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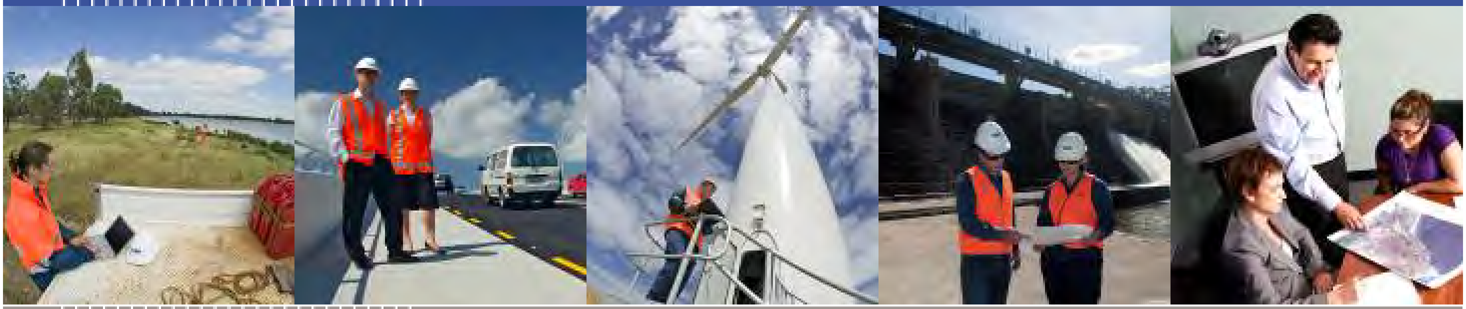
Kevin's Corner Project | Supplementary Environmental Impact Statement

K | Revised Surface Water Hydraulics Report



Report

Kevin's Corner - Revised Hydraulic Technical Report

12 JUNE 2012

Prepared for

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Abbreviations

Abbreviation	Description
ACARP	Australian Coal Association Research Program
AEP	Annual Exceedence Probability
DERM	Department of Environment and Resource Management
EA	Environmental Authority
EIS	Environmental Impact Statement
HEC-RAS	Hydrologic Engineering Centre – River Analysis System
MLA	Mine Lease Area
PB	Parsons Brinkerhoff
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
SEIS	Supplementary Environmental Impact Statement

1 Introduction

1.1 EIS Report Background

As a part of the technical studies for the Kevin's Corner Project Environmental Impact Statement (EIS), URS was engaged to undertake hydraulic modelling of the watercourses in close proximity to the project. The purpose of the study was to estimate the hydraulic characteristics of the watercourses for a range of flood events to be used to perform an impact assessment of the planned project works.

The proposed Kevin's Corner project features an open cut pit operation and underground longwall mine operation. The project EIS requires assessment of potential project impacts on surface water hydrology and watercourses. The watercourses through the project area also pose environmental management risks to the project from flooding. The design of flood protection works for the open cut pits and proposed stream diversions will be important aspects for both risk to the project and risks to the environment.

Design flood estimates from the Kevin's Corner Flood Hydrology Study (2.1) form the input for this hydraulic study. The hydrology study considered a wide range of design flood estimates with Annual Exceedance Probabilities (AEP) ranging up to the Probable Maximum Flood (PMF) including the 1:2, 1:5, 1:10, 1:20, 1:50, 1:100, 1:1,000, 1:2,000 AEP events and the PMF event.

The objectives of this hydraulic flood assessment are to:

- Document the existing hydraulic conditions in order to provide a baseline against which to assess the potential effects of the Kevin's Corner project on flood hydraulics.
- To estimate the impacts of the proposed flood protection levees and creek diversions on the upstream and downstream environment and landholders.

1.2 SEIS Report Revision

As part of the Kevin's Corner Supplementary Environmental Impact Statement (SEIS) in response to comments received, the Kevin's Corner Hydraulics Technical Report has been revised. Revisions within this report include:

a) further review of the HEC-RAS model surrounding areas of anomalous results; and
b) updates to the graphical representation of hydraulic parameters (velocity, stream power and shear stress), which overlay proposed diversion and subsidence conditions upon the baseline results.

The HEC-RAS model was refined to remove and/or reduce the magnitude of anomalous spikes, gaps and troughs in the results arising from model instabilities. Cross-sections with conveyance ratios outside of the HEC-RAS desirable range indicated areas where energy loss or channel velocity changed significantly between adjacent cross-sections, or where the model failed to converge on a solution. Parameters within the model cross-sections or the addition of cross-sections was used to create a more stable model.

In general, stream locations where predicted flow resulted in critical flow depth (Froude number = 1 ± 0.02), or where the water surface defaulted to critical depth, appeared to be where these instabilities occurred most frequently. Subsequently, additional cross-sections were interpolated either side of the largest areas where spikes in hydraulic results, occurred in order to obtain a more reasonable result.

All plots and tables associated with the HEC-RAS model have been subsequently updated in this report to reflect any changes in results.

Methodology

2.1 Overview

This flood analysis has been carried out using a combination of desktop, field, and computational investigations. The analysis has also included examination of previous studies and relevant reports, aerial photographs, and topographic data. The assimilated data was used to assess the potential risks and impacts to the watercourses.

2.2 Available Data

2.2.1 Previous Studies

A recent flood study of the Sandy Creek catchment was completed by Parsons Brinkerhoff (PB) in 2010 for the Alpha Coal mine project, which is adjacent and upstream (south) of the Kevin's Corner project. The PB study was prepared to support studies for the Alpha Coal Project.

No other previous flood studies for the Sandy Creek catchment were identified from a literature search. Previous studies were identified for the nearby Alpha Creek catchment (a major tributary of Native Companion Creek) to the south west of the project area. The previous flood studies for Alpha Creek included:

- "Alpha Town Flood Mitigation Study Final Report – Volume 1" prepared by Connell Wagner Pty Ltd for Barcaldine Regional Council – July 2008
- "Western Queensland Towns Flood Study – Volume 1" prepared by Scott and Furphy Pty Ltd for Queensland Water Resources Commission – January 1991

2.2.2 Design Flood Estimates

Estimates of design peak flood flows were required to assess the existing flooding in the Sandy Creek watershed and the impacts of the planned mine infrastructure, flood protection measures, and Little Sandy and Rocky Creek diversion. For this EIS, estimates of design flood flows have been determined and documented in the Flood Hydrology Study (M2.1).

The flood estimates for the frequent events, 1:2 AEP to 1:50 AEP, were estimated by transposition of an annual-series flood frequency analysis of observed floods at the Native Companion Creek stream gauging station (GS12305A) to the Sandy Creek catchment. The Native Companion Creek gauge is located approximately 60 km to the south east of the planned Project site.

For the larger more extreme events, 1:100 AEP to PMF, an alternative method of estimating the design peak flood flows (and hydrographs) utilising rainfall-runoff routing methods was applied.

2.3 Baseline Hydraulic Modelling Methodology

The Hydrologic Engineering Centre River Analysis System (HEC- RAS) version 4.1.0 was utilized for the hydraulic modelling of frequent flood events (1:2 to 1:50 AEP). HEC-RAS was determined to be an appropriate model for the frequent flood events where the majority of flow is generally confined within defined channels or is conveyed in one direction.

To model the infrequent, extreme flood events, (1:100 AEP to PMF), TUFLOW was utilized. TUFLOW is a one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software package, suitable for modelling braided channel systems or river systems with 2D interactions. It is a widely used and accepted flood modelling software package in Australia.

The purpose of the hydraulic analysis was to quantify key hydraulic parameters for a range of flood events, and to determine the relative impacts associated with the planned diversion and flood protection levees. Hydraulic parameters of interest to characterise the river flood hydraulics are channel flood velocity, shear stress, stream power, and depth of flow. These parameters are further described as follows:

- Flow ***velocity*** (the speed of flow along the river) is commonly used for initial assessments of the potential for erosion.
- The bed ***shear stress*** represents the force between the river flow and resistance to flow provided by the bed and banks of the river channel. Shear stress is commonly used to determine the potential for sediment movement.
- ***Stream power*** provides the most reliable indicator of the potential sedimentation and erosion within the river channel based on the energy dissipation rate of flow along the river. It is a measure of the rate of work done by the river flow and is calculated as the product of shear stress and velocity.

2.4 Proposed Hydraulic Modelling Methodology

As previously discussed, HEC-RAS was used to model frequent flood events (1:2 to 1:50 AEP) where flow is expected to be generally confined within a channel, whereas, TUFLOW was used to model the infrequent, extreme events (1:100 AEP to PMF) where floodplain interaction between creeks is expected. The results on the analyses were used to assess the heights and freeboard of proposed flood protection levees.

2.4.1 HEC-RAS Modelling

The hydraulic performance of the flood protection levees and proposed diversions was assessed based on the following modelling methodology:

1. Use detailed hydraulic analysis of the existing river system (baseline scenario) to define ‘natural’ levels of velocity, shear stress and stream power.
2. Estimate velocity, shear stress and stream power with the planned levees and diversion in place and compare the results to the baseline values and guidelines.
3. Assess the differences in the critical hydraulic parameters to determine if the hydraulic performance of the diversion is acceptable based on ACARP guidelines, geomorphology, and engineering judgement.
4. Modify the design of the diversion by varying the geometry until an acceptable limit of hydraulic performance is attained.

2.4.2 TUFLOW Modelling

The methodology undertaken for TUFLOW modelling of the proposed hydraulics is:

1. Modify the base condition topography to incorporate the planned diversion and flood protection measures
2. Assess the changes to water surface elevations and channel velocity to determine the degree to which the levees and diversion impact the river system.
3. Determine appropriate locations and necessary heights of the flood protection levees based on an acceptable range of hydraulic performance. Key measures for the levees included flood protection

2 Methodology

of the 1:1,000 AEP event to the mine infrastructure and velocities within the channels than can be managed by erosion control measures if necessary.

Existing Channel Characteristics

Individual water courses are described in the Geomorphology Technical Report (Volume 2 Appendix M1). There is a diversity of channel types including alluvial, bedrock controlled, single and multiple thread channels.

3.1 River Morphology and Flooding

The existing geomorphology and flooding hydraulics of the Sandy Creek stream network near the mine site have been assessed to ascertain the likely stability impacts of the proposed river diversion and flood protection levees.

In general, geomorphology characterises physical features of the broad landscape and processes that form and modify the landscape. In this EIS, the surface water aspects of geomorphology relevant to the planned mine operation have focussed on the existing form of the river's main features (channel and floodplain) and the associated hydraulic and fluvial processes that sustain its current form and on-going development (fluvial geomorphology).

Fluvial geomorphology is a specific aspect of river form and behavior, including the processes that govern changes in the physical shape and form of rivers. Environmental variables such as geology, topography, soils, vegetation, hydrology and land use are relevant to the river forming processes. Assessing a river's fluvial geomorphology allows it to be viewed as part of a system rather than operating as a discrete environmental variable.

Baseline Hydraulic Model Development - HEC-RAS

4.1 Model Data and Extents

Topographic data used to define the existing channel geometry in the HEC-RAS model was based on aerial photogrammetric survey (2008) supplemented with detailed ground-based survey.

The model extent for Sandy Creek includes from the downstream most intersection with the mine lease boundary up to 12 km upstream of the mine lease boundary. In addition, Well Creek, Middle Creek, Little Sandy Creek, and Rocky Creek tributaries have been included within the confinements of the mine lease boundary. The layout of the existing conditions HEC-RAS model is presented in Figure 4-1.

In many locations, flood flows, including the 1:20 and 1:50 AEP as well as more infrequent, extreme events, result in sharing of floodplains between two or more reaches. To account for these floodplain interactions, lateral structures were used to connect the reaches at their outer most lateral extents.

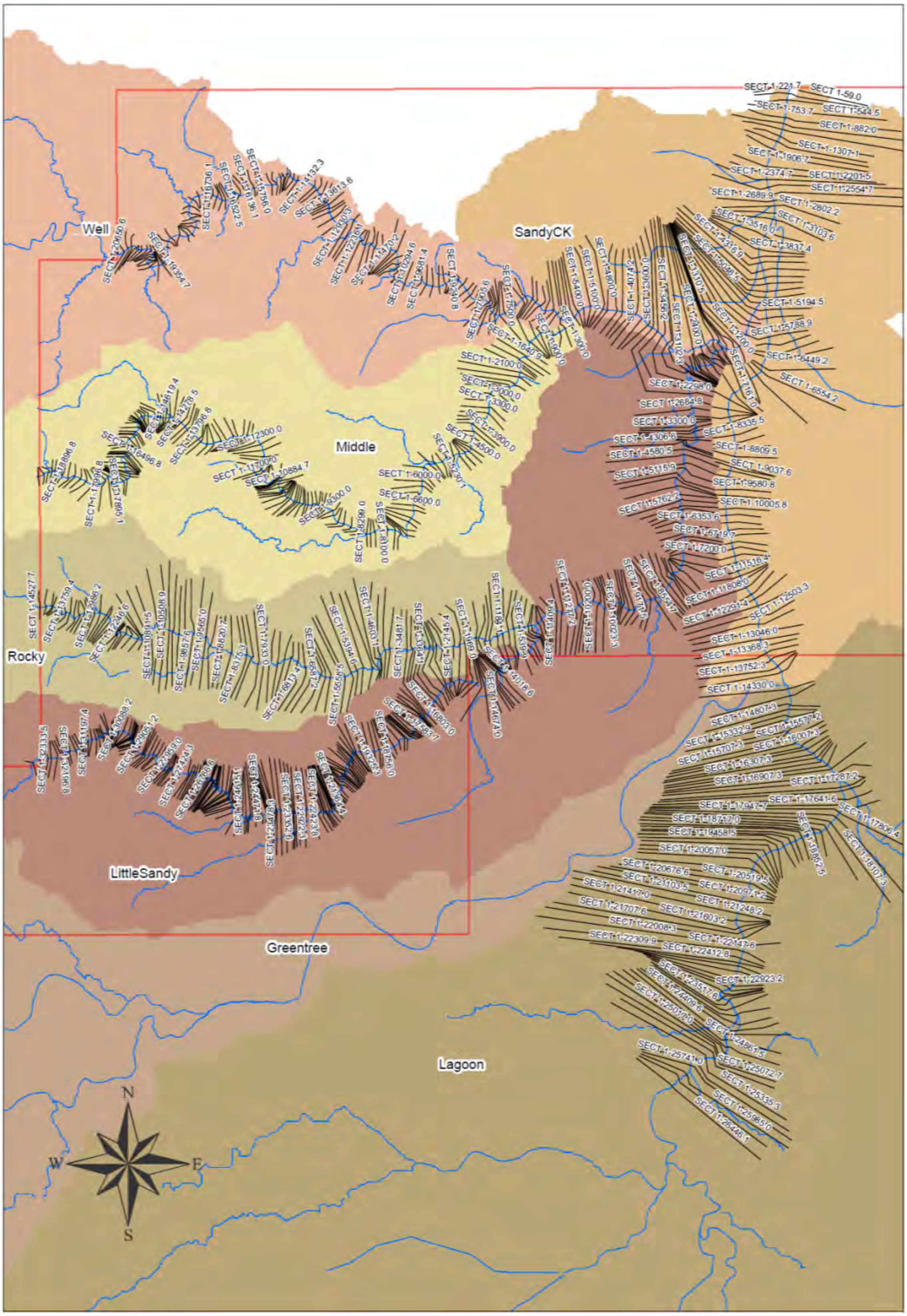
For reference, a summary of the HEC-RAS river reaches and chainages is provided in Table 4-1.

Table 4-1 Summary of Base Conditions HEC-RAS Reaches and Chainages

Stream Name and Reference Location	Starting HEC-RAS Model Chainage (m)	Ending HEC-RAS Model Chainage (m)	Average Channel Bedslope (%)
Sandy Creek: upstream of Greentree confluence (Lagoon)	14,330.0	26,446.1	0.05
Sandy Creek: Greentree Creek confluence to Well Creek confluence	5,194.5	13,903.4	0.13
Sandy Creek: downstream of Well Creek confluence	59.0	4,918.3	0.12
Little Sandy Creek: upstream of Rocky Creek confluence	12,278.8	32,766.2	0.11
Little Sandy Creek: downstream of Rocky Creek confluence	40.8	11,981.0	0.22
Well Creek: upstream of Middle Creek confluence	5,699.6	20,936.1	0.23
Well Creek: Middle Creek confluence to Little Sandy Creek confluence	1,749.4	5,544.0	0.18
Well Creek: downstream of Little Sandy Creek confluence	300.0	1,500.0	0.07
Rocky Creek	124.5	14,527.7	0.29
Middle Creek	147.3	19,796.8	0.34

4 Baseline Hydraulic Model Development - HEC-RAS

Figure 4-1 Base Conditions HEC-RAS Model Schematic



4.2 Hydraulic Roughness

Manning's 'n' roughness values were assigned to the channels and floodplains in the baseline HEC-RAS model based on the general hydrologic characteristics of the streams and were derived from site inspection and site photographs with respect to descriptions of standard Manning's roughness values. A channel roughness of 0.04 was assumed appropriate for the natural streams. Streams with a channel roughness of 0.04 are generally characterised by clean, winding, with some pools and shoals and some weeds and stones. The overbank (floodplains) roughness coefficient was assumed to be 0.06, which is indicative of floodplains with sparse shrubs and trees.

4.3 Reach Boundary Conditions

Model boundary conditions are categorised as both internal and external boundaries. The external boundaries represent boundaries that are physically located at the model extents, while internal boundaries are representative of various stream reach junctions and confluences. The external boundaries have been assumed to be equivalent to normal depth, which is a typical flood modelling assumption where there are no downstream or upstream structures affecting the natural flow regime within the channel.

Due to the variation in bed slope throughout the various stream reaches, the flow is expected to be characterised as both subcritical and supercritical, therefore, a mixed flow simulation was necessary, which requires both upstream and downstream external boundary conditions.

As presented in Table 4-2, a normal depth downstream boundary condition was assumed based on a local bed slope of 0.00125 m/m within Sandy Creek near the downstream limit of the model. Similarly, the upstream boundary conditions were estimated based on the local bed slope near the upstream model boundary within each tributary.

Table 4-2 Summary of Base Conditions Reach Boundary Conditions

Stream Name and Reference Location	Downstream Boundary Condition Bedslope (m/m)	Upstream Boundary Condition Bedslope (m/m)
Sandy Creek upstream of Well Creek confluence	*Junction with Well Creek*	0.003
Sandy Creek downstream of Well Creek confluence	*0.00125*	*Junction with Well Creek*
Little Sandy Creek upstream of Rocky Creek confluence	*Junction with Rocky Creek*	0.0025
Little Sandy Creek downstream of Rocky Creek confluence	*Junction with Well Creek*	*Junction with Rocky Creek*
Well Creek upstream of Middle Creek confluence	*Junction with Middle Creek*	0.0025
Well Creek between Middle Creek and Little Sandy Creek confluences	*Junction with Little Sandy Creek*	*Junction with Middle Creek*
Well Creek downstream of Little Sandy Creek confluence	*Junction with Sandy Creek*	*Junction with Little Sandy Creek*
Rocky Creek	*Junction with Little Sandy Creek*	0.003
Middle Creek	*Junction with Well Creek*	0.0045

4.4 Model Inflows

Model inflows, developed as part of the hydrologic study, vary significantly across the modelled stream network as a result of additional tributary and catchment inflows. The baseline simulation inflows for the 1:2, 1:5, 1:10, 1:20 and 1:50 AEP events are summarised in Appendix A.

4.5 Hydraulic Structures

4.5.1 Lateral Structures

Due to the frequent floodplain interaction of the various stream reaches particularly, during less frequent flood events, lateral structures were used to connect river reaches together in locations where a flow exchange between adjacent reaches could potentially occur. The use of lateral structures, within the model, is necessary to simulate flow exchange. The lateral structures do not represent physical infrastructure, but represent the natural ground at the intersection of two adjacent reach floodplain extents, see Figure 4-1.

4.5.2 Stream Crossings

No significant stream crossings, which would be indicative of significant infrastructure, have been identified within the hydraulic model extents. Several minor road crossings traverse the existing streams, however, these crossings are generally low water crossings and have been assumed to be of little consequence to modelling results. For this reason, stream crossings were not considered when developing the hydraulic model geometry.

Baseline Hydraulic Model Development - TUFLOW

5.1 Model Data and Extents

The same topographic data used to define the channel geometry of the baseline HEC-RAS model (2008 aerial photogrammetric survey) was used to develop a triangulated irregular network (TIN) for use in the TUFLOW model. The topographic data was then interpreted into TUFLOW at a resolution of 20 metres by 20 metres. The resolution chosen was sufficient to adequately resolve the channel network and floodplain terrain while maintaining a reasonable level of data management (i.e. input and output files) and subsequent 2D modelling performance (i.e. model run time).

The 2D model limits covered approximately the same extent as the HEC-RAS model.

5.2 Hydraulic Roughness

The hydraulic roughness coefficients used in the 2D analysis were developed from interpretation of aerial photography (2008). Areas of similar vegetation and terrain were delineated and assigned a Manning's roughness value. A summary of the roughness classifications and associated Manning's roughness values has been listed in Table 5-1.

Table 5-1 Summary of Adopted Hydraulic Roughness Categories and Values

Land Use Category	Adopted Manning's Roughness Value
Grassland and open fields (existing channel)	0.040
Sparse vegetation	0.055
Moderate vegetation	0.070
Dense trees and vegetation	0.100

5.3 Boundary Conditions

5.3.1 Input Flow Locations

The 2D model input locations have been carefully selected to account for changes in flow throughout the river system.

For each of the flood events analysed, 1:100 AEP through PMF, three TUFLOW models were developed. Multiple models were necessary due to the variation in critical storm durations between the larger Sandy Creek catchment and the smaller Little Sandy Creek, Rocky Creek, and Middle Creek catchments. The final results adopted for each storm event are representative of a composite of the three models.

The following reach groups are categorised based on equivalent critical storm durations and represent the reaches of concern for each of the three TUFLOW models:

1. Sandy Creek and Well Creek (18 to 36 hour critical duration)
2. Little Sandy Creek, Rocky Creek, and Middle Creek (3 to 6 hour critical duration)
3. Greentree Creek (12 hour critical duration)

Although a model was developed for the Greentree tributary, the purpose of its inclusion was to simulate potential floodplain interaction with Little Sandy Creek to the North. For this reason, a comprehensive set of results was not reported for Greentree Creek.

5.3.2 Downstream Boundary Conditions

For each of the flood events modelled, a fixed water surface elevation was used as the downstream boundary condition. The water surface elevations were developed using a HEC-RAS model of the most downstream reach of Sandy Creek. The estimated water surface elevations for each of the 2D model simulations have been listed below in Table 5-2.

Table 5-2 Summary of Downstream Water Surface Elevations

AEP	Sandy and Well Creek (mAHD)	Little Sandy, Rocky, and Middle Creek (mAHD)	Greentree Creek (mAHD)
1:100	283.5	282.9	283.0
1:1,000	284.4	284.1	284.3
1:2,000	284.8	284.2	284.7
PMF	288.8	286.8	288.7

6 Baseline Hydraulic Model Results

6.1 Overview

Baseline modelling results for the 1:2 AEP through PMF flood events are presented in this section. The results have been categorised based on stream power, stream velocity, shear stress, flow depth, and inundation extents.

It should be noted that upon simulation of the baseline 1:50 AEP event, the HEC-RAS model failed to converge. As a result, an additional verification assessment was undertaken to determine the reliability of the model results from the 1:50 AEP baseline model simulation.

6.1.1 Verification Assessment of 1:50 AEP Baseline Model Results

Using the default HEC-RAS calculation tolerances, the model flow optimisation routine, used to quantify the flow across the lateral structures, failed to converge during the 1:50 AEP event simulation. As a result, an assessment was undertaken to summarise model input inflow data and associated calculated optimised inflow data at select locations within the model, as presented in Table 6-1. It should be noted that the table is not inclusive of all flow input locations used in the hydraulic model, but presents select locations to illustrate how flow is exchanged between adjacent floodplains during the optimization routine. As a result of the verification assessment, the 1:50 AEP baseline model simulation results appear to be adequately conserving flow, therefore, it is assumed that results will provide a reasonable basis for comparison with additional model simulations.

Table 6-1 Summary of Flow using Optimization Routine

Stream name and reference location	Model Reference Cross-Section	1:50 AEP Input Inflow (m^3/s)	Stream name and reference location	Model Reference Cross-Section
Sandy Creek Outlet	59.0	108.7	108.7	0
Sandy Creek just upstream of Well Creek confluence	5,194.5	974.9	857.4	- 117.5
Sandy Creek upstream of Greentree Creek confluence (Lagoon)	14,330.0	970.9	970.9	0
Little Sandy Creek just upstream of Well Creek confluence	40.8	193.7	427.7	+ 234
Little Sandy Creek just upstream of Rocky Creek confluence	12,278.8	111.8	54.3	- 57.5
Well Creek just upstream of Sandy Creek confluence	300.0	377.3	495.2	+ 117.9
Well Creek just upstream of Little Sandy Creek confluence	1,749.4	377.3	205.2	- 172.1
Well Creek upstream of Middle Creek Confluence	5,699.6	262.3	239.5	- 22.8
Rocky Creek Outlet	124.5	103.7	161.2	+57.5
Middle Creek Outlet	147.3	104.1	126.9	+22.8

6.2 Stream Power, Velocity and Shear Stress (up to 1:50 AEP)

When considering the geomorphic environment of alluvial river channels, a useful concept is that of stream power. Stream power is the rate of energy expenditure in flowing water, and is a useful measure of the energy available to do geomorphic work along the channel. It can be calculated for any discharge, but in geomorphic studies is usually determined for the bankfull discharge event. The bankfull discharge is generally considered to be the channel forming event.

It is important to recognise that velocity and shear stress provide an indication of local and immediate erosion potential only. Velocity and shear stress parameters generally indicate whether there is erosion potential to cause enlargement of the local channel cross section (depth and width). They generally do not indicate if there are other influences present which try to realign and reshape the channel alignment (e.g. meandering). The long-term stability of a channel's alignment is related to the morphological context of the reach. Stream power is a more useful indicator of hydraulic conditions reflecting the morphology of the channel, particularly for 'bank-full' flows that are commonly known to be 'channel forming' events.

A summary of the 10-percentile to 90-percentile channel forming flow velocity, bed-shear stress, and stream power for each of the reaches analysed has been presented in Table 6-2.

Table 6-2 Summary of Base Conditions Channel Forming Hydraulic Results

Creek	Location	Channel Forming Event (1:X) AEP	Stream Power (W/m^2)	Velocity (m/s)	Shear Stress (N/m^2)
Sandy Creek	Upstream of Greentree Creek confluence (Lagoon)	1:5 to 1:10	2 - 29	0.5 - 1.4	3 - 21
Sandy Creek	Greentree Creek confluence to Well Creek confluence	1:5 to 1:10	6 - 43	0.7 - 1.5	8 - 29
Sandy Creek	Downstream of Well Creek confluence (to limit of study)	1:5 to 1:10	7 - 47	0.8 - 1.5	9 - 31
Little Sandy Creek	Upstream of Rocky Creek confluence	1:10 to 1:20	2 - 79	0.4 - 1.7	4 - 47
Little Sandy Creek	Downstream of Rocky Creek confluence	1:5 to 1:10	1 - 58	0.4 - 1.5	2 - 38
Well Creek	Upstream of Middle Creek confluence	1:10 to 1:20	15 - 217	1.1 - 2.6	15 - 85
Well Creek	Middle Creek confluence to Little Sandy Creek confluence	1:10 to 1:20	19 - 113	1.1 – 2.1	17 - 53
Well Creek	Downstream of Little Sandy Creek confluence	1:10 to 1:20	11 - 55	1.0 - 1.7	11 - 34
Rocky Creek	Rocky Creek	1:20 to 1:50	4 - 188	0.6 - 2.4	6 - 81
Middle Creek	Middle Creek	1:5 to 1:10	2 - 74	0.4 - 1.6	3 - 48

Modelled baseline conditions hydraulic results for all streams and AEP events (1:2 AEP through to the PMF) are presented in summary tables in Appendix B alongside modelled results of the proposed diversion and subsidence conditions (discussed further in Sections 7 to 10). Additionally, a series of longitudinal profile plots illustrating these comparisons is presented in Appendix C.

6.3 Sediment Transport Capacity

In order to estimate baseline sediment transport capacities for the creeks, the HEC-RAS model results were compared to approximate critical bed shear stresses (i.e. the threshold point at which movement of a sediment particle begins) for particle type and size. Based on observations, the sediment in the creek beds appeared to be a mixture of medium to coarse grained sand to possibly as large as a fine gravel (no samples were taken). Gradations within the channels appeared to be reasonably similar.

Comparison of the critical shear stress, for the assumed particle size transported by the modelled creek channel system, with the average channel shear stress results is summarised in Table 6-3. The comparison indicates high potential for sediment transport, which is also supported by observations of significant sediment deposition during the site visit.

Table 6-3 Summary of Sediment Transport Capacity for Existing Creeks

<table>
<tr><th>Creek</th><th>Location</th><th>Channel Forming Event (1:X) AEP</th><th>Shear Stress (N/m^2)</th><th>Assumed Particle Classes Present in Reach</th><th>Critical Shear Stress of Assumed Particle Classes (N/m^2)</th></tr>
<tr><td>Sandy Creek</td><td>Upstream of Mine Lease Boundary</td><td>1:5 to1:10</td><td>4 - 21</td><td rowspan="10">Fine Gravel

Very Fine Gravel

Very Coarse Sand

Medium Sand</td><td rowspan="10">2.7

1.3

0.47

0.19</td></tr>
<tr><td>Sandy Creek</td><td>Within Mine Lease Boundary</td><td>1:5 to 1:10</td><td>8 - 30</td></tr>
<tr><td>Little Sandy Creek</td><td>Upstream of Diversion</td><td>1:10 to 1:50</td><td>3 - 70</td></tr>
<tr><td>Little Sandy Creek</td><td>Downstream of Diversion</td><td>1:10 to 1:50</td><td>5 - 46</td></tr>
<tr><td>Rocky Creek</td><td>Upstream of Diversion</td><td>1:20 to 1:50</td><td>5 – 72</td></tr>
<tr><td>Rocky Creek</td><td>Downstream of Diversion</td><td>1:20 to 1:50</td><td>15 - 95</td></tr>
<tr><td>Middle Creek</td><td>Upstream of Diversion</td><td>1:5 to 1:10</td><td>2 - 48</td></tr>
<tr><td>Middle Creek</td><td>Downstream of Diversion</td><td>1:5 to 1:10</td><td>8 - 45</td></tr>
<tr><td>Well Creek</td><td>Upstream of Middle Creek Confluence</td><td>1:10 to 1:20</td><td>15 - 85</td></tr>
<tr><td>Well Creek</td><td>Downstream of Middle Creek Confluence</td><td>1:10 to 1:20</td><td>14 - 51</td></tr>
</table>

Note (1): Critical Shear Stress Values from *Erosion and Sedimentation* (Julien 1995)

6.4 Extreme Events (1:100 AEP to PMF) Flood Modelling Results

The purpose of modelling a range of flood events from the 1:100 AEP flood event to the PMF was to quantify key hydraulic parameters, in particular maximum flood level. The flood levels will serve as baseline elevations for later comparison to the proposed (developed) condition with mine levees in place to protect the mine infrastructure and estimate any impacts to areas outside the mine lease boundary. A description of the model development is presented in Section 5.

Flooding extents for the 1:1,000 AEP flood event for the existing creek system is presented in Figure 6-1 and a summary of the estimated flood elevations at the upstream and downstream boundaries of the mine lease are presented in Table 6-4 (flood elevations for the select frequent events have been included for completeness). Figures illustrating flood extents for all remaining AEP events are presented in Appendix D.

Table 6-4 Estimation of Flood Elevations in Sandy Creek at Mine Lease Boundary

AEP Event	Flood Elevation at Upstream Mine Boundary (mAHD)	Flood Elevation at Downstream Mine Boundary (mAHD)
1:2	296.7	279.2
1:50	299.2	282.0
1:100	300.8	283.5
1:1,000	301.6	284.4
1:2,000	301.6	284.8
PMF	304.4	288.8

URS

REVISED HYDRAULIC TECHNICAL REPORT

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Figure: 6-1

Rev: A

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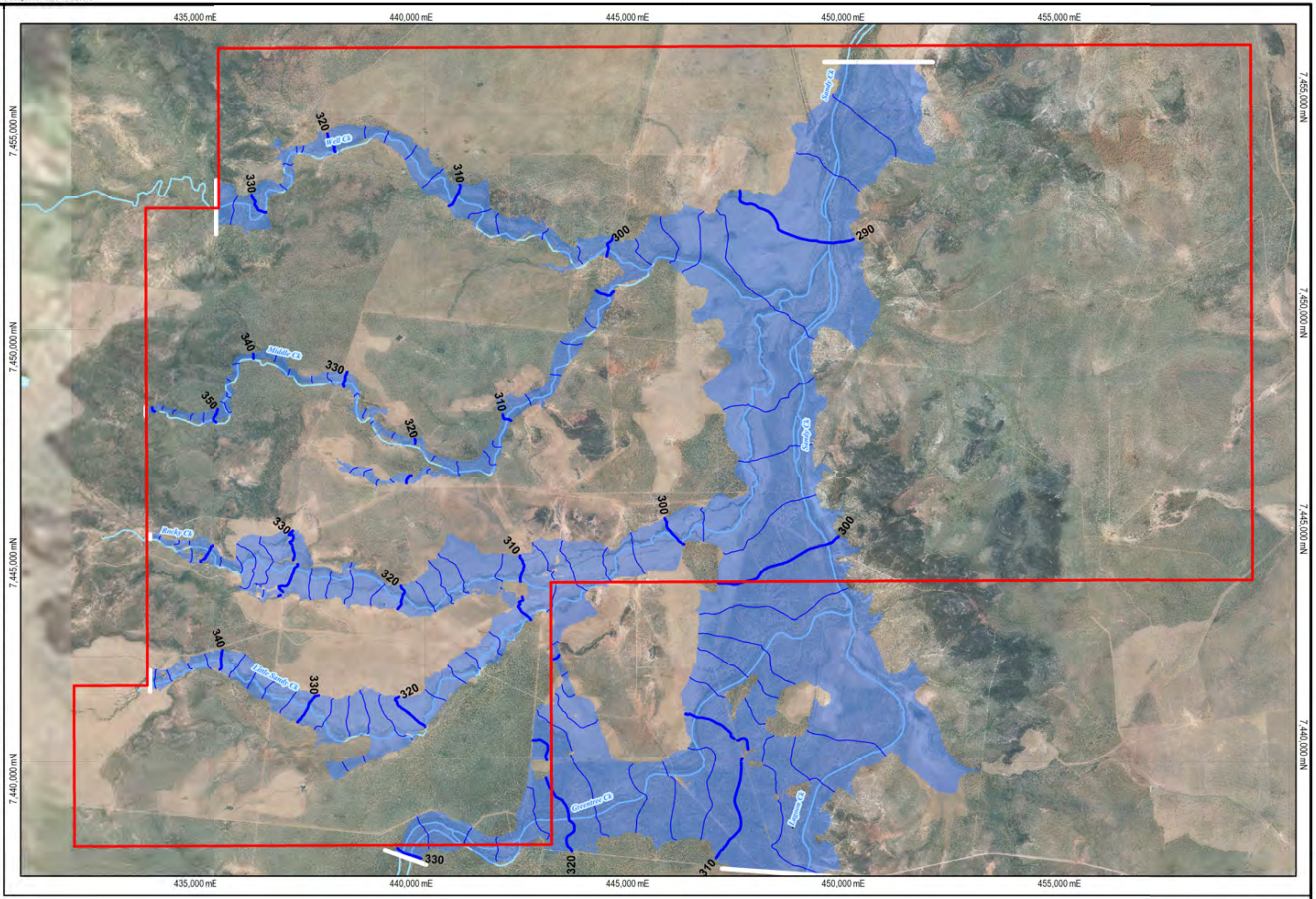
Kevin's Corner Project

Supplementary Environmental Impact Statement

FLOODING EXTENTS FOR THE BASE CONDITIONS 1:1,000 AEP FLOOD EVENT



0 1.25 2.5km

Scale: 1:125,000 (A4)

Mining Lease Application (MLA70425) Boundary

Existing Watercourse

Proposed Creek Diversions and Flood Protection

7.1 Overview

The proposed flood protection works and creek diversions will allow mining activities to proceed with unimpeded access to coal reserves that would have otherwise been inaccessible due to the risk of flooding. The proposed routes will feature significant offsets between the diverted creeks and proposed mining operations, thereby, reducing the potential impact mining operations could have had on the receiving creeks. Little Sandy Creek and Rocky Creek are proposed to be diverted into Middle Creek with slight modifications to Middle Creek at the diversion confluence. Additionally, flood protection levees are proposed adjacent to Sandy Creek and Well Creek, Figure 7-1. The following section describes the conceptual design of the proposed creek diversion.

7.2 Diversion Conceptual Design Objective

The objective for the conceptual design of the Little Sandy and Rocky Creek diversion was to establish hydraulic behaviour that is similar to that of the existing creek system, to ensure that the diverted channel is stable and supportive of revegetation, and to protect the upstream and downstream reaches from any detrimental changes in creek hydraulics.

The selected diversion alignment was determined by the constraints provided by the local topography, the existing channel geometry from each creek, the location of the proposed underground mine longwall mine panels, and the location of the flood protection levee.

7.2.1 Diversion - Hydraulic Performance Guidelines

The Little Sandy Creek and Rocky Creek diversion was conceptually designed with consideration to the guidelines developed by the Australian Coal Association Research Program (ACARP) (Bowen Basin River Diversions – Design and Rehabilitation Criteria July 2002). Although the Kevin's Corner mine lease is not located in the Bowen Basin, the guidelines and recommendations are applicable to the project site. The ACARP guidelines for stream power, velocity and shear stress are outlined in Table 7-1. It is noted that the existing channels generally fall within the recommended ACARP (2002) guidelines for stable, incised channels.

Table 7-1 Bowen Basin River Diversions - Design and Rehabilitation Criteria (Australian Coal Association Research Program (ACARP) 2002)

Scenario	Stream Power (W/m^2)	Velocity (m/s)	Shear Stress (N/m^2)
1:2 AEP (vegetation established)	20 to 60	1.0 to 1.5	< 40
1:50 AEP (vegetation established)	100 to 150	1.5 to 2.5	< 80

Note: The recommendations are based on the establishment of an incised channel with confinement of up to and greater than the 1:20 AEP event

7.3 Adopted Channel Alignment

The diversion channel alignment was selected to contain the excavated channel within a single row of subsidence panels. This criterion reduces the potential for wide scale re-construction or maintenance of the diversion channel should it subside on multiple adjacent panels. The current underground mining strategy is to mine from the north to the south and to the west. Based on this strategy, the two longwall panels would generally be mined within the same timeframe (approximately years 6 to 10), with the northern panel subsiding first, followed by the southern panel. This sequence would allow the northern panel, or the downstream portion of the diversion channel, to subside first, thereby maintaining positive gravity flow, followed by the southern panel, or the upstream portion of the diversion. Impacts due to subsidence and the management strategy of the diversion channel are discussed in Section 10.

The diverted alignment of the new Little Sandy Creek, Rocky Creek, and Middle Creek channel are shown on Figure 7-1, a longitudinal profile of the diversion is shown on Figure 7-2, and typical cross-section is shown on Figure 7-3.

7.4 Adopted Channel Geometry

Previous studies of creek and river diversions in the Bowen Basin in Queensland (ACARP, 2002) have shown that the more frequent flood events (e.g. the 1:2 to 1:5 AEP events) generally have the most geomorphologic influence on re-shaping channel cross-sections and alignments. These more frequently occurring events concentrate the stream flow within the channel banks, and have the potential to produce velocities high enough to induce erosion within the channel. The less frequent flood events, such as the 1:100 AEP, tend to utilise the floodplain for floodwater attenuation, resulting in lower cross-sectional velocities (ACARP, 2002).

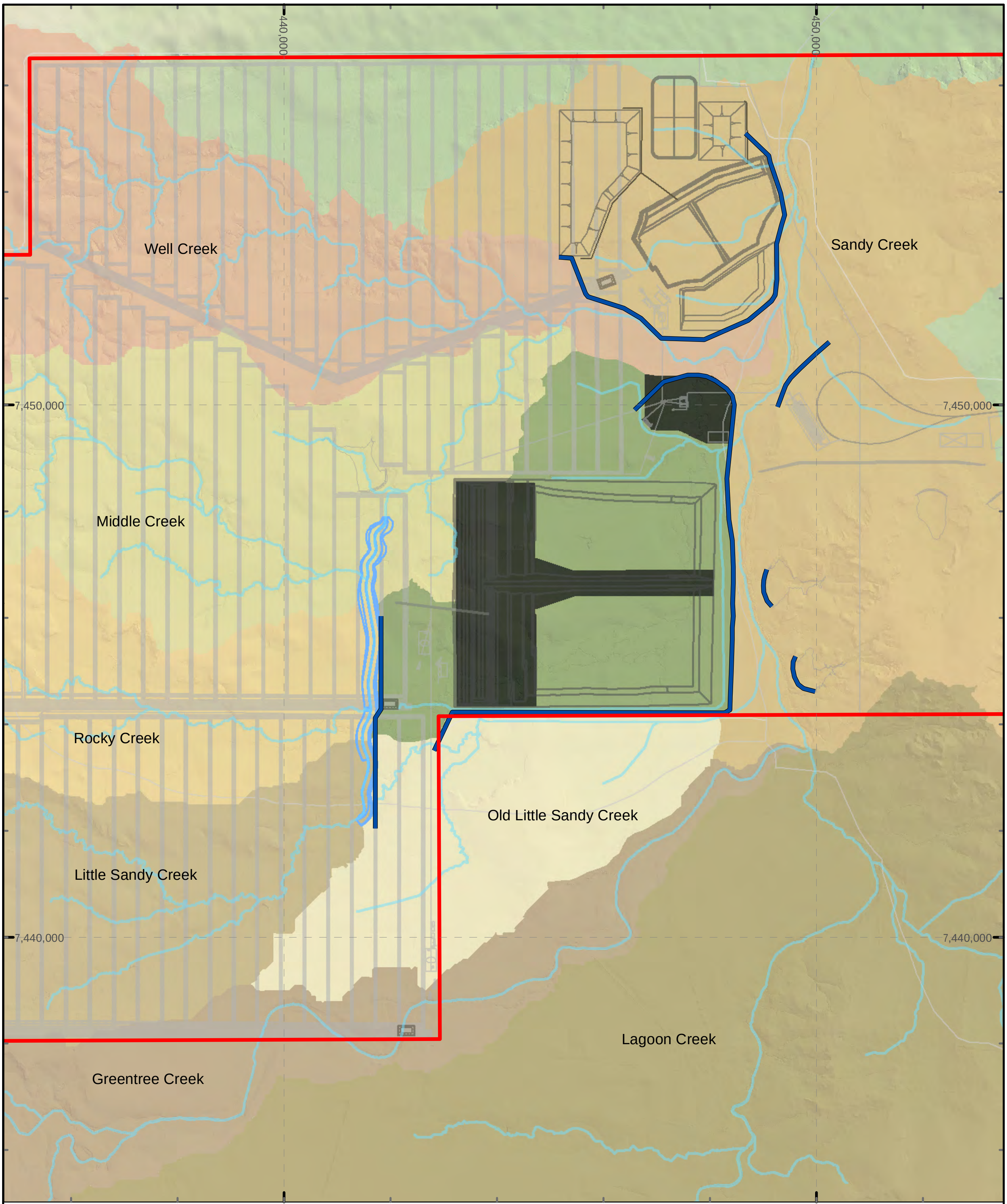
As described in Section 6, “bank-full” discharge in Little Sandy Creek, Rocky Creek, and Middle Creek generally occurs with peak flood flows in excess of the 1:10 AEP. Therefore, a key design condition for the diversion is for the channel flow capacity to replicate the natural creek channel ‘bank-full’ flow capacity. In this instance the ‘bank-full’ flow is approximately equivalent to the peak flows of a 1:5 to 1:10 AEP flood event. For larger flood events, such as the 1:100 AEP, floodplain interaction occurs as per the existing creek system.

The new channel design has been developed to mimic the general geometry of the existing creek low flow channels while also ensuring that the new channels will have acceptable hydraulic performance in terms of creek stability (minimal erosion or deposition risk). The channel shape will be generally consistent with the existing creek channels comprising a trapezoidal shape (flat bed), bank slopes at 1(V) in 3(H), and channel depth approximately 2 m to the terrace (berm) levels.

For the conceptual design of the diversion channel, the following criteria have been adopted for this EIS:

- For modelling purposes, the diversion channel was assumed to be in a fully revegetated condition. It is however recognised that the requirement to ensure acceptable hydraulic performance for a range of diversion vegetation stages, and that revegetation of the channel bank will take some time to fully establish and replicate the hydraulic roughness of the existing river system. The hydraulic performance for lower hydraulic roughness conditions than the existing creek for the initial years following diversion construction, has not been assessed for this level of study, but should be evaluated at the design phase.
- The diversion channel bottom width is uniform along the entire reach of the diversion channel. A uniform bottom width of three metres was utilised at this conceptual level in order simplify the analysis, and demonstrate that the diversion would perform hydraulically. A gradually widening channel, due to increasing contributing catchment area, should be evaluated at the design phase.

The upstream and downstream bed levels of the new diversion channel will match the bed levels at their junctions with the existing stream channels, with exception of Middle Creek, which, with the current conceptual design may require a simple transition. The transition section would be designed similar to a rock chute to convey the water from Middle Creek to the diversion without scouring of the diversion channel or causing head-cutting in Middle Creek. The use of a rock chute or a minor adjustment to the diversion channel alignment or longitudinal slope to match the existing Middle Creek channel should be evaluated further at the design phase.



0 0.8 1.6 2.4 3.2 Km

Scale: 1:100,000 (A4)

Datum: GDA94

Mining Lease Application (MLA70425) Boundary

Levee_Alignment

Diversion Alignment

Source: Bing Maps © 2009 Microsoft Corporation and its data suppliers. ESRI ArcGIS Online 2011, © Mapinfo Australia Pty Ltd and PSMA Australia Ltd., © Commonwealth of Australia (Geoscience Australia) 2006, © The State of Queensland (Department of Environment & Resource Management) 2010, © The State of Queensland (Department of Mines and Energy) 2010, © Hancock Coal Supplied Data 2011.

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Supplementary Environmental Impact Statement

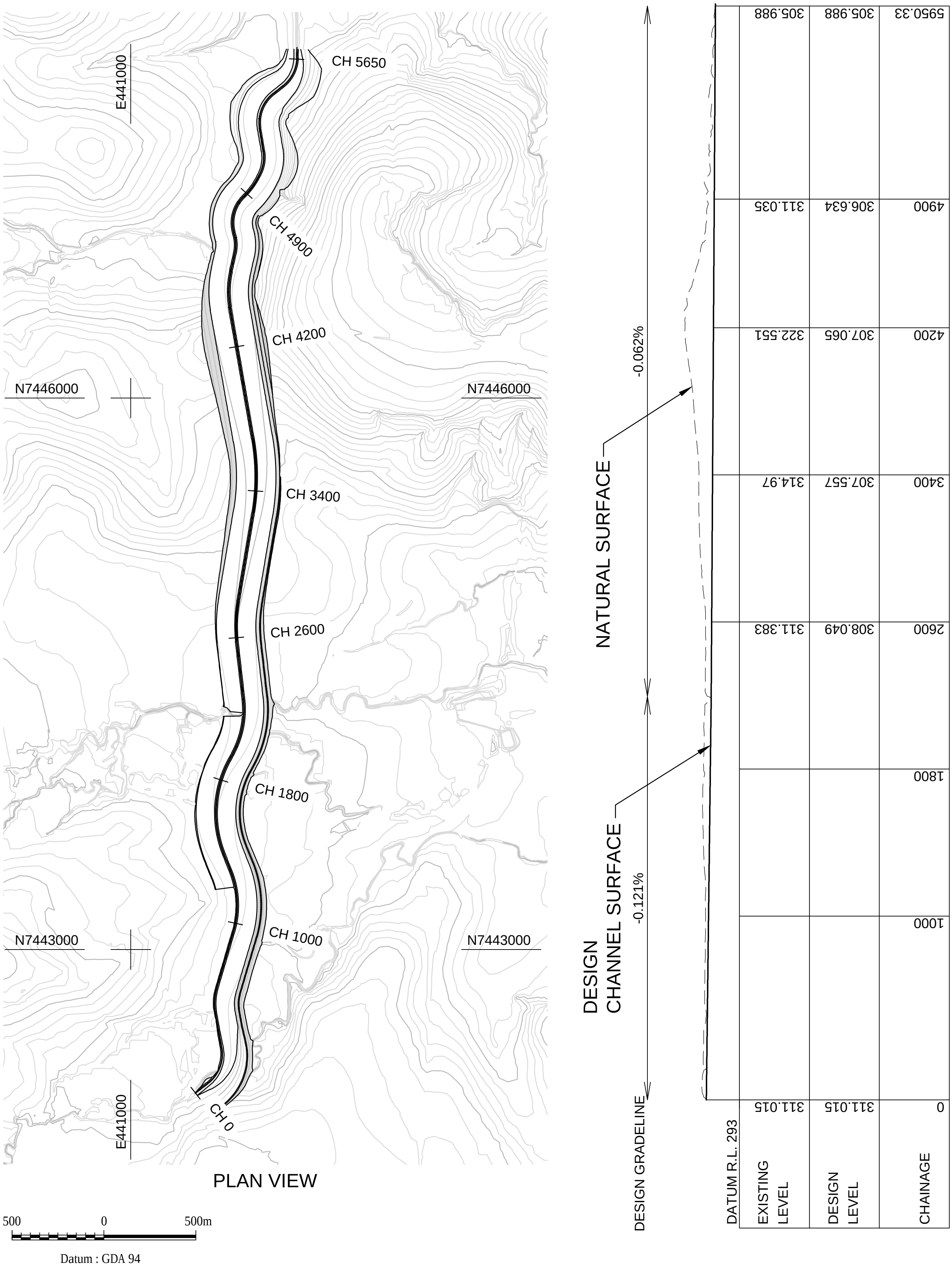
PROPOSED MINE LAYOUT - DIVERSION AND FLOOD PROTECTION LEVEES

URS

REVISED HYDRAULIC TECHNICAL REPORT

Figure: **7-1**

File No: **42626920-g-2068.mxd** Drawn: **RG** Approved: **CP** Date: **15-06-2012** Rev. **A** A4



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Supplementary Environmental Impact Statement

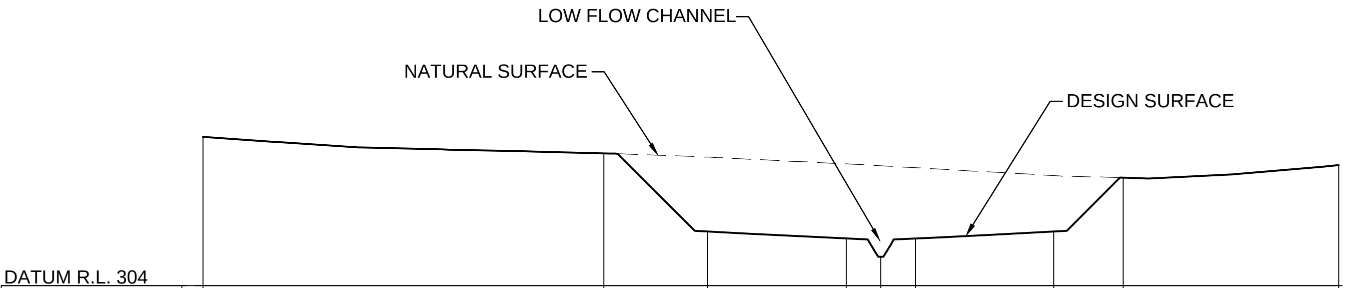
LITTLE SANDY CREEK DIVERSION CHANNEL PLAN AND PROFILE

URS

REVISED HYDRAULIC TECHNICAL REPORT

Figure: **7-2**

File No: **42626920-g-2069.dwg** Drawn: **XL** Approved: **JS** Date: **15-06-2012** Rev. **A** A4



EXISTING LEVEL	321.177	319.26	318.837	318.045	317.847	317.616	316.686	316.465	317.924
DESIGN LEVEL	321.177	319.26	310.246	309.446	307.321	309.446	310.247	316.465	317.924
CHAINAGE	-391.591	-160	-100	-20	0	20	100	140	264.645

CH 3750 TYPICAL CROSS SECTION

SCALE: EXAGGERATION 1x HORIZONTAL
5x VERTICAL

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Supplementary Environmental Impact Statement

**LITTLE SANDY CREEK
DIVERSION CHANNEL
TYPICAL CHANNEL CROSS SECTION**

URS

REVISED HYDRAULIC TECHNICAL REPORT

Figure: **7-3**

File No: **42626920-g-2070.dwg** Drawn: **XL** Approved: **JS** Date: **15-06-2012** Rev. **A** A4

7.5 Flood Protection Levees

7.5.1 Level of Flood Protection

If the mine pit is flooded, the impact on mining operations would be severe and hence a high level of flood immunity is essential. For this reason, the proposed flood protection levee will be conceptually designed to protect the pit from all floods up to a 1:1,000 AEP flood event. The probability of a 1:1,000 AEP flood occurring within the planned 30 year period of open pit mining is 3 per cent.

The appropriate level of flood protection should be based on a risk-based approach and consider the range of options that can be implemented to recover flooded mine pits in an environmentally responsible manner. For example, a flooded mine pit could be recovered with minimal environmental impact if the flood water is appropriately treated to acceptable water quality standards prior to discharge to the waterways, or could be recovered by constructing regulated dams to allow dewatering of the mine pits.

7.5.2 Future Design Consideration of Flood Protection Levees

This report provides hydraulic design criteria for the proposed flood protection levees prior to final design; a geotechnical investigation and analysis would be required for levee design.

A geotechnical investigation required at the detailed design phase, shall at a minimum:

- Characterise the subsurface conditions of the levees to estimate the extent of excavation required to construct a suitable piping cut-off (i.e. formation of an erosion hole from one side of the levee to the other) of the levee foundation. The levee foundation would likely require excavation to rock or an impervious cut-off wall would need to be constructed.
- Identify sources of material that are suitable for construction of the levee embankments. The levee would be designed to impound water for long durations during flooding and would also need to resist erosion from flooding and direct rainfall.

Suitable borrow locations have been identified for use in the levee embankments. However, the extent of material has not yet been evaluated. Potential borrow material locations include the spoil from the diversion channel, the initial Kevin's Corner overburden operations, and the proposed adjacent Alpha mine site. The levee embankment detailed design shall include the following considerations:

- Slope stability
- Erosion protection from flooding in the creeks and from direct rainfall
- Freeboard to account for wave action, settlement, and channel capacity loss due to sedimentation
- Piping failure in the foundation
- Piping failure through the levee embankment
- Ease of maintenance, including sufficiently wide crest for light vehicle access if desired and flat batter slopes for vegetation maintenance.

The flood protection levee banks will be regulated structures with conditions administered through the Environmental Authority. This will require design to be undertaken by a suitably qualified and experienced engineer (as defined by DEHP) and certification of the design and construction of the levee bank. The Environmental Authority conditions will also require certified annual surveillance inspections by a suitably qualified and experience engineer and obligation for the EA holder to rectify deficiencies identified in the annual surveillance outcomes.

7.6 Alignment of Flood Protection Levees

The management of frequent to large and extreme floods for the Kevin's Corner open cut mining operation will be required to protect the proposed mining operations and to protect the downstream environment from uncontrolled releases to a reasonable level of protection as the result of a flood. The mine cannot utilise open cut mining methods without protection from flooding from Sandy Creek, Greentree Creek, Little Sandy Creek, Rocky Creek, Middle Creek, and Well Creek. Hence a flood protection levee will be constructed around most of the perimeter of the mine pit (excluding the high ground in the Northwest corner) to prevent flood waters from entering the pit. Levee embankments for flooding from the surrounding creeks were conceptually designed to protect the mine from floods up the 1:1,000 AEP flood with approximately 1 m of freeboard. The locations and descriptions of the creek realignment (diversion) channel and the flood levees are listed below and shown on Figure 7-1:

- A levee embankment, approximately 6 km long, along the Eastern side of the open cut mine operation for flooding protection from Sandy Creek
- A levee embankment, approximately 6 km long, along the Southern side of the open cut mine operation for flooding protection from Greentree Creek
- A levee embankment, approximately 2 km long, along the Northern side of the open cut mine operation for flooding protection from Well Creek
- A levee embankment, approximately 4 km long, along the Western side of the open cut mine operation for flooding protection from the diverted Little Sandy Creek, Rocky Creek, and Middle Creek
- A levee embankment, approximately 8.5 km long, along the Southern side of the initial North open cut mine operation and tailings storage facility (TSF) for flooding protection from Well Creek and Sandy Creek
- A levee embankment, approximately 1.5 km long, along the Eastern side of Sandy Creek to protect the proposed rail loop for flooding protection from Sandy Creek

Development of Proposed Conditions Hydraulic Model

8.1 Model Results

Conceptual design for the proposed realigned creek channels and flood protection levees has been undertaken. The broad geometric design developed to date was considered sufficient for impact assessment purposes.

