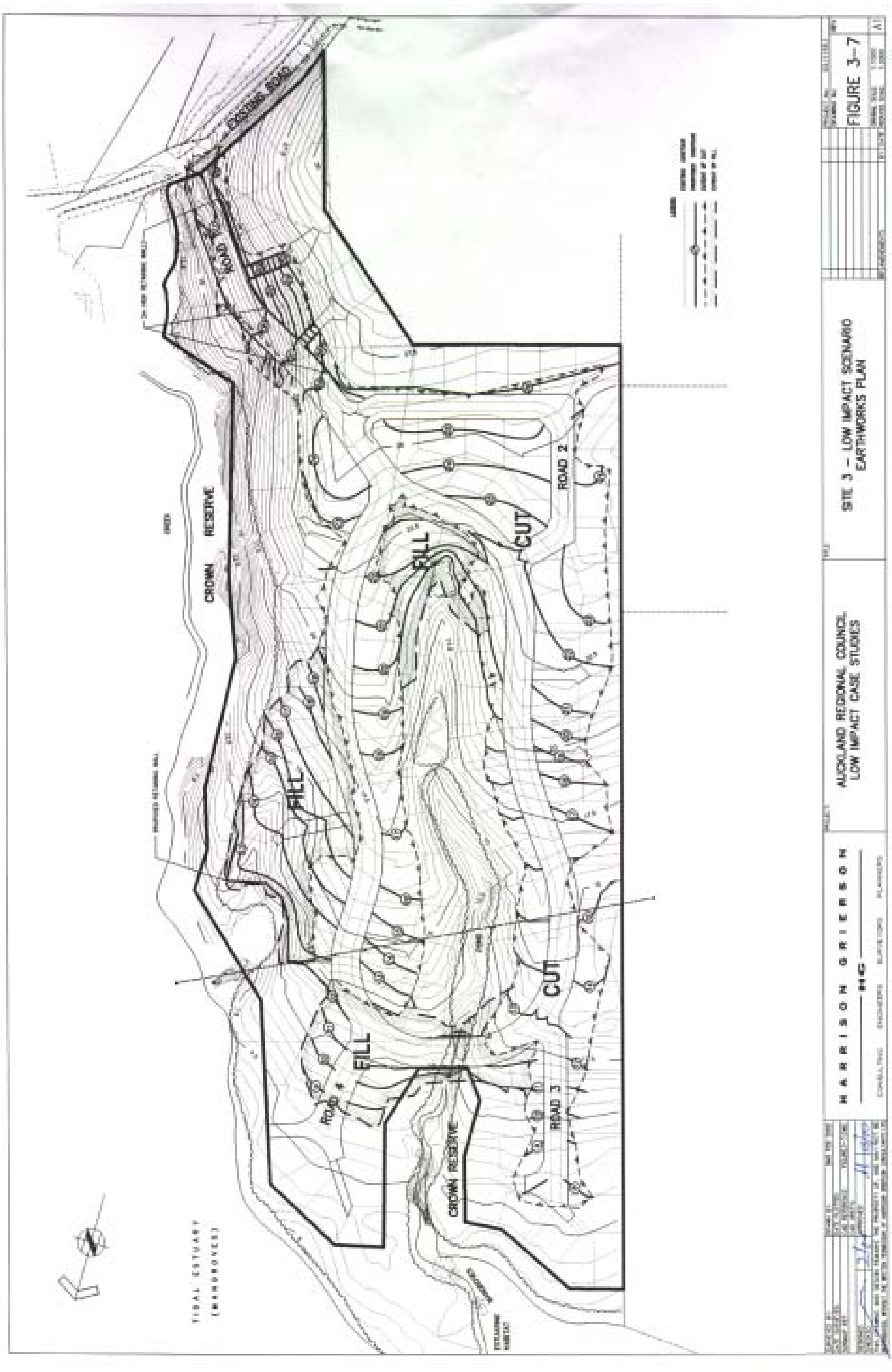


FIGURE 3–7
SITE 3 – LOW IMPACT SCENARIO
EARTHWORKS PLAN
AUCKLAND REGIONAL COUNCIL
LOW IMPACT CASE STUDIES
HARRISON GRIERSON
EXISTING ROAD
ROAD
ROAD 2
ROAD 3
CROWN RESERVE
CROWN RESERVE
FILL
FILL
FILL
CUT
CUT
TIDAL ESTUARY
(MANGROVES)

Table 18: ARC LOW IMPACT STUDIES TOTAL PRICE COMPARISON			
	Cost		
Site	**Standard Subdivision**[1]	**Low Impact Subdivision**[2]	**Difference**
Site 1	$1,844,000	$1,590,000	$254,000
Site 2	$7,218,000	$5,936,000	$1,282,000
Site 3	$5,963,000[3]	$4,478,000	$1,485,000

Notes: 1. Prices from actual construction costs.
2. Prices are estimates based on construction rates.
3. Actual costs for site not available. Amounts shown from preliminary estimates.