Flood modelling for the proposed diversion conditions was performed by modifying the baseline conditions hydraulic models to account for the planned diversion and flood protection levees.

8.2 Changes to HEC-RAS Model Extents

The overall extents of the proposed conditions HEC-RAS model are consistent with the base conditions model, however, a shift in river chainages occurred due to the truncation of Little Sandy Creek and Rocky Creek to account for the planned diversion. All other reach chainages remain as they were in the base conditions. A summary of the differences in river chainage is listed in Table 8-1. The existing conditions chainages listed represent the most downstream cross-sections unaffected by the proposed changes in river alignments.

Table 8-1 Comparison of HEC-RAS River Chainages

Stream Name and Reference Location	Existing Conditions Chainage (m)	Corresponding New Chainage (m)	Difference (m)
Little Sandy Creek	18,158.2	4,663.2	- 13,495.0
Rocky Creek	4,603.1	1,171.0	- 3,432.1

Note: The difference in river chainages does not physically represent a loss in total watercourse lengths only the net difference in reach lengths being modelled.

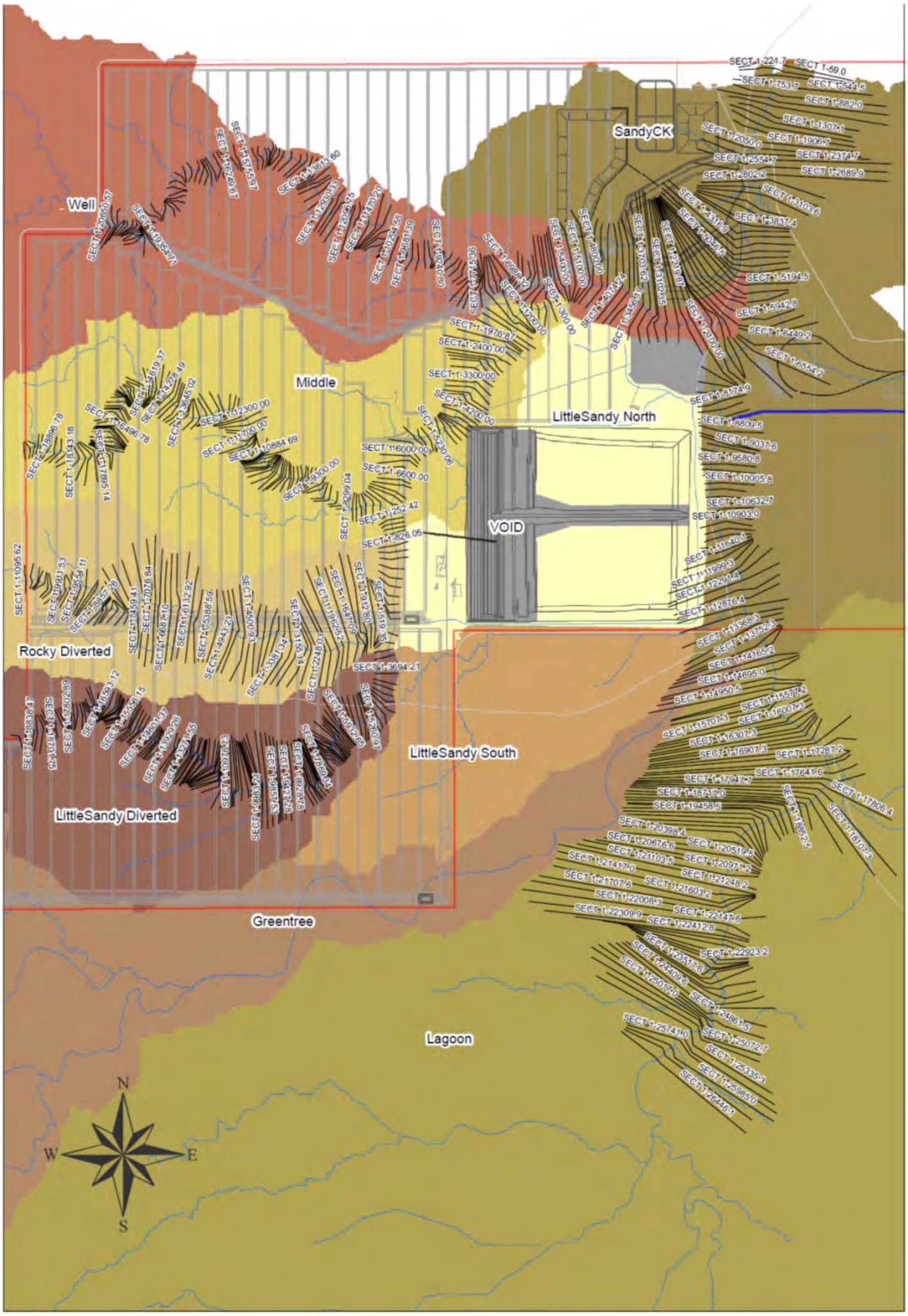
An overall summary of the river chainages for the proposed conditions HEC-RAS model has been listed in Table 8-2. The corresponding graphical representation is presented in Figure 8-1.

Table 8-2 Summary of Proposed HEC-RAS Reaches and Chainages

Stream Name and Reference Location	Starting HEC-RAS Model Chainage (m)	Ending HEC-RAS Model Chainage (m)	Average Channel Bedslope (%)
Sandy Creek upstream of Greentree confluence (Lagoon Creek)	14,330.0	26,446.1	0.05
Sandy Creek between Well Creek and Greentree Creek confluences	5,194.5	13,903.4	0.13
Sandy Creek downstream of Well Creek confluence	59.0	4,918.3	0.12
Little Sandy Creek upstream of Diversion	4,663.2	19,271.2	0.23
Little Sandy Diversion through to Middle Creek	148.8	4,524.4	0.09
Well Creek upstream of Middle Creek Confluence	5,699.6	20,936.1	0.23
Well Creek downstream of Middle Creek confluence	300	5,544.0	0.18
Rocky Creek upstream of Diversion	324.1	11,095.6	0.32
Middle Creek	147.3	19,796.8	0.34

8 Development of Proposed Conditions Hydraulic Model

Figure 8-1 Proposed Conditions HEC-RAS Model Schematic



8.2.1 Proposed HEC-RAS Reach Boundary Conditions

Similar to the baseline study, the proposed diversion HEC-RAS model boundary conditions were based on normal depth at pertinent upstream and downstream boundary locations. The boundary conditions adopted in the baseline study have been retained and applied to the proposed analysis as presented in Table 8-3.

Table 8-3 Summary of Proposed HEC-RAS Reach Boundary Conditions

Stream Name and Reference Location	Downstream Boundary Condition Bedslope (m/m)	Upstream Boundary Condition Bedslope (m/m)
Sandy Creek upstream of Well Creek confluence	*Junction with Well Creek*	0.003
Sandy Creek downstream of Well Creek confluence	0.00125	*Junction with Well Creek*
Little Sandy Creek upstream of Rocky Creek confluence (incl. part Diversion)	*Junction with Rocky Creek*	0.0025
Little Sandy Diversion downstream of Rocky Creek confluence	*Junction with Middle Creek*	*Junction with Rocky Creek*
Well Creek upstream of Middle Creek confluence	*Junction with Middle Creek*	0.0025
Well Creek downstream of Middle Creek confluence	*Junction with Little Sandy Creek*	*Junction with Middle Creek*
Rocky Creek	*Junction with Little Sandy Creek*	0.003
Middle Creek	*Junction with Well Creek*	0.0045

8.2.2 Proposed HEC-RAS Model Inflows

Revised model inflows, developed as part of the hydrologic study with regard to the proposed channel diversion and subsequent catchment reduction, vary significantly across the modelled stream network as a result of additional tributary and catchment inflows. It should be noted that flow change locations, within the model, have changed between the baseline and proposed conditions due the significant changes to catchment outlets and catchment areas resulting from the proposed diversion. The proposed diversion simulation inflows for the 1:2, 1:5, 1:10, 1:20 and 1:50 AEP events are summarised in Appendix A.

8.2.3 Hydraulic Roughness for Diversion

The roughness values for the proposed diversion scenarios were selected based on a similar methodology to that used during roughness selection for the base conditions models. As previously discussed, it has been assumed that vegetation is established within the proposed diversion modelling scenarios. As such, in the HEC-RAS model, a channel roughness of 0.04 was assumed appropriate for the main channel and a roughness of 0.06 was used for the overbanks (floodplains).

Interpretation of Hydraulic Results

9.1 Creek Diversions

Several methods have been developed to quantitatively compare the existing creek hydraulics to those of the diversion channel for design purposes. A common method uses channel velocity to estimate shear stress within the channel. The shear stress can then be related to the potential for erosion or sedimentation within the channel based on the characteristics of the channel bed and banks. Guidelines for maximum permissible velocities to minimise erosion can then be established based on the channel bed material.

It is important to recognise that velocity and shear stress provide an indication of local and immediate erosion potential only. Velocity and shear stress parameters generally indicate whether there is erosion potential to cause enlargement of the local channel cross section (depth and width). They generally do not indicate if there are other influences present which try to realign and reshape the channel alignment (e.g. meandering). The long-term stability of a channel's alignment is related to the morphological context of the reach. Stream power is a more useful indicator of hydraulic conditions reflecting the morphology of the channel, particularly for 'bank-full' flows that are commonly known to be 'channel forming' events.

9.1.1 Frequent Events (up to 1:50 AEP) Flood Modelling Results

Modelling of the diversion channel design described in Section 7 for a range of flood events up to the 1:50 AEP flood event was undertaken by modifying the baseline HEC-RAS model to assess the hydraulic performance of the modified diversion channel. The purpose of the hydraulic analysis was to quantify key hydraulic parameters and compare the hydraulic results to the criteria described below. A description of the model development is presented in Section 8.

The diversion channel hydraulic model results for the 1:2 AEP to the 1:50 AEP were compared to the following criteria to assess the potential impacts:

- Baseline hydraulic results (Section 6)
  - Baseline velocity
  - Baseline stream power
  - Baseline sediment particle transport potential
- ACARP (2002) Guidelines for Incised type streams:
  - Recommended channel velocity range
    - 1:2 AEP flood event: 1.0 to 1.5 m/s
    - 1:50 AEP flood event: 1.5 to 2.5 m/s
  - Recommended channel stream power range
    - 1:2 AEP flood event: 20 to 60 W/m^2
    - 1:50 AEP flood event: 50 to 150 W/m^2

Summaries of the velocity and stream power results for the 1:2 and 1:50 AEP flood events are presented in Table 9-1 and Table 9-2, with corresponding plots (for the Diversion reach) presented in Figure 9-1 to Figure 9-6. These plots show the results for the long-term diversion scenario after revegetation has established, as well as subsided conditions (refer to Section 10). Results for the remaining AEP events are presented in Appendix C along with plots for all creeks. Note that the chainages (x-axes) on these plots have been restricted to regions where differences between baseline and diverted conditions are observable.

9 Interpretation of Hydraulic Results

Table 9-1 Summary of Flood Hydraulics for the Proposed Reach of Sandy Creek

Hydraulic Parameter	Flood Event (AEP)	Proposed through Mine Reach	Existing Channel through Mine Reach	ACARP Guidelines (2002)
Velocity (m/s)	1:2 1:50	0.4 – 1.0 1.3 – 2.2	0.5 – 1.0 1.3 – 2.2	1 – 1.5 1.5 – 2.5
Stream Power (W/m^2)	1:2 1:50	1 - 18 28 - 114	1 – 18 26 - 114	20 – 60 50 – 150

Table 9-2 Summary of Flood Hydraulics for Diversion Little Sandy, Rocky, Middle Creeks

Hydraulic Parameter	Flood Event (AEP)	Proposed Diversion Reach	Existing Channel Upstream and Downstream of Diversion	ACARP Guidelines (2002)
Diversion Channel of Little Sandy Creek to Confluence with Rocky Creek				
Velocity (m/s)	1:2 1:50	0.3 - 1.0 0.5 - 2.1	0.3 - 1.0 0.6 - 2.4	1 – 1.5 1.5 – 2.5
Stream Power (W/m^2)	1:2 1:50	0.7 - 21 1.7 - 139	0.3 - 25 3.8 - 188	20 – 60 50 – 150
Diversion Channel from Rocky Creek to Confluence with Middle Creek				
Velocity (m/s)	1:2 1:50	0.5 - 0.6 1.2 - 1.2	0.3 - 1.2 0.5 - 2.1	1 – 1.5 1.5 – 2.5
Stream Power (W/m^2)	1:2 1:50	2.7 - 3.3 19 - 21	0.4 - 43 2.2 - 133	20 – 60 50 – 150
Diversion Channel from Middle Creek to Confluence with Well Creek				
Velocity (m/s)	1:2 1:50	0.5 - 2.7 1.2 - 2.6	0.2 - 1.0 0.9 - 2.2	1 – 1.5 1.5 – 2.5
Stream Power (W/m^2)	1:2 1:50	1 - 29 19 - 196	0.4 - 27 12 - 147	20 – 60 50 – 150

Figure 9-1 Comparison of Channel Stream Power along the Diversion for a 1:2 AEP Event

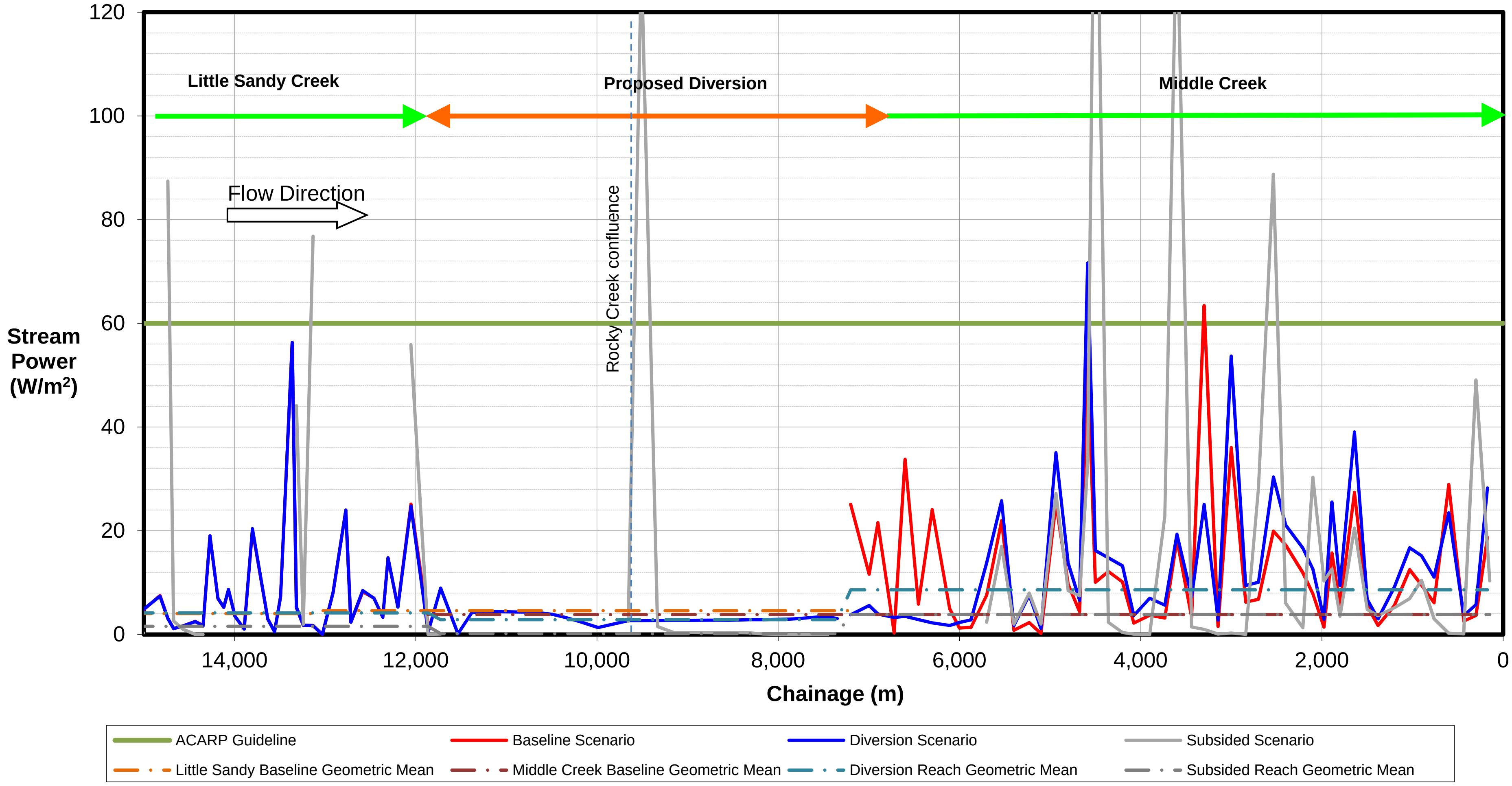


Figure 9-3 Comparison of Channel Stream Power along the Diversion for a 1:50 AEP Event

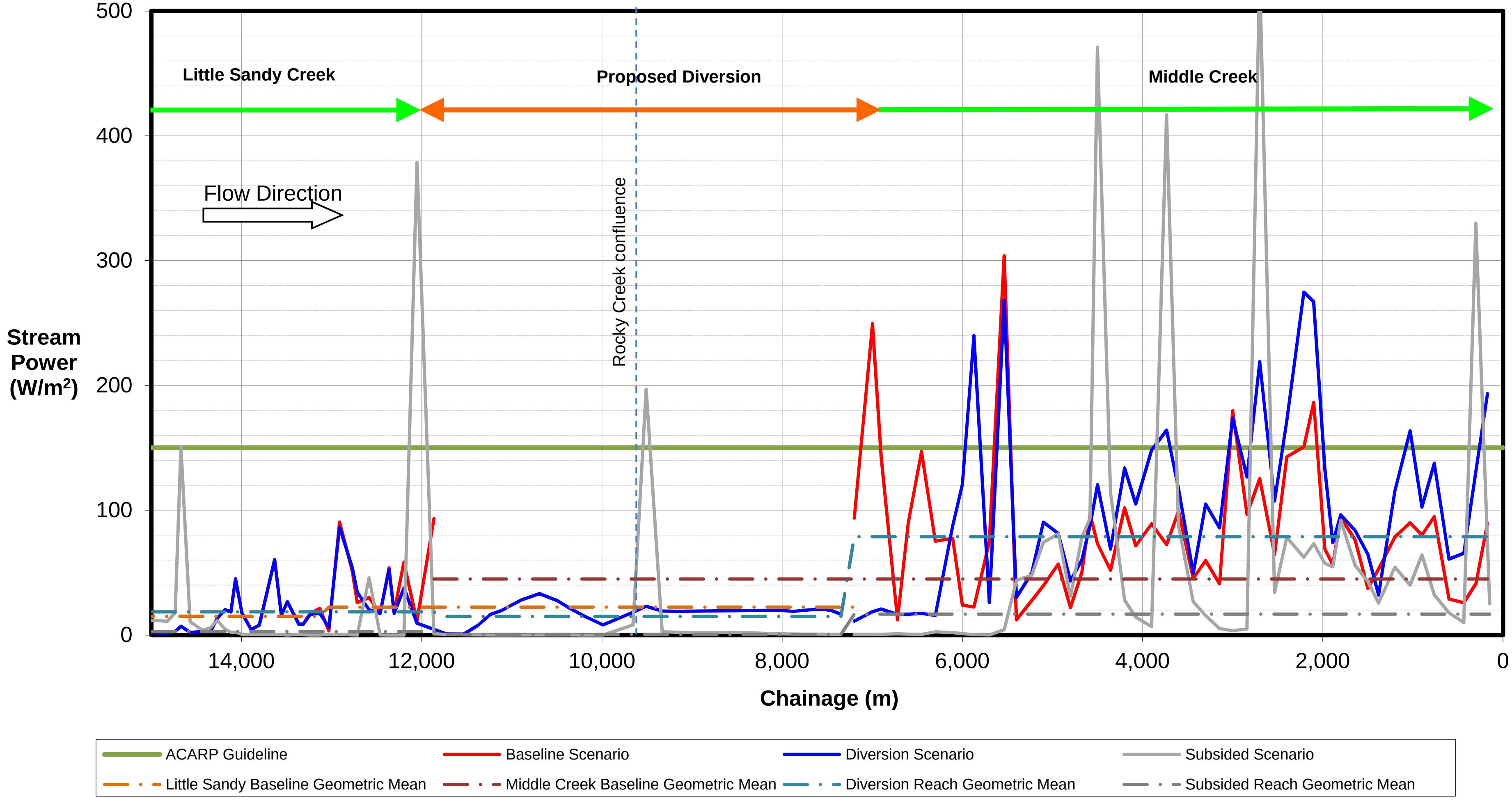


Figure 9-4 Comparison of Channel Velocity along the Diversion for a 1:2 AEP Event

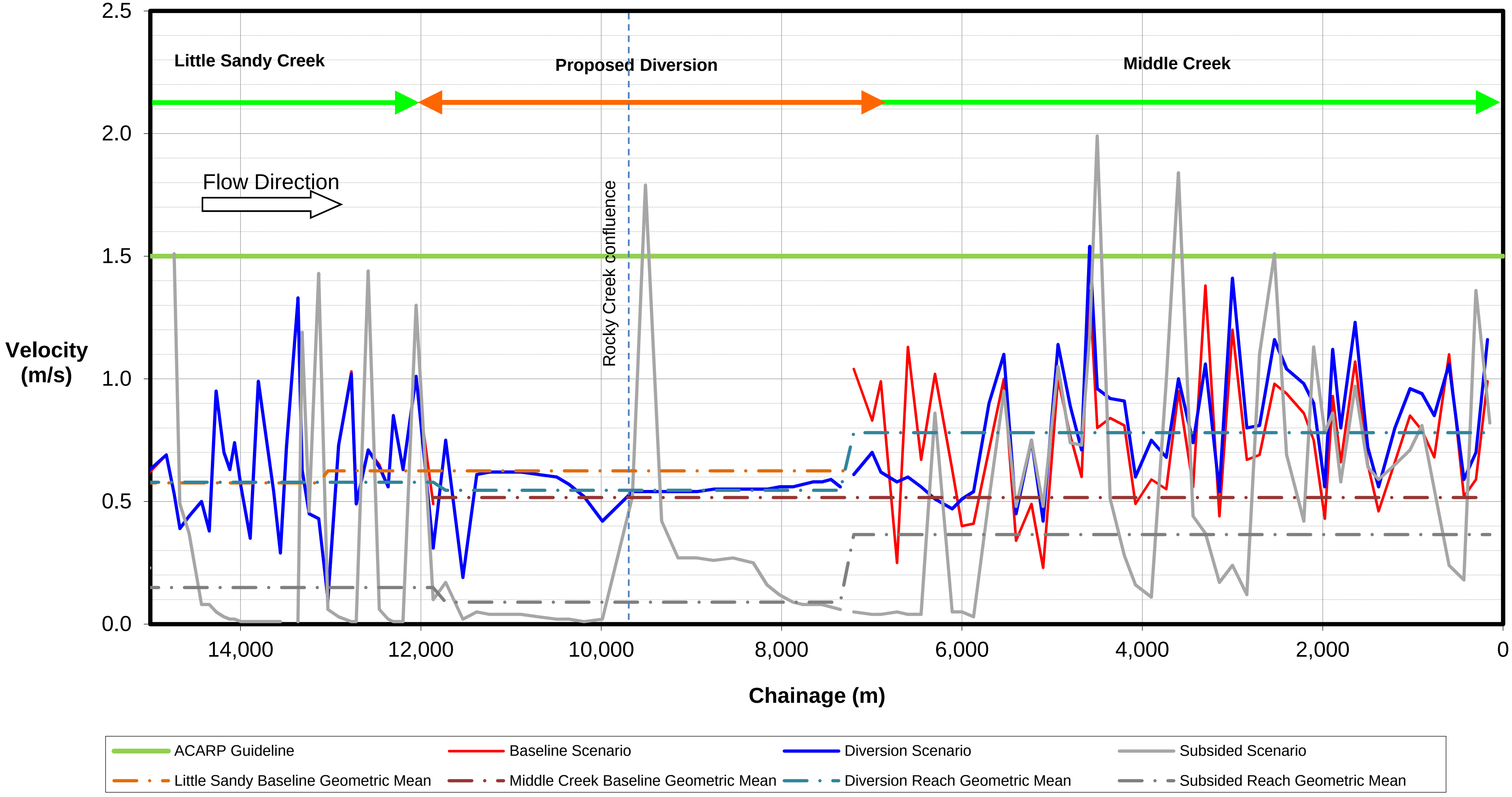
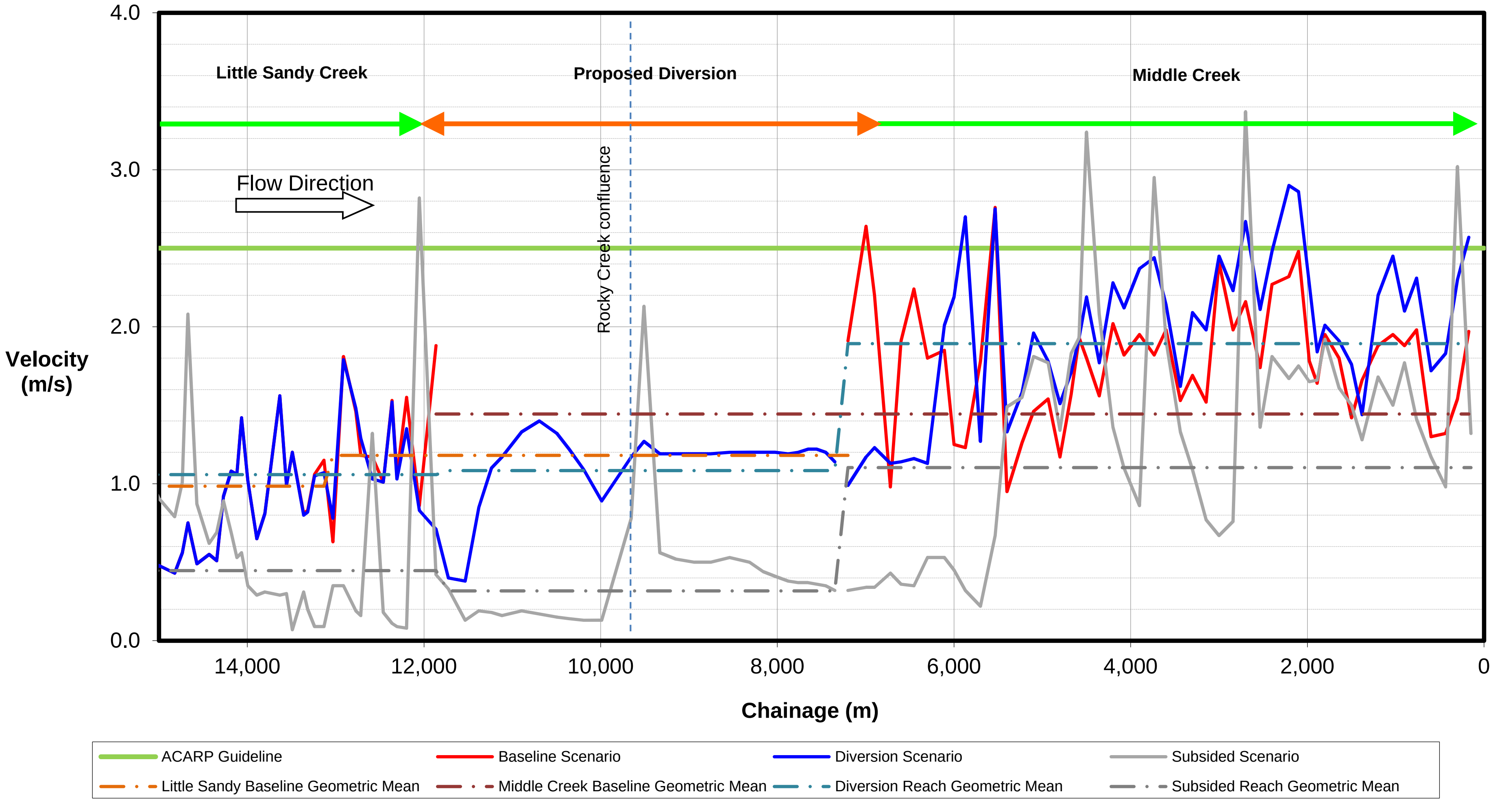


Figure 9-5 Comparison of Channel Velocity along the Diversion for a 1:50 AEP Event



9 Interpretation of Hydraulic Results

Figure 9-6 Comparison of Channel Shear Stress along the Diversion for a 1:2 AEP Event

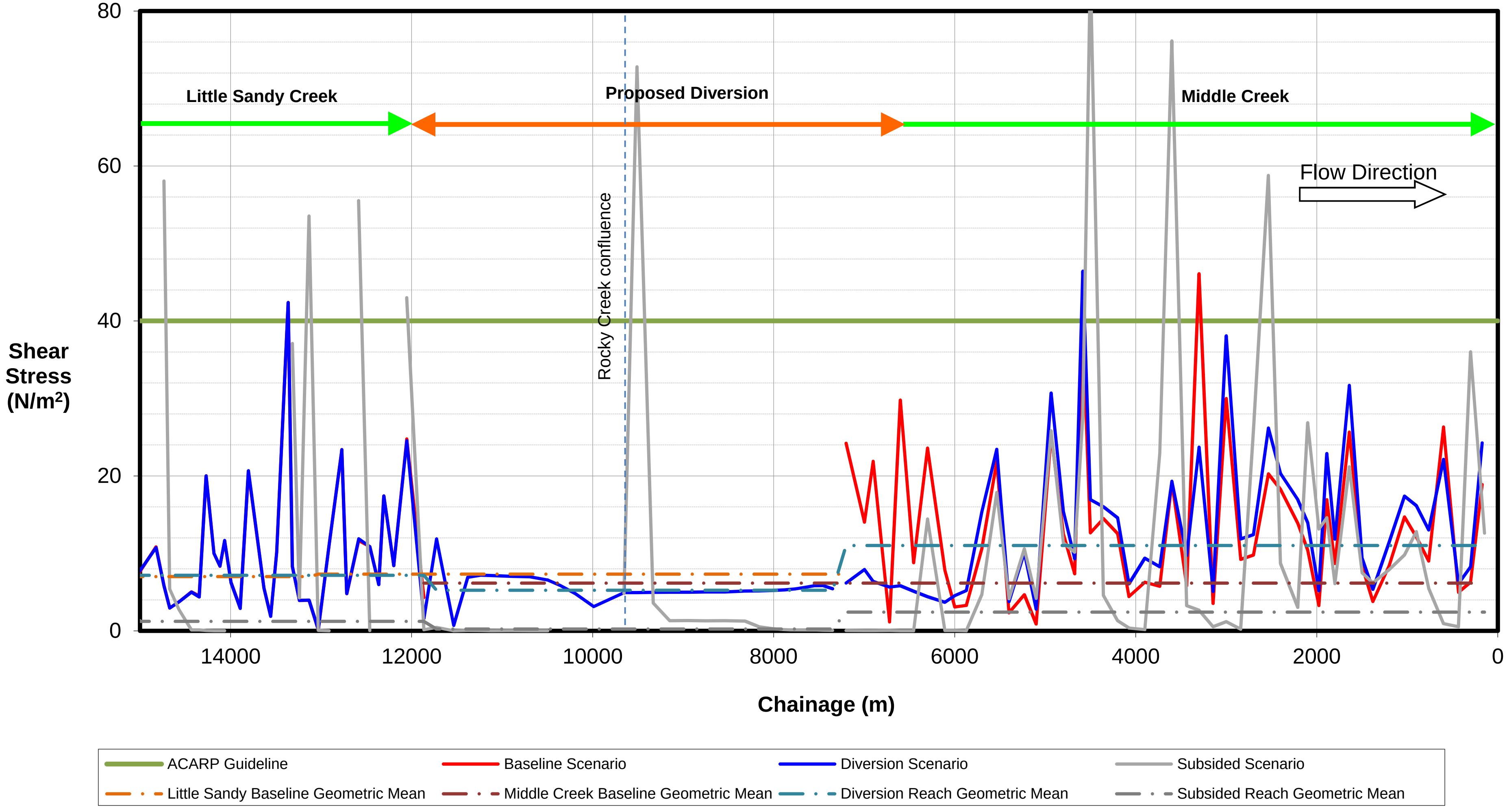
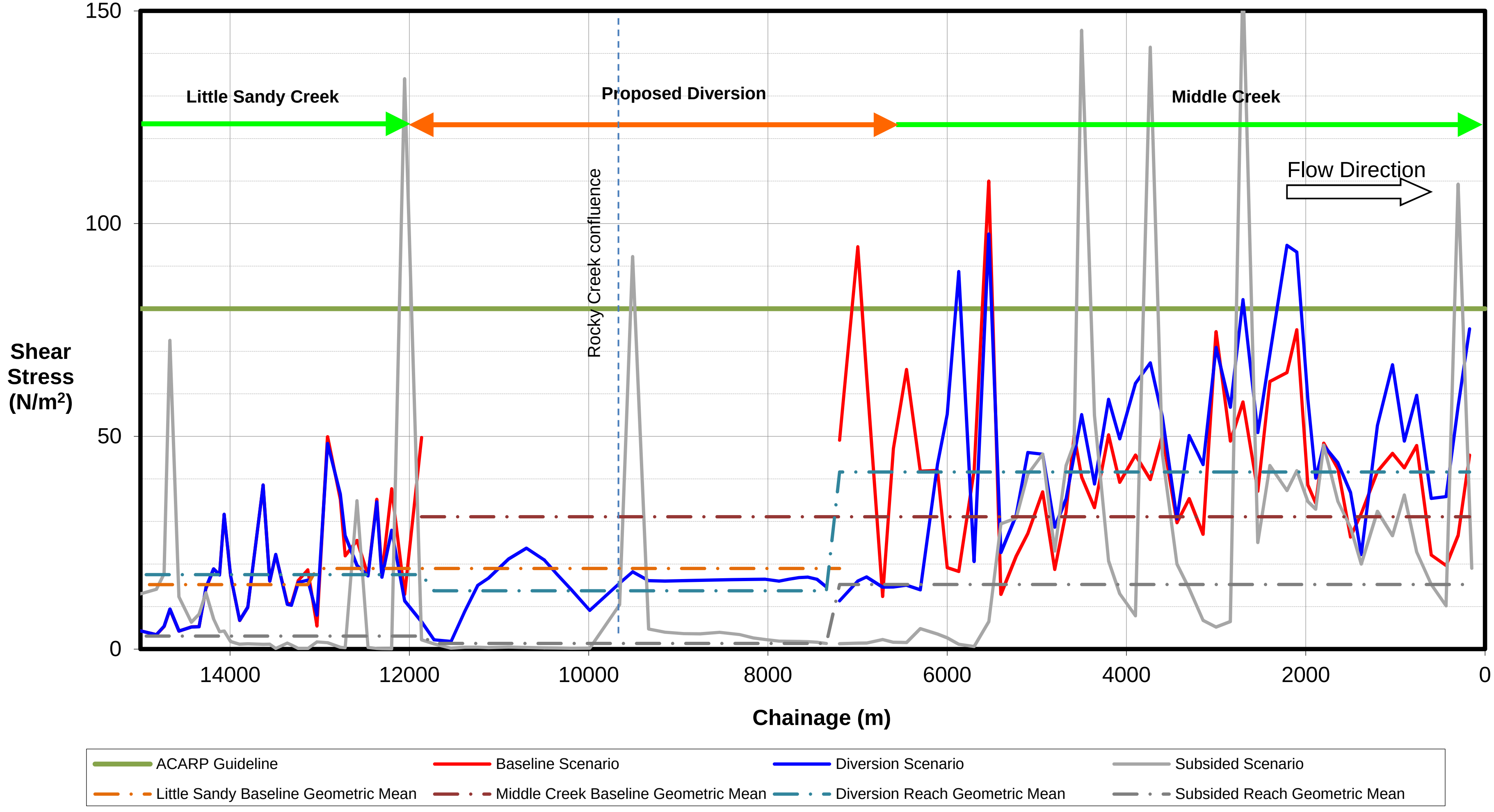


Figure 9-7 Comparison of Channel Shear Stress along the Diversion for a 1:50 AEP Event



Lastly, a comparison of the critical shear stress for the size of particle predicted to be transported by the proposed creek channel systems was estimated based on the average shear stress channel results, as summarised in Table 9-3. The results show that although the average shear stresses would be lower in the diversion channel, the diversion channel should be able to mobilise and transport the existing sediment material, based on the assumed grain sizes.

Table 9-3 Summary of Sediment Transport Capacity for Proposed Creeks

<table>
<tr><th>Creek</th><th>Location</th><th>Channel Forming Event (1:X) AEP</th><th>Shear Stress (N/m^2)</th><th>Assumed Particle Classes Present in Reach</th><th>Critical Shear Stress of Assumed Particle Classes (N/m^2)</th></tr>
<tr><td>Sandy Creek</td><td>Upstream of Mine Lease Boundary</td><td>1:5 to 1:10</td><td>4 - 21</td><td rowspan="8">Fine Gravel

Very Fine Gravel

Very Coarse Sand

Medium Sand</td><td rowspan="8">2.7

1.3

0.47

0.19</td></tr>
<tr><td>Sandy Creek</td><td>Within Mine Lease Boundary</td><td>1:5 to 1:10</td><td>8 - 30</td></tr>
<tr><td>Little Sandy Creek</td><td>Upstream of Diversion</td><td>1:10 to 1:50</td><td>3 - 38</td></tr>
<tr><td>Little Sandy Creek</td><td>Downstream of Diversion</td><td>1:10 to 1:50</td><td>4 - 72</td></tr>
<tr><td>Rocky Creek</td><td>Upstream of Diversion</td><td>1:20 to 1:50</td><td>4 - 73</td></tr>
<tr><td>Middle Creek</td><td>Upstream of Diversion</td><td>1:5 to 1:10</td><td>2 - 44</td></tr>
<tr><td>Well Creek</td><td>Upstream of Middle Creek Confluence</td><td>1:10 to 1:20</td><td>14 - 85</td></tr>
<tr><td>Well Creek</td><td>Downstream of Middle Creek Confluence</td><td>1:10 to 1:20</td><td>11 - 51</td></tr>
</table>

Note (1): Values from *Erosion and Sedimentation* (Julien 1995)

9.1.2 Rare and Extreme Events (1:100 AEP to PMF) Flood Modelling Results

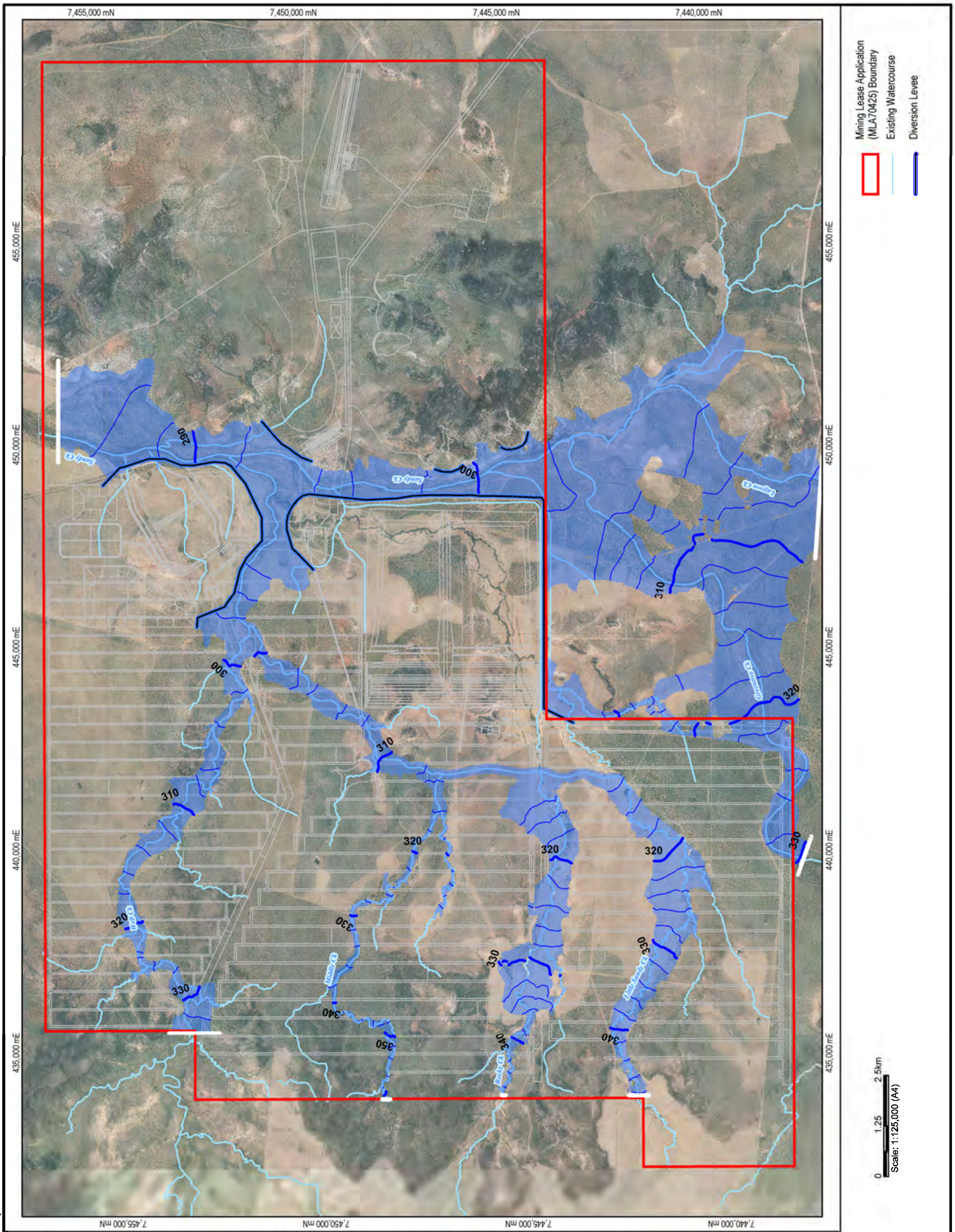
A two-dimensional finite-difference hydraulic model (TUFLOW) was developed to assess the hydraulic conditions of the Sandy Creek and stream diversion for the Little Sandy Creek, Rocky Creek, and Middle Creek for proposed conditions for the rare to extreme flood events. The purpose of the hydraulic analysis was to quantify key hydraulic parameters, in particular maximum flood level and predicted velocity against the levee banks, for a range of flood events from the 1:100 AEP flood event to the PMF. The flood levels were used for estimating crest levels of flood protection levees around the mine operations and also to compare to the baseline elevations to estimate any impacts to areas outside the mine lease boundary. The velocity estimates against the flood levees were estimated for sizing erosion protection.

9.1.2.1 Flood Level Estimates

Flooding extents for the 1:1,000 AEP flood event for the proposed creek system is presented in Figure 9-7 and a summary of the estimated flood elevations at the upstream and downstream boundaries of the mine lease are presented in Table 9-4 (flood elevations for the select frequent events are included for completeness). Figures illustrating flood extents for all remaining AEP events are presented in Appendix D.

Table 9-4 Estimation of Flood Elevations in Sandy Creek at Mine Lease Boundary (Proposed)

AEP Event	Flood Elevation at Upstream Mine Boundary (mAHD)	Flood Elevation at Downstream Mine Boundary (mAHD)
1:2	296.6	279.2
1:50	299.1	282.0
1:100	301.0	283.5
1:1,000	301.7	284.4
1:2,000	302.2	284.8
PMF	307.9	288.9



N E S W

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Kevin's Corner Project
Supplementary Environmental Impact Statement

PROPOSED CONDITIONS FLOOD EXTENTS FOR KEVIN'S CORNER AREA FOR 1:1,000 AEP FLOOD EVENT

URS

REVISED HYDRAULIC TECHNICAL REPORT

Figure: 9-8

File No: 42626920-g-2071.wor | Drawn: XL | Approved: JS | Date: 15-06-2012 | Rev: A | A4

9.2 Flood Protection Levees

9.2.1 Flood Risks to Project along Sandy and Well Creeks

The planned flood protection measures along Sandy and Well Creeks will encroach upon the existing Sandy and Well Creek floodplains. As a result, the water surface elevations, including the 1:100 AEP event and greater within the MLA, along Sandy and Well Creeks will subsequently be higher than those in the base conditions. Comparisons of the water surface elevations at the upstream mine boundary in Sandy Creek and in the vicinity of the Sandy and Well Creek confluence in Well Creek are listed in Table 9-5 and Table 9-6.

It should be noted that differences in flow will exist between the existing and proposed conditions, within both Sandy and Well Creeks, due to the proposed diversion works within the Kevin's Corner mine lease. Although, these flow differences may be significant in some locations, the effect on critical hydraulic parameters (i.e. water level, velocity, stream power, etc.) is expected to be generally localised within reaches and will not significantly impact overall modelling results. As a result, comparison of various hydraulic parameters, resulting from existing and proposed conditions, is considered appropriate.

The effects of the flood protection levees around the open cut mine will influence flood levels upstream of the mine lease in the Sandy and Well Creeks for floods greater than the 1:100 AEP event. The impacts of the increased water levels during flood events would not necessarily produce adverse environmental impacts on the existing vegetation and ecology along the river, however, it is recognised that the raised water levels could impact on the proposed Alpha mine project. The impacts of increased flood levels through the Kevin's Corner mine lease would not adversely affect the proposed mining operations. All key mine infrastructure (open cut, concentrator plant and industrial area) will be located within the flood protection levee, which would be designed to protect against floods up to the 1:1,000 AEP event.

Discussions have been held with the Alpha mine designers regarding the need for possible additional flood mitigation measures.

Table 9-5 Comparison of Water Surface Elevations at Upstream Mine Lease Boundary

AEP Event	Flood Elevation at Upstream Mine Boundary – Existing (mAHD)	Flood Elevation at Upstream Mine Boundary – Proposed (mAHD)	Difference in Water Levels
1:2	1296.7	2296.7	0.0
1:50	3299.2	4299.2	0.0
1:100	300.8	301.0	+ 0.2
1:1,000	301.6	301.7	+ 0.1
1:2,000	301.6	302.2	+ 0.6
PMF	304.4	307.9	+ 3.5

Table 9-6 Comparison of Water Surface Elevations at the Confluence of Well and Sandy Creeks

AEP Event	Flood Elevation at Confluence – Existing (mAHD)	Flood Elevation at Confluence – Proposed (mAHD)	Difference in Water Levels (mAHD)
1:2	1284.9	2284.7	+ 0.2
1:50	3288.0	4288.1	+ 0.1
1:100	290.5	292.5	+ 2.0
1:1,000	289.5	290.6	+ 1.1
1:2,000	290.3	292.0	+ 1.7
PMF	293.9	298.1	+ 4.2

As presented in Tables 9-5 and 9-6, considerable variation in water level is expected as a result of proposed flood protection levees, particularly during infrequent flood events, however, little difference is expected during the 1:2 and 1:50 AEP flood events. As a consequence, the differences between stream power and velocity, as a result of proposed flood protection levees during the 1:2 and 1:50 AEP flood events, are also expected to be relatively minor. Tables 9-7 present a summary of the aforementioned data as a basis of comparison to ACARP guidelines.

Table 9-7 Summary of Flood Hydraulics for the Proposed Sandy and Well Creek Reaches

Hydraulic Parameter	Flood Event (AEP)	Proposed Channel Reach	Existing Channel Reach	ACARP Guidelines (2002)
Sandy Creek – Downstream of Southern Mine Boundary				
Velocity		Velocity		Velocity
(m/s)	1:2	(m/s)	1:2	(m/s)
Well Creek – Downstream of Little Sandy Creek Confluence (Old)				
Velocity		Velocity		Velocity
(m/s)	1:2	(m/s)	1:2	(m/s)

9.2.1.1 Flood Levee Freeboard Allowance

Flood protection levee embankments are proposed to have crest levels one metre above (freeboard) the estimated 1:1,000 AEP flood. The one metre of freeboard generally accounts for the following:

- Any wave action within the creeks to prevent splash over the embankment that could lead to erosion and potential failure of the levee.
- Minor sedimentation in the creek systems through the Kevin’s Corner mine area
- Settlement of the levee banks beyond the camber (additional height accounting for natural settlement) designed for the levees.
- Additional factor of safety above the design flood event, in this case the 1:1,000 AEP.

9.2.1.2 Flood Levee Erosion Protection

The hydraulic results show that the maximum velocity against the proposed levee banks will vary from approximately 2.5 m/s to 3.0 m/s based on the location. Rock riprap is a typical engineering mitigation method for the protection of soil material from erosion. Based on predicted velocities resulting from the 1:1000 AEP flood event, rock riprap was sized using relationships (Julien, 2002) that relate velocity to median rock diameter (D50), as shown in Table 9-8. Suitable rock riprap (non-dispersive) could be sourced from the mining operations or nearby quarry material.

Table 9-8 Levee Protection Riprap Sizing in Well and Sandy Creeks

Levee Location	Maximum Velocity against Levee (m/s)	Median Rock Riprap Size, D50 (mm)
Sandy Creek Upstream of Well Creek Confluence	2.5 - 3	200 - 300
Sandy Creek Downstream of Well Creek Confluence	2.5 - 3	200 - 300
Well Creek Downstream of Middle Creek Confluence	2.5 - 3	200 - 300

Note (1): Median rock riprap size has been estimated from *River Mechanics* (Julien, 2002)

10

Subsidence

10.1 Overview

In longwall mining, a panel of coal, typically about 400 m wide (max) and 4.5 km to 6 km long and 2.8 to 4.5 m thick, is totally removed by long wall shearing machinery, which travels back and forth across the coalface. The area immediately in front of the coalface is supported by a series of hydraulic roof supports, which temporarily hold up the roof strata and provide a working space for the shearing machinery and face conveyor. After each slice of coal is removed, the hydraulic roof supports, the face conveyor and the shearing machinery are moved forward.

When coal is extracted using this method, the roof above the seam is allowed to collapse into the void that is left as the face retreats. This void is referred to as a goaf. As the roof collapses into the goaf, the fracturing settlement of the rock progresses through the overlying strata and results in sagging and bending of the near surface and subsidence of the ground above.

Generally, subsidence occurs over the centre of the longwall panel and tapers off around the perimeter of the long wall. The subsidence is typically less than the thickness of the coal extracted underground.

Where several panels are mined in a series and chain pillars are left between the panels, the chain pillars crush and distort as the coal is removed from both sides of them. Usually they do not totally collapse and, hence the pillar provides a considerable amount of support to the strata above them.

The subsidence at the surface does not occur suddenly but develops progressively as the coal is extracted within the area of influence of the extracted panel. As further adjacent panels are extracted, additional subsidence is experienced, above the previously mined panel or panels. However, a point is also reached where a maximum value of subsidence is observed over the series of panels irrespective of whether more panels are later extracted. The subsidence effect at the surface occurs in the form of a very slow moving wave.

Tabulated and plotted hydraulic model results for the subsidence conditions models have been included in Appendices B and C, respectively. Modelled flood inundation and velocity maps are also presented in Appendix D.

10.2 Potential Impacts

Due to underground mining, channels and floodplains situated directly over longwall panels will drop by approximately one to three metres. Potential impacts to the drainage and channel system from subsidence include:

- Impacts to catchment boundaries, potentially resulting in self contained catchment areas where water that would have runoff to the creek channels prior to subsidence would now pool within the subsided area and be lost to groundwater due to percolation
- Localised loss of surface water flow through surface cracking;
- Change to stream bed profiles between long wall panels, resulting in erosion between adjacent long wall panels and sedimentation over the tops of the long wall panels.
- Potentially reduced flood capacity in channels, resulting in more frequent inundation of floodplain areas.
- Reduce stability of the proposed diversion channel due to subsidence over multiple panels
- Reduce stability of the proposed levees within the subsidence area and increasing the risk of a piping failure during a flood event.

10 Subsidence

Hydraulic modelling of the effects of subsidence on the channel and floodplain for Little Sandy Creek, Rocky Creek, Middle Creek and Well Creek, indicates that there could be an increase in the velocity, bed shear, and stream power in each creek channel, where it crosses into longwall block subsidence areas. Sedimentation is predicted to occur in the troughs. Additionally, the hydraulic analysis suggests that erosion may occur between these blocks during the same time period.

The results indicate that the relative impact of erosion and sedimentation between the longwall blocks in each creek channel is more pronounced during more frequent events when flows approach bankfull conditions, and less pronounced for larger flood events with significant flows on the floodplain. The events which are predicted to create more pronounced erosion and sedimentation rates within each creek channel are as follows:

- Little Sandy Creek – 1:5 to 1:20 AEP
- Rocky Creek – 1:20 to 1:50 AEP
- Middle Creek – 1:5 to 1:10 AEP
- Well Creek – 1:10 to 1:20 AEP

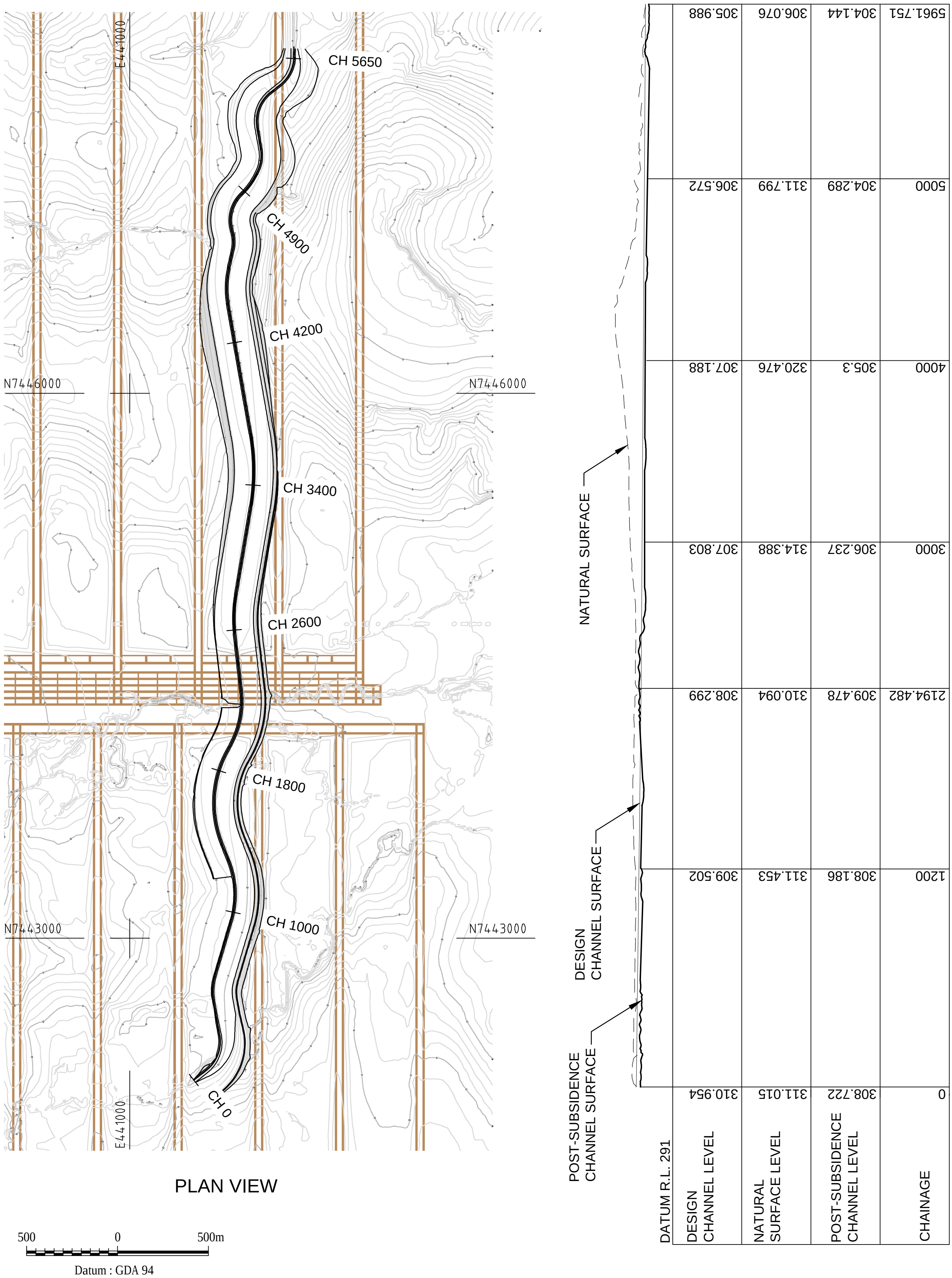
With no other changes to catchment hydrology and sediment supply from the catchment to the creek channels, it is expected that over a medium to long period after subsidence (indicatively say 20 years), the bed profile would adjust through sedimentation and erosion to form an even graded bed profile at similar slope to the existing creek. As this occurs, the channel hydraulic capacity may be reduced, resulting in more frequent inundation of the floodplain.

10.2.1 Hydraulic Impacts of Subsidence on Proposed Diversion Channel

Hydraulic modelling of the proposed diversion channel and floodplain with post subsidence topography indicates there would likely be marginal differences in hydraulic performance since the diversion channel is generally contained within the two longwall panels and would generally subside similarly, Figure 10-1. Unlike the natural streams, the removal of the higher areas between panels and at the confluences with the creeks will be required in order to maintain a similar hydraulic capacity as the pre-subsidence channel.

10.2.2 Impacts of Subsidence on Levees

The proposed alignments of the flood protection levee embankments on the western side of the open cut operations generally follow the un-subsided areas between long wall panels in order to reduce the potential for structural stability, and to reduce the potential for reconstruction.



CHAINAGE	DESIGN CHANNEL LEVEL	NATURAL SURFACE LEVEL	POST-SUBSIDENCE CHANNEL LEVEL
0	310.954	311.015	308.722
1200	309.502	311.453	308.186
2194.482	308.299	310.094	309.478
3000	307.803	314.388	306.237
4000	307.188	320.476	305.3
5000	306.572	311.799	304.289
5961.751	305.988	306.076	304.144

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POST-SUBSIDENCE LITTLE SANDY CREEK DIVERSION CHANNEL PLAN AND PROFILE

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Figure: **10-1**

File No: **42626920-g-2072.dwg** Drawn: **XL** Approved: **JS** Date: **15-06-2012** Rev. **A** A4

10.3 Mitigation Measures

10.3.1 Natural Creek Bed Profile Mitigation

Hydraulic modelling results indicate that erosion due to subsidence impacts on the channel bed profile will occur in the areas between longwall blocks and sedimentation will occur over the middle portion of the longwall block. This process would naturally continue until the system achieves equilibrium (i.e. bed profile restored to an even slope similar to predevelopment conditions) and the quantity of water that ponds in the channel bed depressions will decrease over time. As part of the subsidence monitoring program, the ponding volumes and/or surface area extent of ponding will be monitored over time.

In the event that natural channel erosion and sedimentation does not reduce the volume of channel bed depressions (and consequent ponded water volumes), remedial works to reinstate an evenly graded bed profile (i.e. free draining channel) can be considered as a contingency measure. This would involve excavating the “high” points in the subsided channel bed profile, typically between the blocks where subsidence is less than the subsidence that occurs within the blocks. If required, the works would be completed to match the existing channel characteristics including geometry, substrate and vegetation. Excavated bank areas would need temporary erosion matting to protect the works until vegetation is established.

It should be noted that this contingency measure, with excavation to drain pooled areas, would be extensive and cause significant disturbance to the drainage system and vegetation. It is therefore to be adopted as a last resort option that will only be considered if triggered by the subsidence monitoring program and demonstrated that unsustainable deleterious effects on environmental values and downstream water resources availability would continue if the works are not undertaken.

10.3.2 Diversion Channel Bed Profile Mitigation

Hydraulic modelling results indicate that the post-subsidence diversion channel should perform similar to the diversion channel prior to subsidence, once all the panels that affect the diversion channel have been subsided, Figure 10-1. Additional consideration must be given for the time period after the first major panel has subsided, where there would likely be a two to three metre drop in grade from upstream to downstream. The proposed underground mining sequence would allow water to continue to flow by gravity. However, additional structural measures may be required once the first panel subsides, including;

- Excavation of the potential “high point” between the downstream subsided panel and the yet to subside upstream panel so that the high point is not remaining when the second panel subsides, thereby maintaining continuity of the channel system for stormwater conveyance.
- Addition of a rock chute (i.e. rock armouring in steep channel section to reduce potential for erosion.
- After the second panel subsides, the rock armouring should either be removed or arranged so as not to impede flow.

Following subsidence, the diversion channel should be assessed for surface cracking. For further information refer to the Interim Subsidence Management Plan in Appendix N of this SEIS.

10.3.3 Levee Mitigation from Subsidence

Protection of the mine from flooding up to the design flood event is critical to the operation of the mine for the duration of the mine life. As such, the levee embankment alignments that could potentially be affected by subsidence have been aligned on top of the un-subsided areas between the long wall panels. At present, only the flood protection levee to the west side of the open cut pit, adjacent the diversion, has the potential to be affected by subsidence. Additionally, these reaches of levee embankments would be assessed for cracking during the subsidence monitoring program. Reconstruction would be recommended where any cracking had the potential for piping risk.

References

Australian Coal Association Research Program (ACARP) (2002) *Maintenance of Geomorphic Processes in Bowen Basin River Diversions*. Research Projects C8030 and C9068.

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Julien, P.Y., 2002. River Mechanics. Cambridge University Press.

U.S. Army Corps of Engineers, 2010. HEC-RAS v.4.1.0, Hydrologic Engineering Center.

12 Limitations

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Hancock Coal Pty Ltd and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 23 July 2010.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared based on investigations undertaken between October 2010 and May 2012 and is based on the conditions encountered, information available at the time of preparation and limited to the data described in this report. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Appendix A HEC-RAS Model Inflow Data

Appendix A - HEC-RAS Model Inflow Data

A.1 Index of Tables

Appendix A - HEC-RAS Model Inflow Data

Table A-1 Summary of Base Conditions HEC-RAS Model Inflows

River	RS	1:2	1:5	1:10	1:20	1:50
Little Sandy	32,766.2	1.5	6.2	12.6	22.4	42.2
Little Sandy	31,297.9	1.6	6.6	13.5	24.0	45.2
Little Sandy	30,088.2	1.7	7.1	14.4	25.6	48.2
Little Sandy	28,338.9	1.8	7.5	15.3	27.2	51.3
Little Sandy	26,766.6	2.0	8.0	16.3	29.0	54.6
Little Sandy	25,099.6	2.4	9.7	19.8	35.2	66.3
Little Sandy	23,352.6	2.9	11.8	24.0	42.6	80.2
Little Sandy	21,685.5	3.1	12.6	25.6	45.4	85.6
Little Sandy	19,207.0	3.2	13.2	26.8	47.6	89.6
Little Sandy	17,230.5	3.3	13.5	27.5	48.9	92.1
Little Sandy	14,674.0	4.0	16.3	33.1	58.8	110.8
Little Sandy	13,046.0	4.0	16.4	33.4	59.4	111.8
Little Sandy	11,981.0	5.9	24.0	48.8	86.7	163.4
Little Sandy	11,100.0	6.0	24.4	49.7	88.3	166.4
Little Sandy	9,013.0	6.3	25.7	52.3	92.9	174.9
Little Sandy	8,554.7	6.4	26.0	52.9	93.9	177.0
Little Sandy	6,858.3	6.4	26.3	53.5	95.0	179.0
Little Sandy	5,762.2	6.5	26.5	54.0	95.9	180.6
Little Sandy	3,789.0	6.8	27.7	56.5	100.3	188.9
Little Sandy	1,976.4	7.0	28.4	57.8	102.7	193.4
Little Sandy	793.7	7.0	28.4	57.9	102.8	193.7
Little Sandy TRI	4,529.8	0.1	0.1	0.1	0.1	0.1
Middle Creek	19,796.8	0.9	3.7	7.6	13.5	25.5
Middle Creek	19,081.1	1.0	4.1	8.3	14.8	27.9
Middle Creek	18,143.2	1.2	4.7	9.6	17.1	32.2
Middle Creek	16,424.8	1.3	5.3	10.8	19.2	36.2
Middle Creek	14,696.0	1.7	6.9	14.1	25.1	47.2
Middle Creek	14,278.5	1.8	7.2	14.7	26.1	49.2
Middle Creek	12,779.6	2.0	8.2	16.7	29.6	55.8
Middle Creek	10,723.9	2.1	8.5	17.3	30.8	57.9
Middle Creek	9,900.0	2.1	8.7	17.7	31.5	59.3
Middle Creek	8,866.5	2.6	10.7	21.7	38.6	72.7
Middle Creek	7,974.3	2.7	10.9	22.2	39.5	74.4
Middle Creek	6,453.5	2.8	11.2	22.9	40.6	76.5
Middle Creek	4,935.1	3.4	14.0	28.4	50.5	95.2
Middle Creek	3,437.4	3.5	14.5	29.4	52.3	98.5
Middle Creek	2,400.0	3.7	15.0	30.6	54.3	102.3
Middle Creek	1,200.0	3.7	15.3	31.1	55.3	104.1
Rocky Creek	14,527.7	2.0	8.2	16.7	29.6	55.8
Rocky Creek	12,772.1	2.1	8.7	17.8	31.6	59.4
Rocky Creek	10,620.8	2.4	9.7	19.7	35.1	66.1
Rocky Creek	9,565.0	2.4	10.0	20.4	36.2	68.1
Rocky Creek	8,509.4	3.0	12.2	24.9	44.3	83.4
Rocky Creek	7,401.3	3.1	12.6	25.7	45.7	86.1
Rocky Creek	6,108.2	3.2	13.0	26.5	47.2	88.8
Rocky Creek	3,951.4	3.5	14.1	28.8	51.1	96.3
Rocky Creek	2,145.4	3.6	14.8	30.2	53.7	101.1

Appendix A - HEC-RAS Model Inflow Data

River	RS	1:2	1:5	1:10	1:20	1:50
Rocky Creek	845.1	3.7	15.2	31.0	55.0	103.7
Sandy Creek	26,446.1	29.5	120.5	245.2	435.6	820.6
Sandy Creek	17,806.0	30.6	124.8	254.0	451.3	850.1
Sandy Creek	14,330.0	34.9	142.5	290.1	515.4	970.9
Sandy Creek	10,767.6	35.1	143.1	291.4	517.5	974.9
Sandy Creek	4,918.3	39.2	160.1	326.0	579.1	1090.8
Sandy Creek	4,612.9	39.6	161.8	329.4	585.2	1102.4
Sandy Creek	1,906.7	39.9	162.7	331.3	588.6	1108.7
Well Creek	20,936.1	8.8	36.1	73.4	130.4	245.7
Well Creek	17,026.5	9.0	36.6	74.5	132.3	249.2
Well Creek	14,336.1	9.2	37.4	76.2	135.4	255.0
Well Creek	8,036.0	9.4	38.5	78.4	139.2	262.3
Well Creek	5,544.0	10.6	43.4	88.5	157.1	296.0
Well Creek	4,378.0	10.7	43.6	88.8	157.7	297.0
Well Creek	3,000.0	13.6	55.4	112.8	200.3	377.3
Well Creek	1,500.0	13.6	55.4	112.9	200.5	377.7

Table A-2 Summary of Diversion Conditions HEC-RAS Model Inflows

River	RS	1:2	1:5	1:10	1:20	1:50
Little Sandy	19,271.3	1.5	6.2	12.6	22.4	42.2
Little Sandy	17,802.9	1.6	6.6	13.5	24.0	45.2
Little Sandy	16,593.1	1.7	7.1	14.4	25.6	48.2
Little Sandy	14,843.8	1.8	7.5	15.3	27.2	51.3
Little Sandy	13,271.6	2.0	8.0	16.3	29.0	54.6
Little Sandy	11,604.4	2.4	9.7	19.8	35.2	66.3
Little Sandy	9,857.5	2.9	11.8	24.0	42.6	80.2
Little Sandy	8,190.5	3.1	12.6	25.6	45.4	85.6
Little Sandy	5,711.9	3.2	13.1	26.8	47.5	89.5
Little Sandy	4,179.8	3.3	13.4	27.2	48.3	91.0
Little Sandy	2,453.6	5.1	20.8	42.3	75.2	141.7
Little Sandy	1,554.9	5.1	20.9	42.5	75.5	142.3
Middle Creek	19,796.8	0.9	3.7	7.6	13.5	25.5
Middle Creek	19,081.1	1.0	4.1	8.3	14.8	27.9
Middle Creek	18,143.2	1.2	4.7	9.6	17.1	32.2
Middle Creek	16,424.8	1.3	5.3	10.8	19.2	36.2
Middle Creek	14,696.0	1.7	6.9	14.1	25.1	47.2
Middle Creek	14,278.5	1.8	7.2	14.7	26.1	49.2
Middle Creek	12,779.6	2.0	8.2	16.7	29.6	55.8
Middle Creek	10,723.9	2.1	8.5	17.3	30.8	57.9
Middle Creek	9,900.0	2.1	8.7	17.7	31.5	59.3
Middle Creek	8,866.5	2.2	8.8	18.0	32.0	60.3
Middle Creek	8,100.0	2.6	10.7	21.7	38.6	72.7
Middle Creek	7,200.0	6.1	24.9	50.7	90.0	169.6
Middle Creek	6900	6.1	25.1	51.0	90.7	170.8
Middle Creek	5,400.0	6.5	26.4	53.7	95.4	179.7
Middle Creek	4,935.1	6.5	26.6	54.2	96.4	181.5
Middle Creek	3,437.4	6.6	26.9	54.8	97.4	183.4

Appendix A - HEC-RAS Model Inflow Data

River	RS	1:2	1:5	1:10	1:20	1:50
Middle Creek	2,400.0	6.7	27.3	55.6	98.7	186.0
Middle Creek	1,200.0	6.7	27.5	55.9	99.4	187.2
Rocky Creek	11,095.6	2.0	8.2	16.7	29.6	55.8
Rocky Creek	9,340.0	2.1	8.7	17.8	31.6	59.4
Rocky Creek	7,188.7	2.4	9.7	19.7	35.1	66.1
Rocky Creek	6,132.9	2.4	10.0	20.4	36.2	68.1
Rocky Creek	5,077.3	3.0	12.2	24.9	44.3	83.4
Rocky Creek	3,969.2	3.1	12.6	25.7	45.7	86.1
Rocky Creek	2,676.1	3.2	13.0	26.5	47.2	88.8
Sandy Creek	26,446.1	29.5	120.5	245.2	435.6	820.6
Sandy Creek	17,806.0	30.6	124.8	254.0	451.3	850.1
Sandy Creek	14,330.0	34.9	142.5	290.1	515.4	970.9
Sandy Creek	10,767.6	35.5	145.0	295.3	524.5	988.1
Sandy Creek	4,787.9	39.1	159.8	325.4	577.9	1088.7
Sandy Creek	4,612.9	39.5	161.5	328.7	583.9	1100.0
Sandy Creek	1,906.7	39.8	162.4	330.6	587.3	1106.3
Well Creek	20,936.1	8.8	36.1	73.4	130.4	245.7
Well Creek	17,026.5	9.0	36.6	74.5	132.3	249.2
Well Creek	14,336.1	9.2	37.4	76.2	135.4	255.0
Well Creek	8,036.0	9.4	38.5	78.4	139.2	262.3
Well Creek	5,544.0	12.4	50.6	103.1	183.1	345.0
Well Creek	4,378.0	12.5	51.0	103.8	184.3	347.2
Well Creek	1,500.0	12.5	51.0	103.9	184.6	347.7

Appendix B Modelling Results – Summary Tables

Appendix B - Modelling Results – Summary Tables

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Appendix B - Modelling Results – Summary Tables

Table B-1 Comparison Summary of Channel Stream Power Results (10-percentile to 90-percentile)

CREEK	LOCATION	SCENARIO	STREAM POWER (W/m^2)								
			1:2 AEP	1:5 AEP	1:10 AEP	1:20 AEP	1:50 AEP	1:100 AEP	1:1000 AEP	1:2000 AEP	PMF
Sandy Creek	Upstream of Greentree Creek confluence	Baseline	0.7 - 12	1.9 - 26	1.8 - 29	1.2 - 40	0.9 - 70	4.3 - 99	11 - 210	15 - 260	30 - 600
		Diversion	0.7 - 12	2.1 - 22	2.3 - 29	1.4 - 40	1.0 - 70	4.4 - 100	10 - 210	13 - 260	23 - 490
		Subsidence	0.8 - 14	2.1 - 22	2.3 - 32	1.4 - 39	1.0 - 68				
Sandy Creek	Well Creek confluence to Greentree Creek confluence	Baseline	1.1 - 18	5.9 - 33	10 - 43	17 - 70	27 - 110	36 - 140	27 - 190	28 - 210	40 - 390
		Diversion	1.1 - 18	5.4 - 32	11 - 43	17 - 62	29 - 110	37 - 143	38 - 240	39 - 260	110 - 740
		Subsidence	1.1 - 26	5.0 - 45	9.4 - 79	17 - 88	32 - 140				
Sandy Creek	Downstream of Well Creek confluence	Baseline	1.8 - 14	7.0 - 37	15 - 47	26 - 88	18 - 160	50 - 120	62 - 160	67 - 180	120 - 340
		Diversion	1.7 - 14	6.9 - 37	15 - 49	27 - 95	33 - 143	77 - 190	86 - 330	86 - 380	200–1400
		Subsidence	1.7 - 14	6.9 - 38	12 - 65	25 - 79	22 - 160				
Little Sandy Creek	Upstream of Rocky Creek confluence	Baseline	0.9 - 25	2.2 - 57	1.7 - 72	1.9 - 79	2.2 - 130	2.1 - 64	6.2 - 82	8.7 - 90	25 - 210
	Upstream of Diversion	Diversion	0.6 - 22	1.8 - 60	1.2 - 56	1.6 - 76	2.1 - 160	2.3 - 75	5.2 - 66	6.7 - 82	21 - 140
		Subsidence	0.0 - 71	0.0 - 140	0.0 - 180	0.0 - 250	0.0 - 290				
Little Sandy Creek	Downstream of Rocky Creek confluence	Baseline	0.3 - 17	0.8 - 58	1.8 - 41	3.1 - 80	5.0 - 78	4.1 - 50	7.7 - 85	9.7 - 100	44 - 430
	Diversion Reach	Diversion	2.6 - 4.4	4.5 - 9.2	5.6 - 14	6.9 - 18	7.9 - 25	2.1 - 9.4	2.5 - 18	2.3 - 24	3.3 - 110
		Subsidence	0.0 - 2.0	0.0 - 2.4	0.0 - 0.9	0.0 - 1.3	0.0 - 2.3				
Well Creek	Upstream of Middle Creek confluence	Baseline	3.2 - 53	9.1 - 78	15 - 150	19 - 220	33 - 300	19 - 100	30 - 220	34 - 250	57 - 590
		Diversion	3.2 - 53	9.1 - 78	15 - 140	19 - 220	33 - 280	20 - 110	30 - 220	33 - 250	52 - 530
		Subsidence	0.2 - 130	0.4 - 230	0.8 - 250	2.3 - 310	5.8 - 390				

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Appendix B - Modelling Results – Summary Tables

CREEK	LOCATION	SCENARIO	STREAM POWER (W/m^2)								
			1:2 AEP	1:5 AEP	1:10 AEP	1:20 AEP	1:50 AEP	1:100 AEP	1:1000 AEP	1:2000 AEP	PMF
Well Creek	Little Sandy Creek confluence to Middle Creek confluence	Baseline	3.1 - 32	12 - 61	22 - 60	19 - 110	7.5 - 200	8.1 - 150	11 - 250	13 - 280	33 - 620
		Diversion	2.9 - 26	3.4 - 66	5.2 - 92	9.6 - 140	12 - 190	6.5 - 130	11 - 220	13 - 260	38 - 670
		Subsidence	0.0 - 49	0.2 - 77	0.6 - 110	0.9 - 93	3.8 - 220				
Well Creek	Downstream of existing Little Sandy Creek confluence	Baseline	0.6 - 34	4.7 - 55	11 - 55	18 - 55	30 - 84	23 - 36	31 - 50	33 - 53	47 - 87
		Diversion	0.5 - 47	4.1 - 61	12 - 58	31 - 55	33 - 96	13 - 32	19 - 56	21 - 66	49 - 310
		Subsidence	0.4 - 33	3.1 - 36	9.7 - 31	13 - 48	20 - 78				
Rocky Creek	Entire reach	Baseline	0.4 - 43	2.3 - 94	1.8 - 160	3.5 - 160	3.8 - 190	2.9 - 91	7.6 - 160	11 - 200	40 - 420
	Upstream of Diversion	Diversion	0.4 - 35	1.8 - 81	2.1 - 150	2.3 - 150	2.4 - 140	2.0 - 170	3.7 - 130	4.8 - 170	12 - 280
		Subsidence	0.0 - 80	0.0 - 150	0.0 - 210	0.0 - 260	0.0 - 370				
Middle Creek	Entire reach	Baseline	0.4 - 27	1.6 - 50	3.0 - 74	5.2 - 100	12 - 150	14 - 130	26 - 250	36 - 230	64 - 410
	Upstream of Diversion	Diversion	0.4 - 29	1.4 - 65	3.1 - 86	5.7 - 110	11 - 170	5.9 - 220	17 - 230	17 - 290	49 - 400
		Subsidence	0.0 - 48	0.0 - 99	0.1 - 160	0.2 - 190	0.5 - 230				

Table notes: All values rounded to two significant figures

Appendix B - Modelling Results – Summary Tables

Table B-2 Comparison Summary of Channel Velocity Results (10-percentile to 90-percentile)

CREEK	LOCATION	SCENARIO	VELOCITY (m/s) 1:2 AEP	1:5 AEP	1:10 AEP	1:20 AEP	1:50 AEP	1:100 AEP	1:1000 AEP	1:2000 AEP	PMF
Sandy Creek	Upstream of Greentree Creek confluence	Baseline	0.4 - 0.9	0.5 - 1.2	0.5 - 1.4	0.5 - 1.6	0.5 - 2.0	0.5 - 1.8	0.7 - 2.3	0.8 - 2.5	1.2 - 3.4
		Diversion	0.4 - 0.9	0.6 - 1.2	0.6 - 1.4	0.5 - 1.6	0.5 - 2.0	0.5 - 1.8	0.7 - 2.3	0.7 - 2.5	1.0 - 3.2
		Subsidence	0.4 - 1.0	0.6 - 1.2	0.6 - 1.4	0.5 - 1.6	0.5 - 2.0				
Sandy Creek	Well Creek confluence to Greentree Creek confluence	Baseline	0.4 - 1.0	0.7 - 1.3	0.9 - 1.5	1.1 - 1.8	1.3 - 2.2	1.0 - 1.7	0.9 - 1.9	0.9 - 2.0	1.1 - 2.7
		Diversion	0.4 - 1.0	0.7 - 1.3	0.9 - 1.5	1.1 - 1.7	1.3 - 2.2	1.0 - 1.8	1.1 - 2.1	1.1 - 2.2	1.7 - 3.4
		Subsidence	0.4 - 1.2	0.7 - 1.4	0.9 - 1.8	1.1 - 2.0	1.4 - 2.4				
Sandy Creek	Downstream of Well Creek confluence	Baseline	0.5 - 0.9	0.8 - 1.4	1.1 - 1.5	1.3 - 1.9	1.2 - 2.4	1.2 - 1.6	1.3 - 1.7	1.3 - 1.8	1.7 - 2.4
		Diversion	0.5 - 0.9	0.8 - 1.4	1.1 - 1.6	1.3 - 2.0	1.5 - 2.3	1.3 - 1.8	1.4 - 2.3	1.4 - 2.4	2.0 - 3.9
		Subsidence	0.5 - 0.9	0.8 - 1.4	1.0 - 1.7	1.3 - 1.9	1.3 - 2.5				
Little Sandy Creek	Upstream of Rocky Creek confluence	Baseline	0.4 - 1.0	0.5 - 1.4	0.4 - 1.6	0.5 - 1.7	0.5 - 2.1	0.3 - 1.0	0.5 - 1.2	0.5 - 1.3	0.9 - 1.9
	Upstream of Diversion	Diversion	0.3 - 1.0	0.5 - 1.4	0.4 - 1.4	0.4 - 1.6	0.5 - 2.1	0.3 - 0.9	0.4 - 1.1	0.5 - 1.2	0.8 - 1.6
		Subsidence	0.0 - 1.3	0.0 - 1.7	0.0 - 2.0	0.1 - 2.3	0.1 - 2.4				
Little Sandy Creek	Downstream of Rocky Creek confluence	Baseline	0.3 - 1.0	0.4 - 1.5	0.5 - 1.4	0.6 - 1.7	0.7 - 1.8	0.4 - 1.1	0.6 - 1.4	0.6 - 1.5	1.1 - 2.5
	Diversion Reach	Diversion	0.5 - 0.6	0.7 - 0.9	0.7 - 1.0	0.8 - 1.1	0.9 - 1.3	0.5 - 0.8	0.5 - 1.0	0.5 - 1.1	0.6 - 2.0
		Subsidence	0.0 - 0.3	0.0 - 0.3	0.1 - 0.3	0.1 - 0.4	0.1 - 0.5				
Well Creek	Upstream of Middle Creek confluence	Baseline	0.6 - 1.4	0.9 - 1.7	1.1 - 2.2	1.1 - 2.6	1.4 - 2.9	0.7 - 1.5	0.9 - 2.1	1.0 - 2.2	1.3 - 3.1
		Diversion	0.6 - 1.4	0.9 - 1.7	1.1 - 2.2	1.1 - 2.5	1.4 - 2.9	0.7 - 1.6	0.9 - 2.0	0.9 - 2.1	1.2 - 3.0
		Subsidence	0.2 - 1.8	0.3 - 2.4	0.4 - 2.5	0.6 - 2.7	0.8 - 3.1				

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Appendix B - **Modelling Results – Summary Tables**

CREEK	LOCATION	SCENARIO	VELOCITY (m/s)								
			1:2 AEP	1:5 AEP	1:10 AEP	1:20 AEP	1:50 AEP	1:100 AEP	1:1000 AEP	1:2000 AEP	PMF
Well Creek	Little Sandy Creek confluence to Middle Creek confluence	Baseline	0.6 - 1.2	1.0 - 1.6	1.2 - 1.7	1.1 - 2.1	0.8 - 2.6	0.5 - 1.6	0.6 - 1.9	0.6 - 2.0	1.0 - 2.7
		Diversion	0.5 - 1.1	0.6 - 1.7	0.7 - 1.9	0.8 - 2.3	0.9 - 2.6	0.5 - 1.6	0.6 - 1.9	0.7 - 2.0	1.1 - 2.9
		Subsidence	0.1 - 1.4	0.2 - 1.7	0.4 - 2	0.4 - 2.0	0.7 - 2.5				
Well Creek	Downstream of Little Sandy Creek confluence	Baseline	0.3 - 1.2	0.7 - 1.5	1.0 - 1.6	1.2 - 1.7	1.3 - 2.0	0.8 - 1.0	1.0 - 1.1	1.0 - 1.2	1.2 - 1.5
		Diversion	0.3 - 1.3	0.7 - 1.5	1.0 - 1.6	1.4 - 1.7	1.4 - 2.1	0.7 - 1.0	0.8 - 1.2	0.9 - 1.3	1.3 - 2.4
		Subsidence	0.3 - 1.1	0.6 - 1.3	0.9 - 1.3	1.0 - 1.6	1.2 - 1.9				
Rocky Creek	Entire reach	Baseline	0.3 - 1.2	0.5 - 1.7	0.5 - 2.1	0.6 - 2.1	0.6 - 2.4	0.3 - 1.1	0.5 - 1.4	0.6 - 1.7	1.0 - 2.5
	Upstream of Diversion	Diversion	0.3 - 1.2	0.4 - 1.6	0.5 - 2.0	0.4 - 2.1	0.5 - 2.2	0.2 - 1.0	0.3 - 1.4	0.4 - 1.4	0.6 - 2.2
		Subsidence	0.0 - 1.4	0.0 - 1.7	0.0 - 2.0	0.0 - 2.2	0.1 - 2.6				
Middle Creek	Entire reach	Baseline	0.2 - 1.0	0.4 - 1.4	0.5 - 1.6	0.7 - 1.9	0.9 - 2.2	0.7 - 1.4	0.8 - 1.8	1.0 - 1.9	1.3 - 2.6
	Upstream of Diversion	Diversion	0.2 - 1.1	0.4 - 1.5	0.5 - 1.7	0.7 - 2.0	0.9 - 2.4	0.4 - 1.5	0.7 - 1.8	0.7 - 1.9	1.1 - 2.5
		Subsidence	0.0 - 1.2	0.1 - 1.6	0.2 - 2.0	0.2 - 2.1	0.3 - 2.3				

Appendix B - Modelling Results – Summary Tables

Table B-3 Comparison Summary of Bed Shear Stress Results (10-percentile to 90-percentile)

CREEK	LOCATION	SCENARIO	SHEAR STRESS (N/m^2)								
			1:2 AEP	1:5 AEP	1:10 AEP	1:20 AEP	1:50 AEP	1:100 AEP	1:1000 AEP	1:2000 AEP	PMF
Sandy Creek	Upstream of Greentree Creek confluence	Baseline	2.0 - 14	3.6 - 19	3.3 - 21	2.5 - 26	2.0 - 37	10 - 56	15 - 88	17 - 100	23 - 170
		Diversion	2.0 - 14	3.7 - 19	4 - 21	2.8 - 26	2.2 - 37	8.3 - 56	14 - 89	17 - 100	21 - 150
		Subsidence	2.1 - 14	3.7 - 19	4 - 22	2.8 - 25	2.2 - 36				
Sandy Creek	Well Creek confluence to Greentree Creek confluence	Baseline	2.5 - 18	7.7 - 24	11 - 29	15 - 39	21 - 52	34 - 83	27 - 95	28 - 100	34 - 150
		Diversion	2.8 - 17	7.4 - 25	12 - 29	16 - 36	21 - 51	34 - 83	33 - 116	34 - 120	62 - 220
		Subsidence	2.8 - 23	7.2 - 31	10 - 43	16 - 45	23 - 60				
Sandy Creek	Downstream of Well Creek confluence	Baseline	3.6 - 15	8.7 - 26	14 - 31	20 - 46	15 - 67	42 - 77	48 - 91	50 - 95	68 - 140
		Diversion	3.4 - 15	8.7 - 26	14 - 31	20 - 48	22 - 61	56 - 100	60 - 140	59 - 160	97 - 340
		Subsidence	3.4 - 15	8.7 - 26	12 - 38	19 - 42	17 - 67				
Little Sandy Creek	Upstream of Rocky Creek confluence	Baseline	2.4 - 24	4.4 - 38	3.8 - 44	3.9 - 47	4.3 - 67	4.4 - 86	11 - 78	14 - 73	27 - 110
	Upstream of Diversion	Diversion	2.0 - 23	3.8 - 41	2.9 - 38	3.6 - 46	4.3 - 72	5.3 - 72	9.1 - 57	11 - 65	21 - 78
		Subsidence	0.0 - 49	0.0 - 74	0.0 - 86	0.0 - 103	0.1 - 110				
Little Sandy Creek	Downstream of Rocky Creek confluence	Baseline	1.1 - 18	2.0 - 38	3.7 - 29	4.8 - 43	7.1 - 41	8.7 - 44	14 - 63	17 - 71	37 - 170
	Diversion Reach	Diversion	4.9 - 7.1	6.6 - 11	7.6 - 14	8.5 - 16	9.0 - 19	4.0 - 11	4.5 - 17	3.9 - 20	4.9 - 52
		Subsidence	0.0 - 2.9	0.0 - 2.2	0.0 - 2.0	0.1 - 3.0	0.2 - 4.3				
Well Creek	Upstream of Middle Creek confluence	Baseline	5.6 - 37	10 - 46	15 - 67	17 - 85	24 - 100	23 - 70	30 - 100	31 - 110	44 - 190
		Diversion	5.6 - 37	10 - 46	14 - 65	17 - 84	24 - 98	21 - 73	29 - 100	31 - 110	42 - 180
		Subsidence	0.9 - 71	1.3 - 97	2.0 - 100	4.2 - 120	7.4 - 130				

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Appendix B - Modelling Results – Summary Tables

CREEK	LOCATION	SCENARIO	SHEAR STRESS (N/m²)								
			1:2 AEP	1:5 AEP	1:10 AEP	1:20 AEP	1:50 AEP	1:100 AEP	1:1000 AEP	1:2000 AEP	PMF
Well Creek	Little Sandy Creek confluence to Middle Creek confluence	Baseline	5.5 - 26	12 - 38	18 - 36	17 - 53	9.0 - 77	14 - 91	15 - 120	17 - 130	31 - 220
		Diversion	4.9 - 22	5.0 - 39	6.8 - 49	9.7 - 62	11 - 74	12 - 82	15 - 113	17 - 124	34 - 230
		Subsidence	0.3 - 35	0.7 - 44	1.6 - 55	2.1 - 47	5.6 - 84				
Well Creek	Downstream of Little Sandy Creek confluence	Baseline	1.6 - 28	6.4 - 36	10.7 - 34	15 - 33	22 - 42	25 - 36	31 - 42	31 - 44	38 - 57
		Diversion	1.5 - 34	5.9 - 40	12 - 35	22 - 33	24 - 45	18 - 30	21 - 43	23 - 48	38 - 130
		Subsidence	1.3 - 27	5.0 - 28	9.9 - 25	13 - 30	17 - 41				
Rocky Creek	Entire reach	Baseline	1.8 - 35	4.4 - 56	3.9 - 76	6.3 - 76	6.4 - 81	9.1 - 290	15 - 150	18 - 150	33 - 170
	Upstream of Diversion	Diversion	1.6 - 32	4.0 - 51	4.0 - 73	4.7 - 73	4.3 - 67	4.7 - 110	8.4 - 95	9.4 - 110	13 - 120
		Subsidence	0.0 - 53	0.0 - 73	0.0 - 80	0.0 - 99	0.1 - 120				
Middle Creek	Entire reach	Baseline	1.3 - 27	3.3 - 35	5.4 - 48	8.2 - 58	12 - 66	19 - 180	30 - 190	33 - 180	48 - 170
	Upstream of Diversion	Diversion	1.4 - 28	3.2 - 44	5.4 - 50	8.7 - 59	12 - 73	11 - 150	21 - 130	21 - 170	41 - 170
		Subsidence	0.0 - 36	0.2 - 57	0.4 - 78	0.8 - 89	1.4 - 98				

Table notes: All values rounded to two significant figures

Appendix B - Modelling Results – Summary Tables

Table B-4 Comparison Summary of Maximum Channel Water Depth Results (10-percentile to 90-percentile)

CREEK	LOCATION	SCENARIO	FLOW DEPTH (m)								
			1:2 AEP	1:5 AEP	1:10 AEP	1:20 AEP	1:50 AEP	1:100 AEP	1:1000 AEP	1:2000 AEP	PMF
Sandy Creek	Upstream of Greentree Creek confluence	Baseline	1.6 - 2.4	2.5 - 3.3	3.1 - 4.0	3.7 - 4.7	4.6 - 5.7	4.9 - 6.6	5.8 - 8.0	6.2 - 8.5	9.0 - 11.8
		Diversion	1.6 - 2.4	2.5 - 3.3	3.2 - 4.0	3.7 - 4.7	4.6 - 5.7	5.0 - 6.7	5.9 - 8.0	6.2 - 8.5	10.8- 2.3
		Subsidence	1.6 - 2.4	2.5 - 3.3	3.2 - 4.0	3.7 - 4.7	4.7 - 5.7				
Sandy Creek	Well Creek confluence to Greentree Creek confluence	Baseline	1.1 - 2.0	1.8 - 2.9	2.5 - 3.5	3.1 - 4.2	3.7 - 5.0	3.7 - 5.9	4.1 - 6.4	4.4 - 6.6	7.3 - 9.4
		Diversion	1.1 - 2.0	1.9 - 2.9	2.5 - 3.6	3.1 - 4.2	3.8 - 5.1	4.6 - 6.7	5.7 - 8.1	6.2 - 8.6	11.6-13.9
		Subsidence	1.1 - 2.0	1.9 - 3.2	2.5 - 4.0	3.1 - 4.6	3.9 - 5.1				
Sandy Creek	Downstream of Well Creek confluence	Baseline	1.4 - 2.2	2.3 - 3.2	3.0 - 3.9	3.7 - 4.7	4.2 - 5.4	5.0 - 6.3	5.8 - 7.1	6.0 - 7.4	9.6 - 11.0
		Diversion	1.4 - 2.2	2.3 - 3.2	3.0 - 4.0	3.6 - 4.8	4.1 - 5.4	5.0 - 6.7	5.9 - 8.0	6.2 - 8.5	10.1-13.5
		Subsidence	1.4 - 2.2	2.3 - 3.2	3.1 - 4.0	3.8 - 4.8	4.4 - 5.5				
Little Sandy Creek	Upstream of Rocky Creek confluence	Baseline	0.6 - 1.3	1.0 - 2.0	0.8 - 2.3	1.1 - 2.5	1.3 - 2.7	0.6 - 1.9	0.8 - 2.4	0.9 - 2.6	1.4 - 3.8
	Upstream of Diversion	Diversion	0.5 - 1.1	0.9 - 1.7	0.7 - 1.9	0.9 - 2.1	1.3 - 2.5	0.5 - 1.6	0.7 - 1.8	0.7 - 1.9	1.2 - 2.8
		Subsidence	0.3 - 1.9	0.5 - 2.3	0.7 - 2.6	0.8 - 2.8	0.9 - 3.0				
Little Sandy Creek	Downstream of Rocky Creek confluence	Baseline	0.9 - 2.0	1.6 - 2.8	1.7 - 3.3	1.9 - 3.8	2.3 - 4.3	1.3 - 4.5	1.7 - 5.3	1.8 - 5.6	3.4 - 8.6
	Diversion Reach	Diversion	0.9 - 1.3	1.8 - 2.4	2.2 - 2.8	2.5 - 3.1	2.9 - 3.6	2.4 - 4.1	3.1 - 5.3	3.4 - 5.7	6.3 - 8.6
		Subsidence	1.1 - 2.8	2.0 - 3.7	2.4 - 4.0	2.6 - 4.3	2.9 - 4.6				
Well Creek	Upstream of Middle Creek confluence	Baseline	0.8 - 1.7	1.6 - 2.6	2.1 - 3.2	2.5 - 3.7	2.9 - 4.2	2.3 - 3.6	3.1 - 4.8	3.2 - 5.0	4.8 - 7.5
		Diversion	0.8 - 1.7	1.6 - 2.6	2.1 - 3.2	2.5 - 3.7	2.9 - 4.2	2.4 - 3.7	3.1 - 4.8	3.2 - 5.1	4.7 - 7.4
		Subsidence	0.7 - 2.0	1.3 - 2.8	1.8 - 3.3	2.1 - 3.6	2.5 - 4.2				

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Appendix B - Modelling Results – Summary Tables

CREEK	LOCATION	SCENARIO	FLOW DEPTH (m)								
			1:2 AEP	1:5 AEP	1:10 AEP	1:20 AEP	1:50 AEP	1:100 AEP	1:1000 AEP	1:2000 AEP	PMF
Well Creek	Little Sandy Creek confluence to Middle Creek confluence	Baseline	0.9 - 1.5	1.8 - 2.4	2.3 - 2.8	2.4 - 3.2	2.5 - 3.9	2.3 - 4.2	2.5 - 5.0	2.7 - 5.2	4.6 - 7.1
		Diversion	0.9 - 1.4	1.8 - 2.4	2.3 - 2.9	2.6 - 3.4	2.9 - 4.0	2.8 - 4.6	3.6 - 5.6	3.8 - 6.0	7.8 - 11.1
		Subsidence	1.0 - 2.4	1.9 - 3.2	2.2 - 3.9	2.5 - 4.3	2.8 - 4.7				
Well Creek	Downstream of Little Sandy Creek confluence	Baseline	1.0 - 2.4	1.9 - 3.2	2.5 - 3.8	3.0 - 4.5	3.4 - 5.0	4.0 - 4.9	4.7 - 5.7	5.0 - 5.9	8.0 - 9.3
		Diversion	1.0 - 2.4	1.8 - 3.2	2.4 - 3.8	2.9 - 4.5	3.5 - 5.1	4.7 - 6.0	6.2 - 7.4	6.7 - 7.9	12.4-13.5
		Subsidence	1.0 - 2.3	2.0 - 3.2	2.5 - 3.8	2.9 - 4.5	3.5 - 5.1				
Rocky Creek	Entire reach	Baseline	0.1 - 1.3	0.4 - 2.0	0.3 - 2.4	0.5 - 2.7	0.8 - 3.0	0.3 - 2.5	0.5 - 3.1	0.6 - 3.5	1.1 - 4.8
	Upstream of Diversion	Diversion	0.0 - 1.1	0.7 - 1.8	0.0 - 2.3	0.0 - 2.5	0.3 - 3.0	0.3 - 2.4	0.4 - 3.1	0.4 - 3.2	0.7 - 5.2
		Subsidence	0.2 - 2.1	0.5 - 2.6	0.4 - 2.8	0.4 - 3.0	0.4 - 3.4				
Middle Creek	Entire reach	Baseline	0.3 - 1.3	0.4 - 2.0	0.5 - 2.3	0.7 - 2.7	0.9 - 3.2	1.1 - 2.7	1.5 - 3.4	1.8 - 3.8	2.8 - 5.4
	Upstream of Diversion	Diversion	0.3 - 1.5	0.4 - 2.3	0.6 - 2.8	0.7 - 3.2	0.9 - 3.7	0.3 – 1.5	1.1 - 4.7	1.1 - 5.0	1.8 - 7.2
		Subsidence	0.2 - 2.2	0.4 - 2.8	0.5 - 3.2	0.6 - 3.6	0.8 - 4.2				

C

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Figure Appendix C-1 Comparison of Channel Stream Power along Proposed Diversion for a 1:5 AEP Event

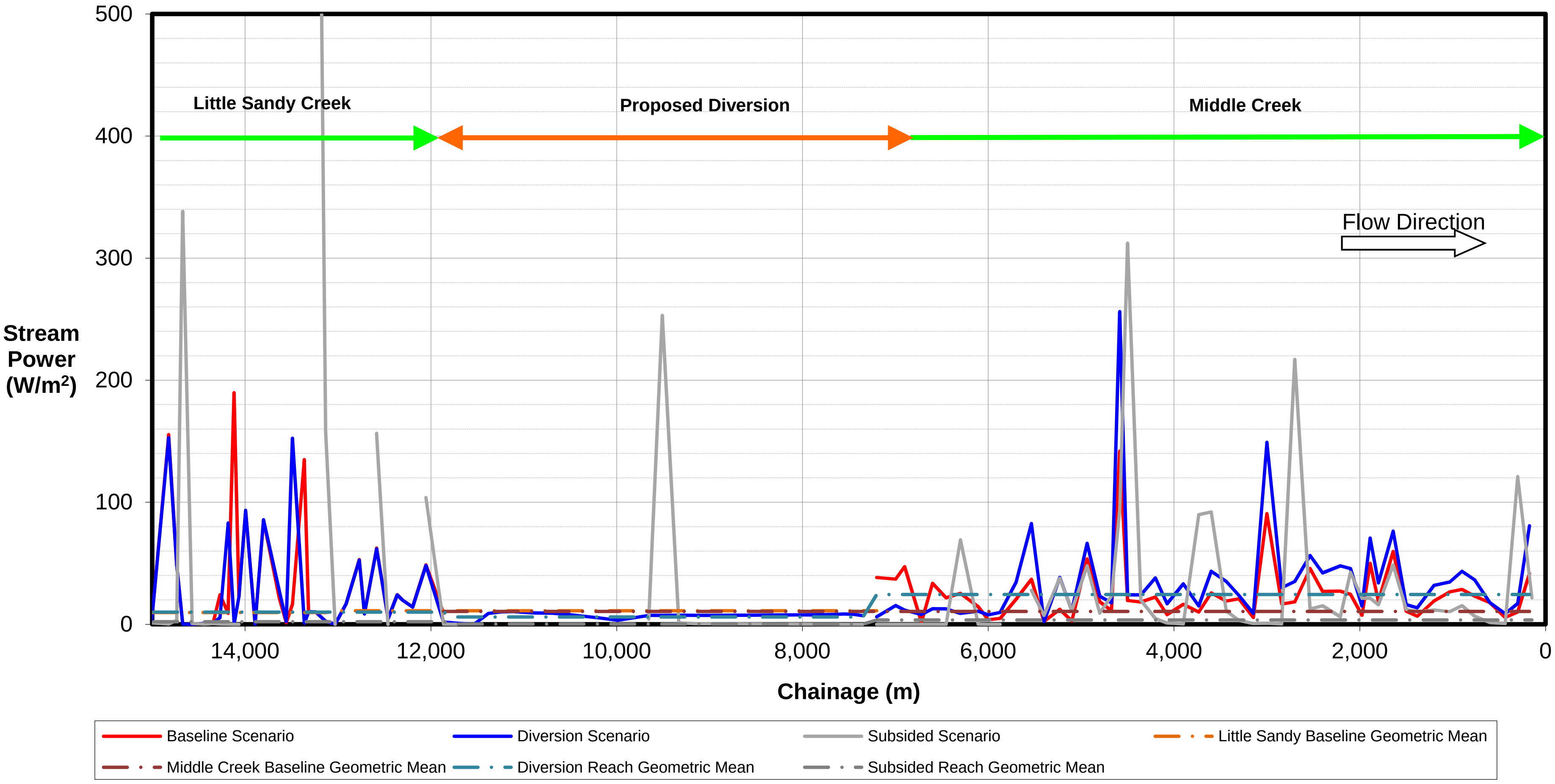

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Figure Appendix C-2 Comparison of Channel Stream Power along Proposed Diversion for a 1:10 AEP Event

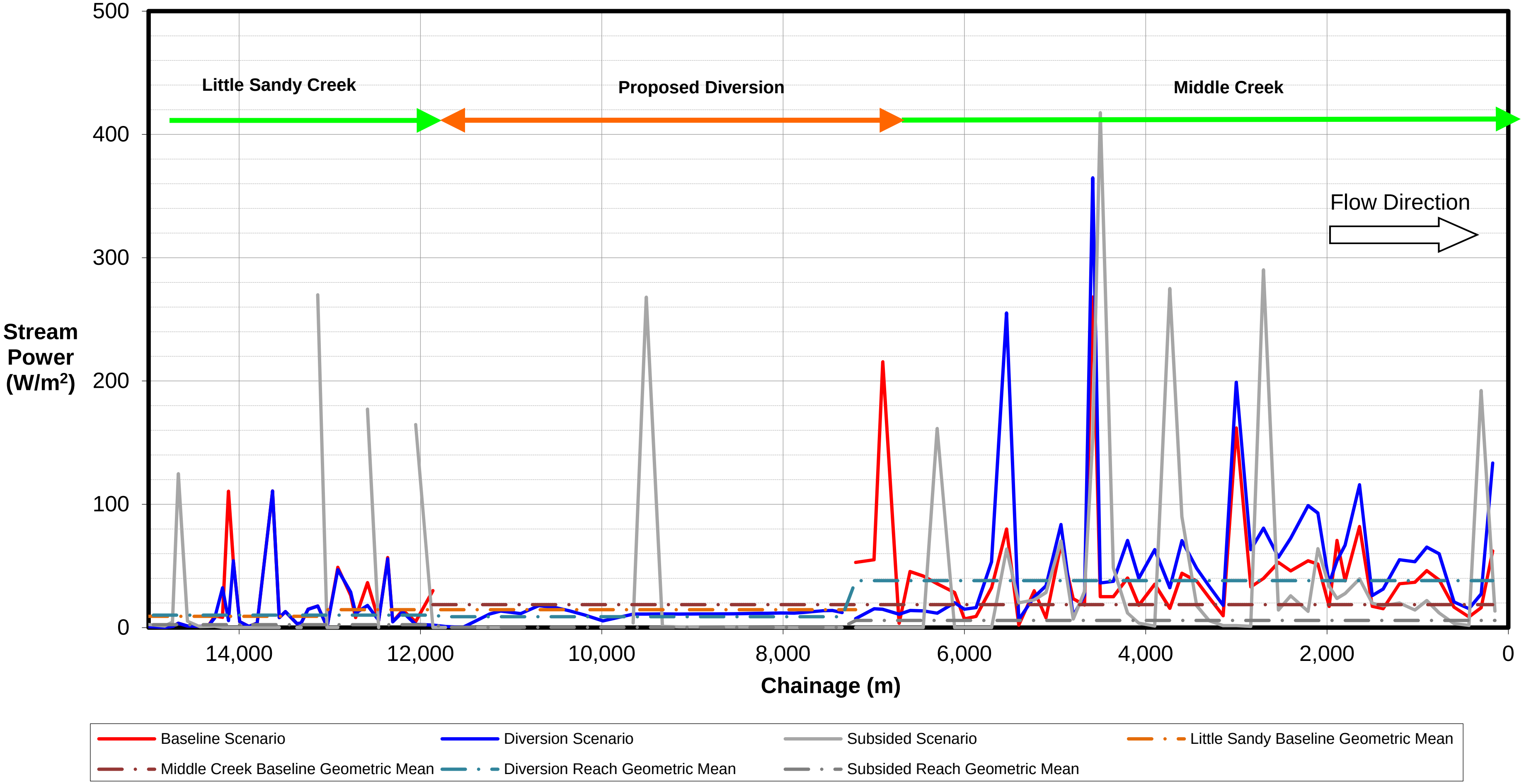

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Figure Appendix C-3 Comparison of Channel Stream Power along Proposed Diversion for a 1:20 AEP Event

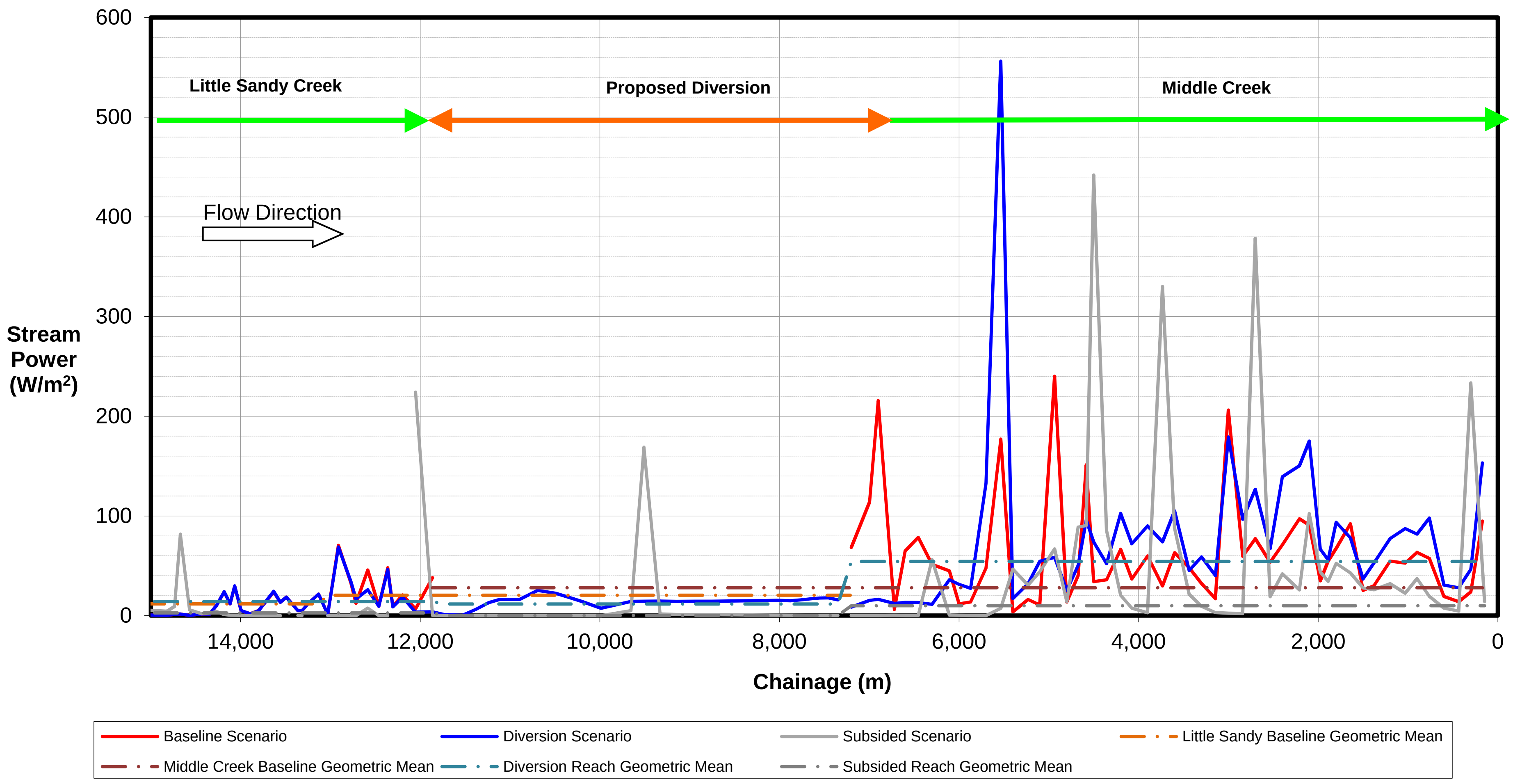

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Figure Appendix C-4 Comparison of Channel Stream Power along Proposed Diversion for a 1:100 AEP Event

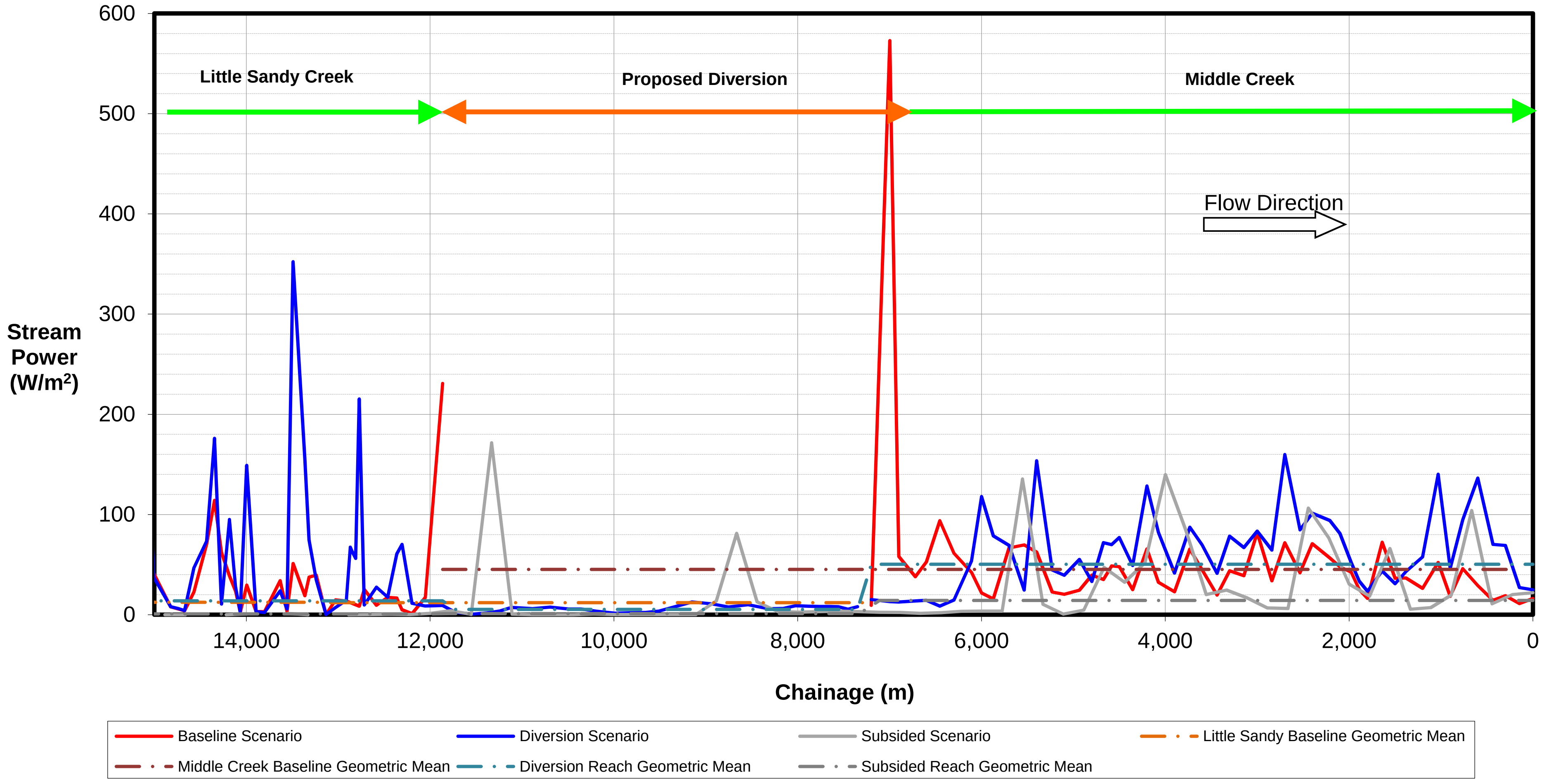

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Figure Appendix C-5 Comparison of Channel Stream Power along Proposed Diversion for a 1:1000 AEP Event

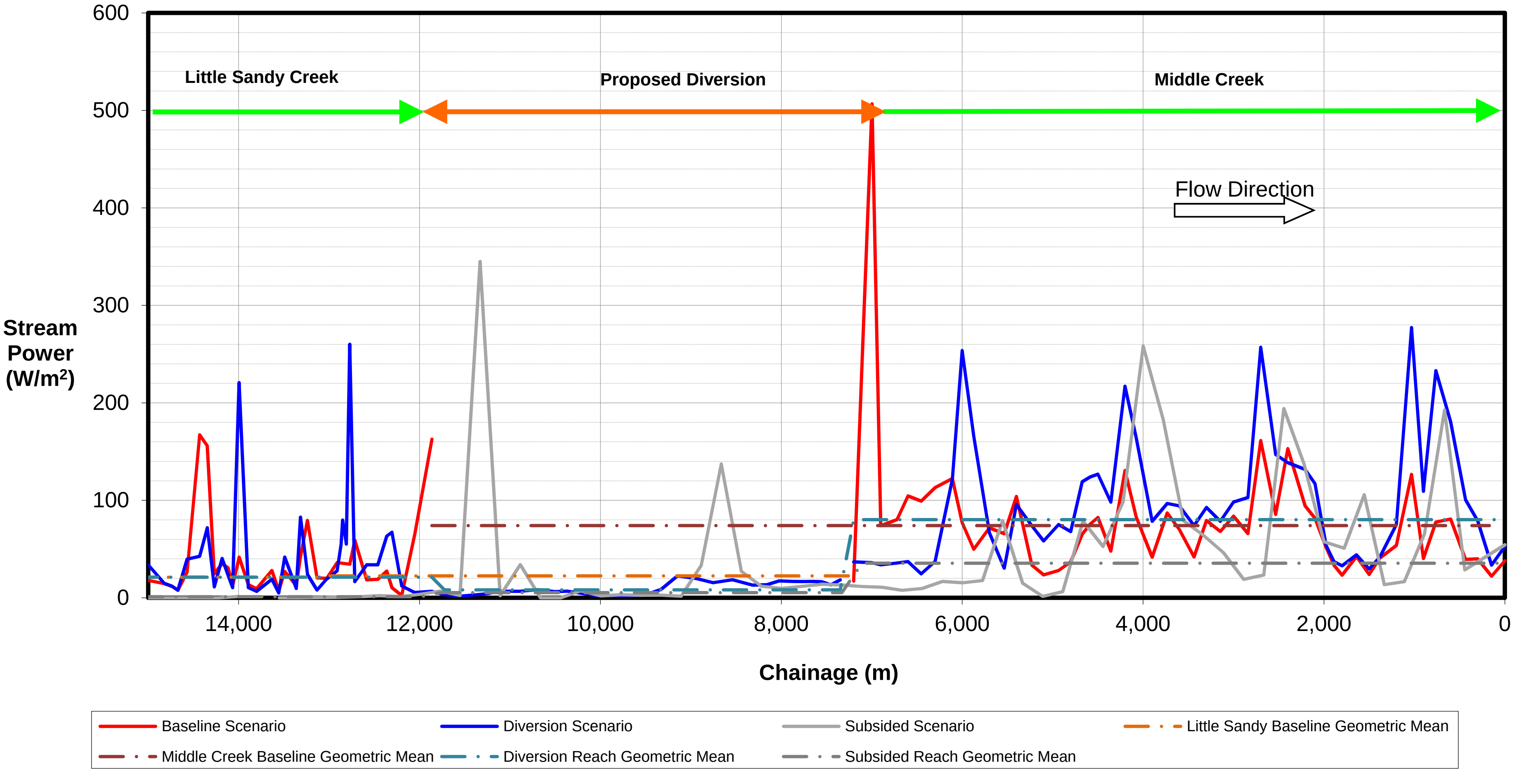

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Figure Appendix C-6 Comparison of Channel Stream Power along Proposed Diversion for a 1:2000 AEP Event

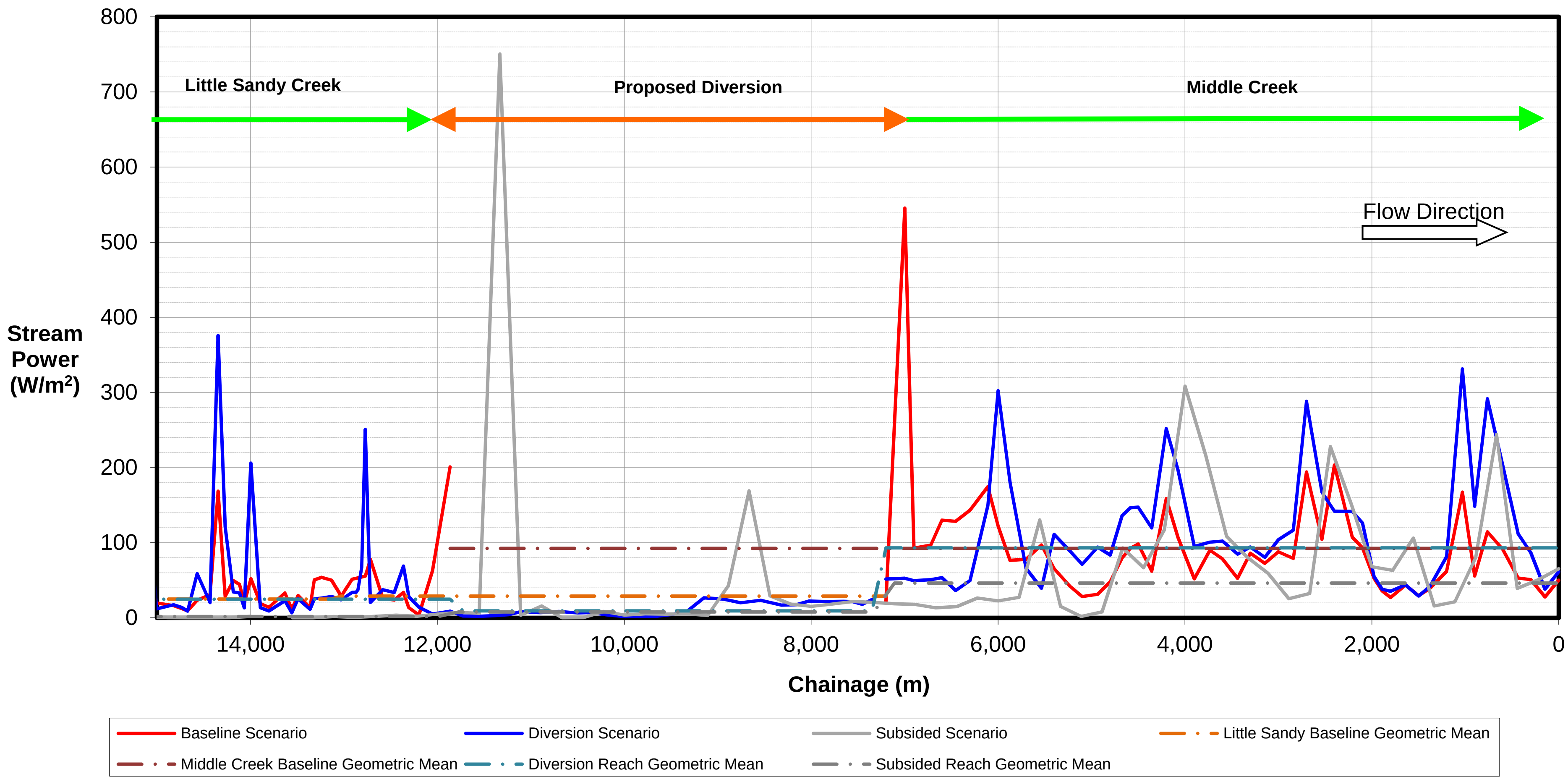

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Figure Appendix C-7 Comparison of Channel Stream Power along Proposed Diversion for a PMF Event

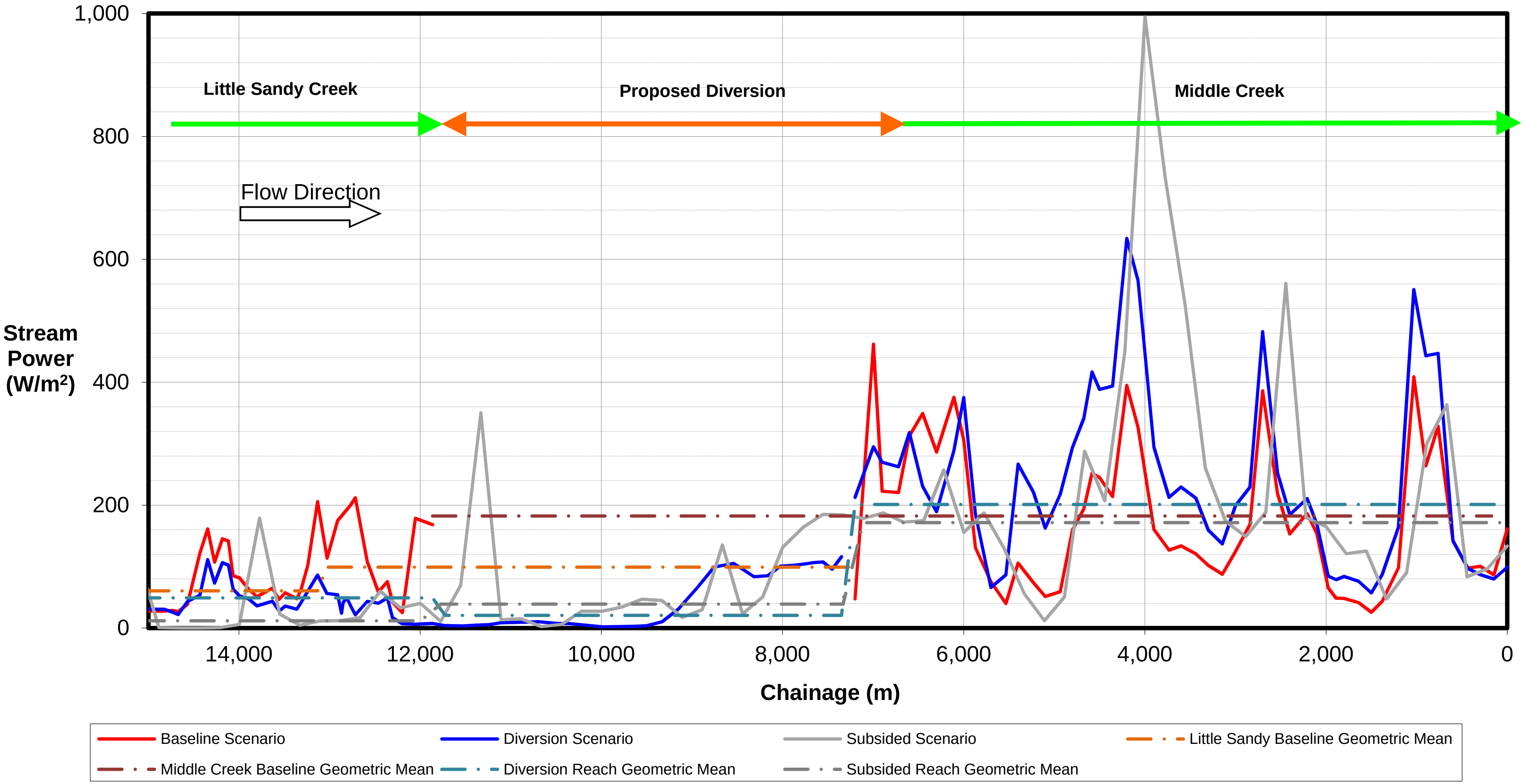

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Figure Appendix C-8 Comparison of Channel Velocity along Proposed Diversion for a 1:5 AEP Event

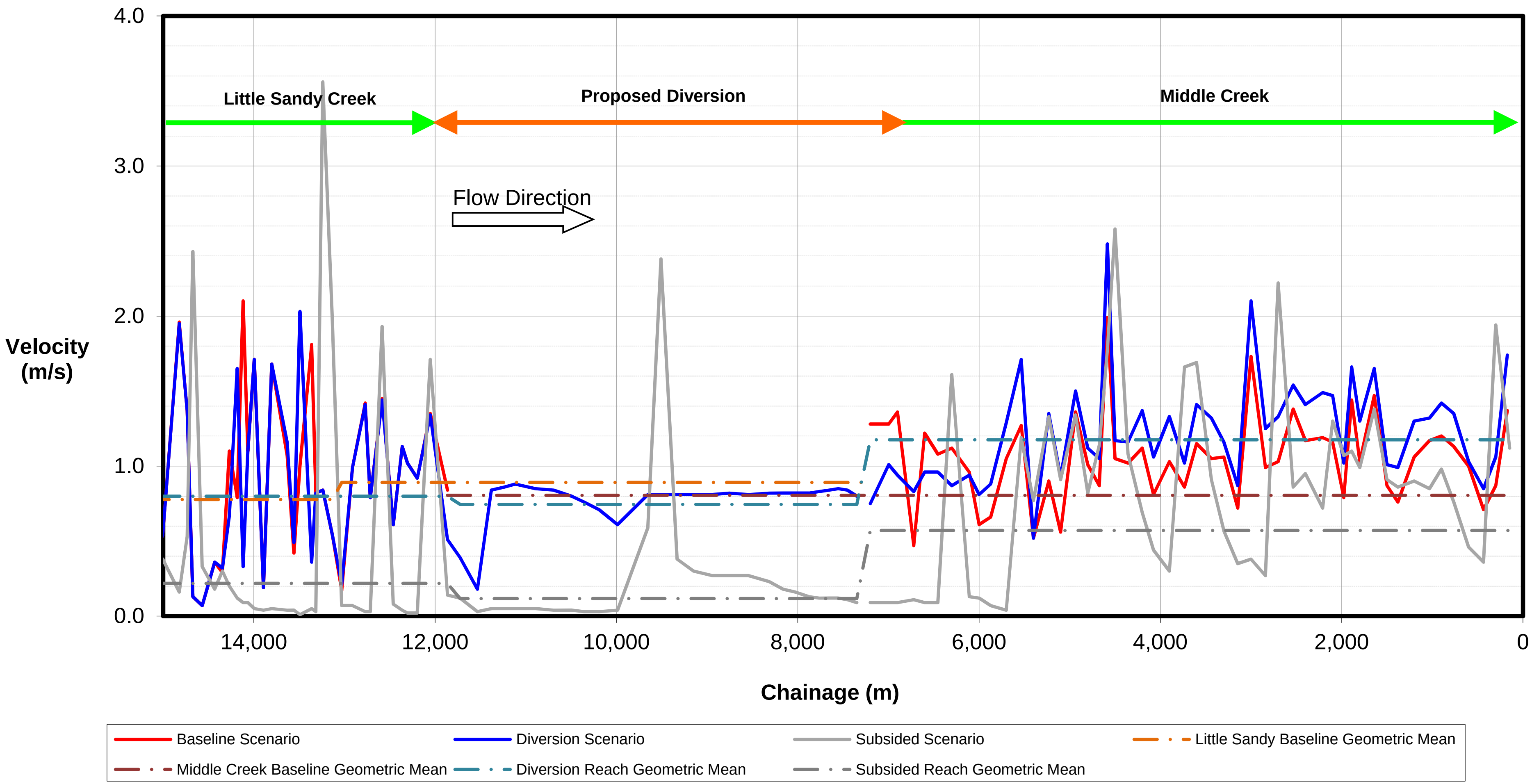

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Figure Appendix C-9 Comparison of Channel Velocity along Proposed Diversion for a 1:10 AEP Event

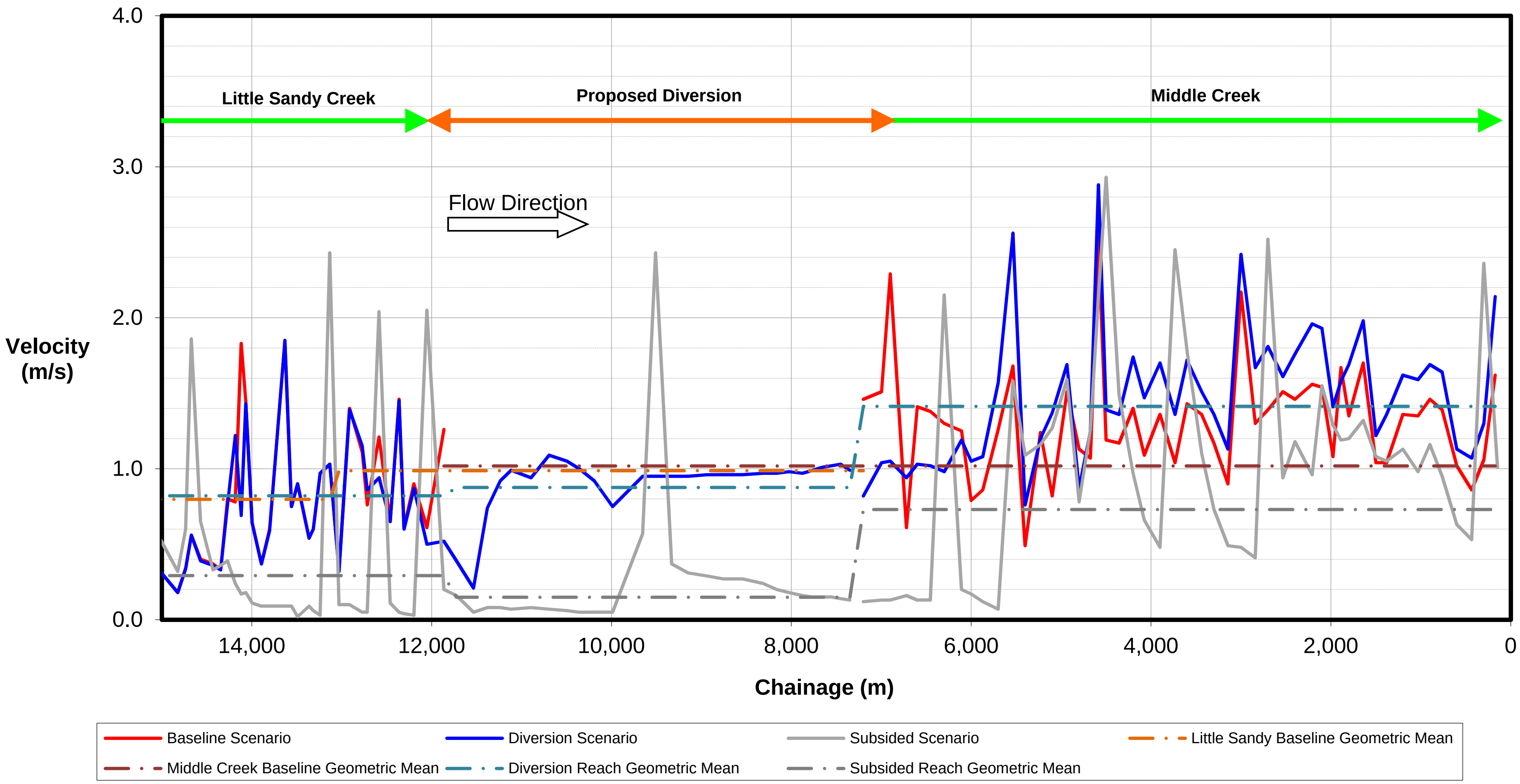

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Figure Appendix C-10 Comparison of Channel Velocity along Proposed Diversion for a 1:20 AEP Event

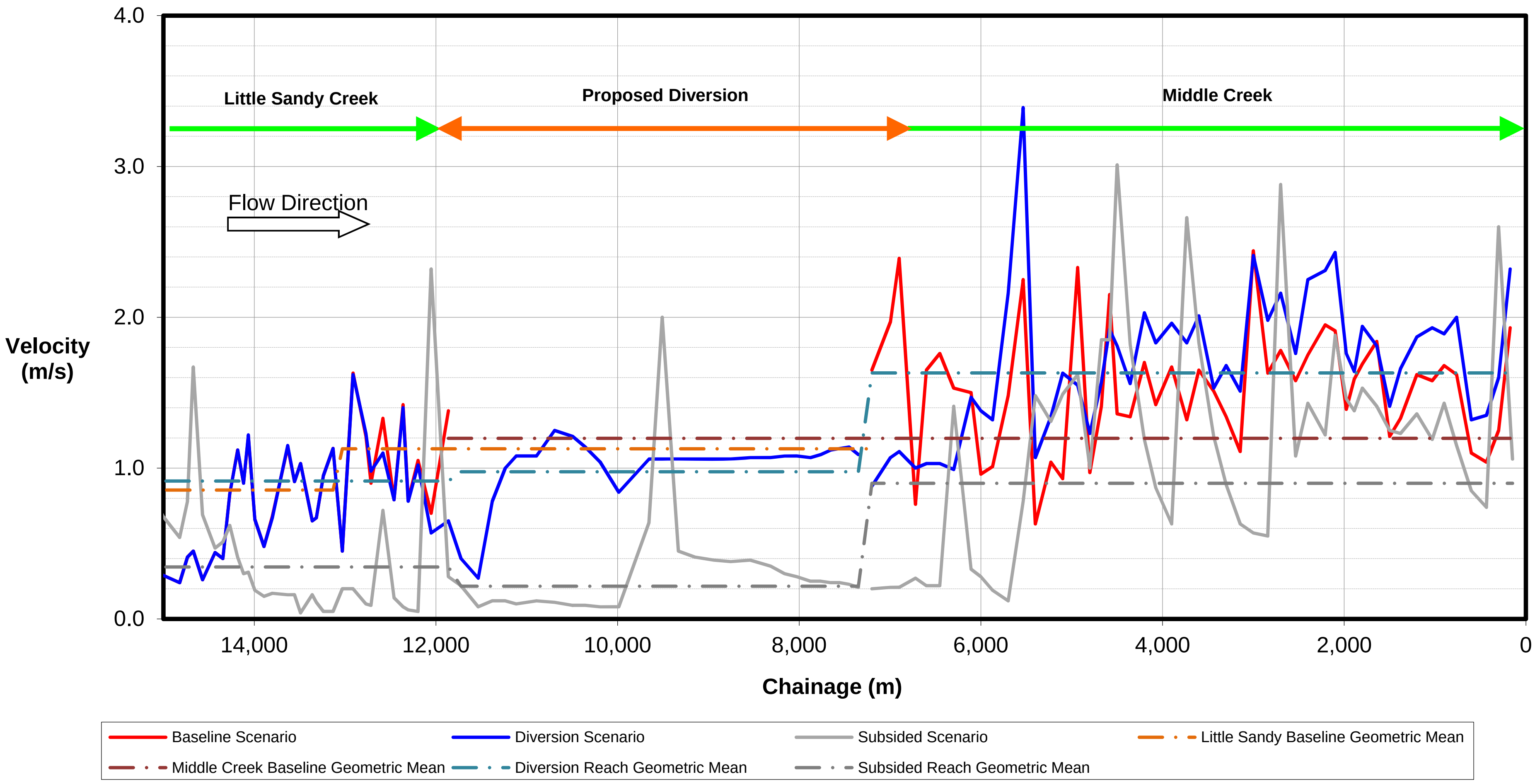

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Figure Appendix C-11 Comparison of Channel Velocity along Proposed Diversion for a 1:100 AEP Event

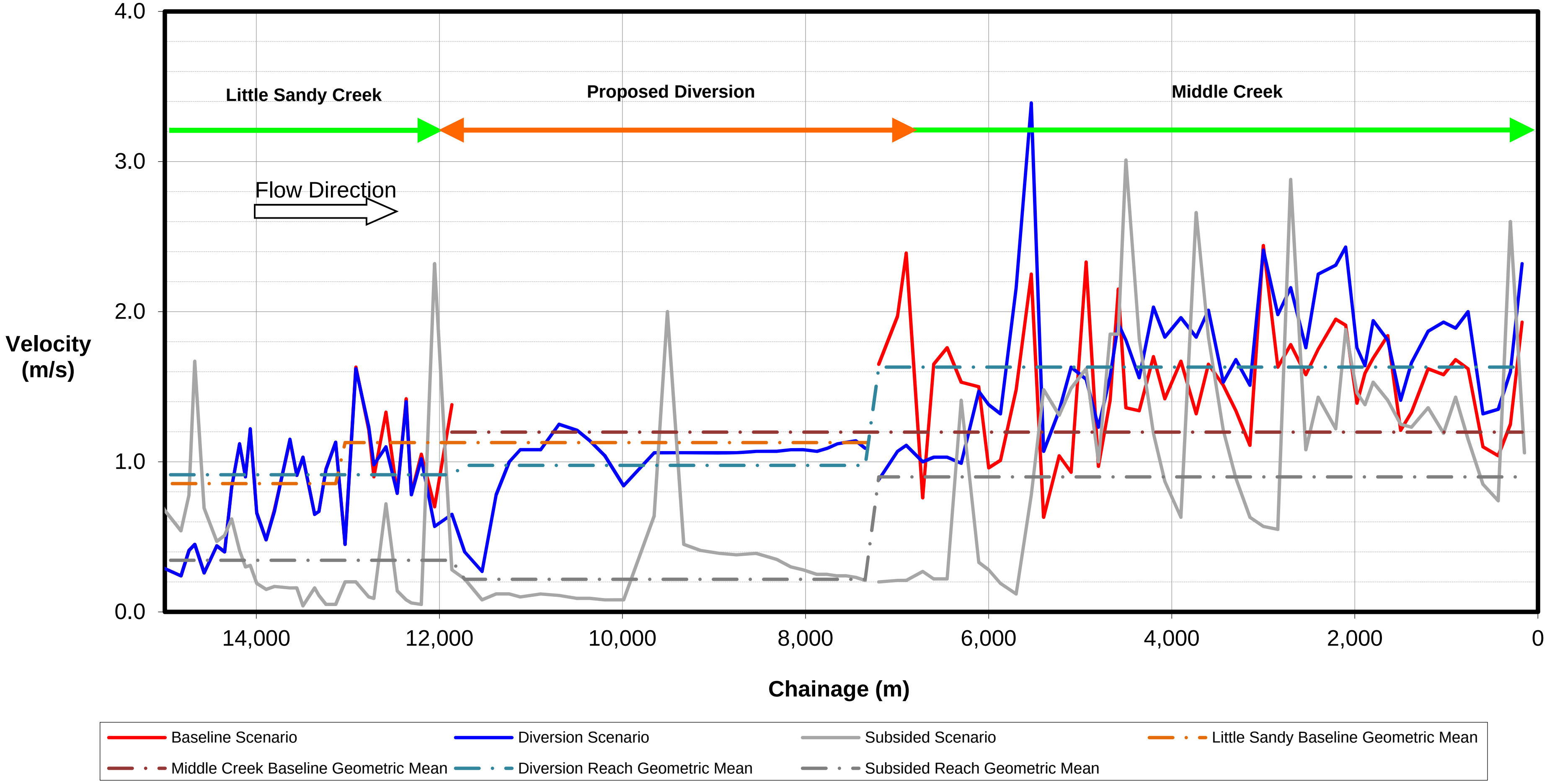

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Figure Appendix C-12 Comparison of Channel Velocity along Proposed Diversion for a 1:1000 AEP Event

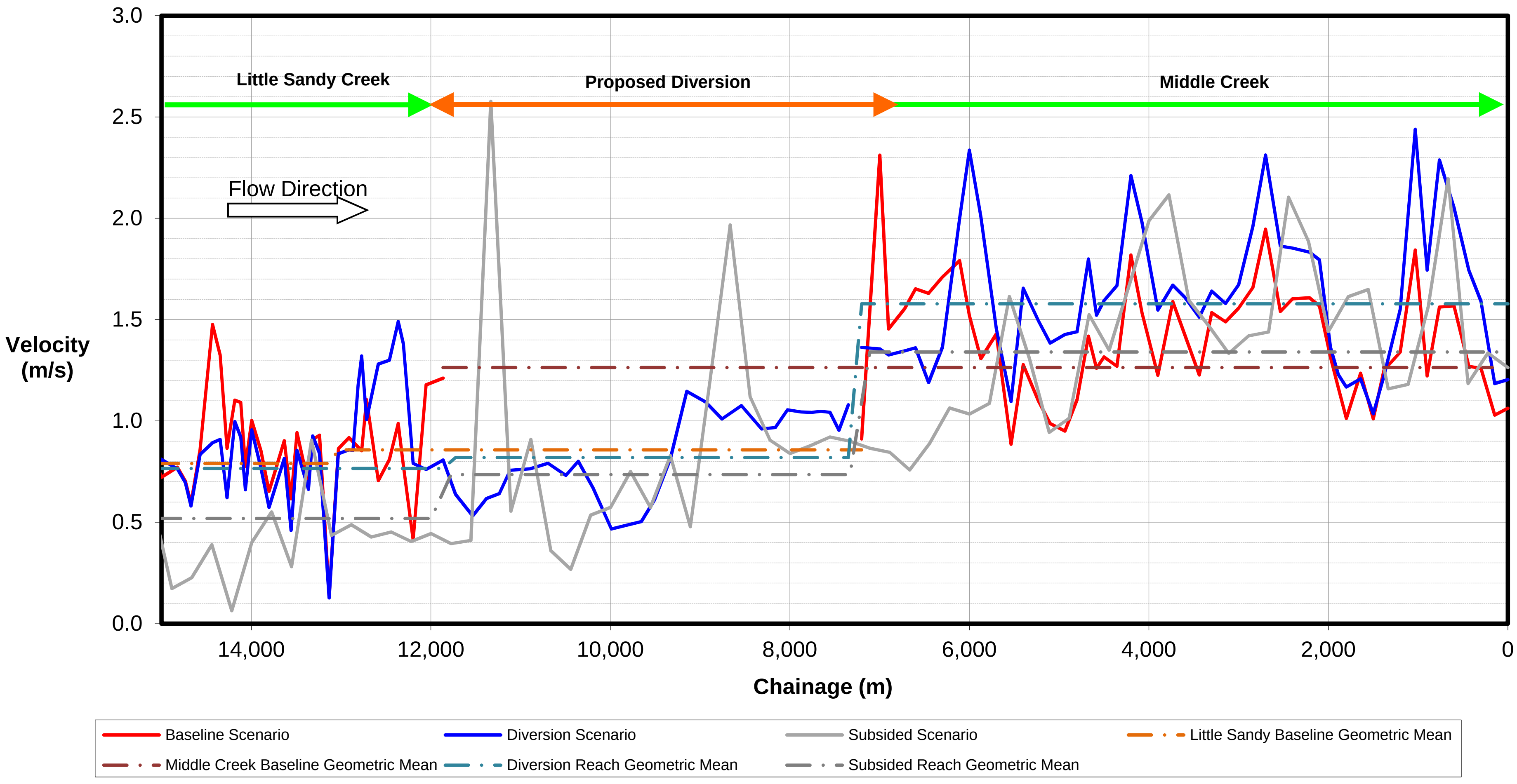

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Figure Appendix C-13 Comparison of Channel Velocity along Proposed Diversion for a 1:2000 AEP Event

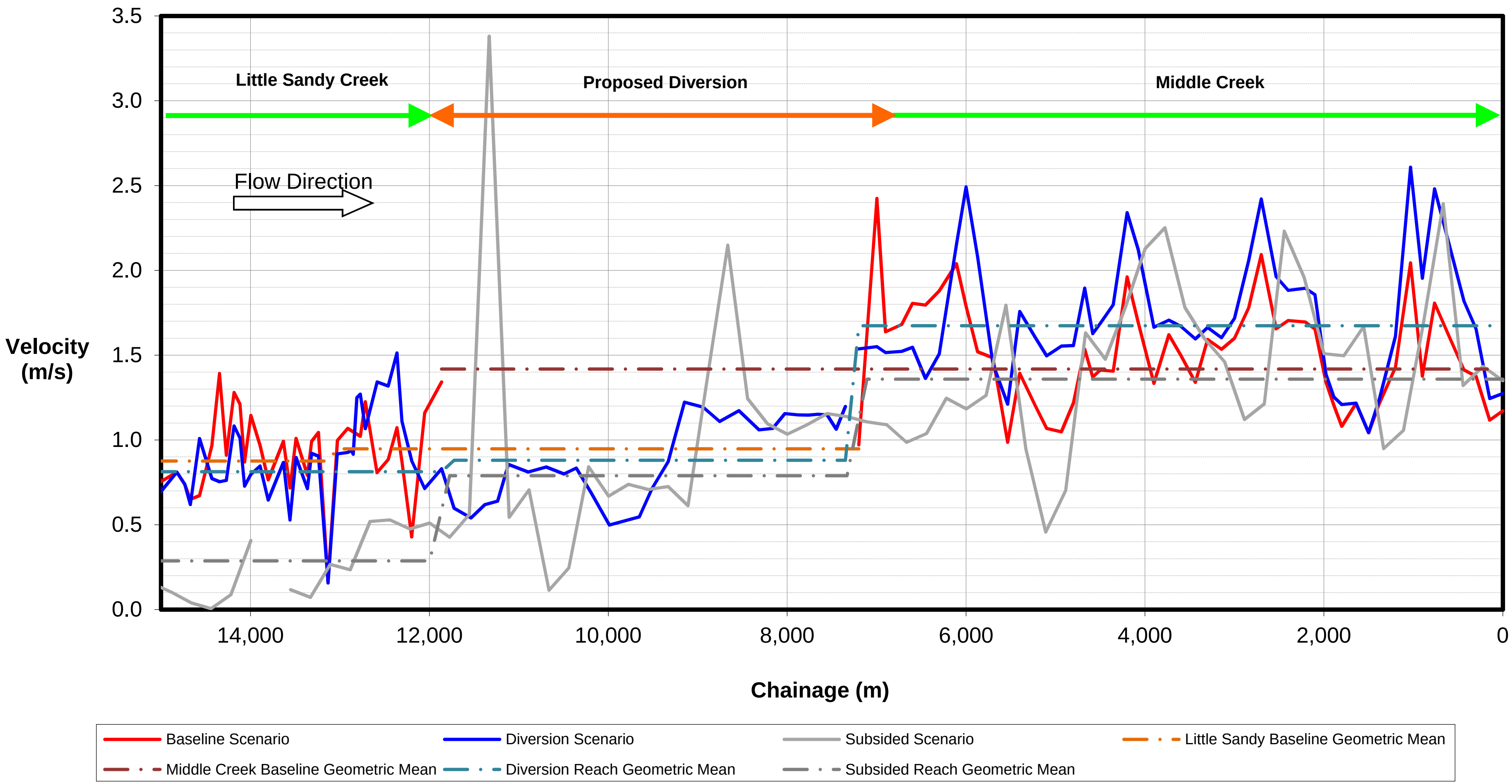

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Figure Appendix C-14 Comparison of Channel Velocity along Proposed Diversion for a PMF Event

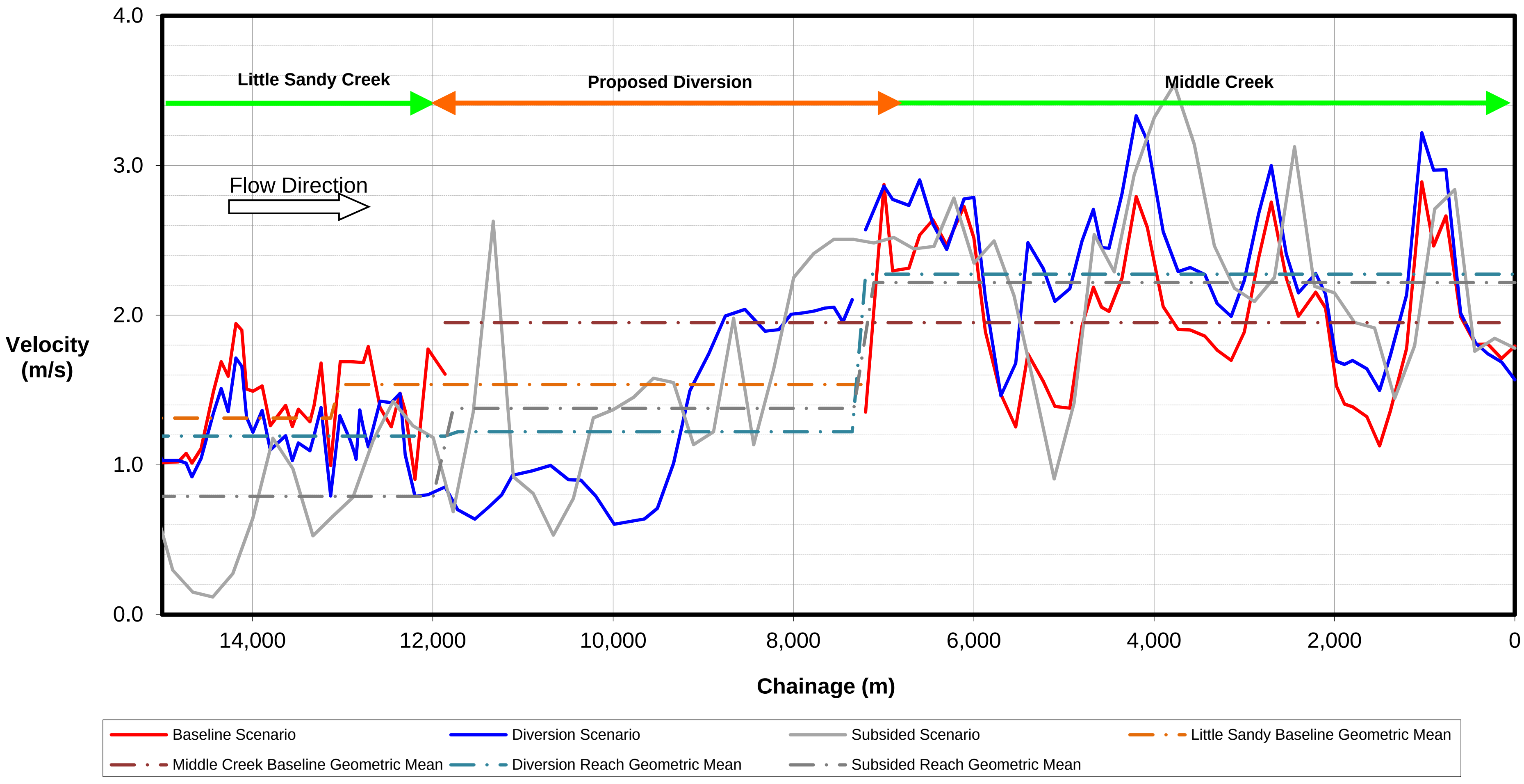

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Figure Appendix C-15 Comparison of Bed Shear Stress along Proposed Diversion for a 1:5 AEP Event

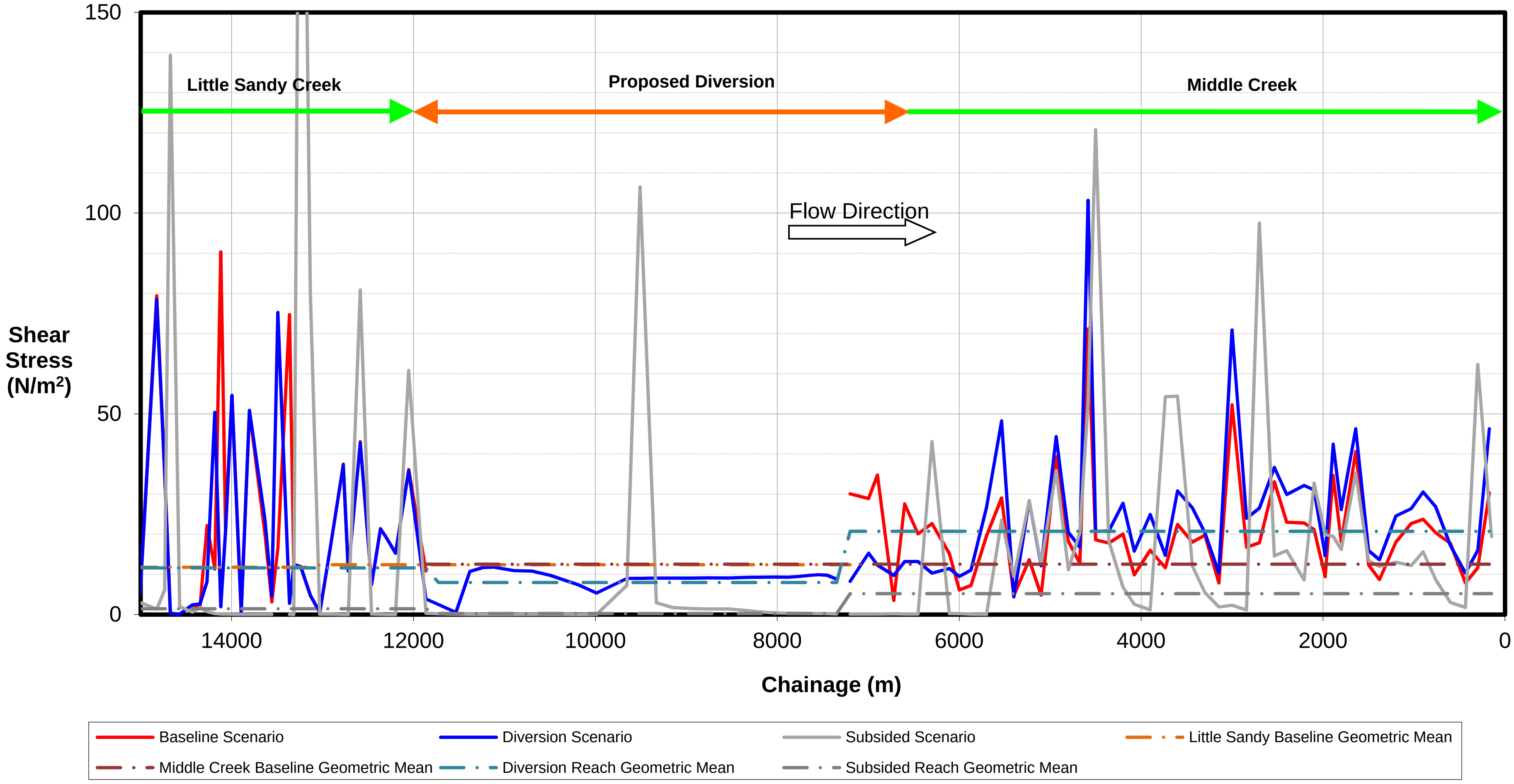

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Figure Appendix C-16 Comparison of Bed Shear Stress along Proposed Diversion for a 1:10 AEP Event

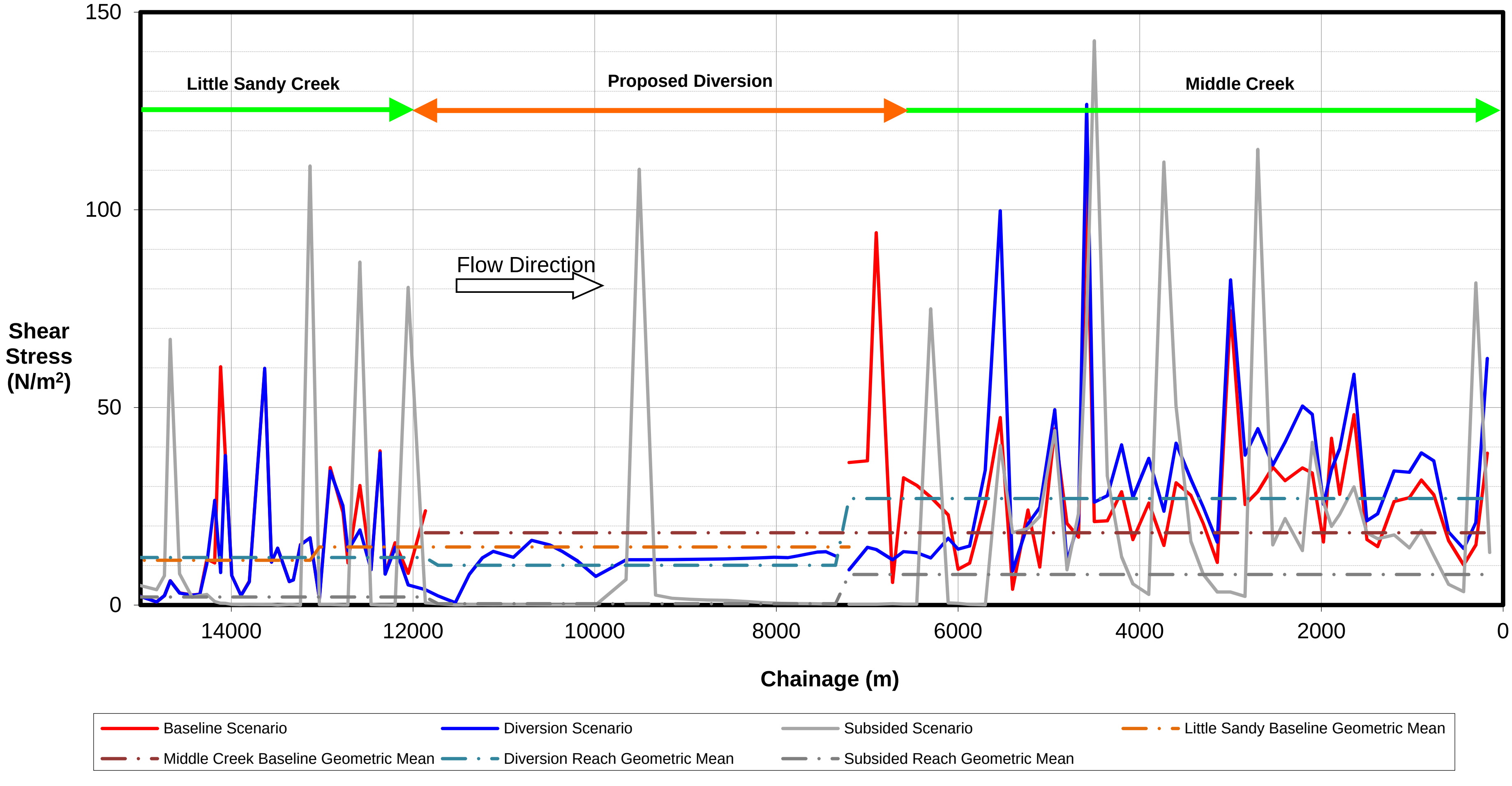

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Figure Appendix C-17 Comparison of Bed Shear Stress along Proposed Diversion for a 1:20 AEP Event

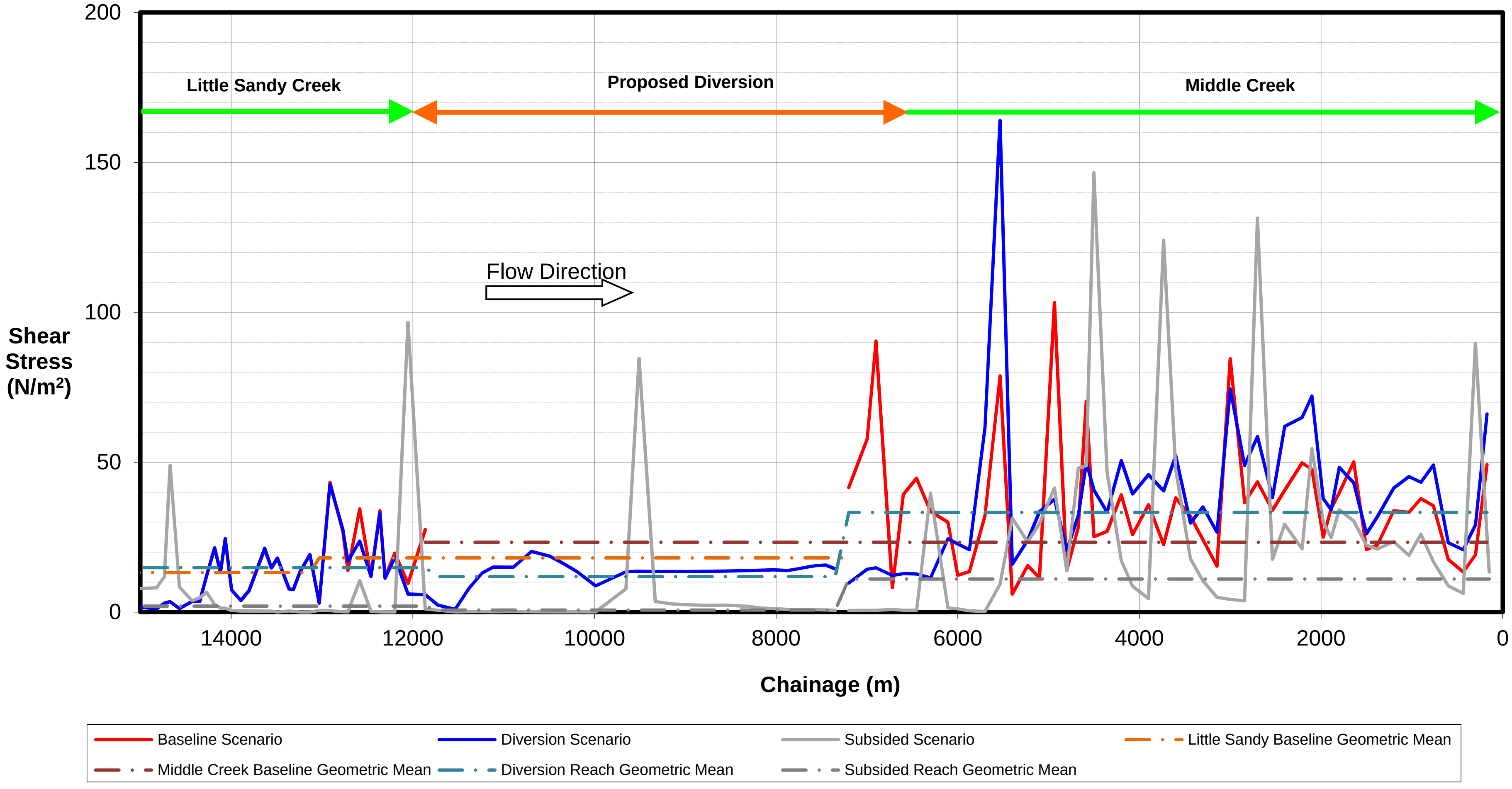

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Figure Appendix C-18 Comparison of Bed Shear Stress along Proposed Diversion for a 1:100 AEP Event

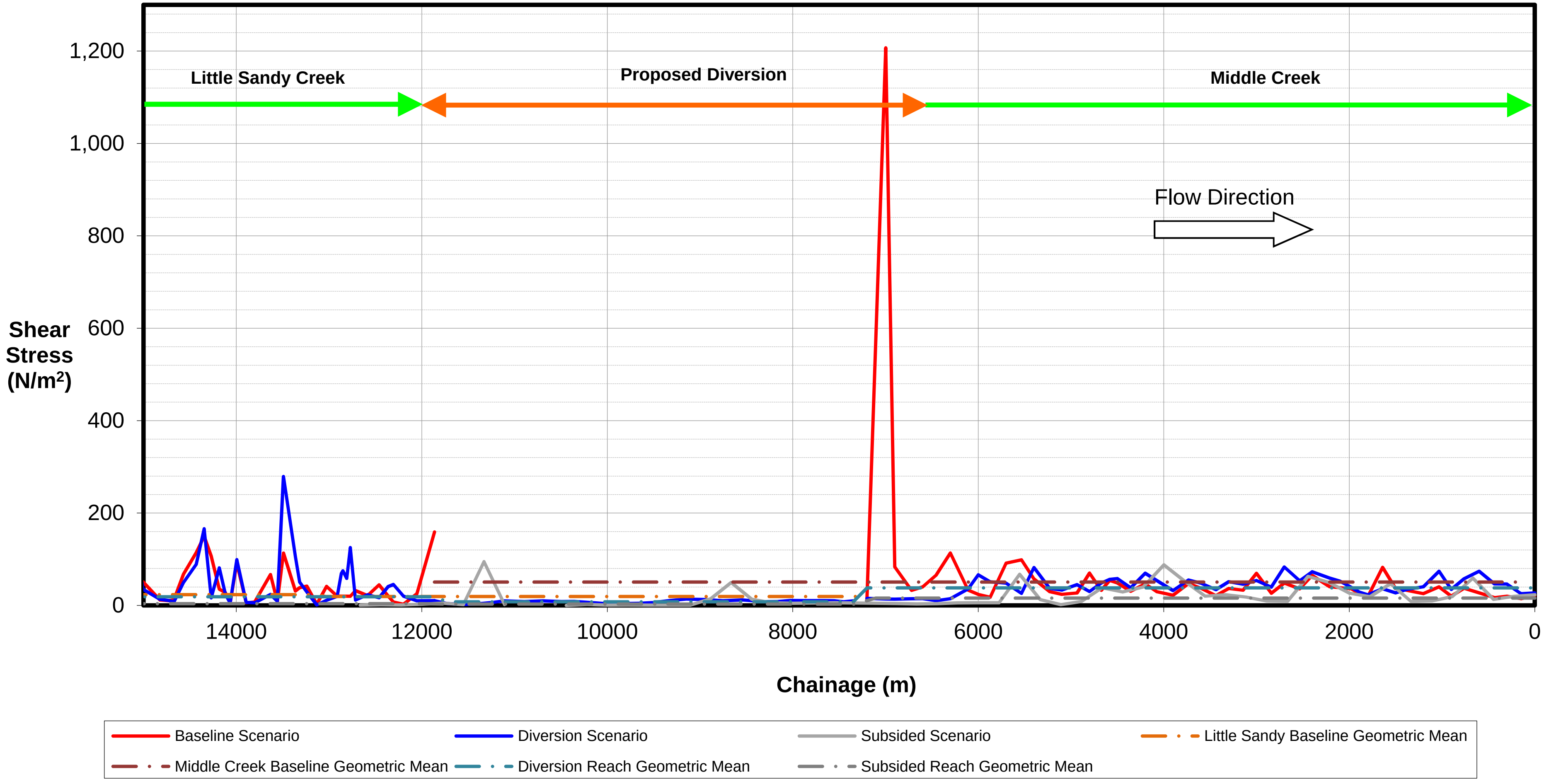

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Figure Appendix C-19 Comparison of Bed Shear Stress along Proposed Diversion for a 1:1000 AEP Event

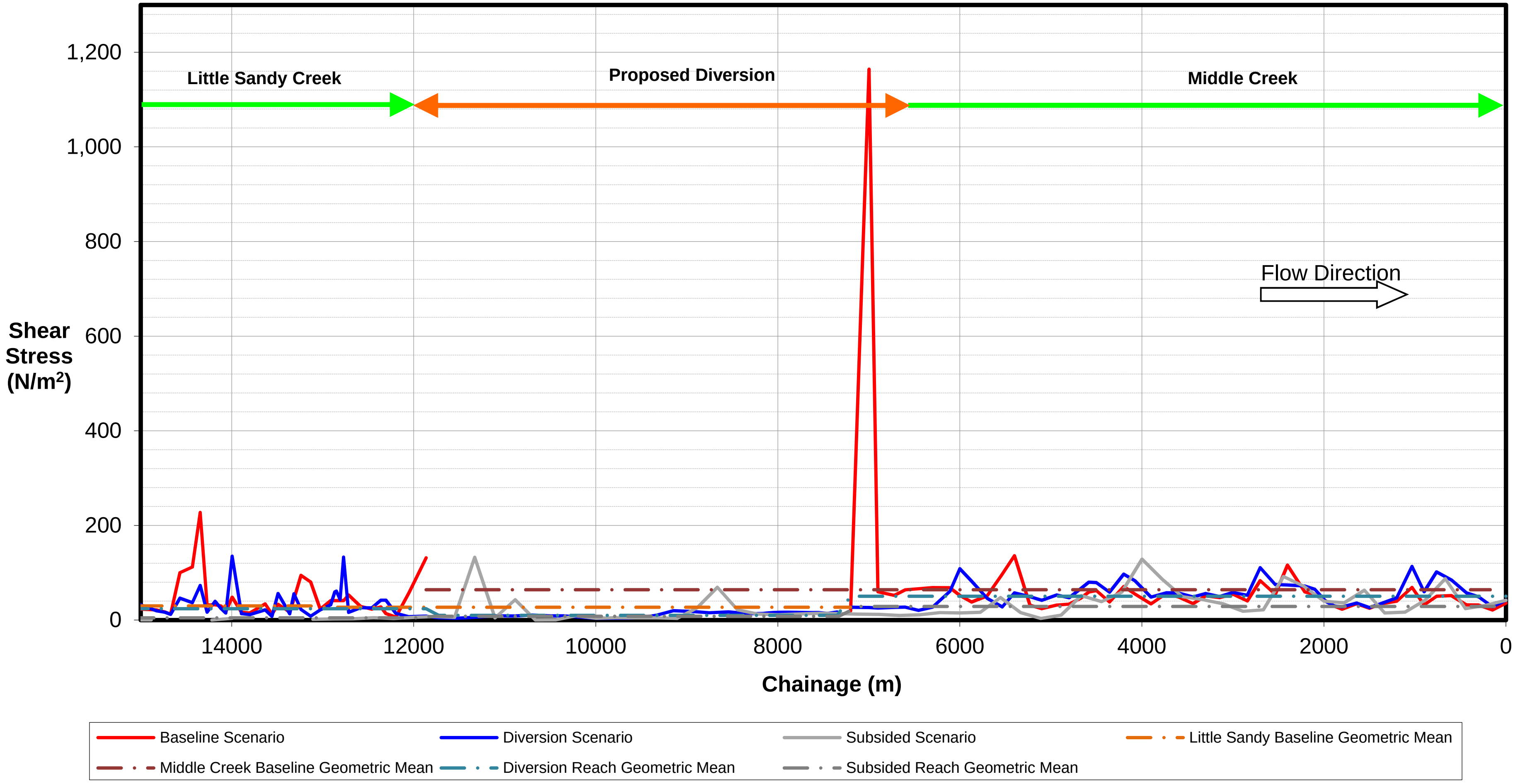

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Figure Appendix C-20 Comparison of Bed Shear Stress along Proposed Diversion for a 1:2000 AEP Event

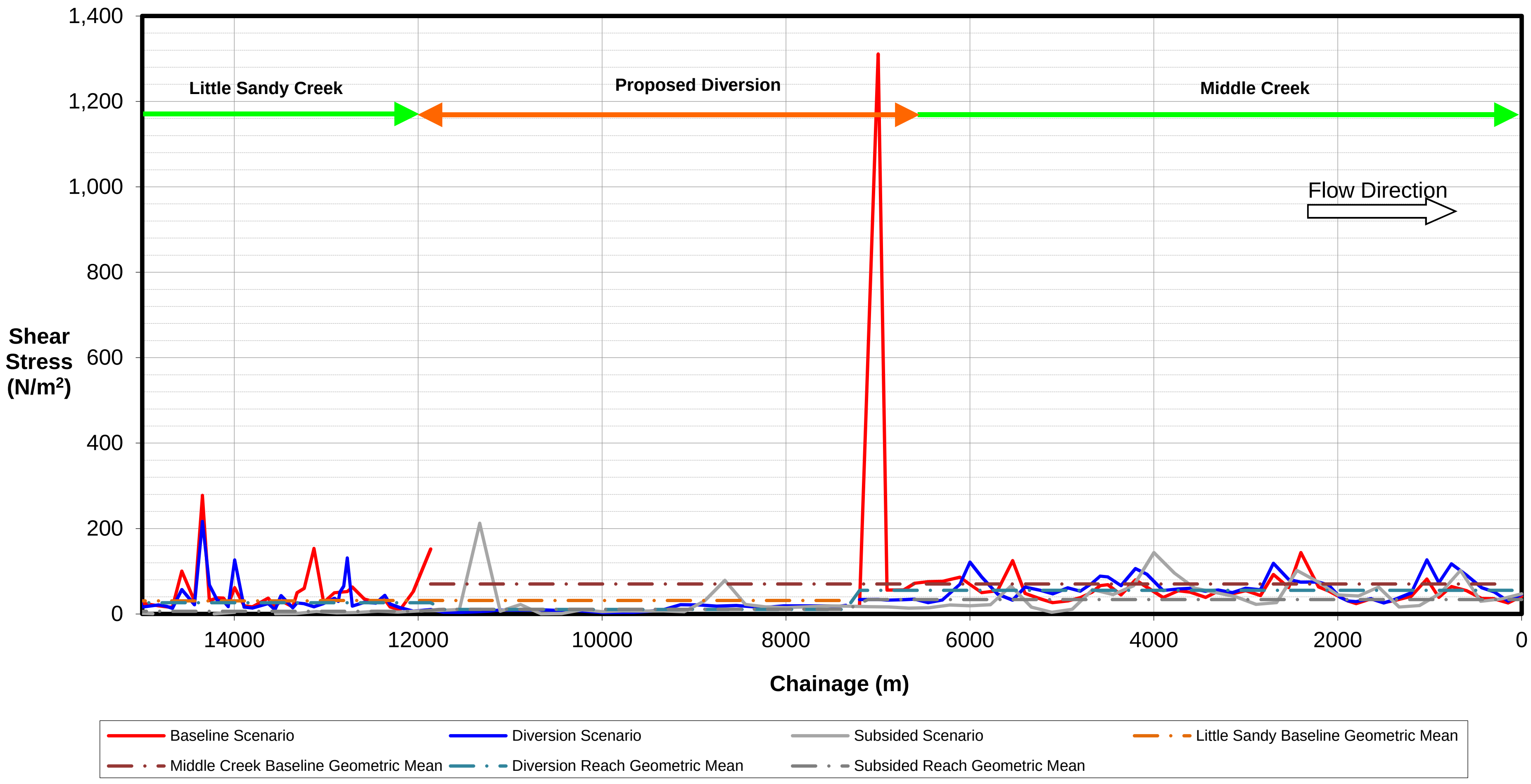

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Figure Appendix C-21 Comparison of Bed Shear Stress along Proposed Diversion for a PMF Event

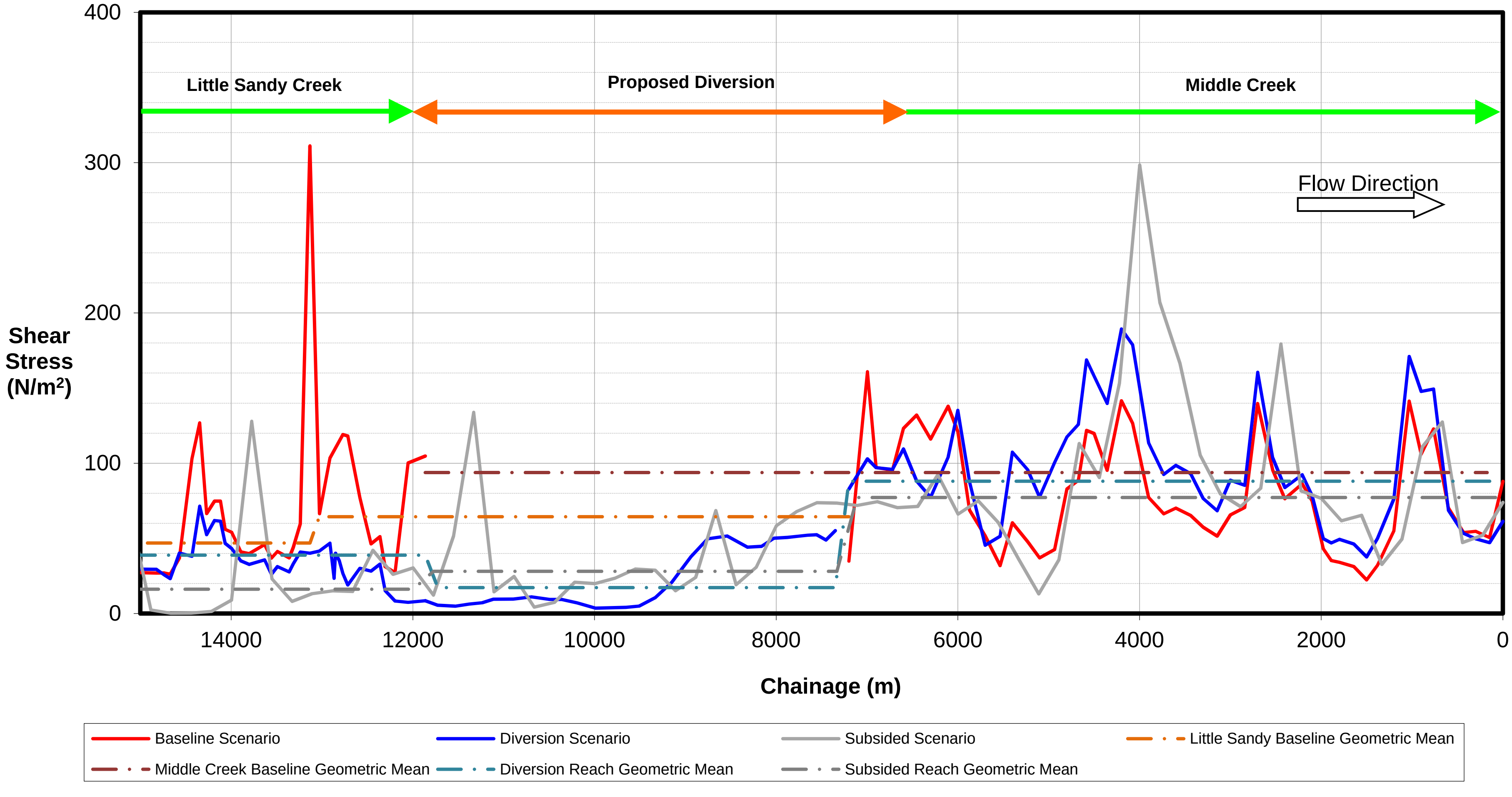

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Figure Appendix C-22 Comparison of Channel Stream Power along Sandy Creek for a 1:2 AEP Event

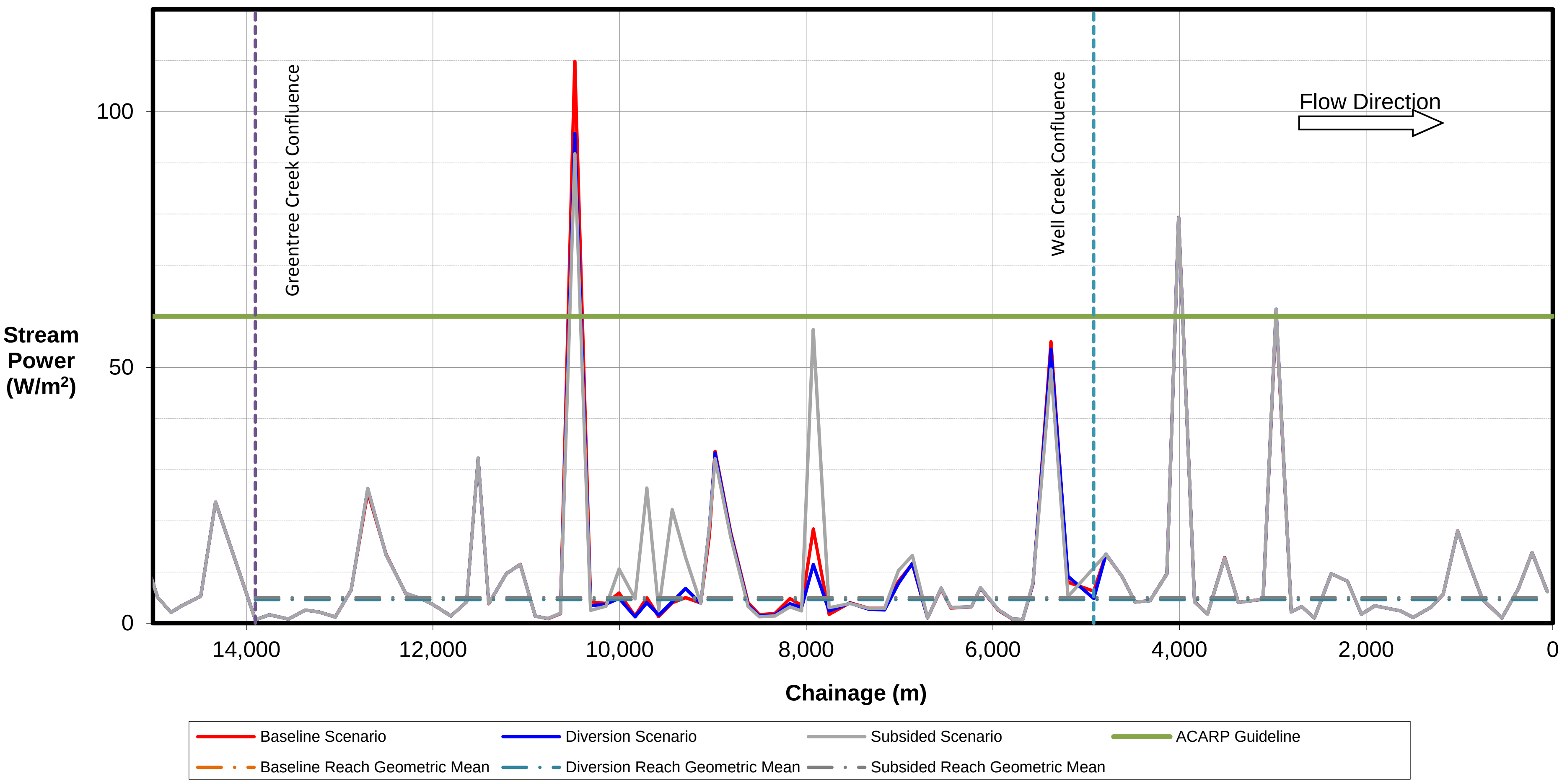

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Figure Appendix C-23 Comparison of Channel Stream Power along Sandy Creek for a 1:5 AEP Event

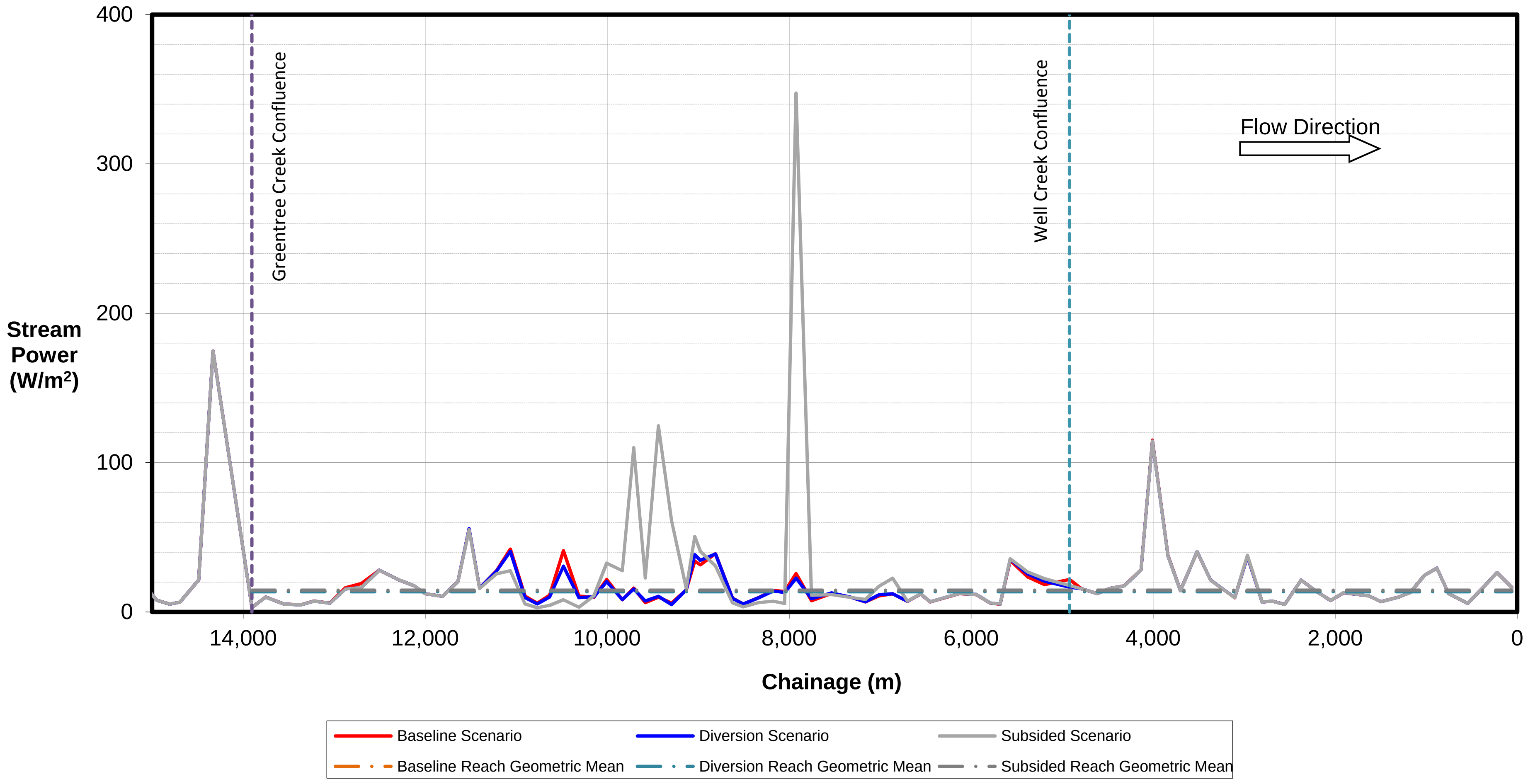

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Figure Appendix C-24 Comparison of Channel Stream Power along Sandy Creek for a 1:10 AEP Event

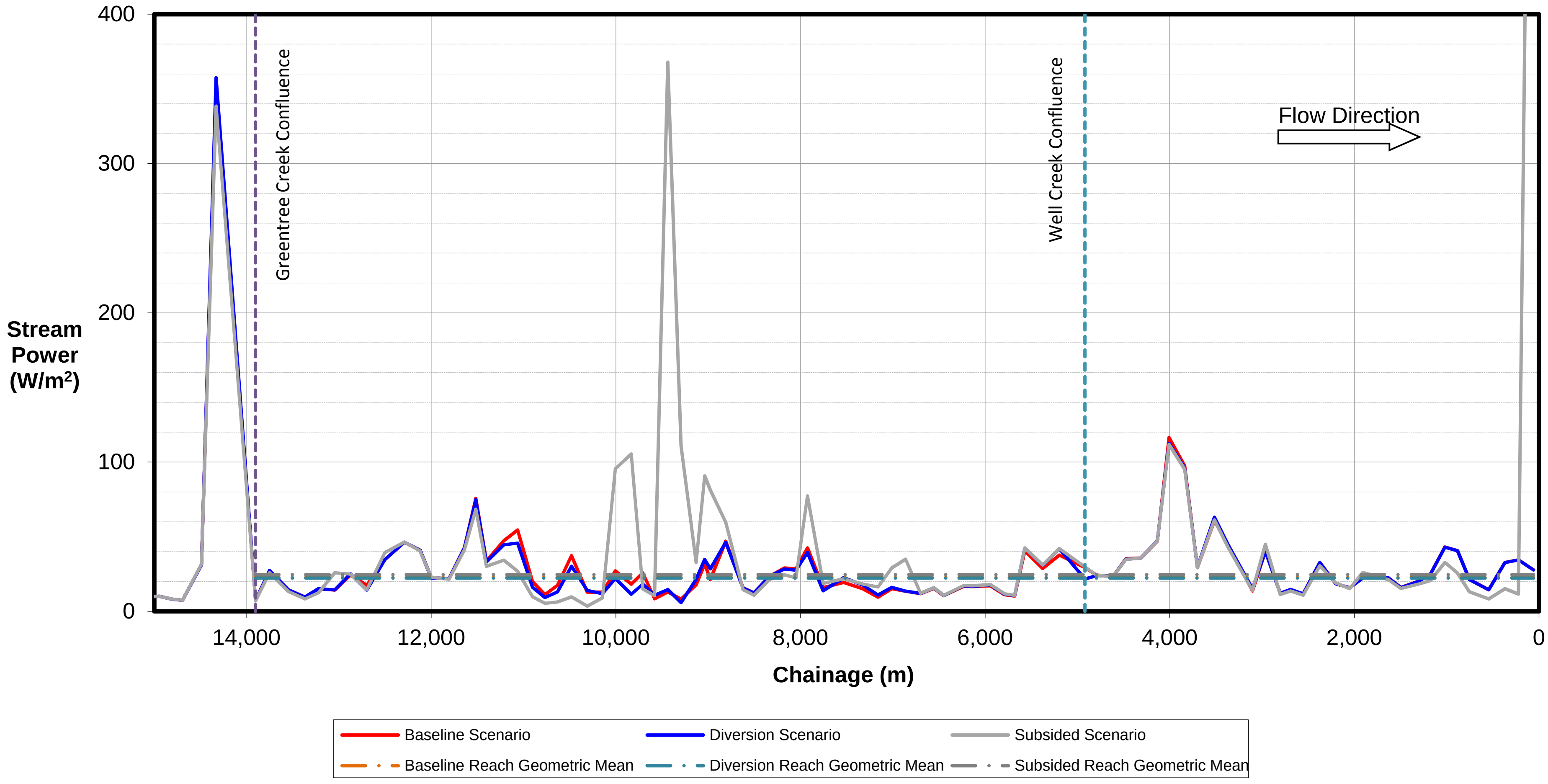

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Figure Appendix C-25 Comparison of Channel Stream Power along Sandy Creek for a 1:20 AEP Event

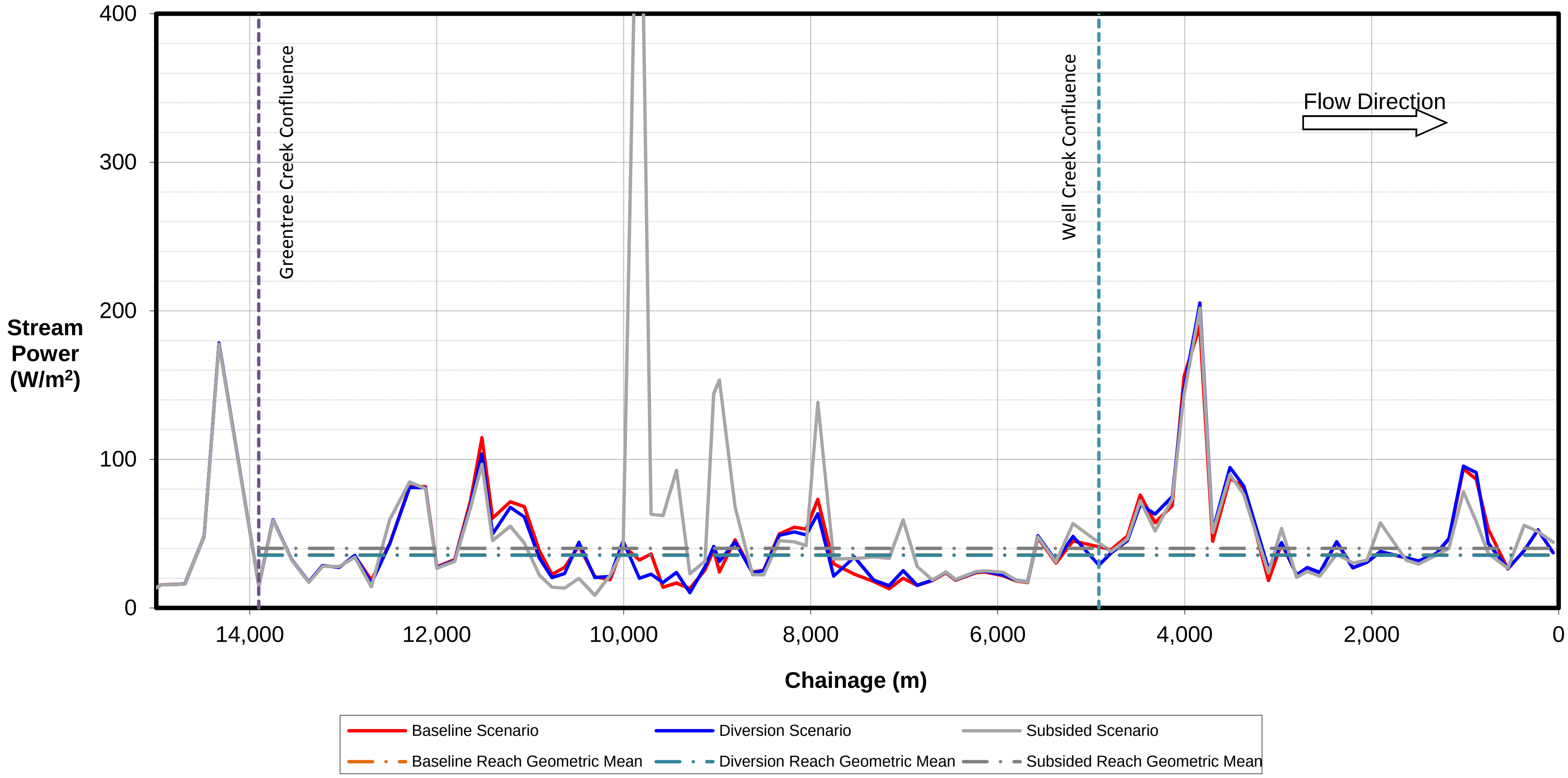

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Figure Appendix C-26 Comparison of Channel Stream Power along Sandy Creek for a 1:50 AEP Event

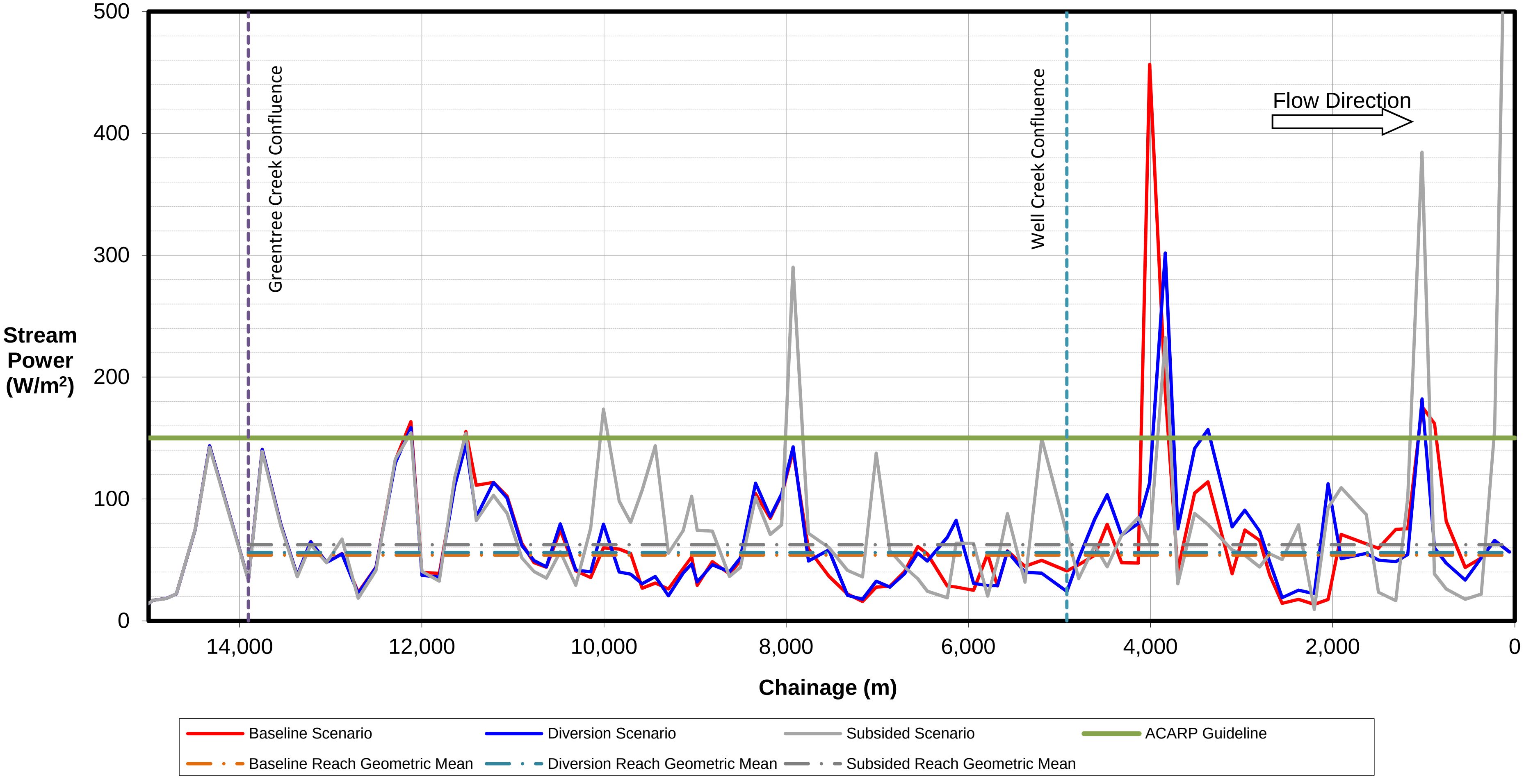

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Figure Appendix C-27 Comparison of Channel Stream Power along Sandy Creek for a 1:100 AEP Event

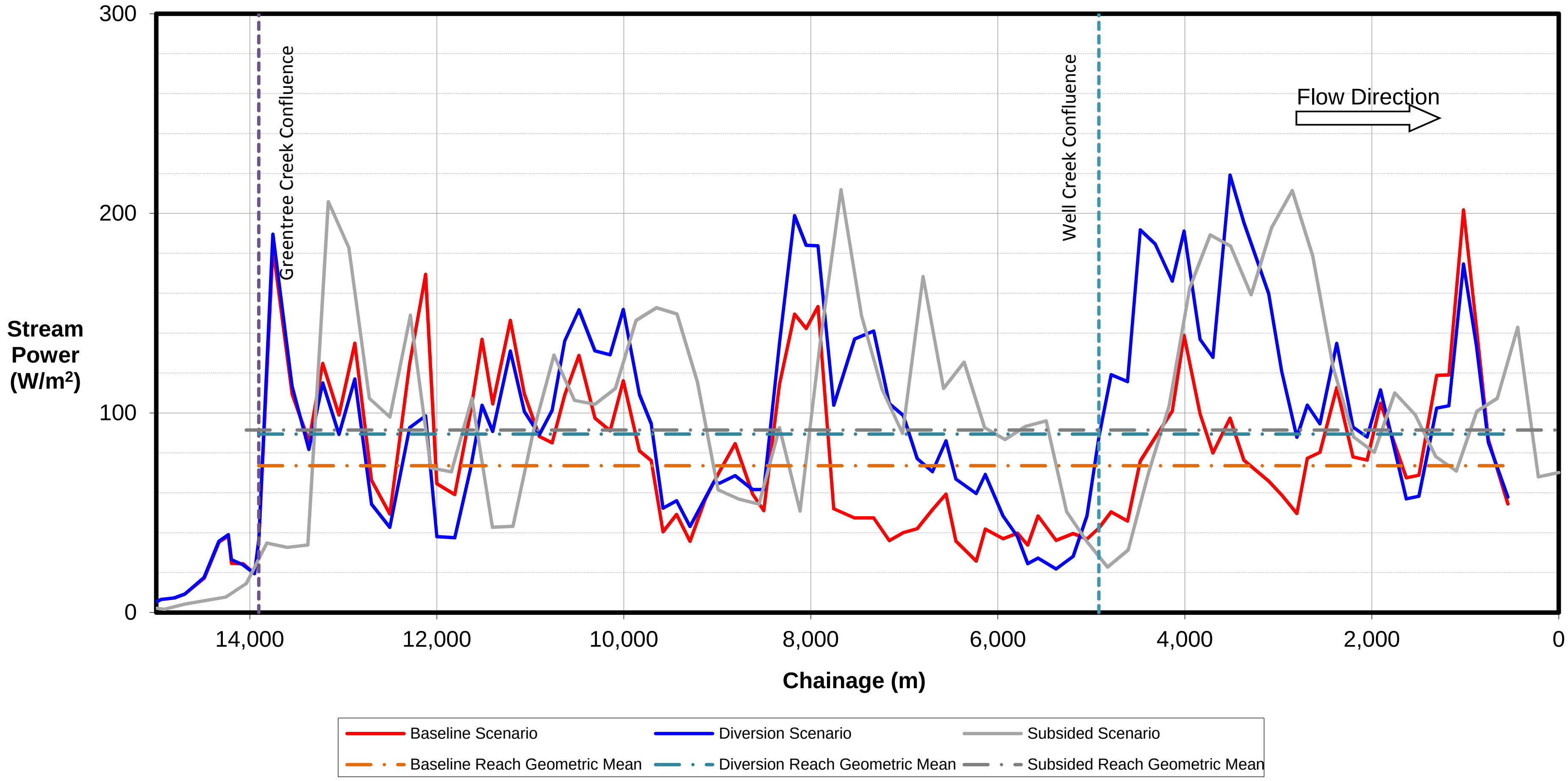

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Figure Appendix C-28 Comparison of Channel Stream Power along Sandy Creek for a 1:1000 AEP Event

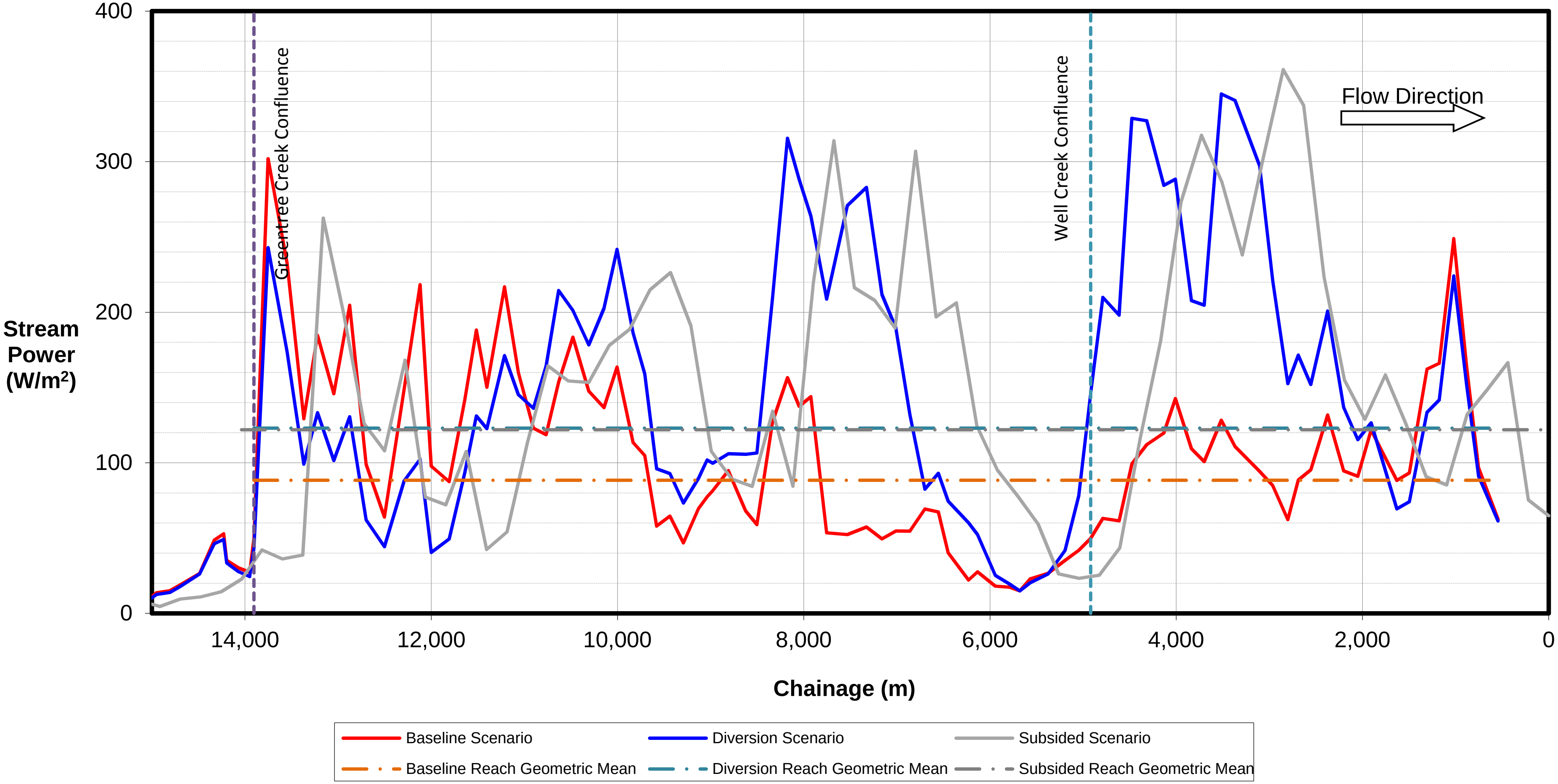

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Figure Appendix C-29 Comparison of Channel Stream Power along Sandy Creek for a 1:2000 AEP Event

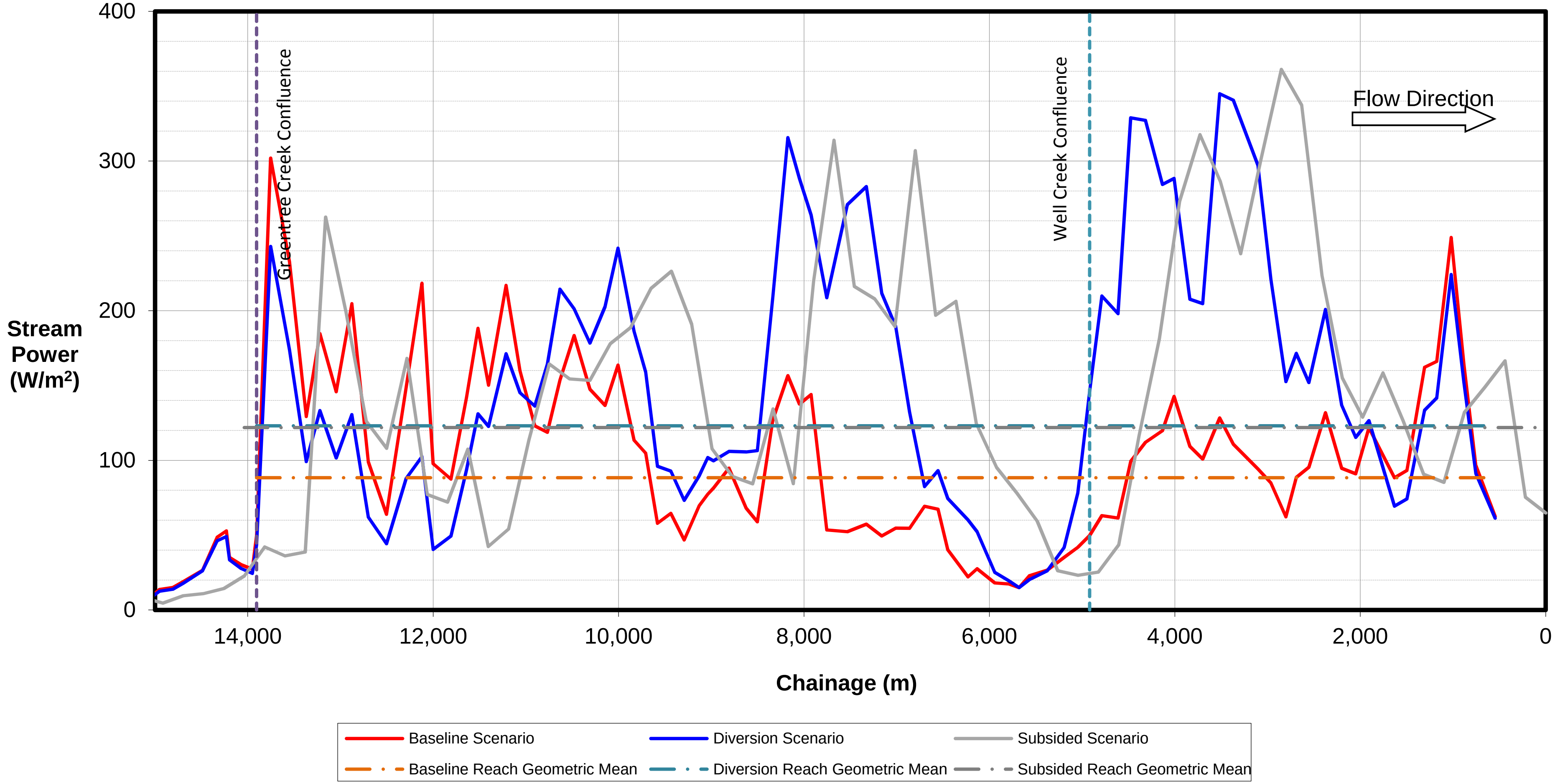

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Figure Appendix C-30 Comparison of Channel Stream Power along Sandy Creek for a PMF Event

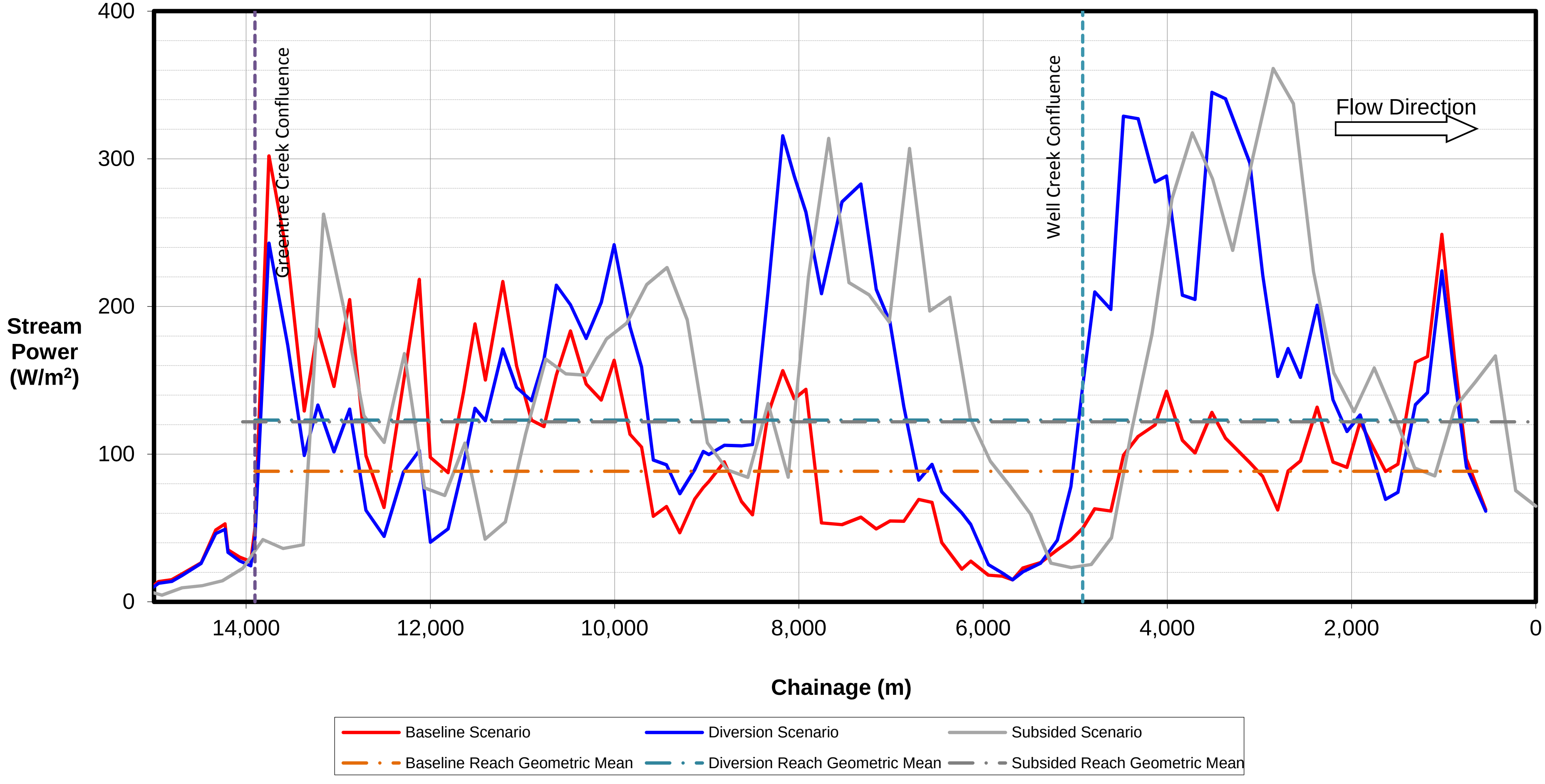

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Figure Appendix C-31 Comparison of Channel Velocity along Sandy Creek for a 1:2 AEP Event

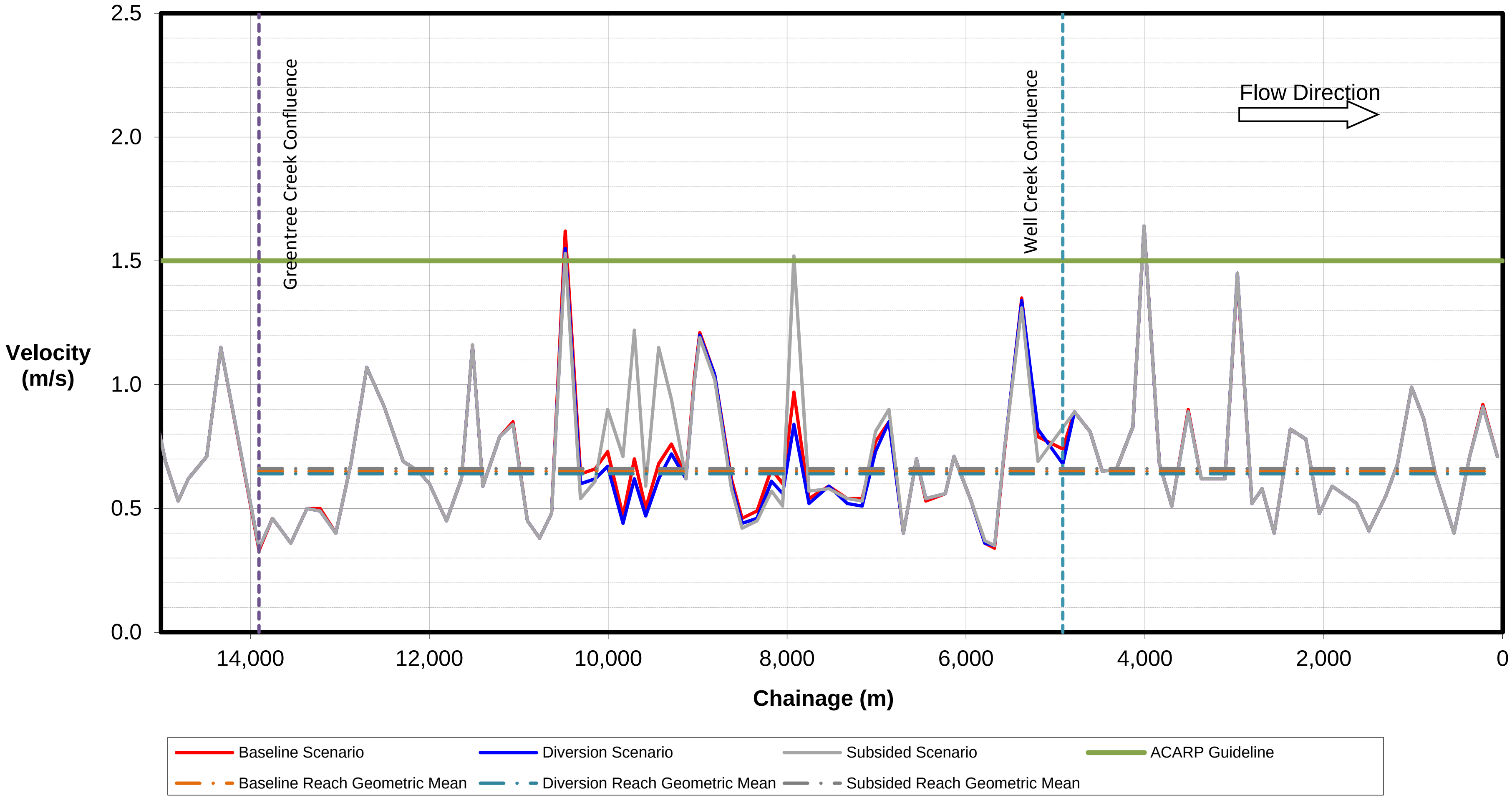

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Figure Appendix C-32 Comparison of Channel Velocity along Sandy Creek for a 1:5 AEP Event

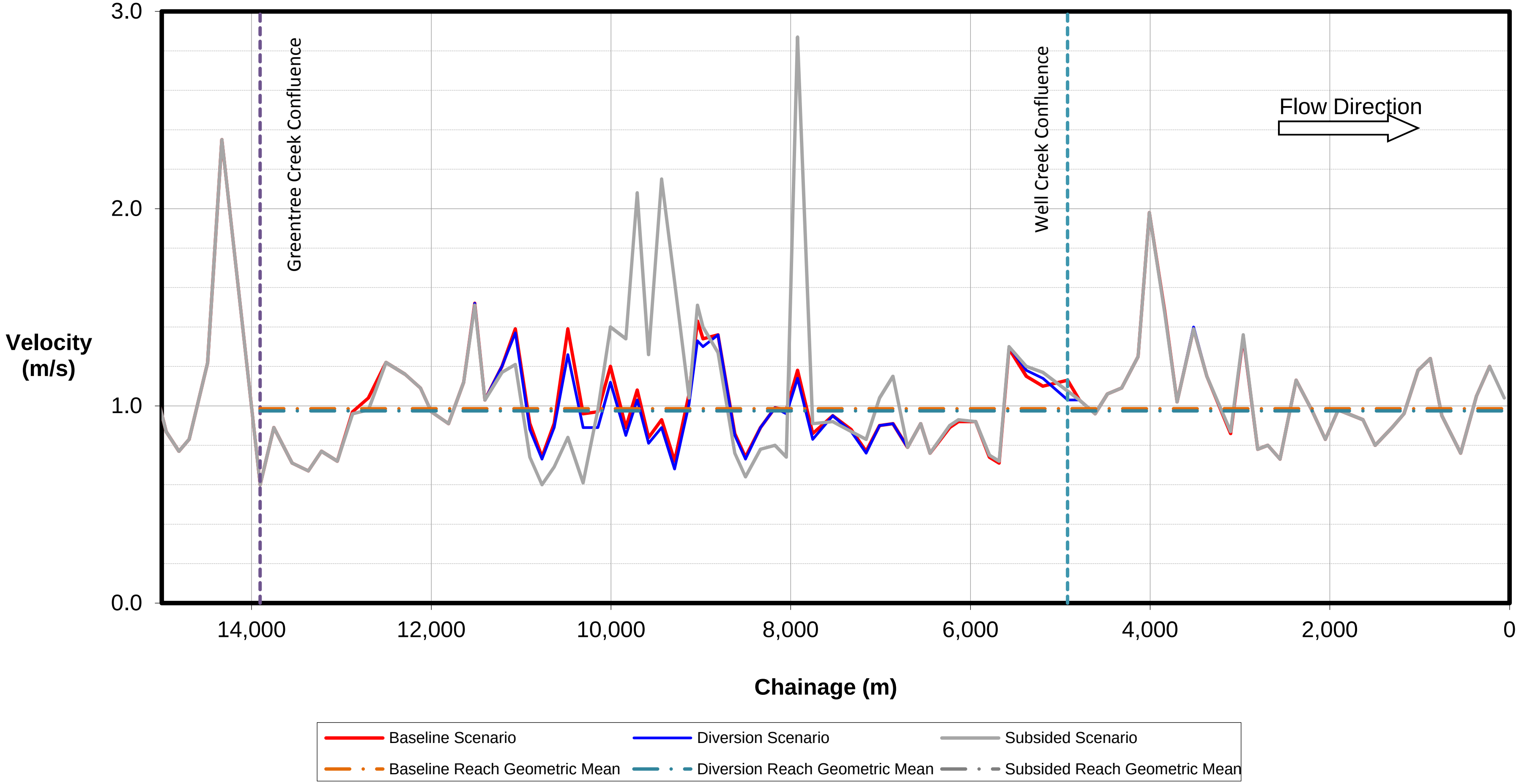

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Figure Appendix C-33 Comparison of Channel Velocity along Sandy Creek for a 1:10 AEP Event

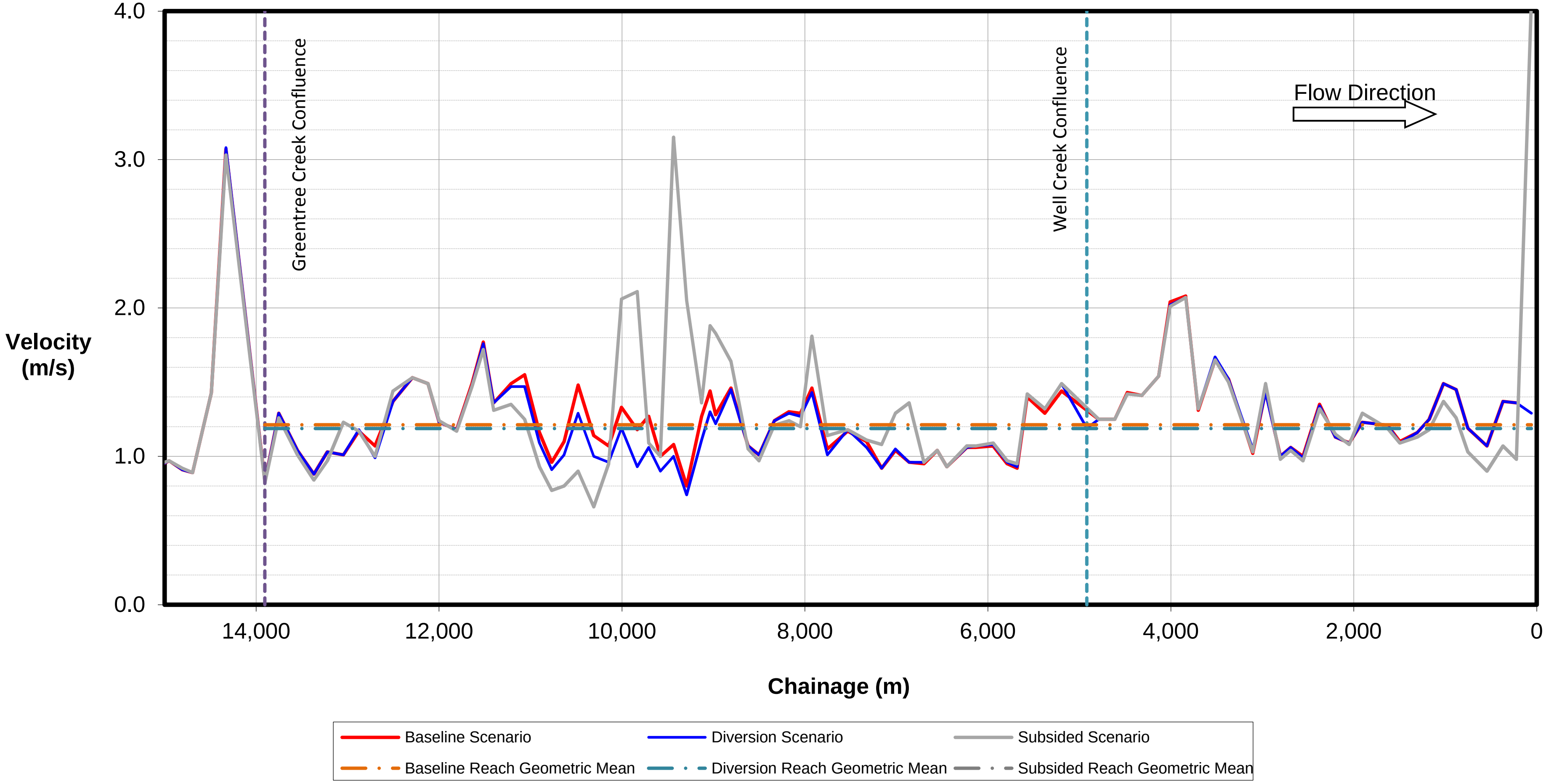

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Figure Appendix C-34 Comparison of Channel Velocity along Sandy Creek for a 1:20 AEP Event

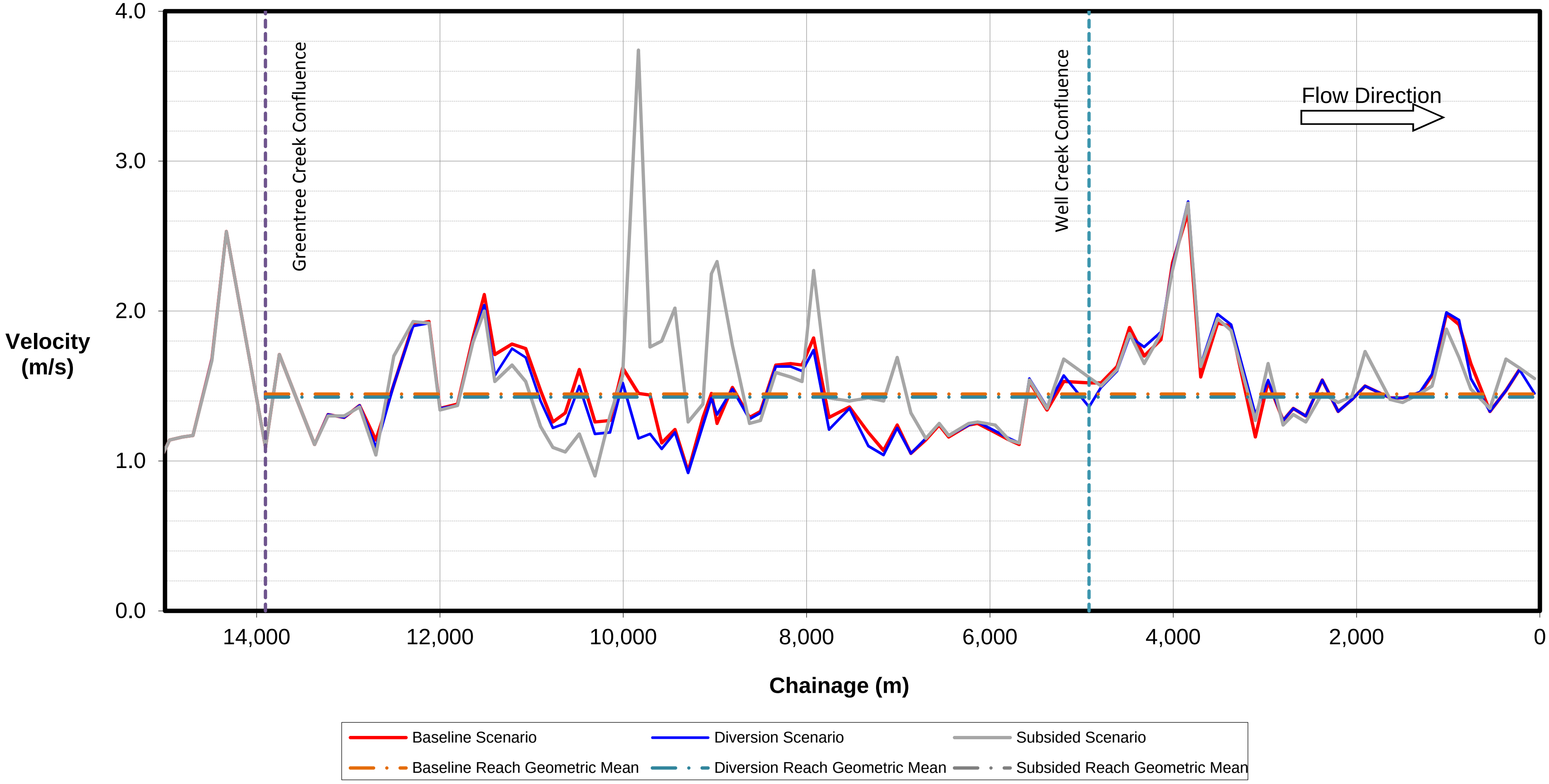

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Figure Appendix C-35 Comparison of Channel Velocity along Sandy Creek for a 1:50 AEP Event

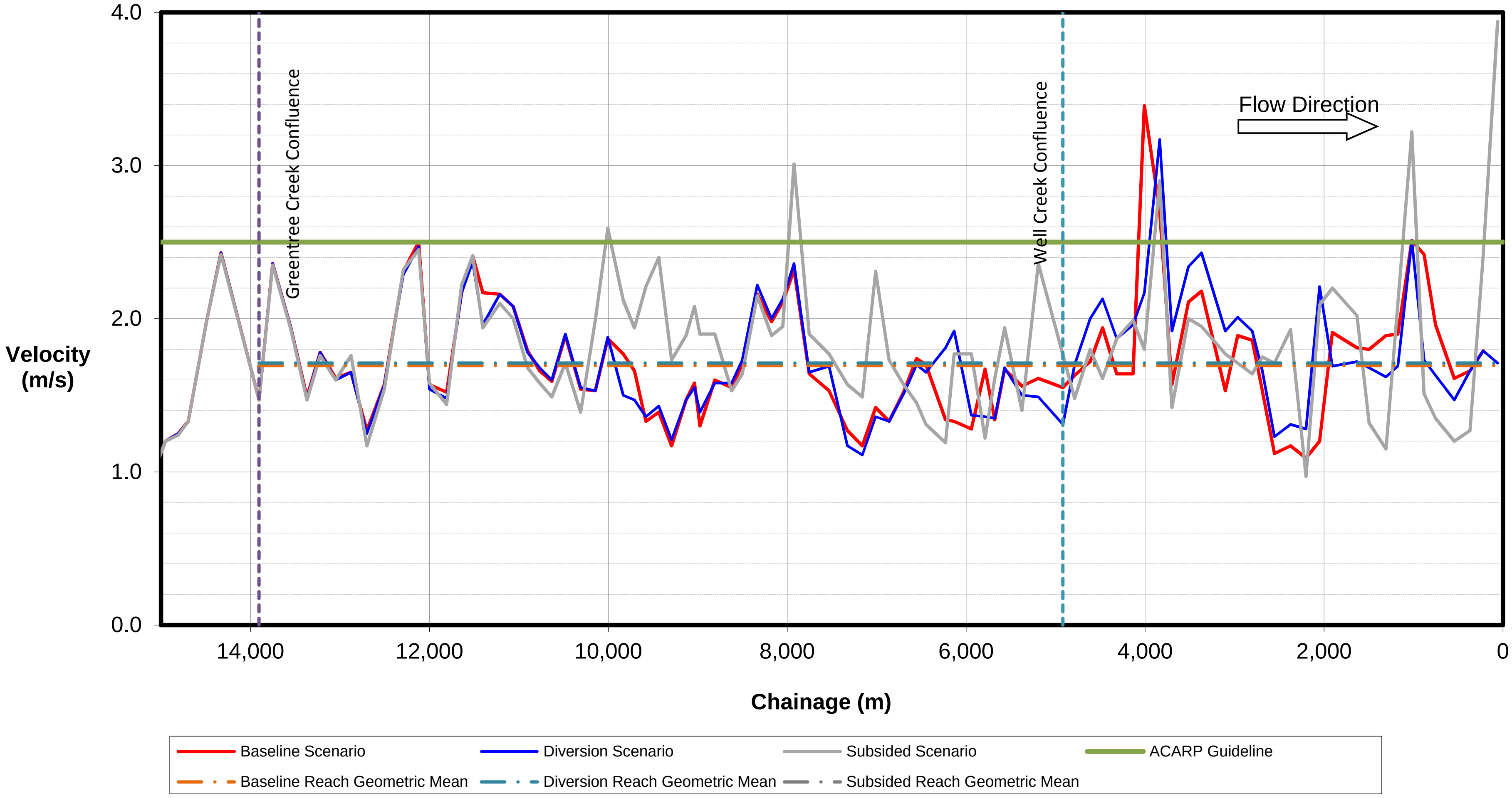

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Figure Appendix C-36 Comparison of Channel Velocity along Sandy Creek for a 1:100 AEP Event

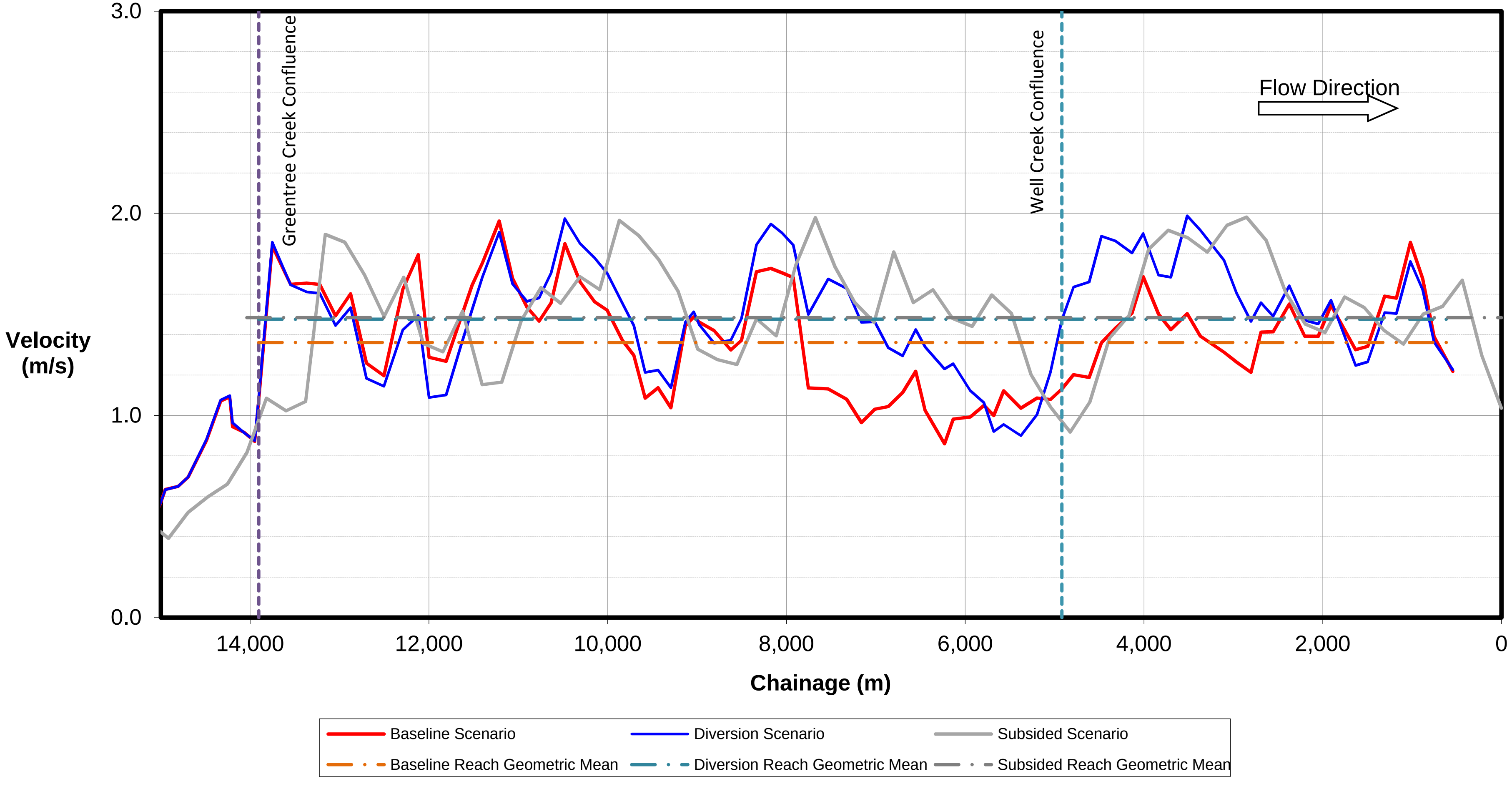

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Figure Appendix C-37 Comparison of Channel Velocity along Sandy Creek for a 1:1000 AEP Event

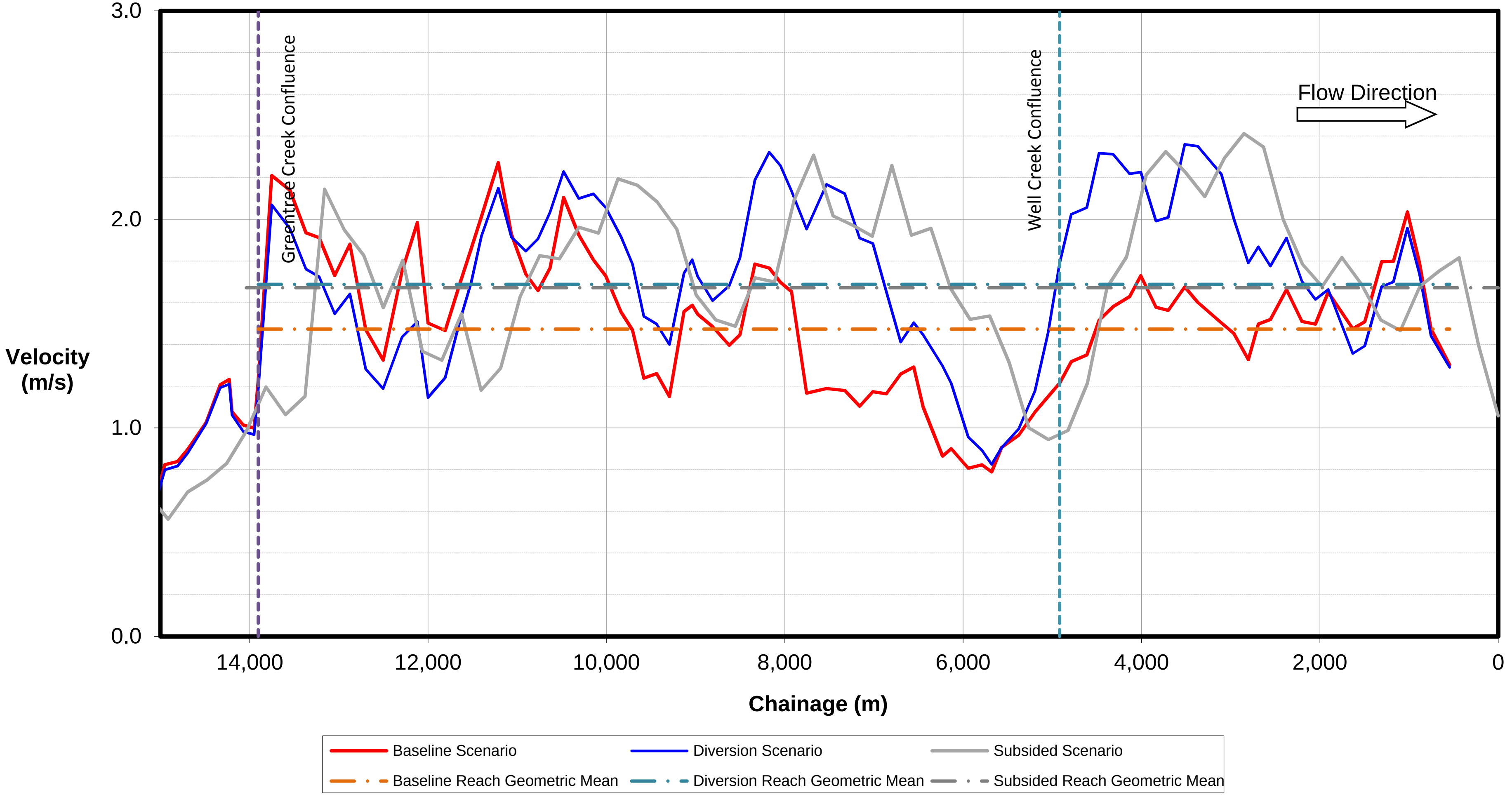

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Figure Appendix C-38 Comparison of Channel Velocity along Sandy Creek for a 1:2000 AEP Event

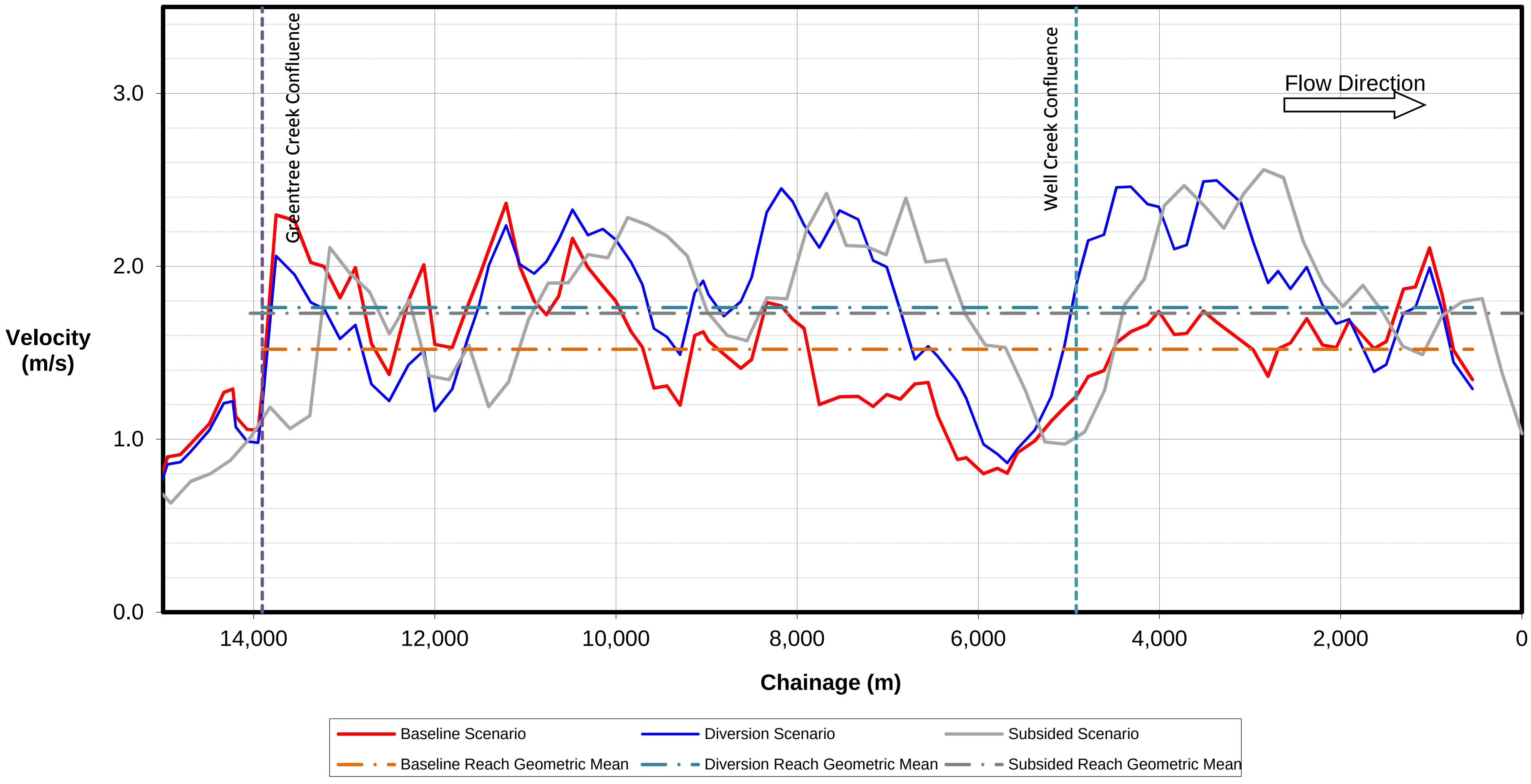

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Figure Appendix C-39 Comparison of Channel Velocity along Sandy Creek for a PMF Event

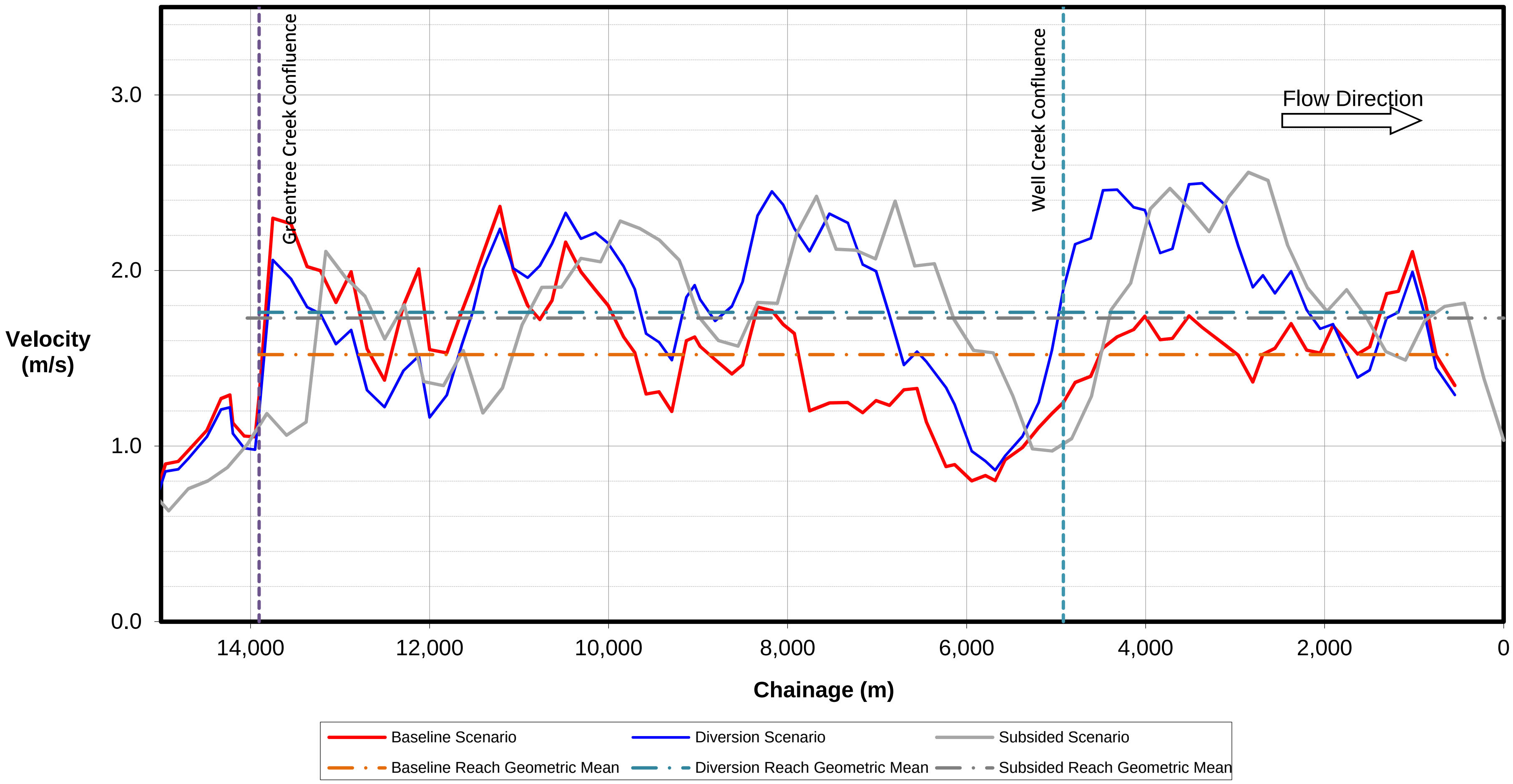

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Figure Appendix C-40 Comparison of Bed Shear Stress along Sandy Creek for a 1:2 AEP Event

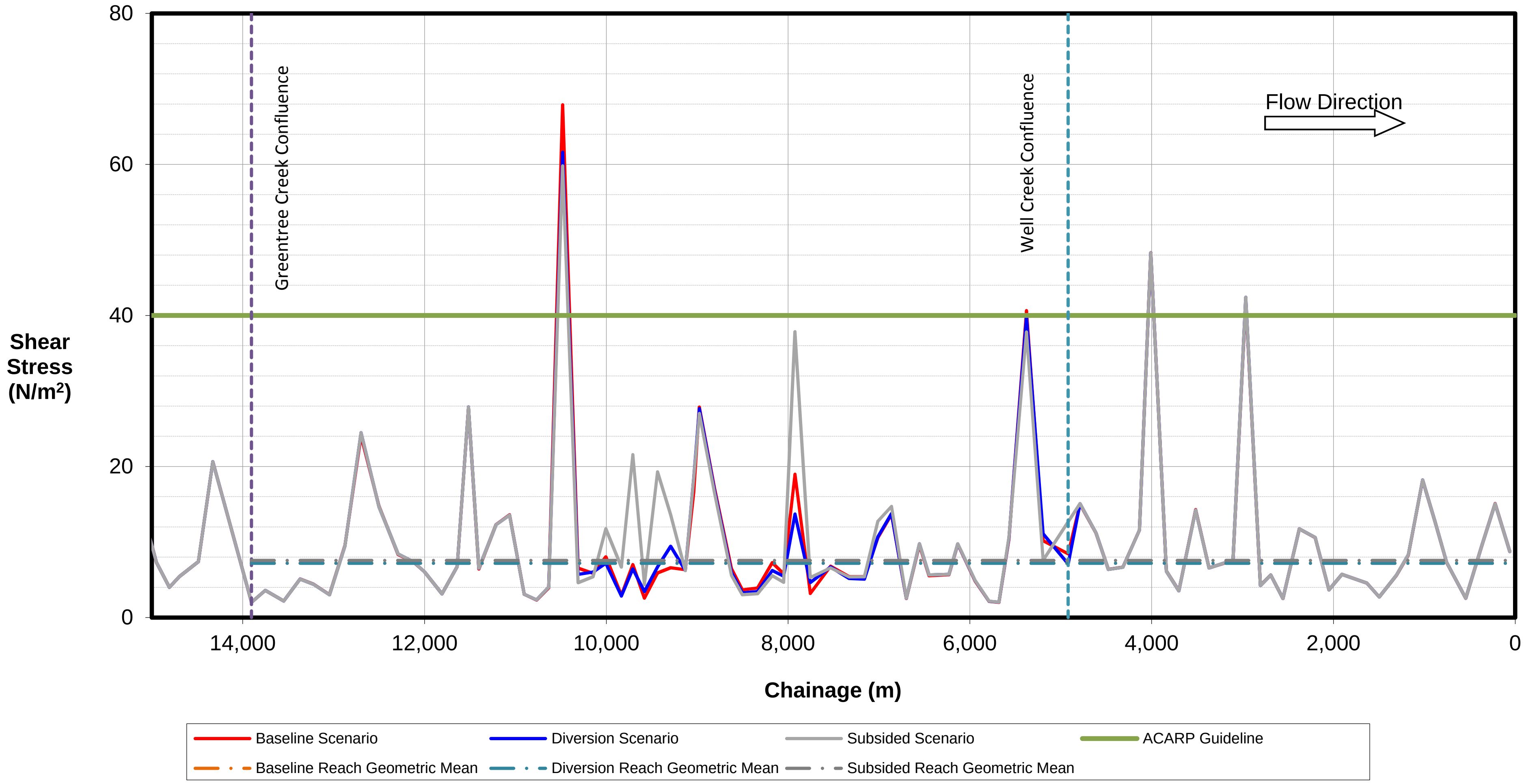

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Figure Appendix C-41 Comparison of Bed Shear Stress along Sandy Creek for a 1:5 AEP Event

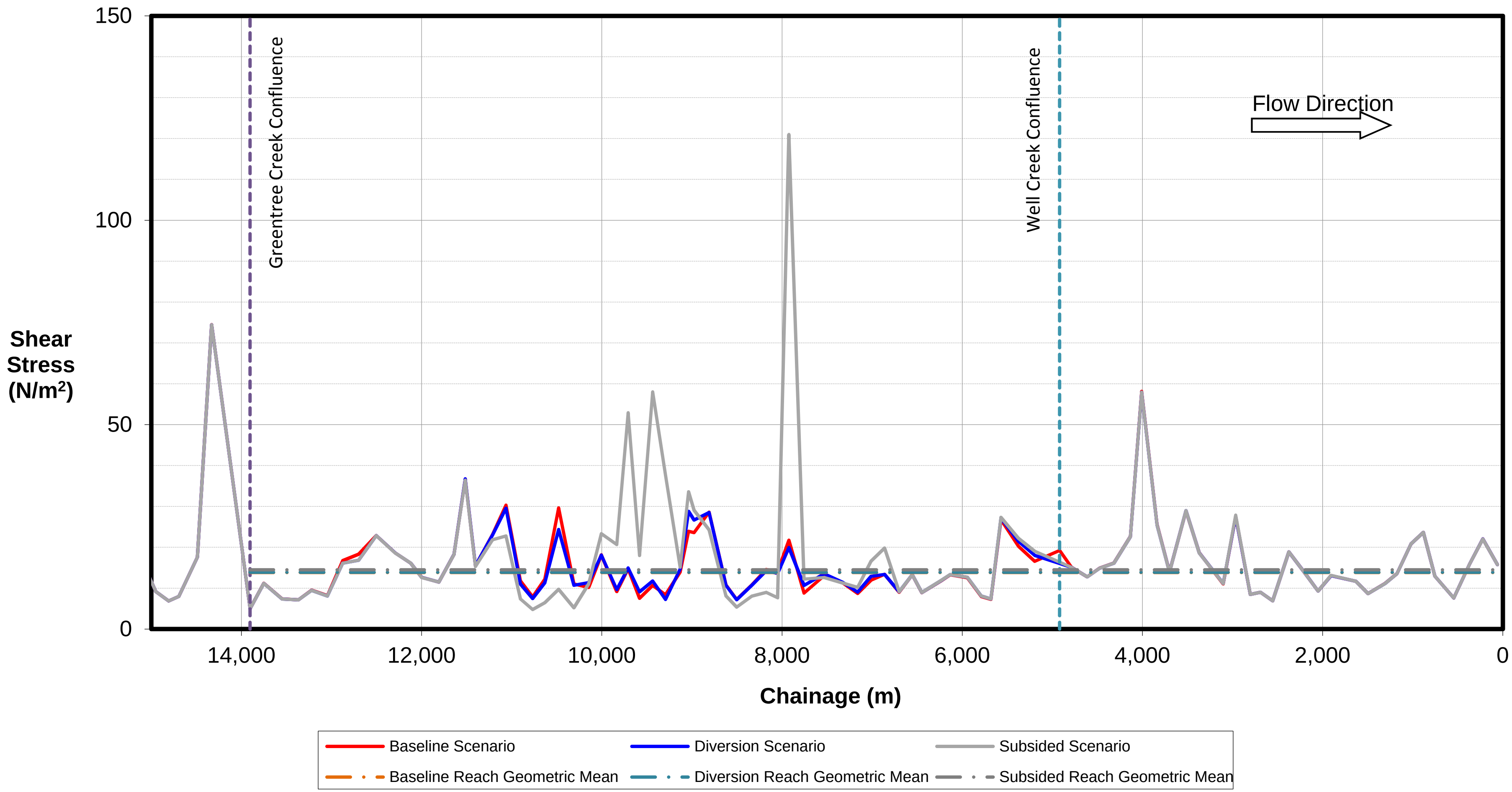

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Figure Appendix C-42 Comparison of Bed Shear Stress along Sandy Creek for a 1:10 AEP Event

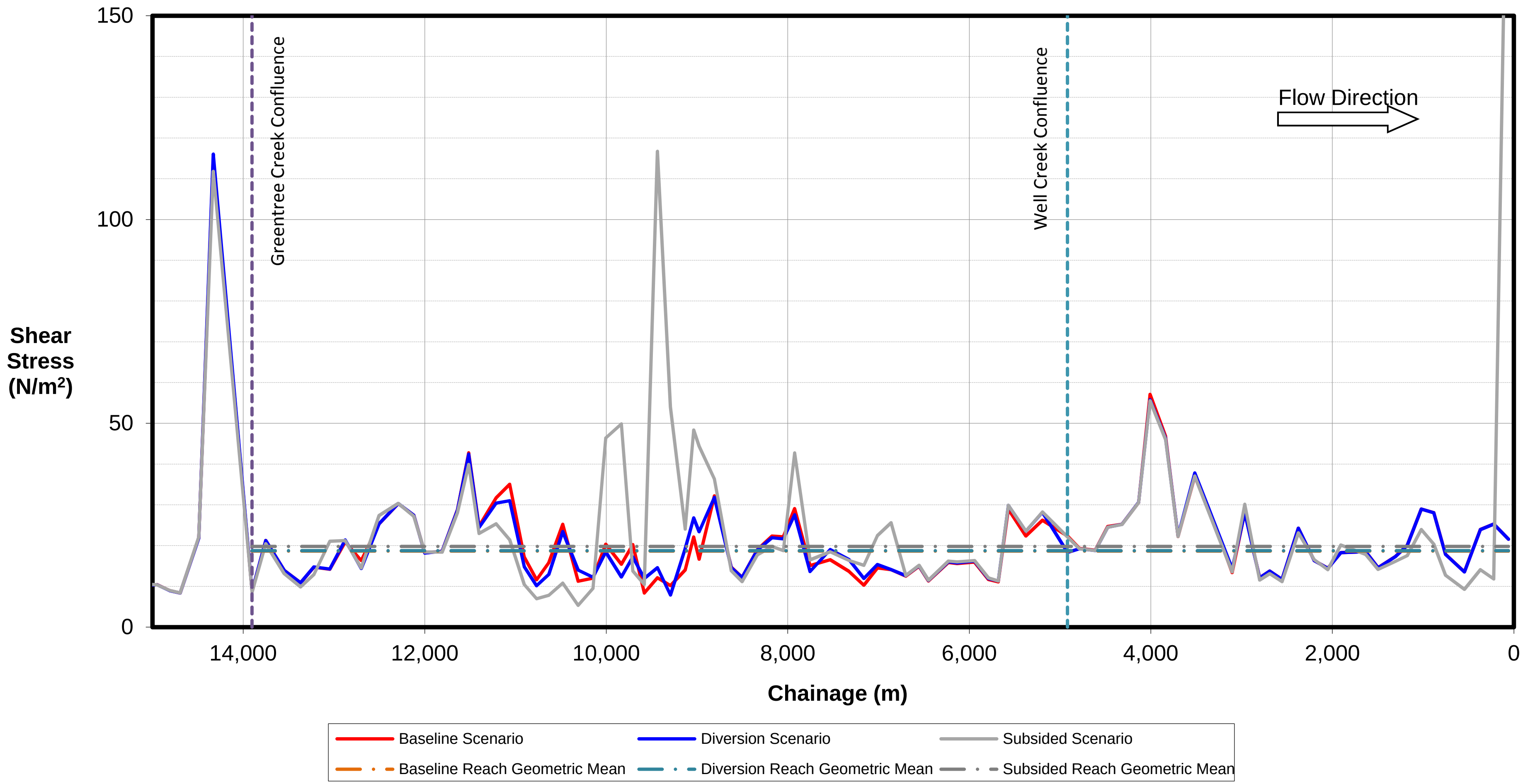

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Figure Appendix C-43 Comparison of Bed Shear Stress along Sandy Creek for a 1:20 AEP Event

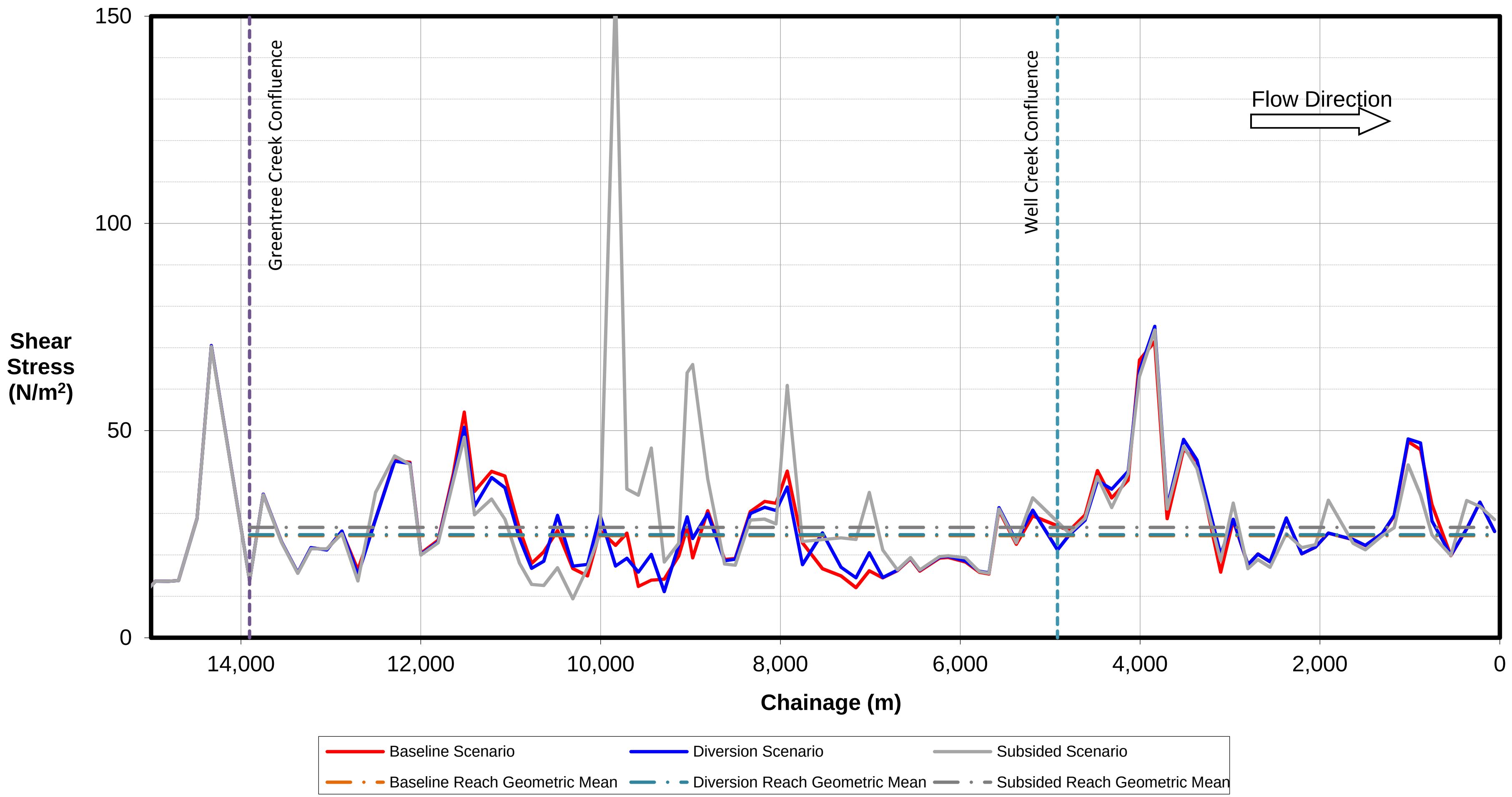

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Figure Appendix C-44 Comparison of Bed Shear Stress along Sandy Creek for a 1:50 AEP Event

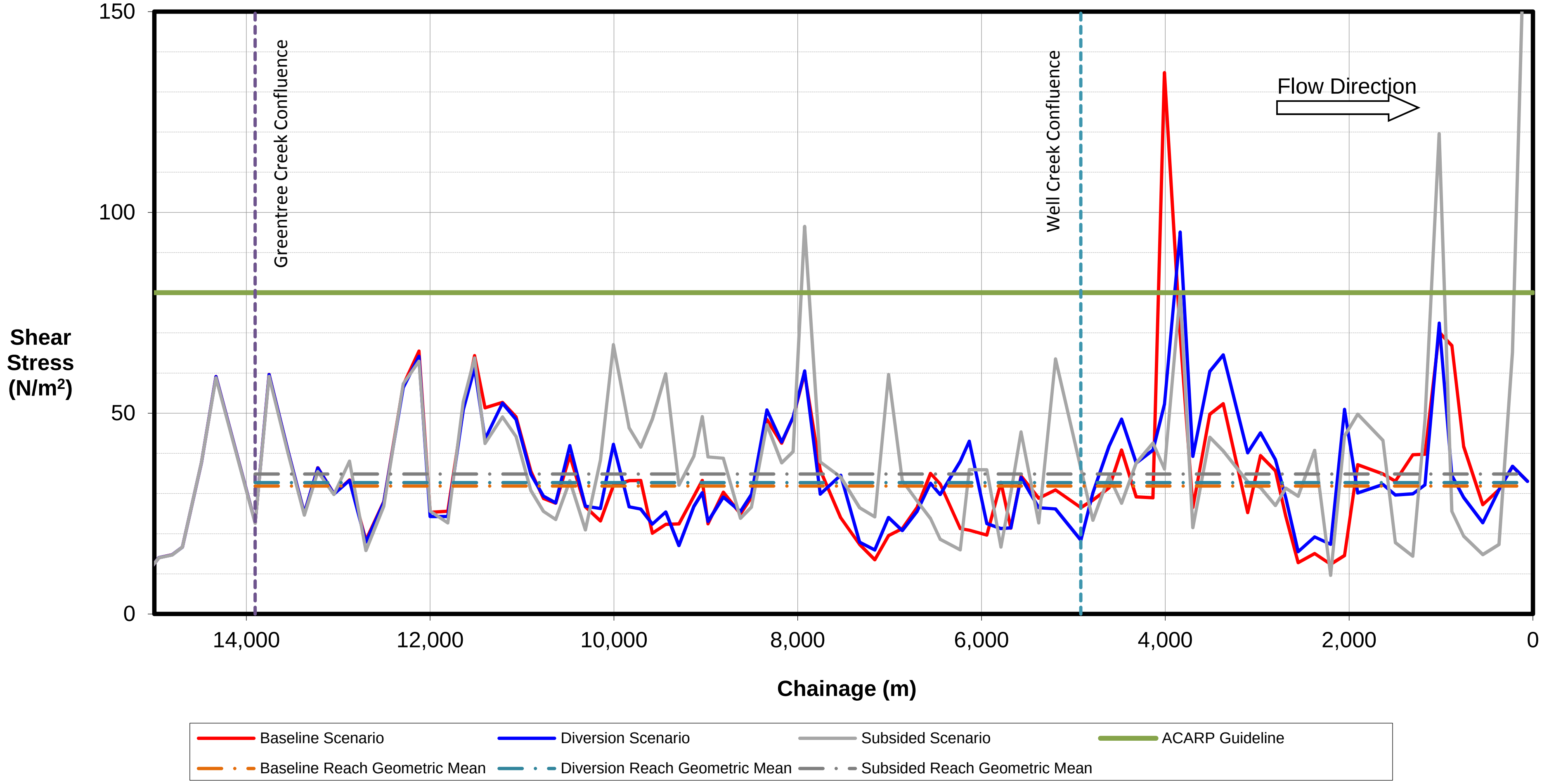

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Figure Appendix C-45 Comparison of Bed Shear Stress along Sandy Creek for a 1:100 AEP Event

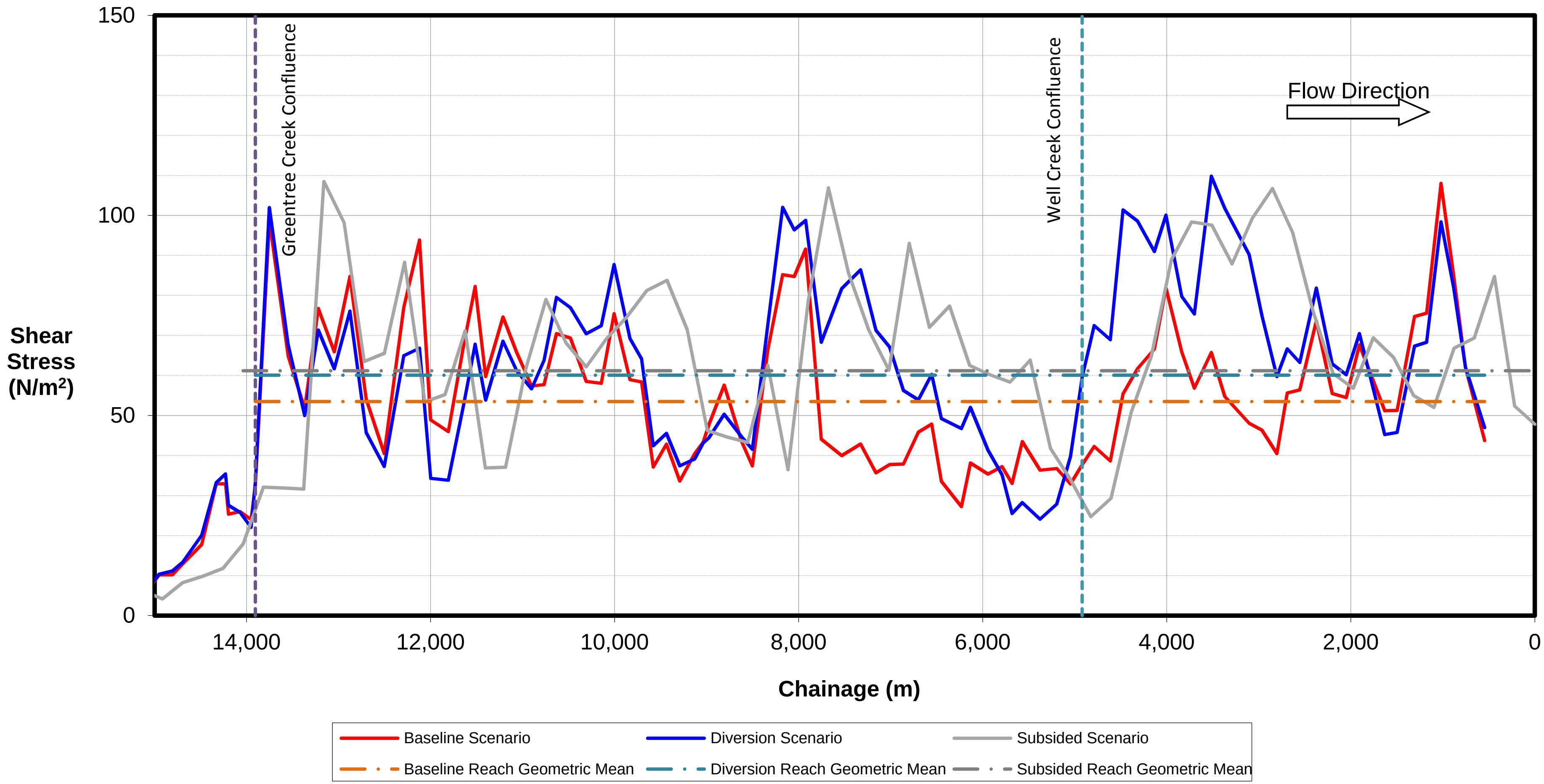

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Figure Appendix C-46 Comparison of Bed Shear Stress along Sandy Creek for a 1:1000 AEP Event

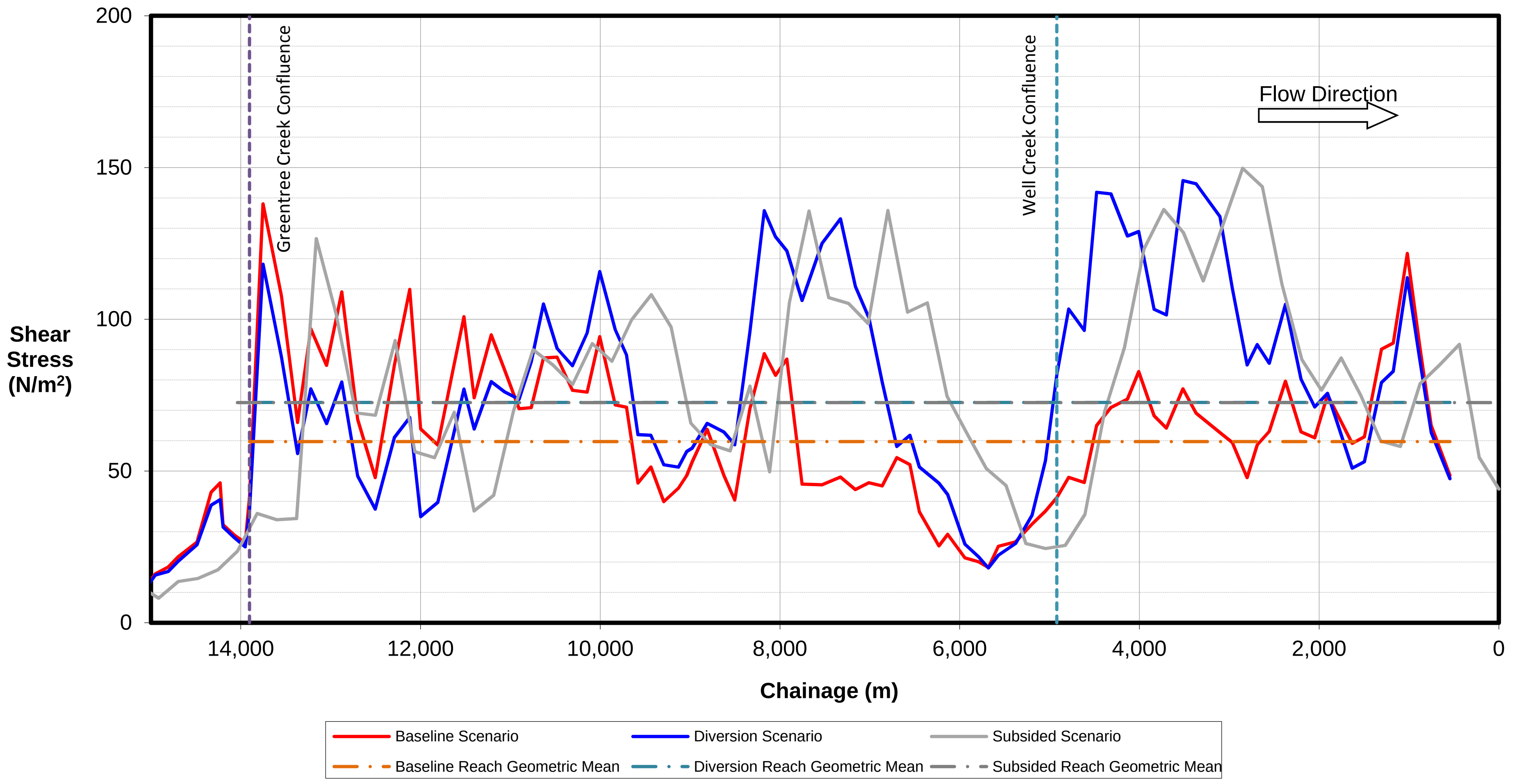

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Figure Appendix C-47 Comparison of Bed Shear Stress along Sandy Creek for a 1:2000 AEP Event

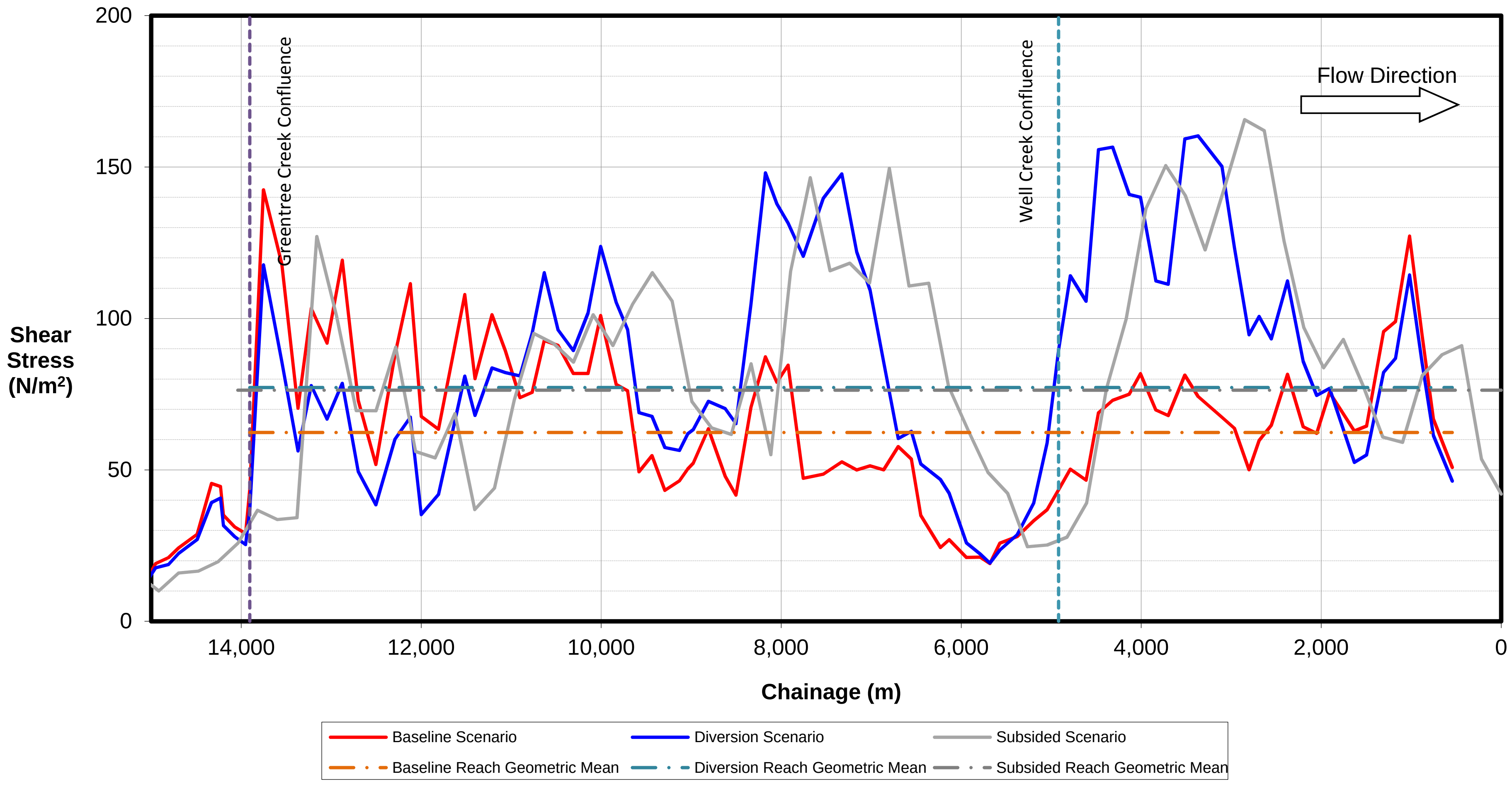

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Figure Appendix C-48 Comparison of Bed Shear Stress along Sandy Creek for a PMF Event

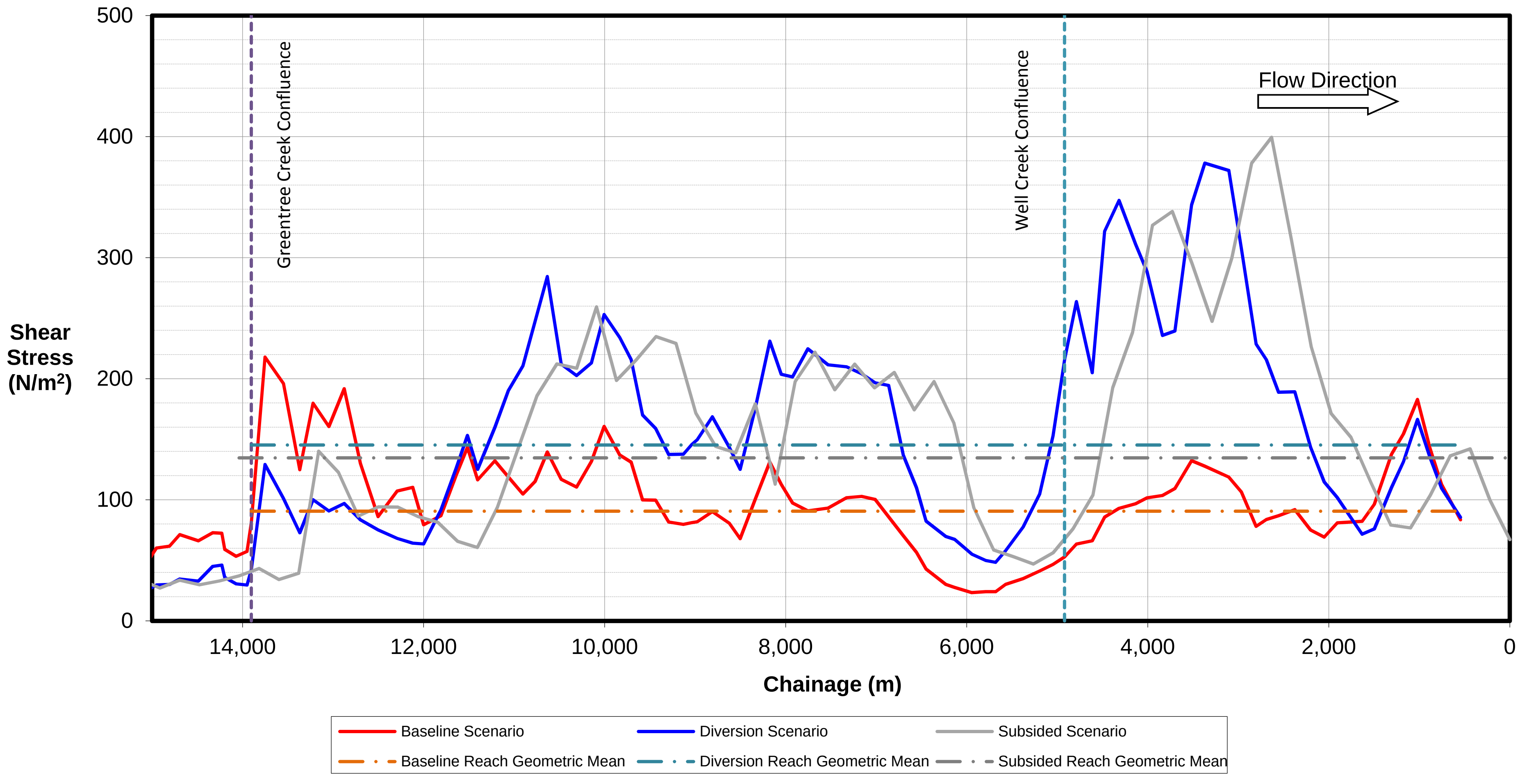

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Figure Appendix C-49 Comparison of Channel Stream Power along Well Creek for a 1:2 AEP Event

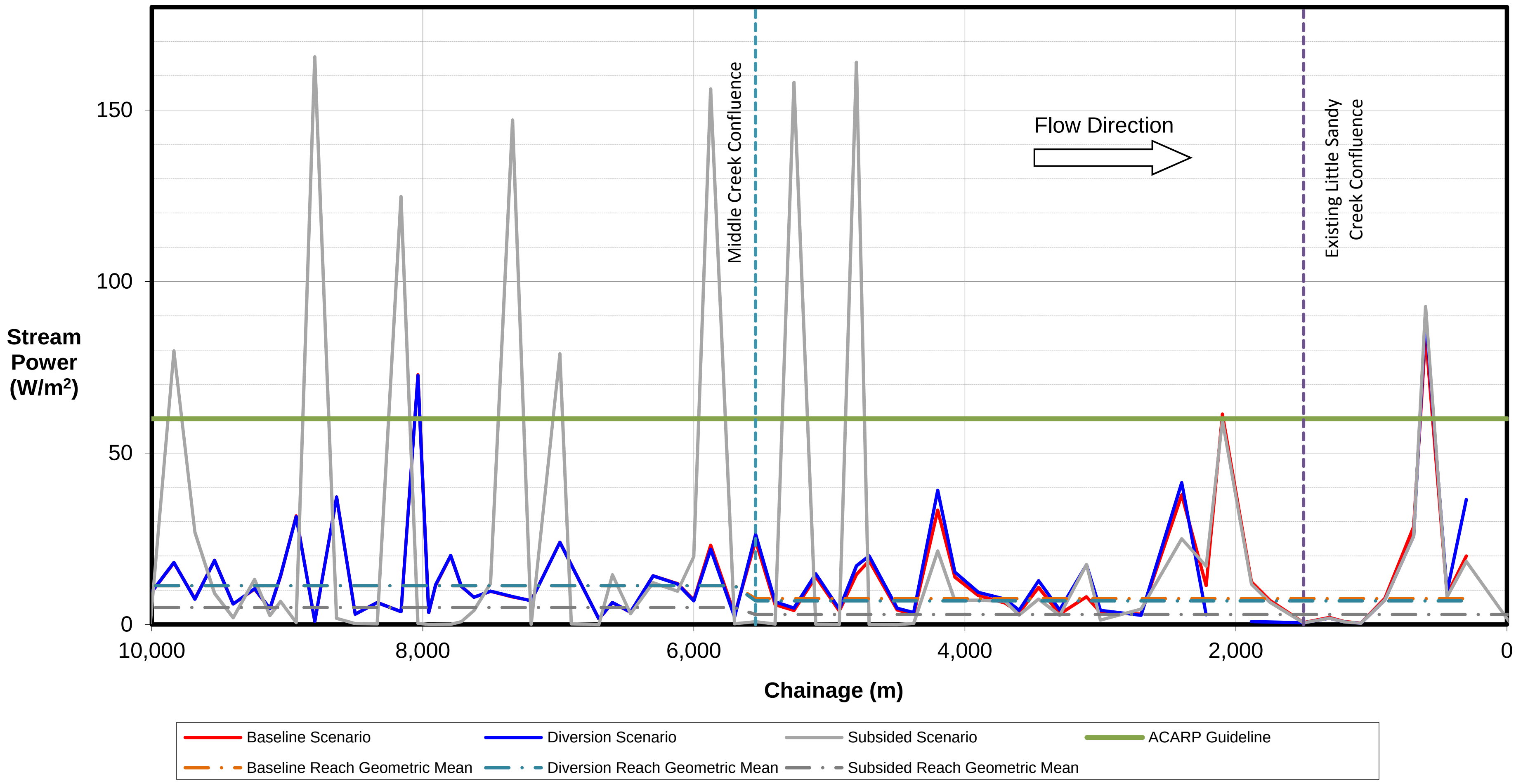

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Figure Appendix C-50 Comparison of Channel Stream Power along Well Creek for a 1:5 AEP Event

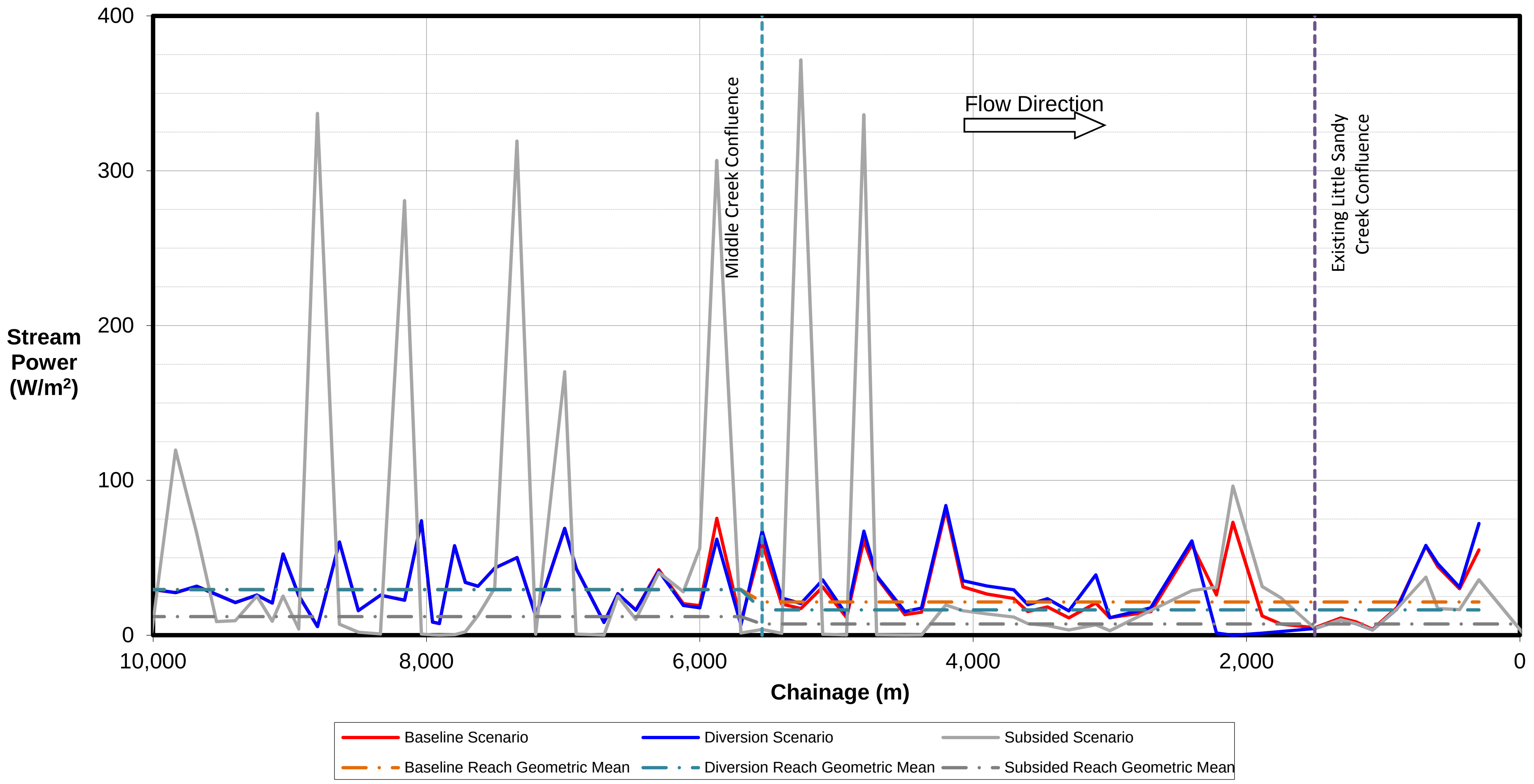

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Figure Appendix C-51 Comparison of Channel Stream Power along Well Creek for a 1:10 AEP Event

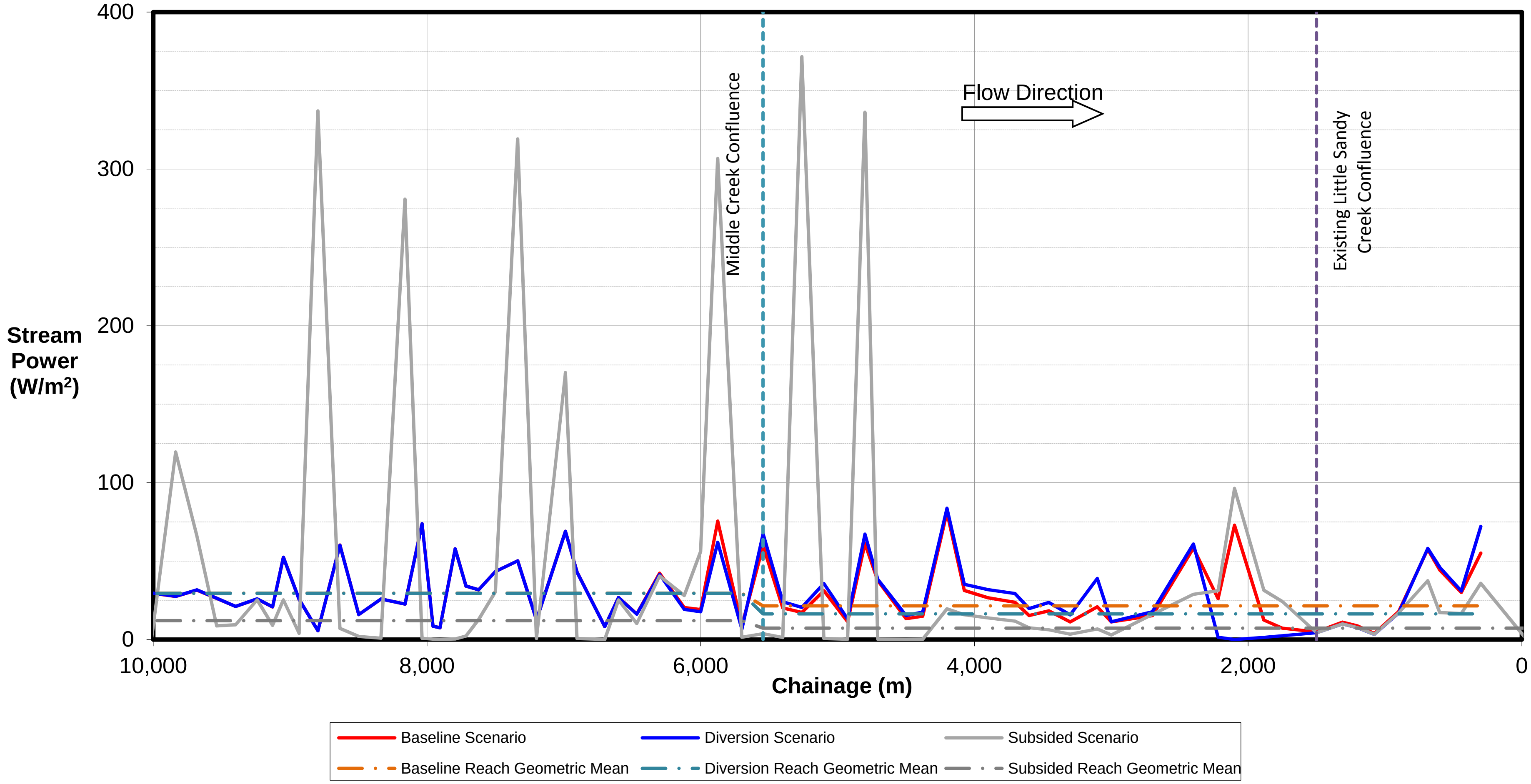

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Figure Appendix C-52 Comparison of Channel Stream Power along Well Creek for a 1:20 AEP Event

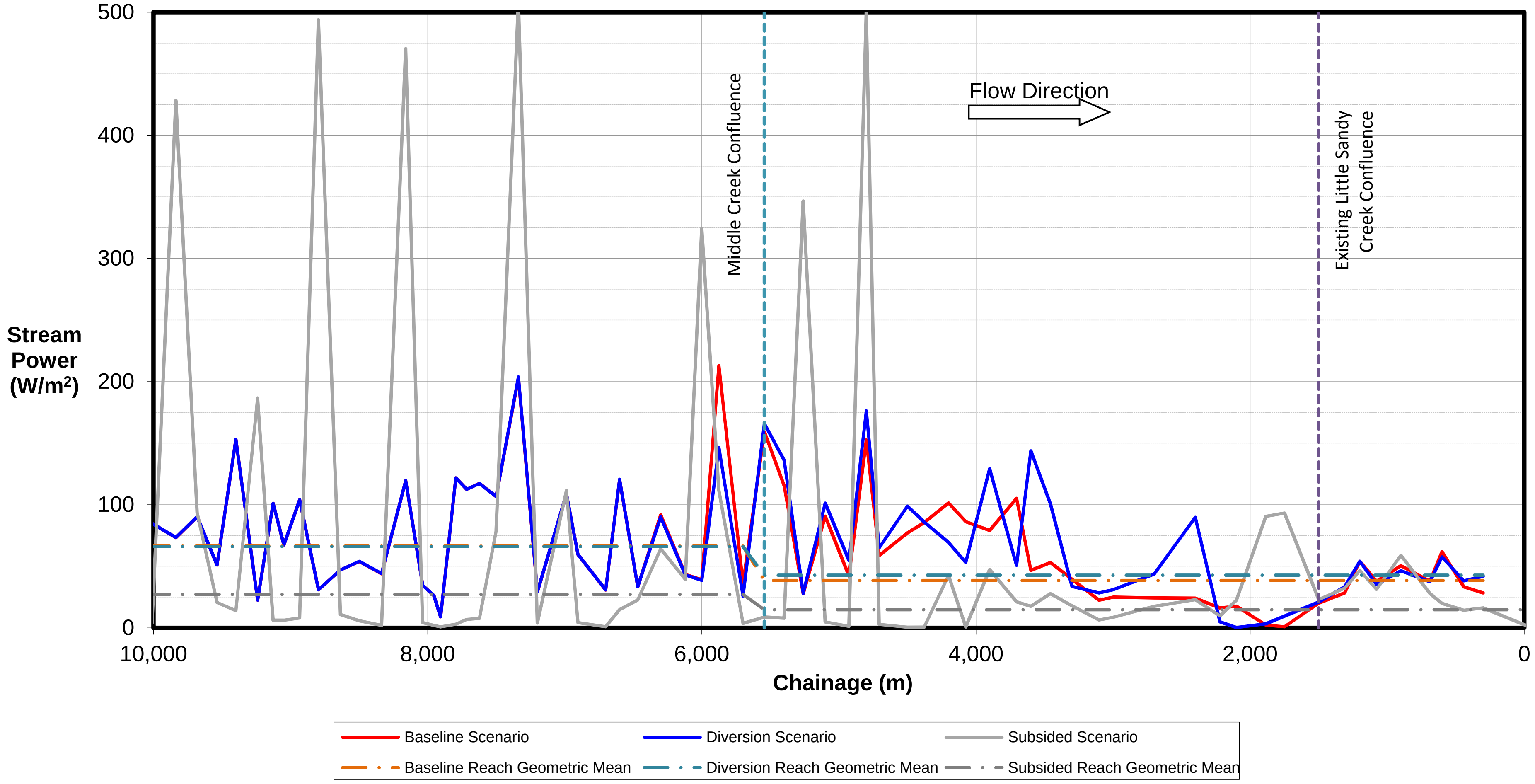

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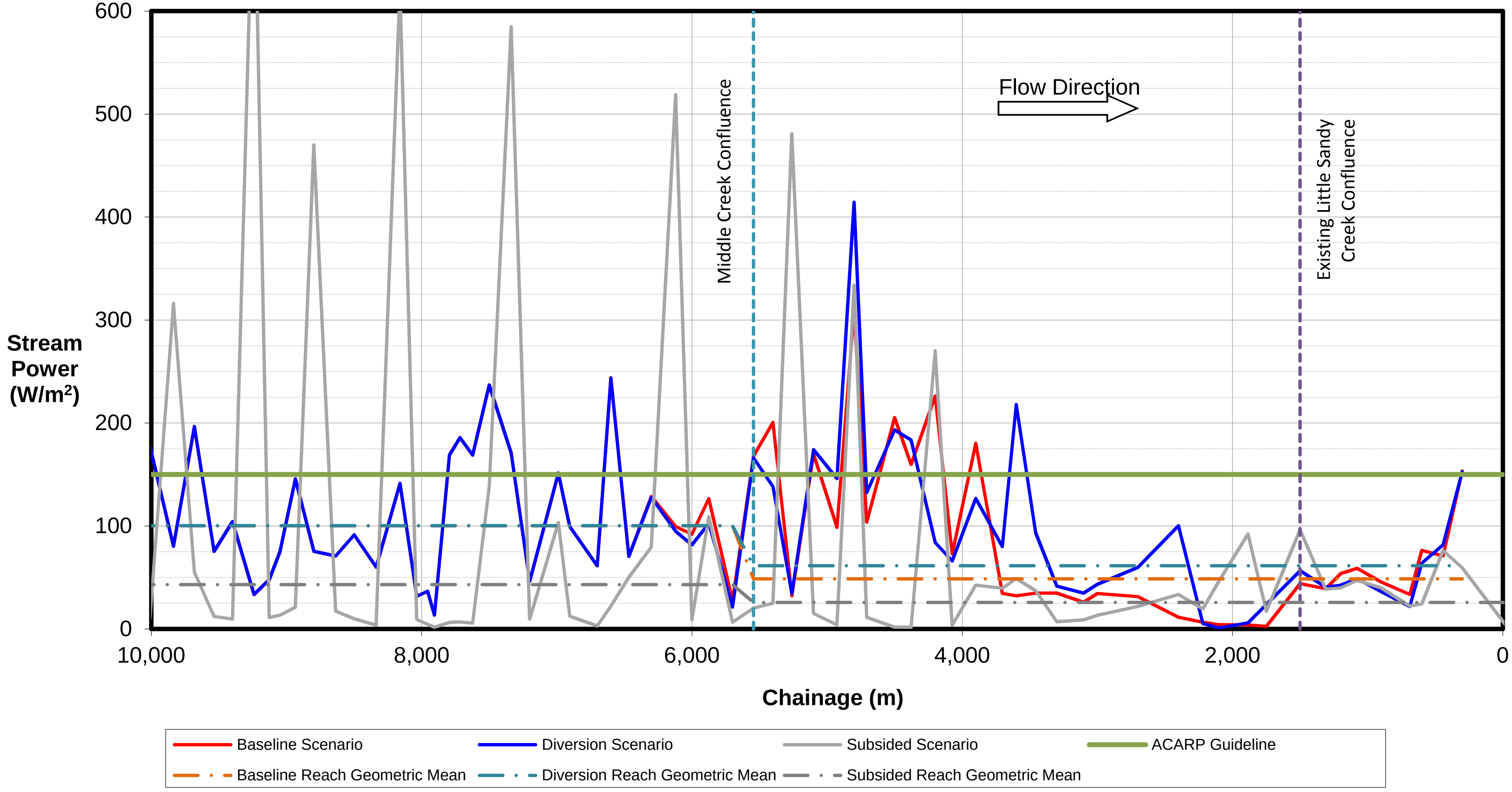
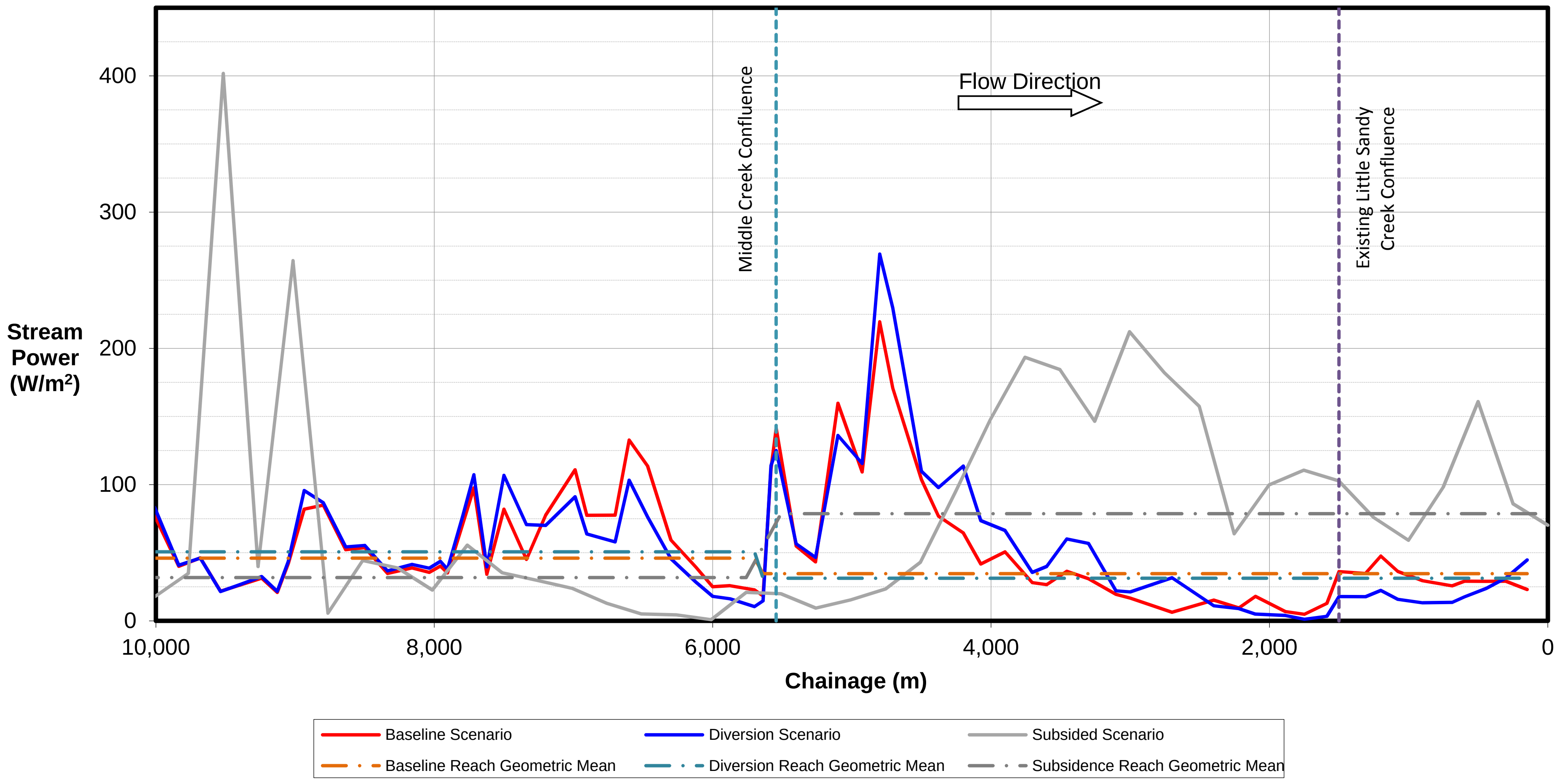
Figure Appendix C-53 Comparison of Channel Stream Power along Well Creek for a 1:50 AEP Event



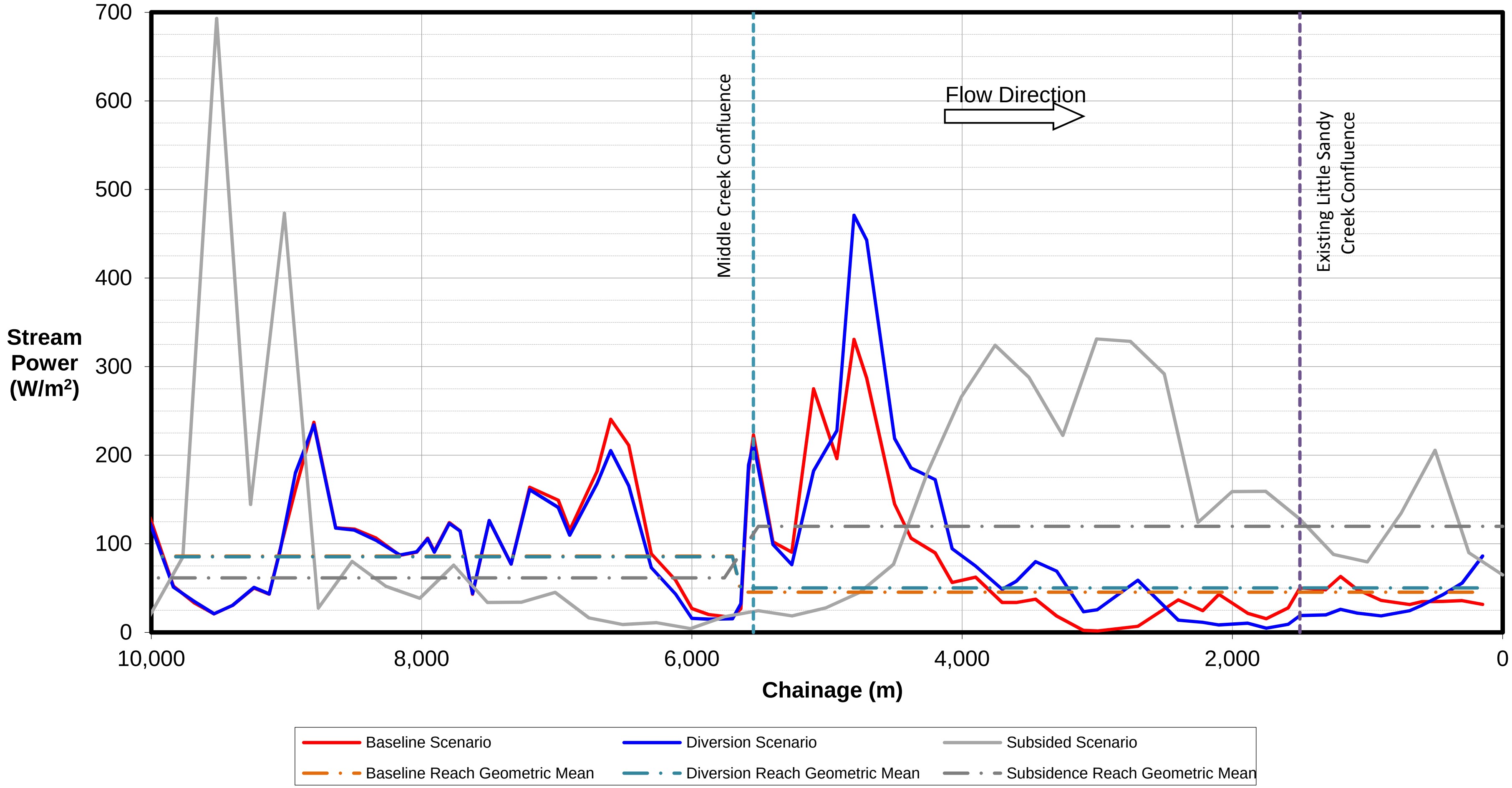
Appendix C - **Modelling Results – Profile Comparison Plots**

Figure Appendix C-54 Comparison of Channel Stream Power along Well Creek for a 1:100 AEP Event



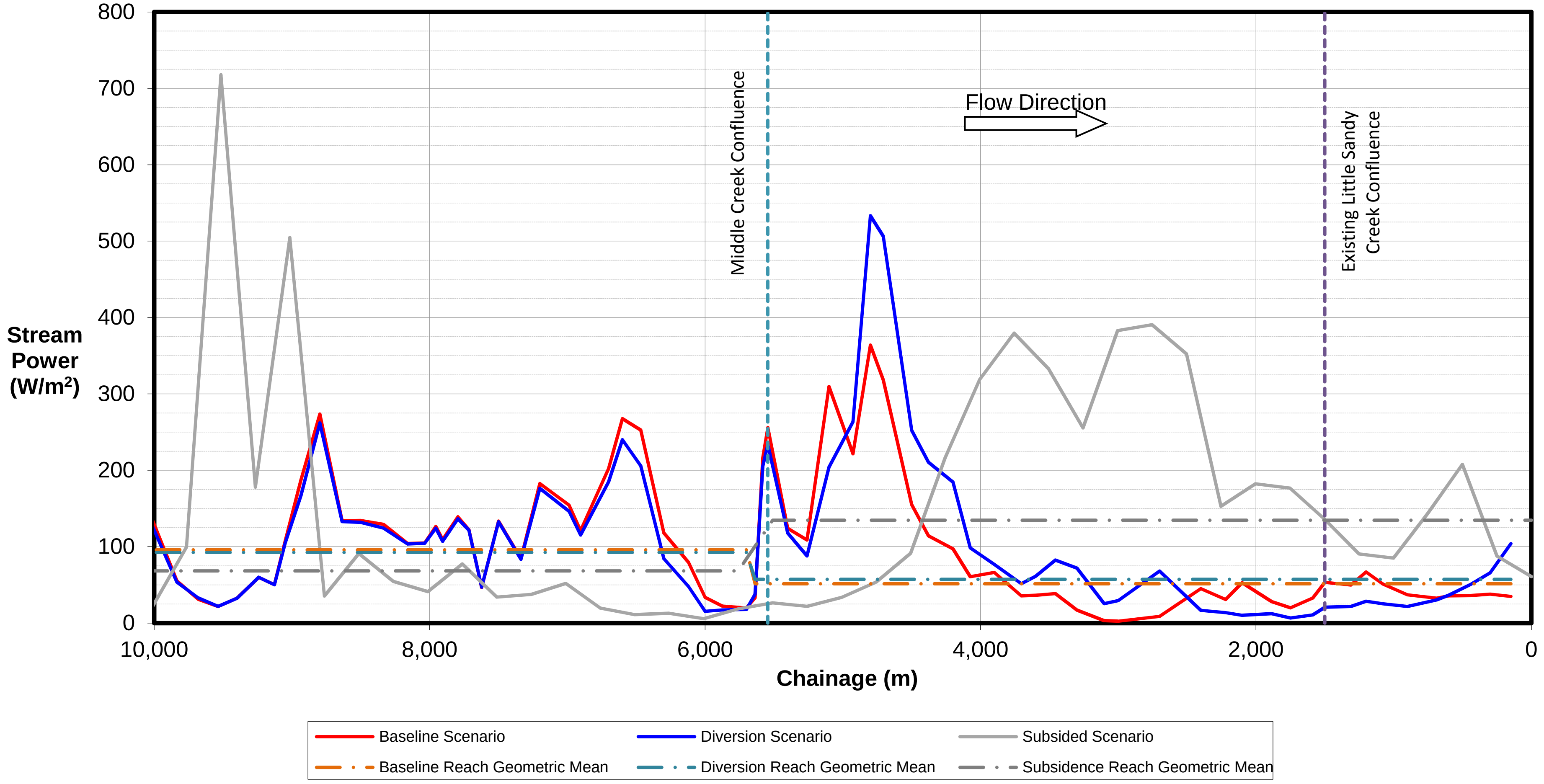
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-55 Comparison of Channel Stream Power along Well Creek for a 1:1000 AEP Event



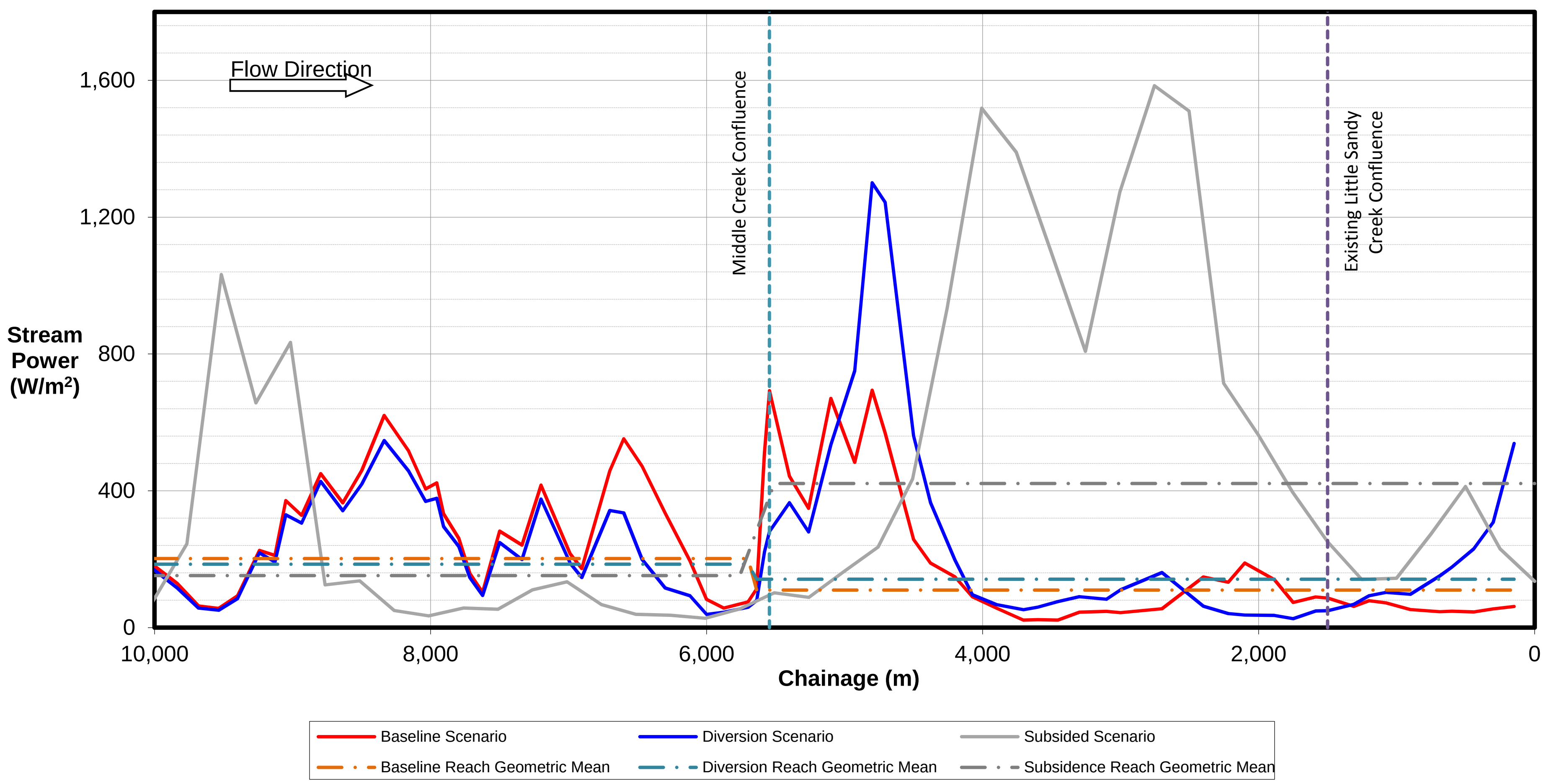
Appendix C - **Modelling Results – Profile Comparison Plots**

Figure Appendix C-56 Comparison of Channel Stream Power along Well Creek for a 1:2000 AEP Event



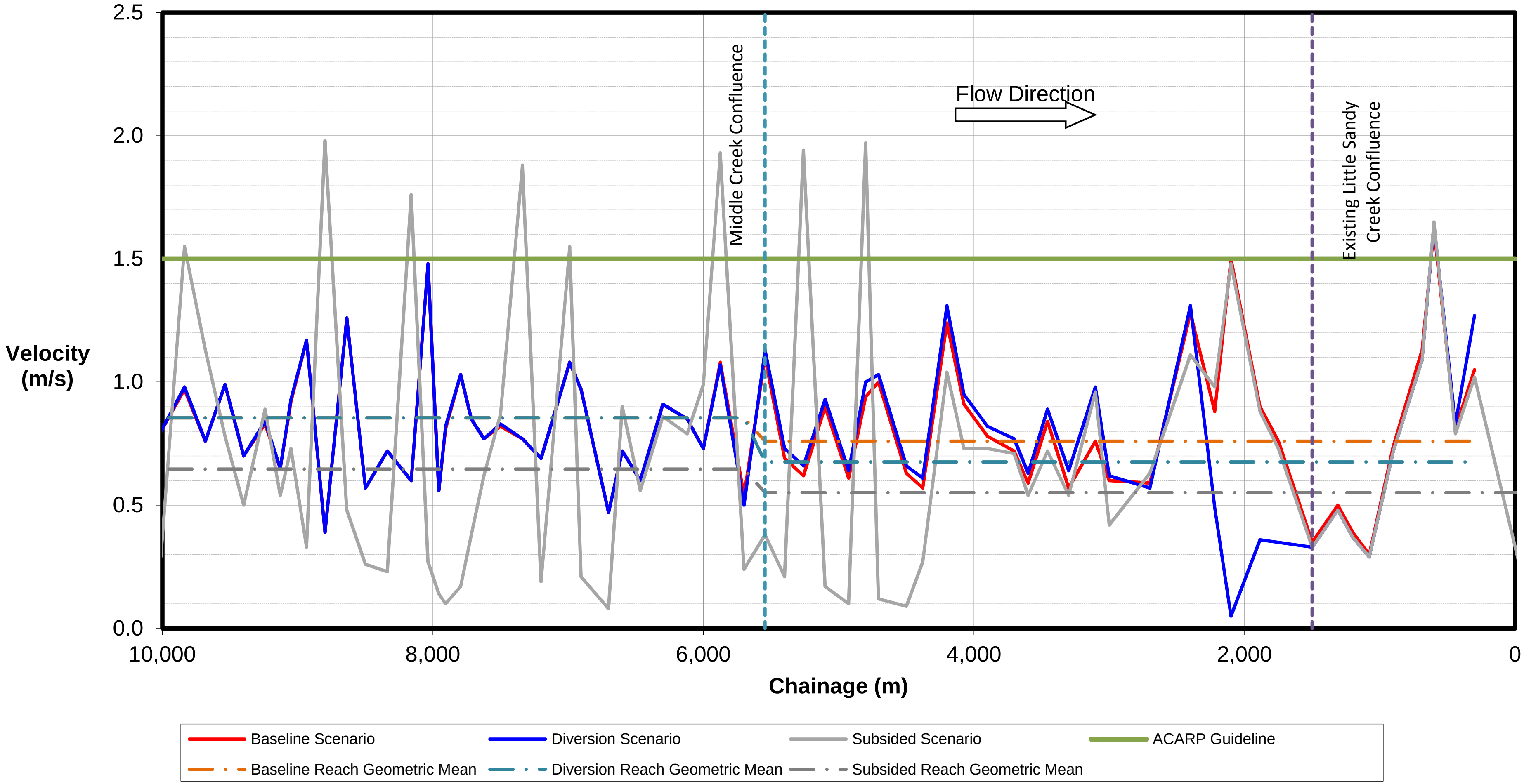
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-57 Comparison of Channel Stream Power along Well Creek for a PMF Event



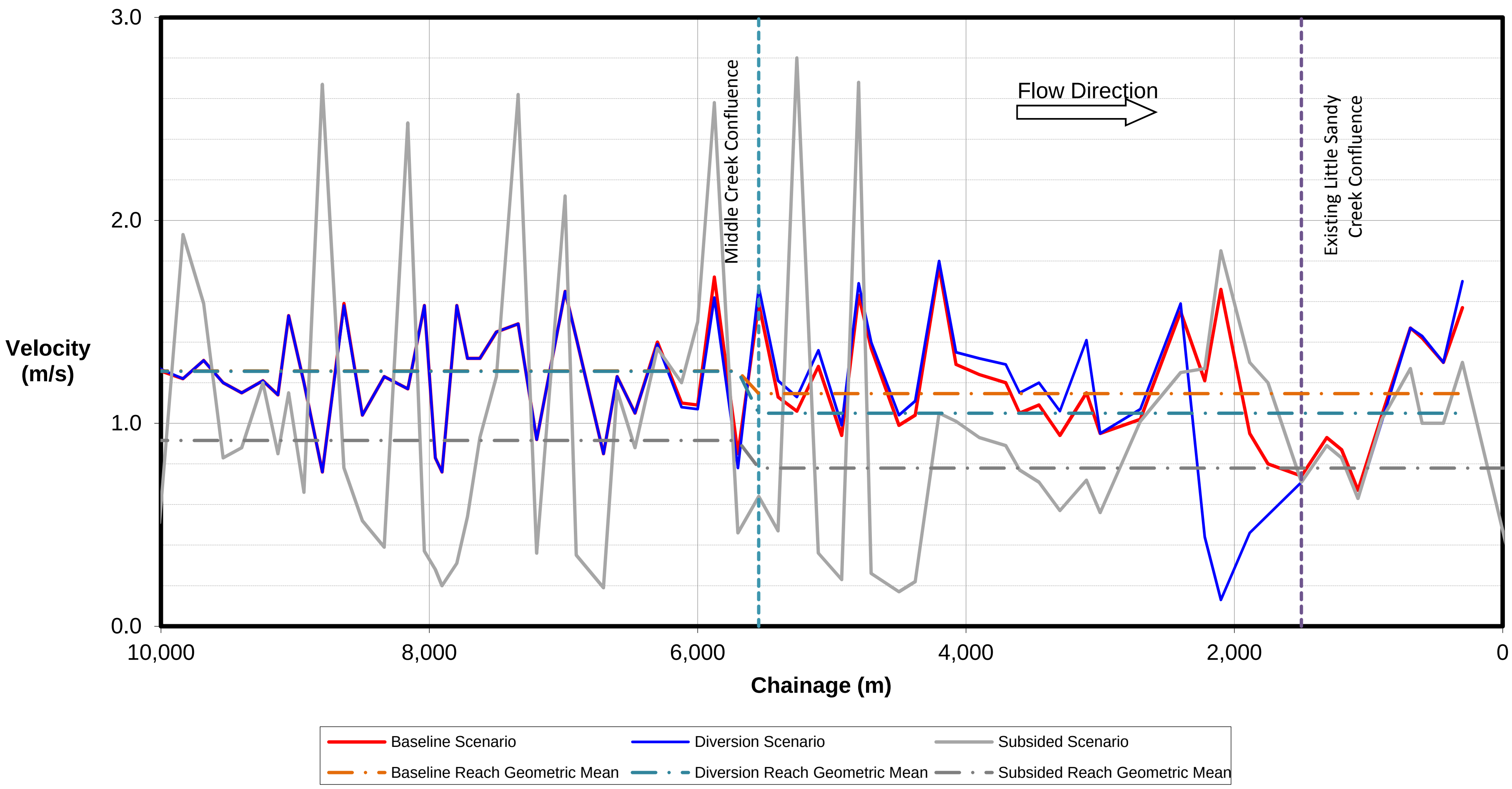
Appendix C - **Modelling Results – Profile Comparison Plots**

Figure Appendix C-58 Comparison of Channel Velocity along Well Creek for a 1:2 AEP Event



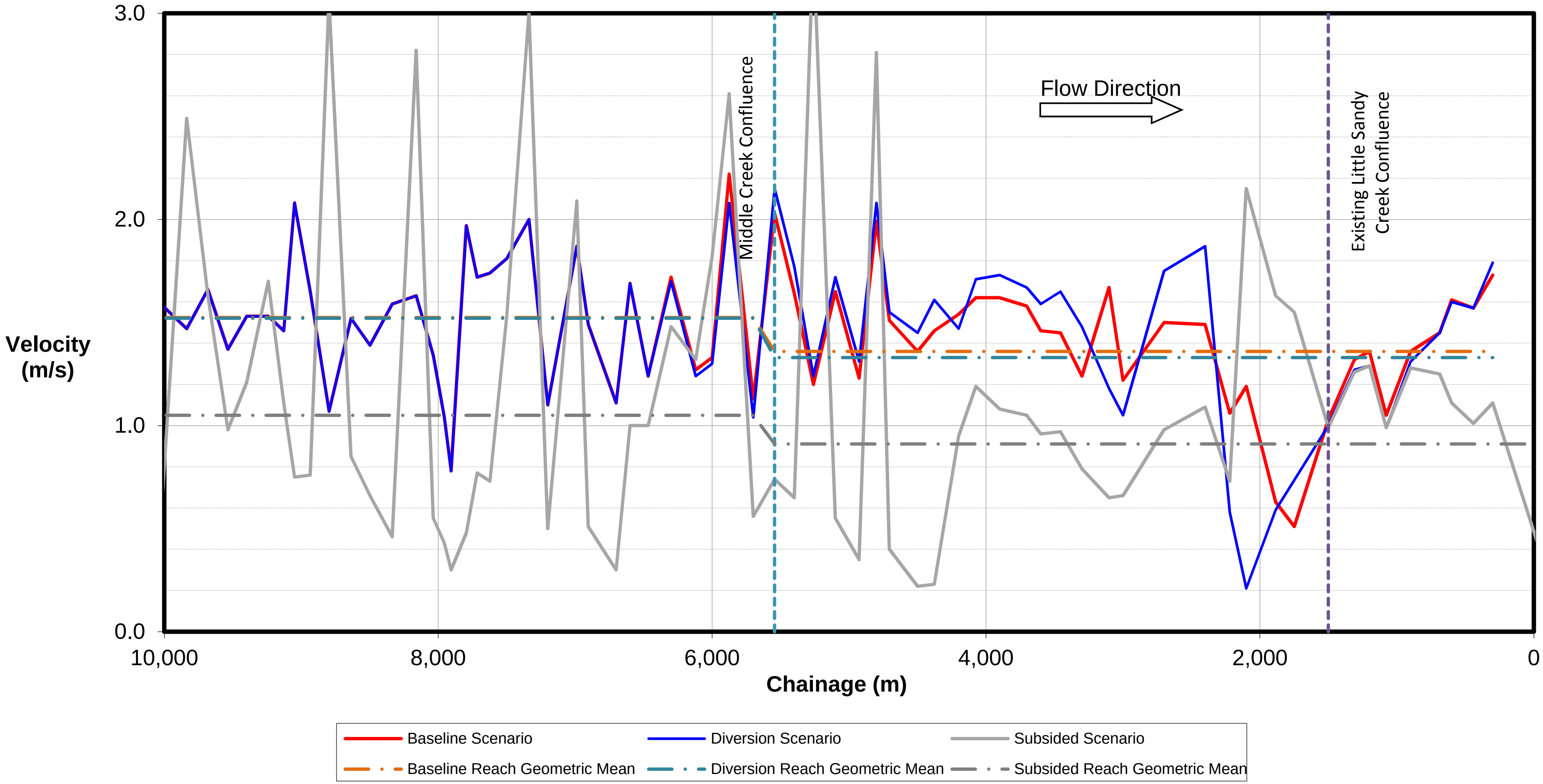
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-59 Comparison of Channel Velocity along Well Creek for a 1:5 AEP Event



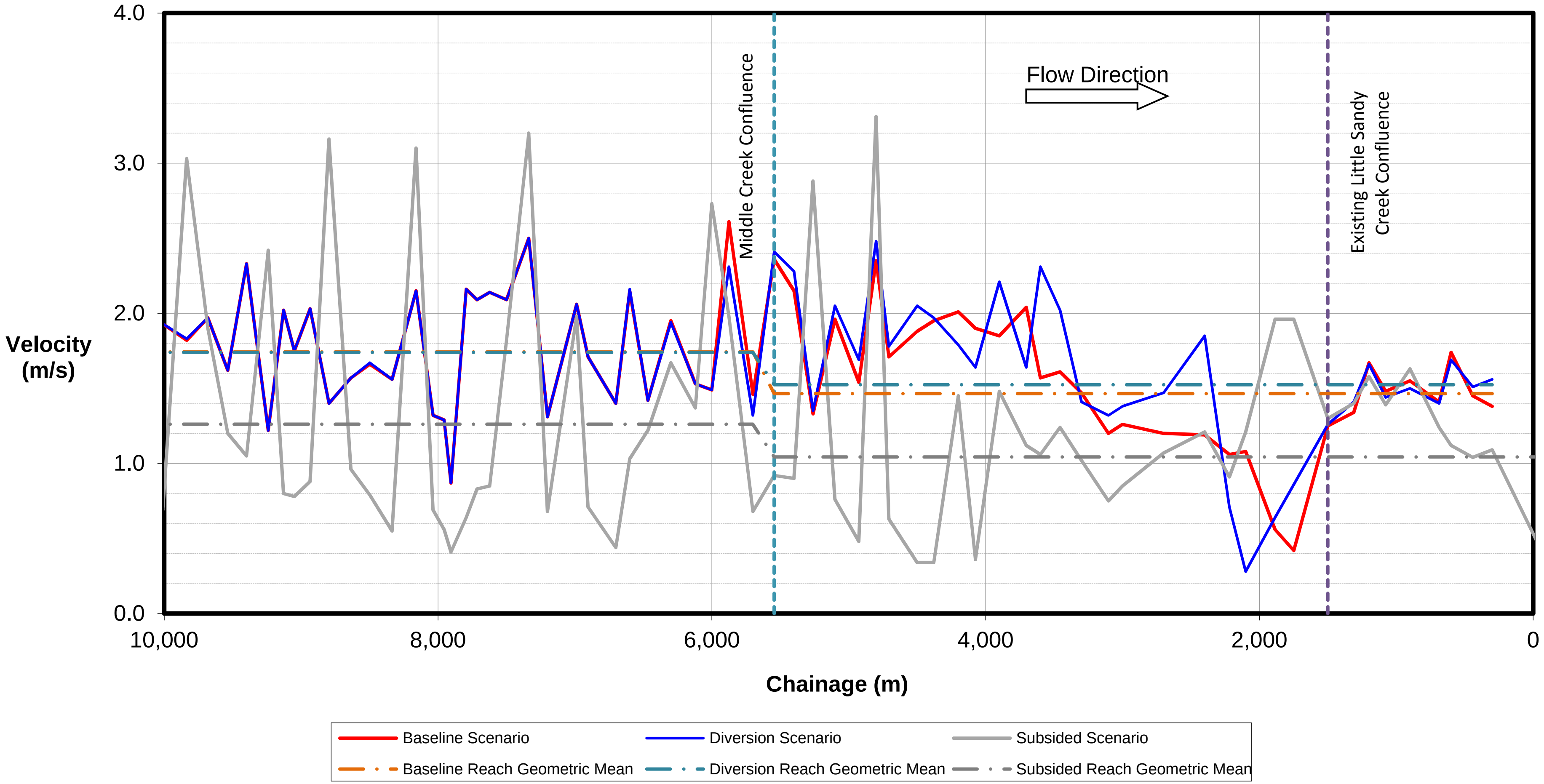
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-60 Comparison of Channel Velocity along Well Creek for a 1:10 AEP Event



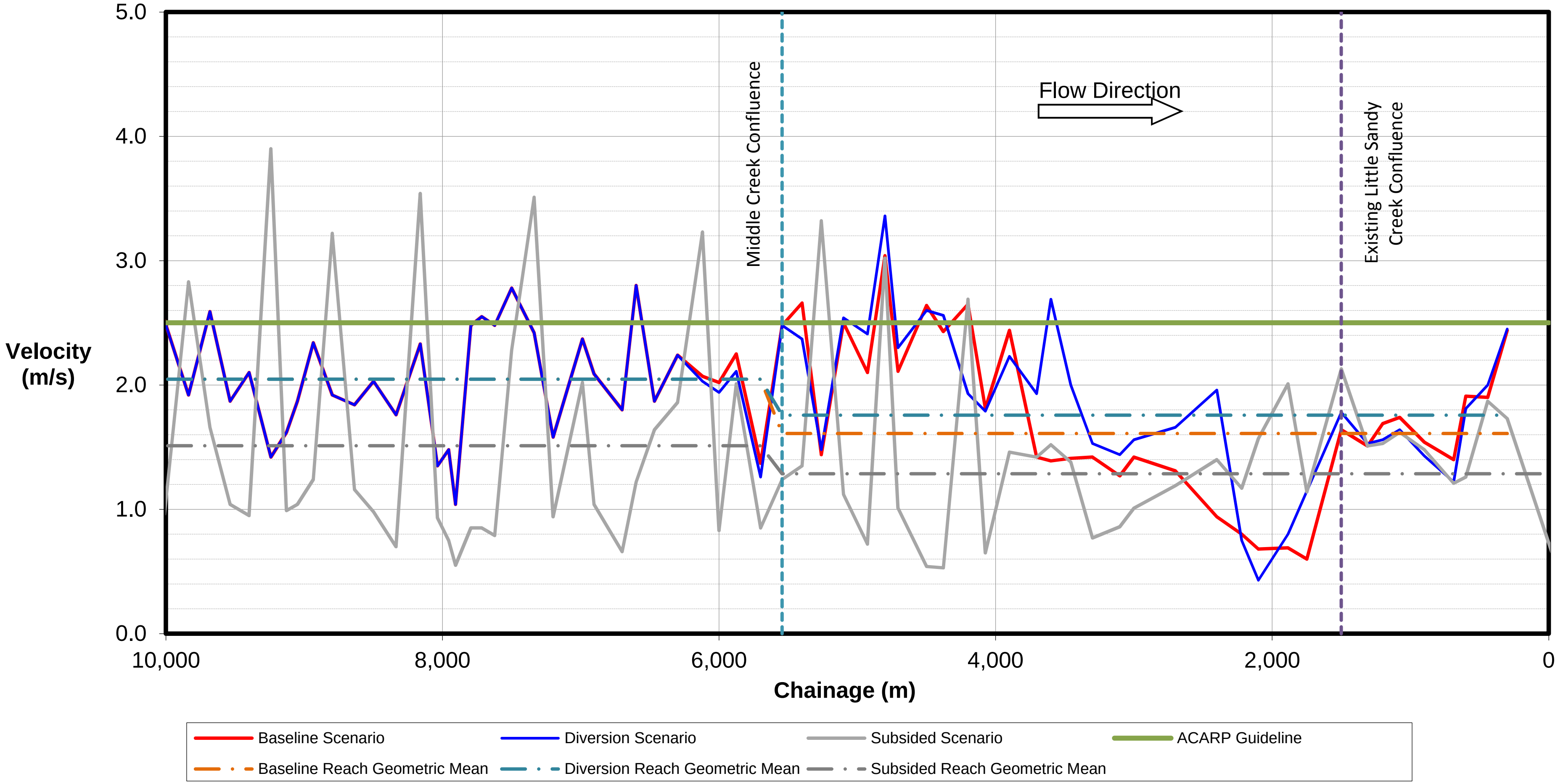
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-61 Comparison of Channel Velocity along Well Creek for a 1:20 AEP Event



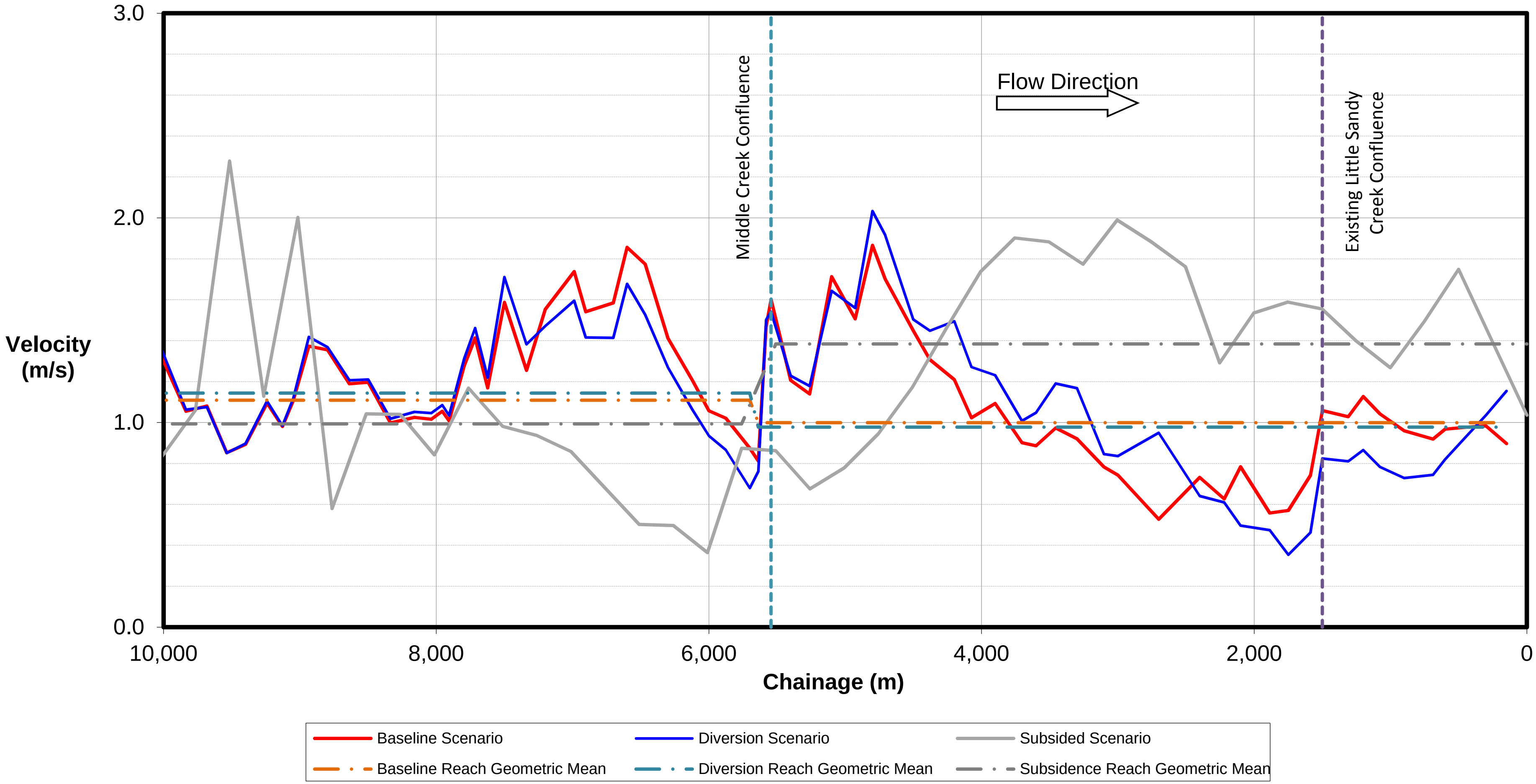
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-62 Comparison of Channel Velocity along Well Creek for a 1:50 AEP Event



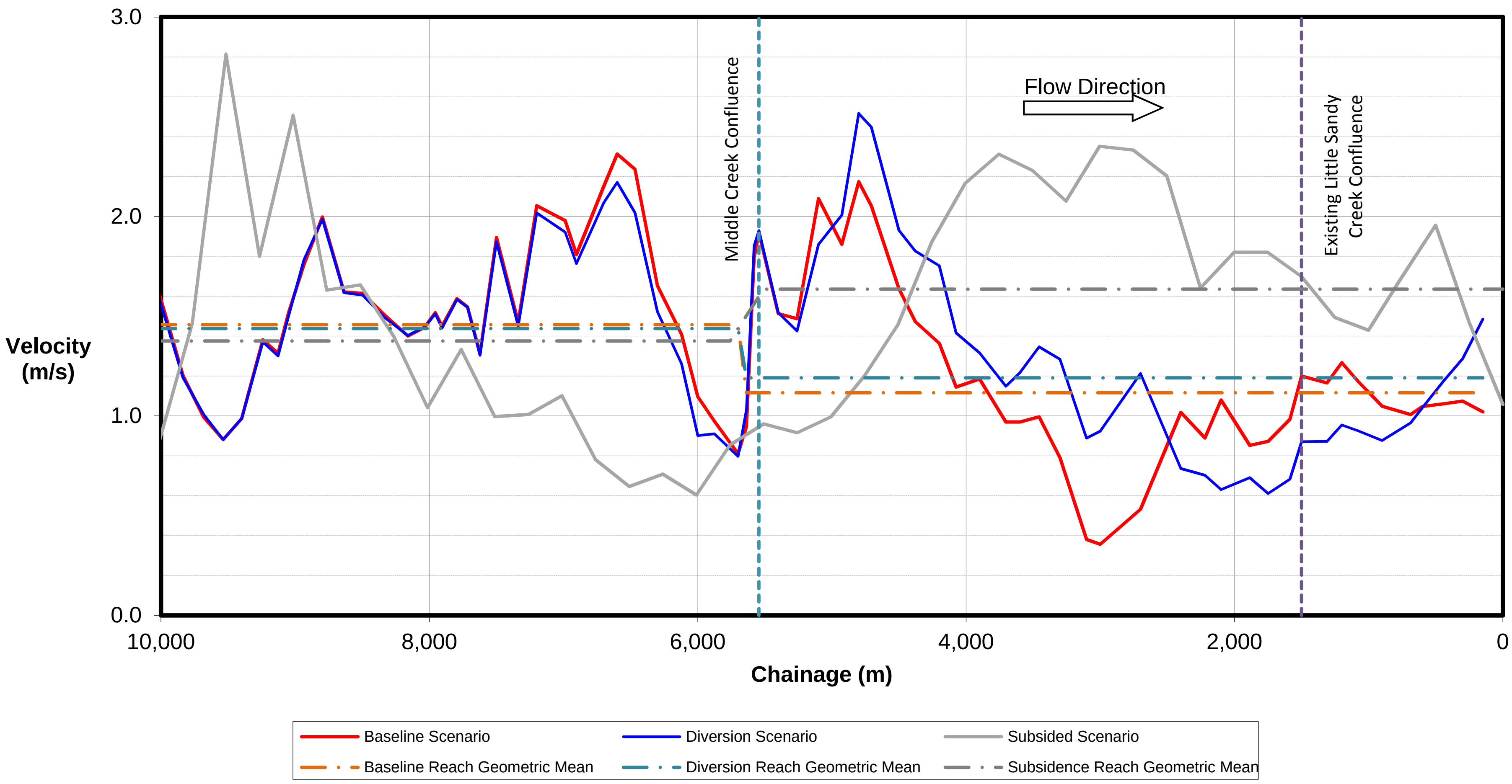
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-63 Comparison of Channel Velocity along Well Creek for a 1:100 AEP Event



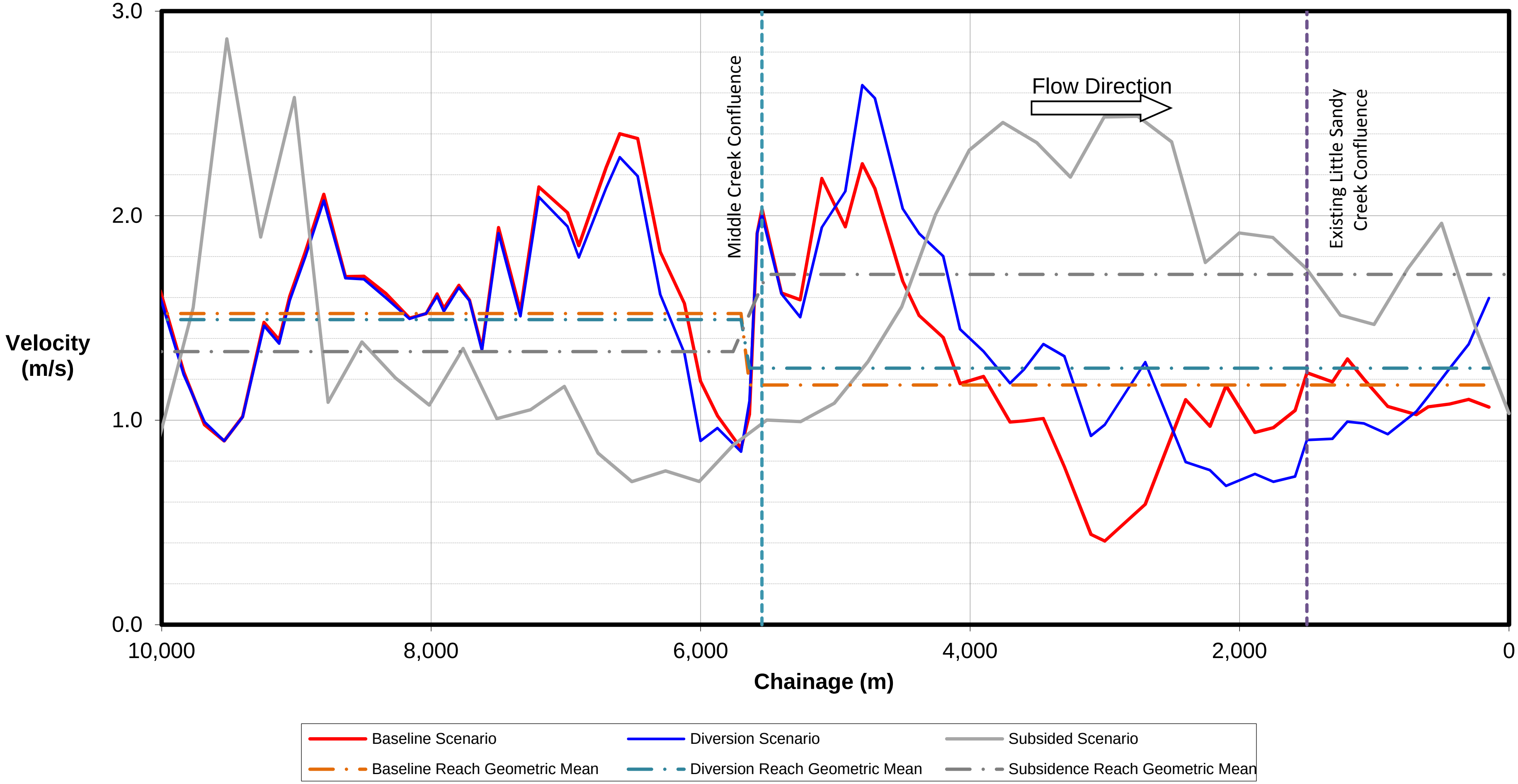
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-64 Comparison of Channel Velocity along Well Creek for a 1:1000 AEP Event



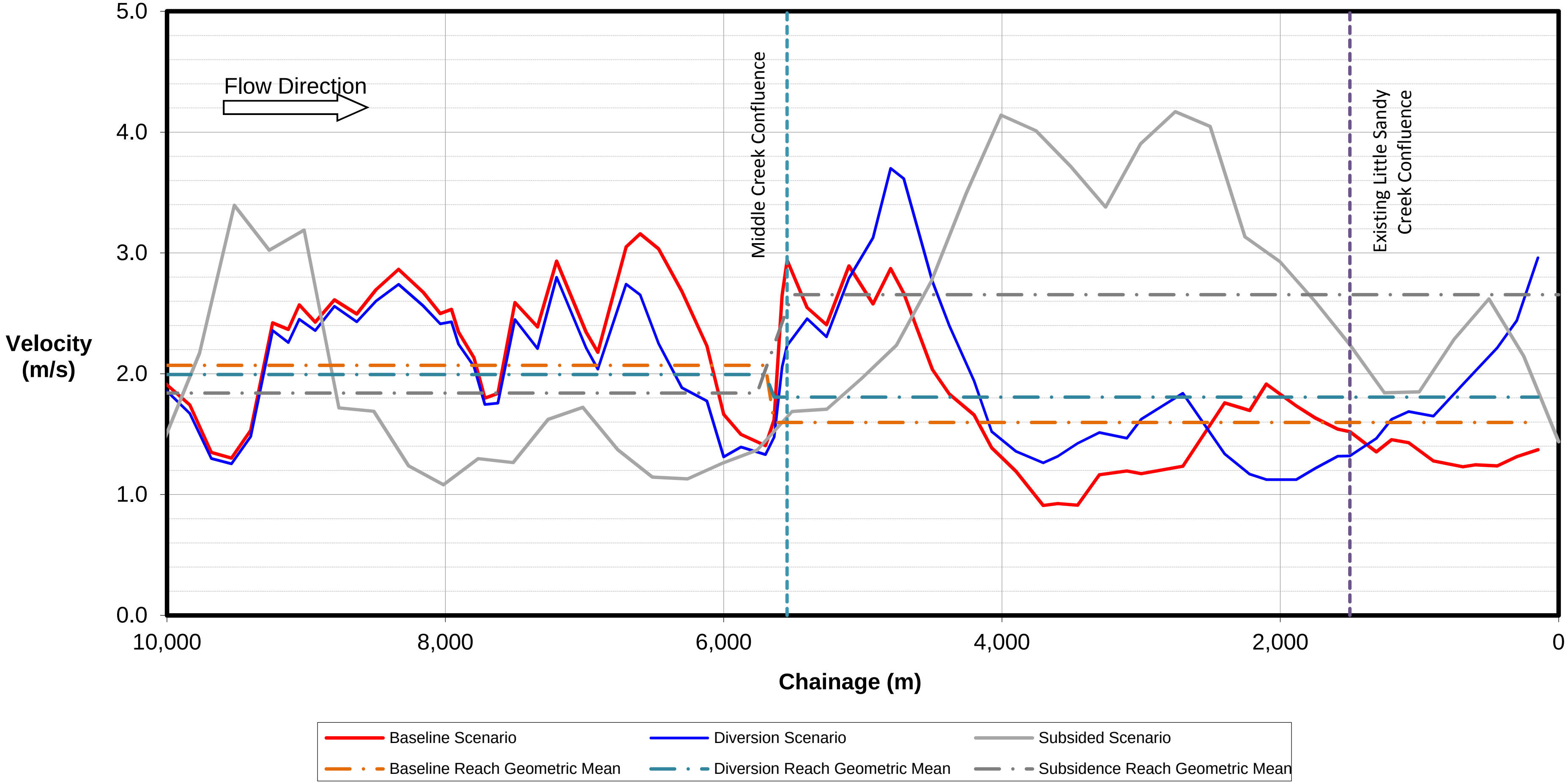
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-65 Comparison of Channel Velocity along Well Creek for a 1:2000 AEP Event



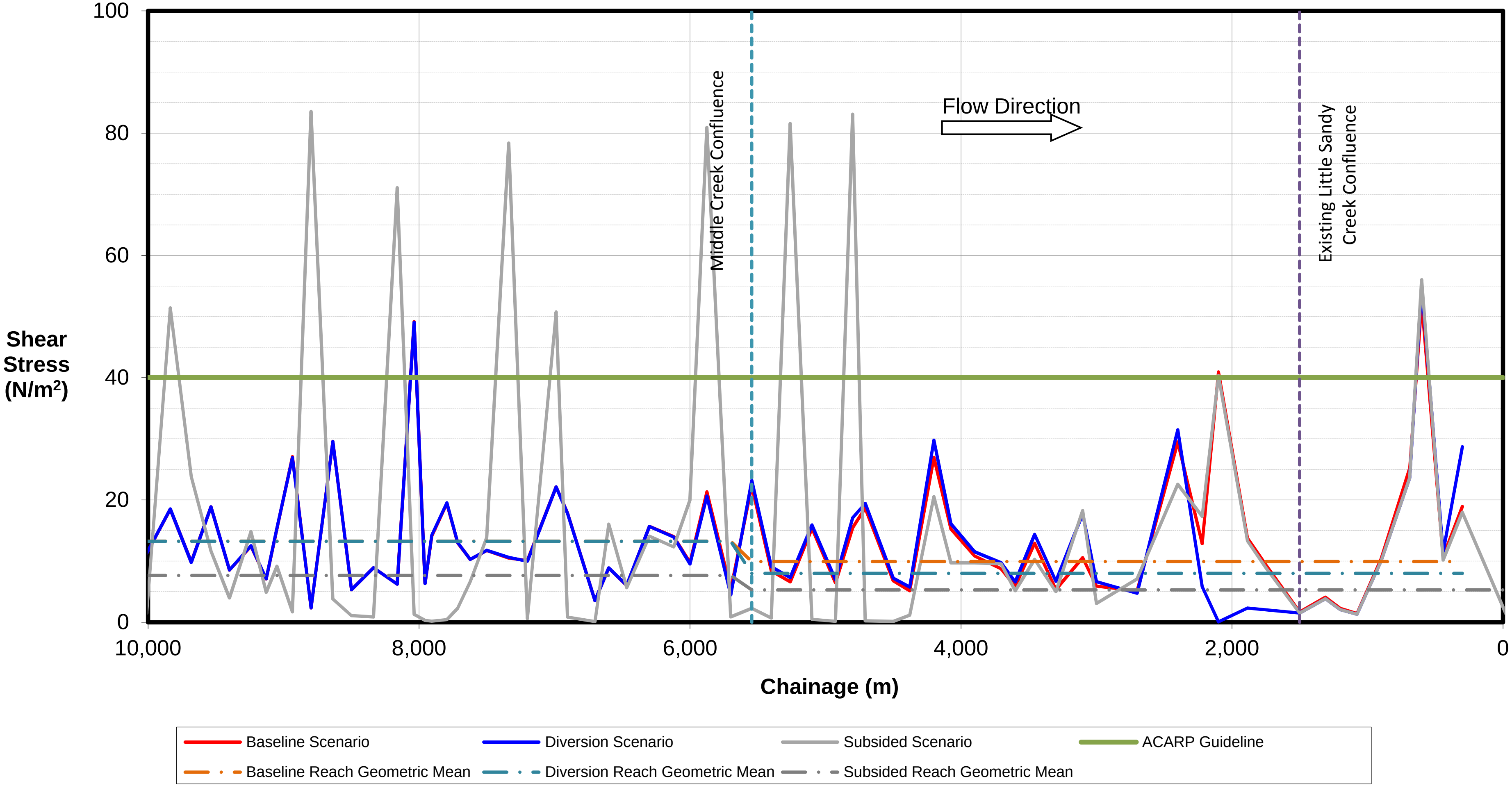
Appendix C - **Modelling Results – Profile Comparison Plots**

Figure Appendix C-66 Comparison of Channel Velocity along Well Creek for a PMF Event



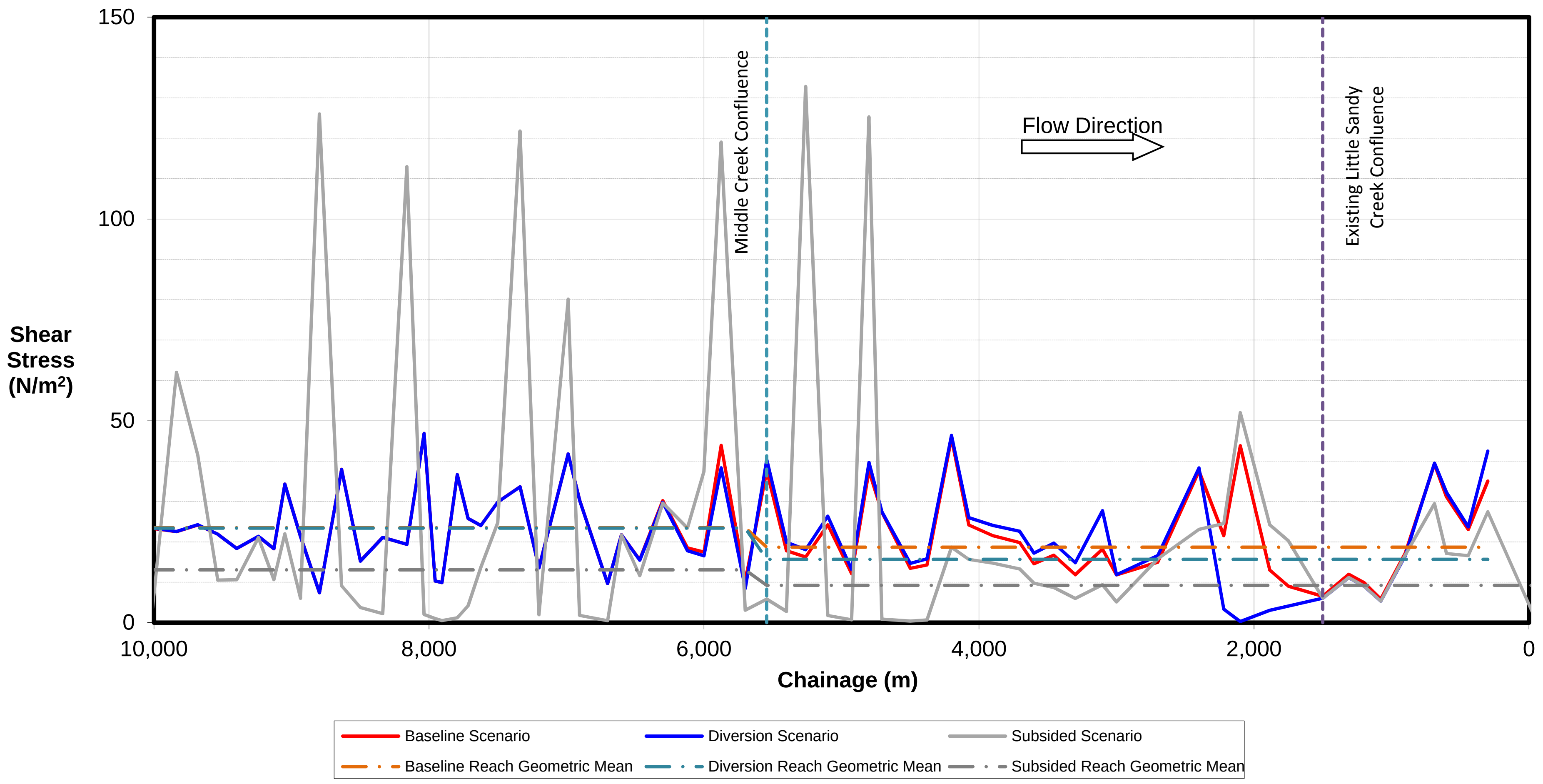
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-67 Comparison of Bed Shear Stress along Well Creek for a 1:2 AEP Event



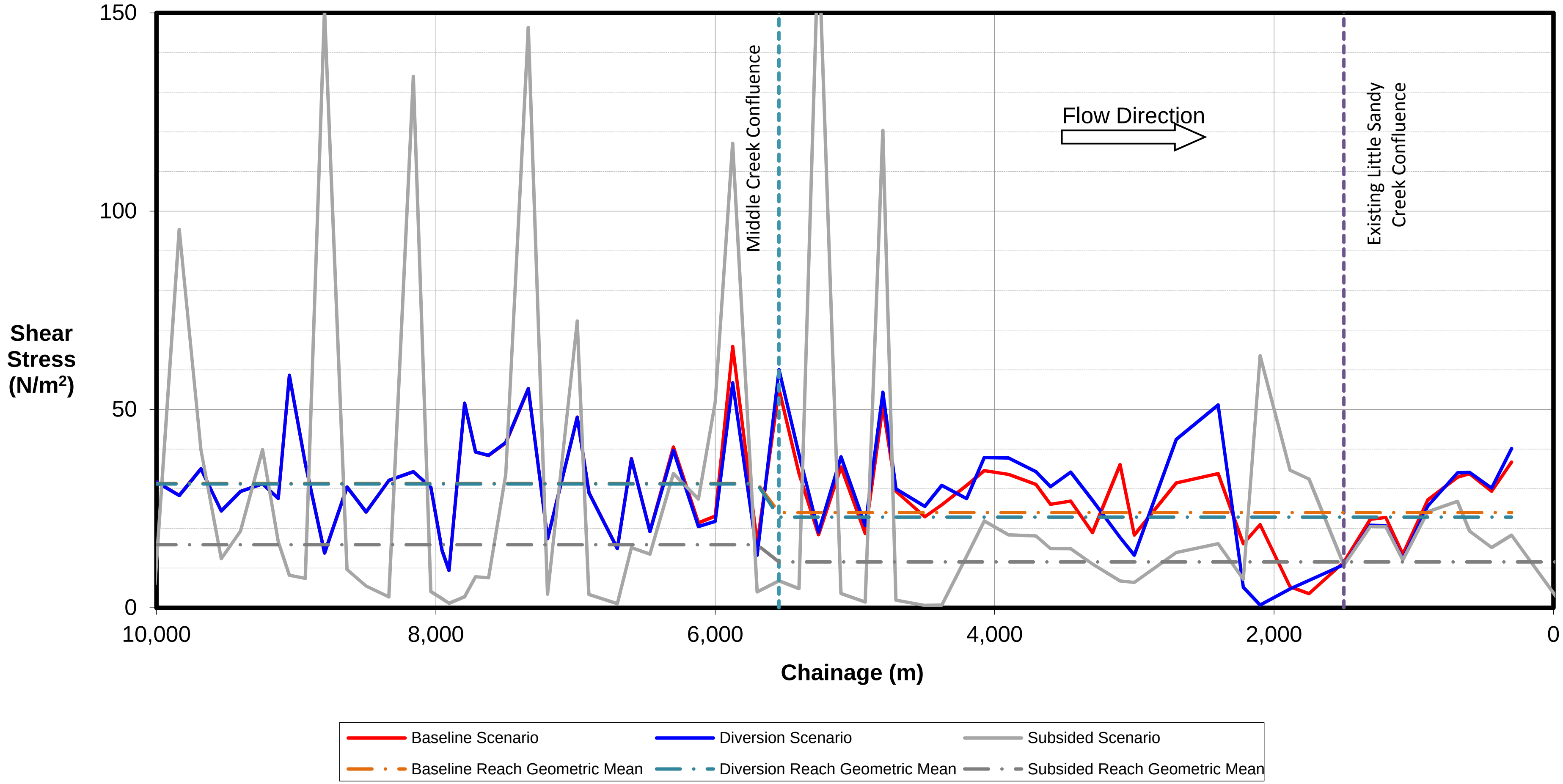
Appendix C - **Modelling Results – Profile Comparison Plots**

Figure Appendix C-68 Comparison of Bed Shear Stress along Well Creek for a 1:5 AEP Event



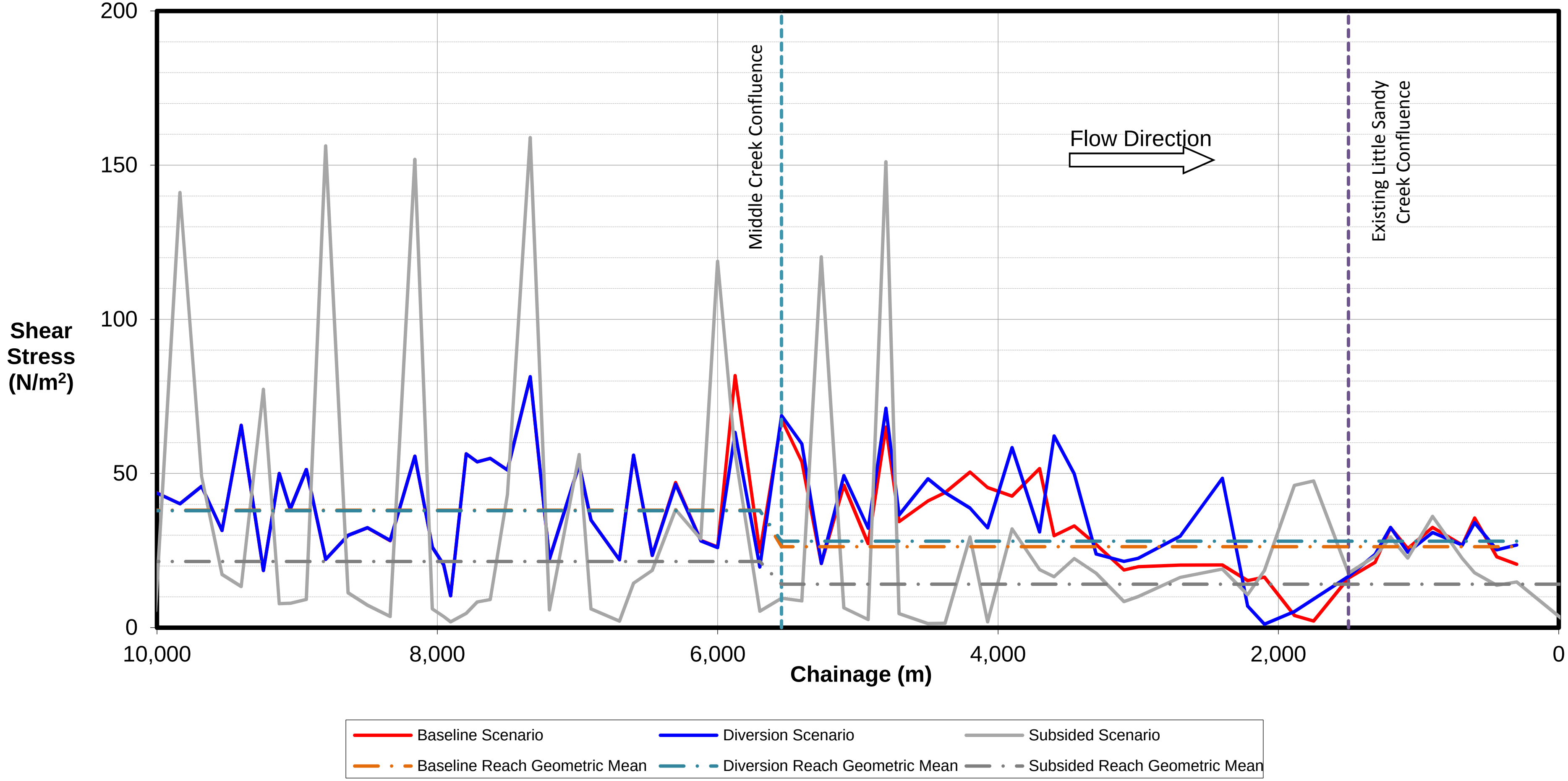
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-69 Comparison of Bed Shear Stress along Well Creek for a 1:10 AEP Event



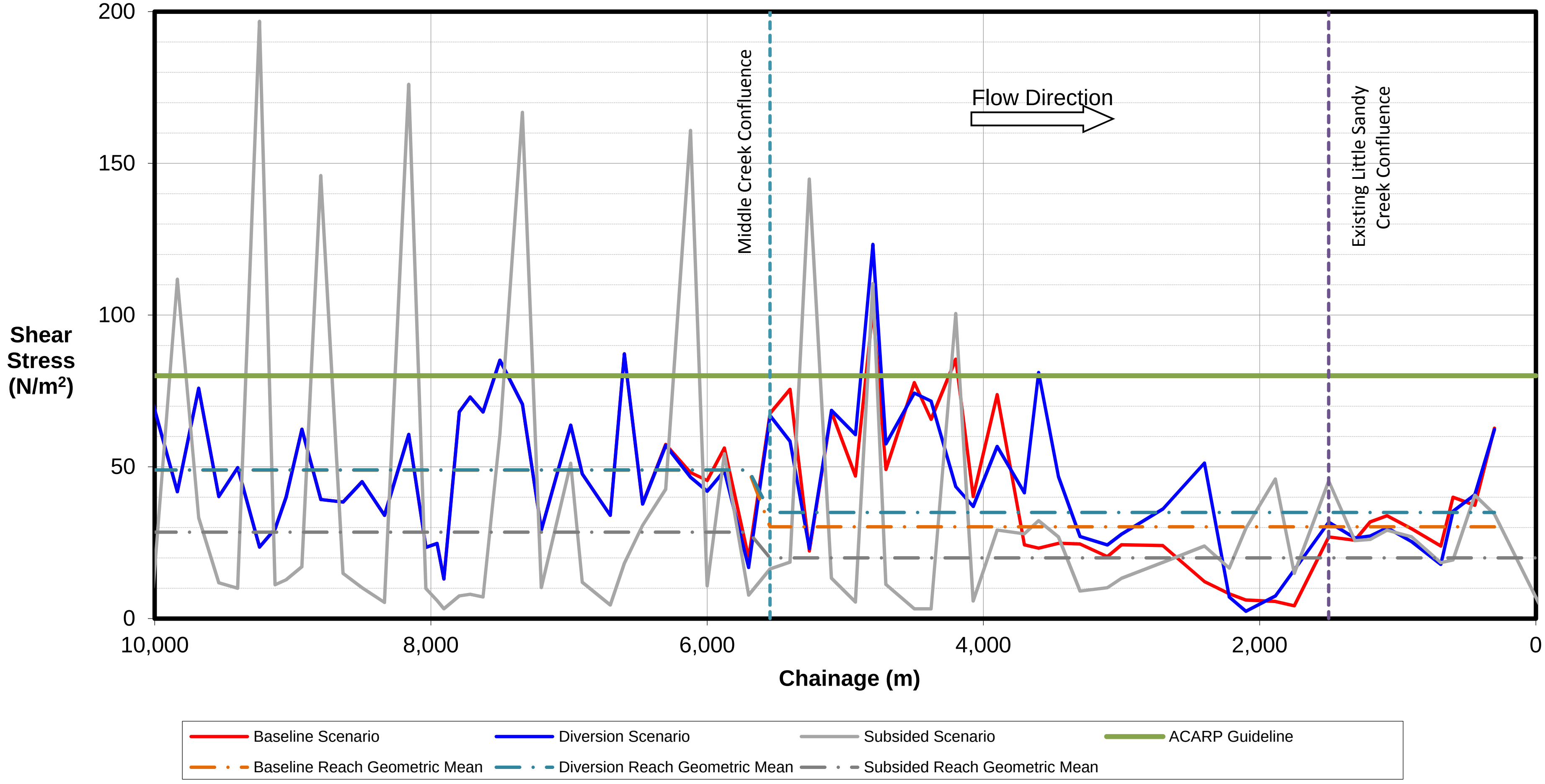
Appendix C - **Modelling Results – Profile Comparison Plots**

Figure Appendix C-70 Comparison of Bed Shear Stress along Well Creek for a 1:20 AEP Event



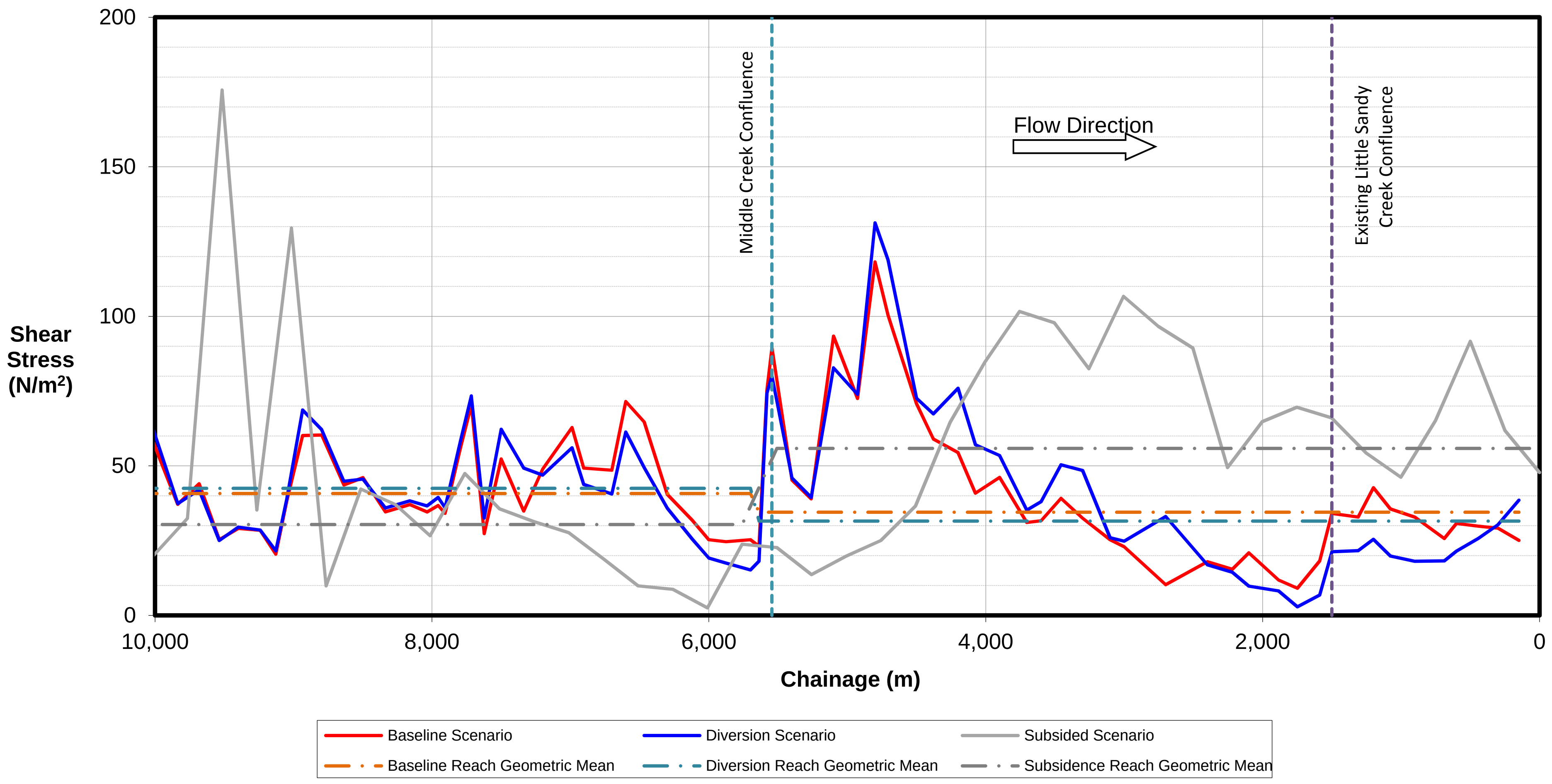
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-71 Comparison of Bed Shear Stress along Well Creek for a 1:50 AEP Event



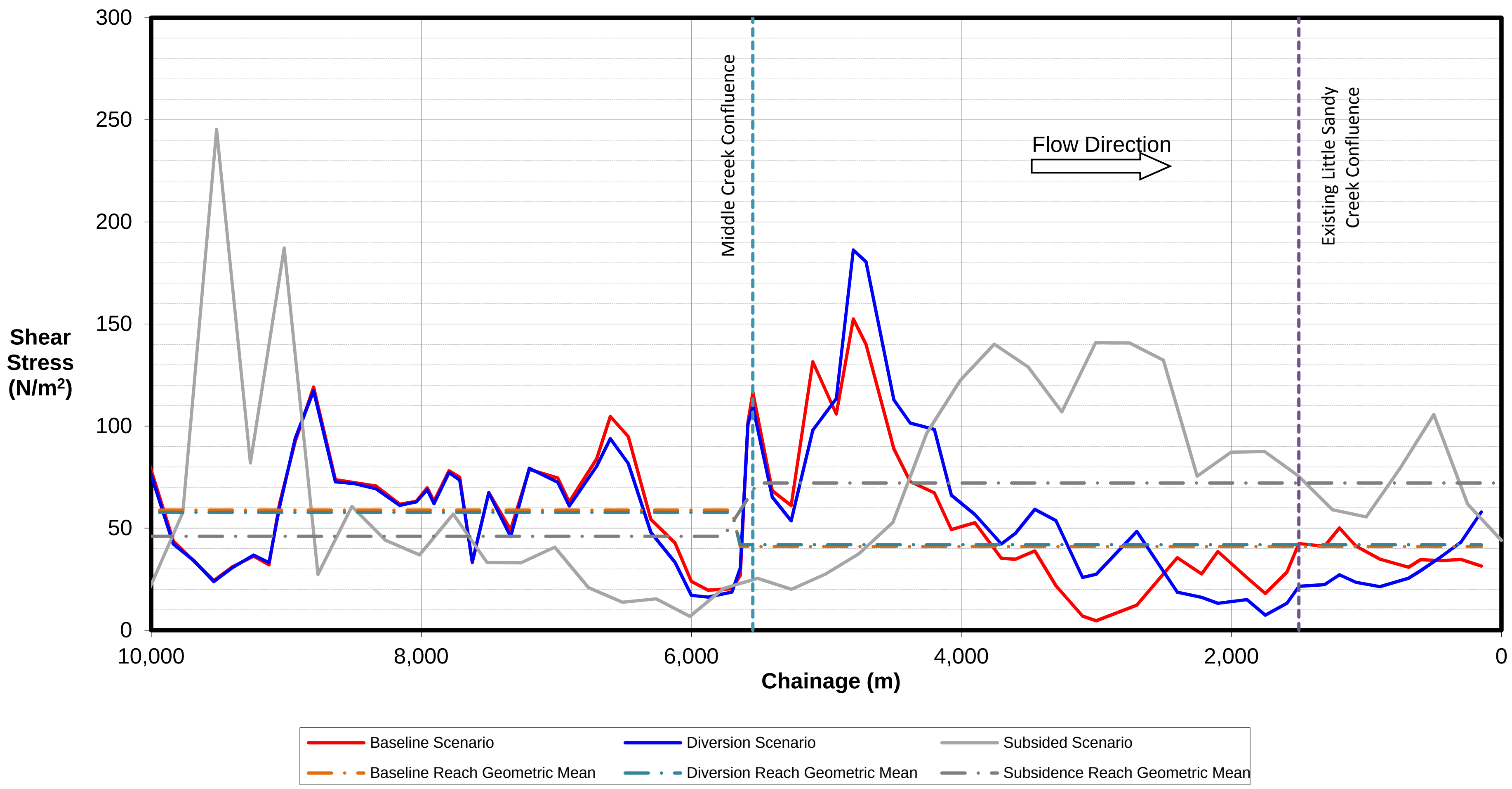
Appendix C - **Modelling Results – Profile Comparison Plots**

Figure Appendix C-72 Comparison of Bed Shear Stress along Well Creek for a 1:100 AEP Event



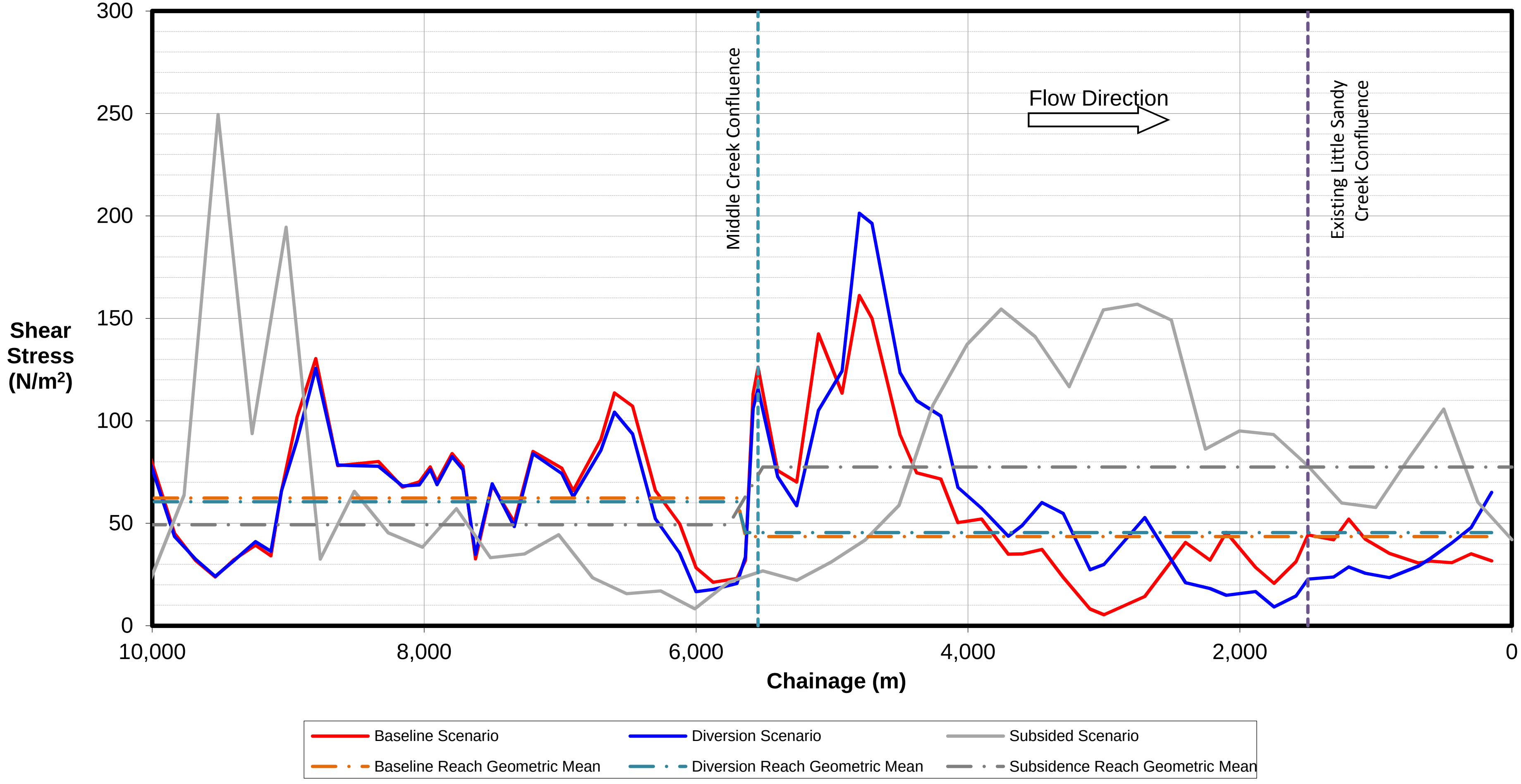
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-73 Comparison of Bed Shear Stress along Well Creek for a 1:1000 AEP Event



Appendix C - **Modelling Results – Profile Comparison Plots**

Figure Appendix C-74 Comparison of Bed Shear Stress along Well Creek for a 1:2000 AEP Event



Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-75 Comparison of Bed Shear Stress along Well Creek for a PMF Event

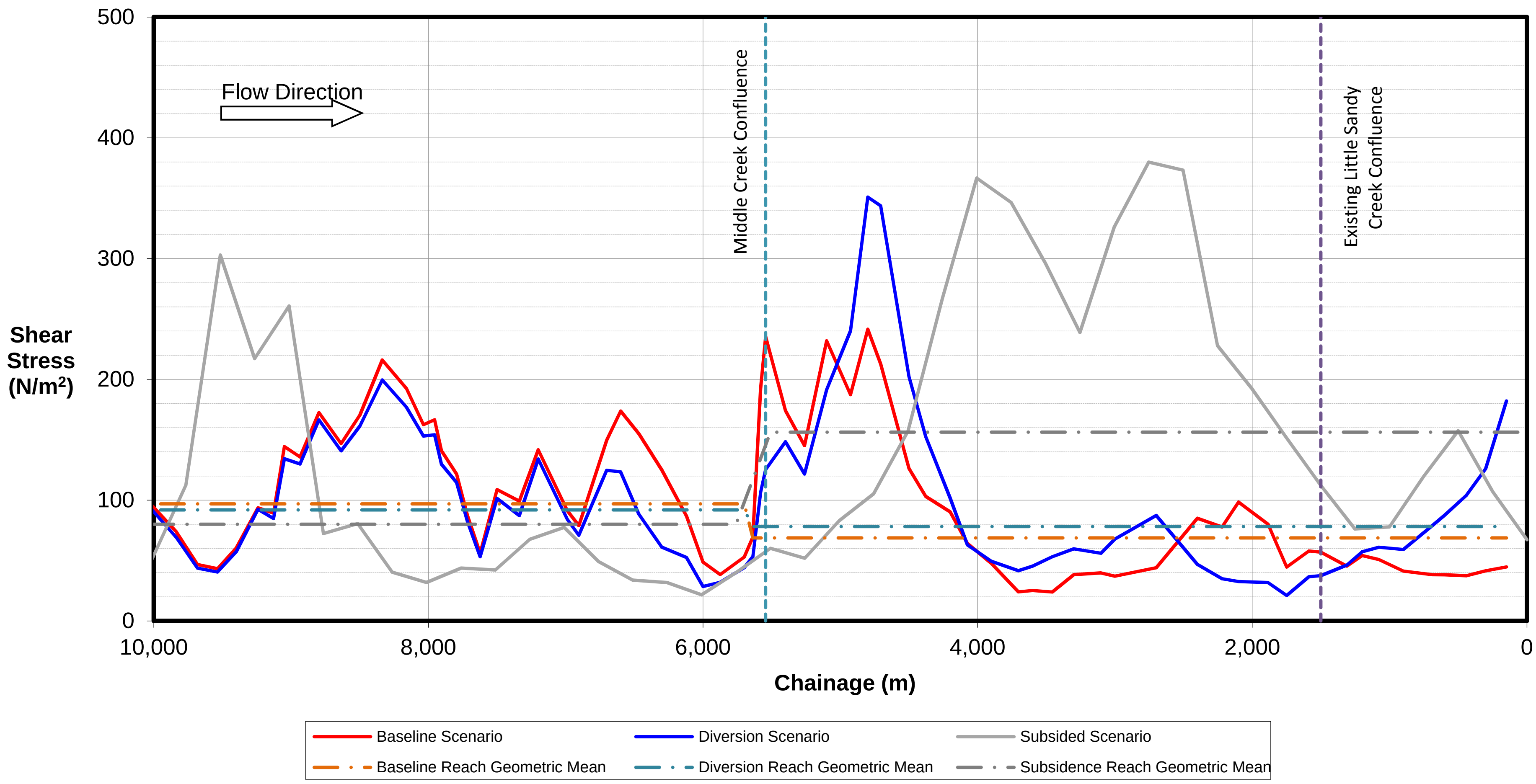
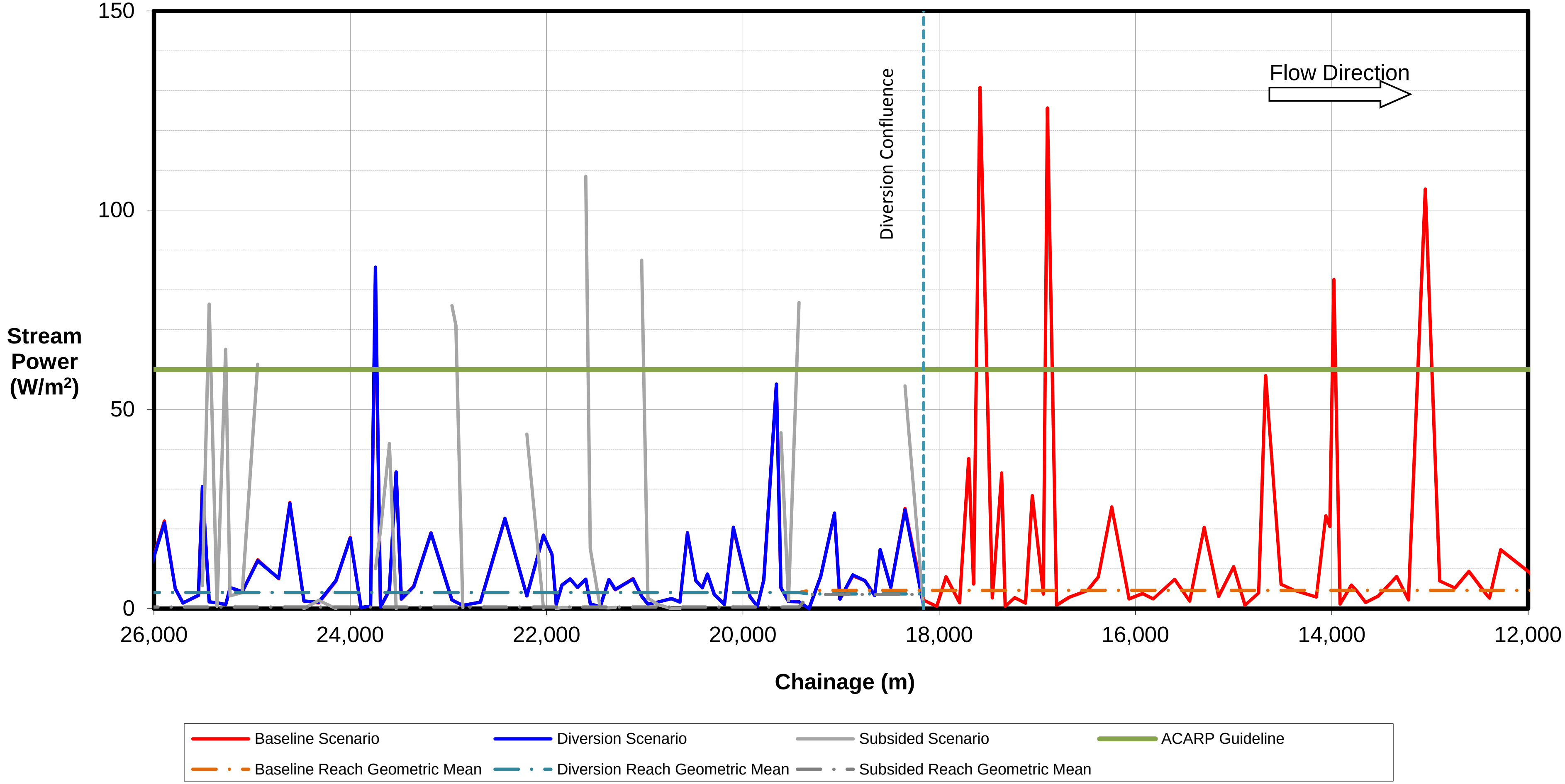
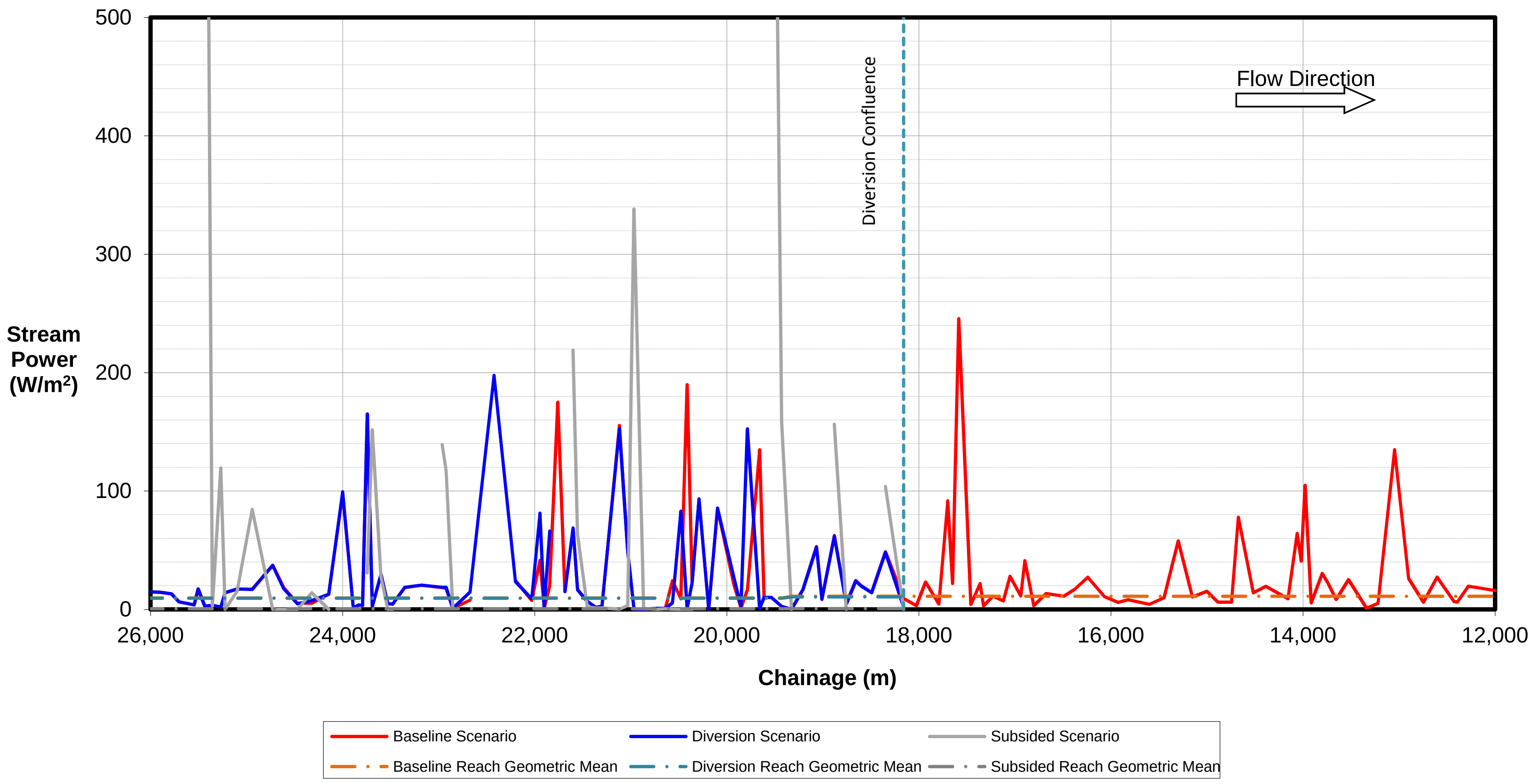


Figure Appendix C-76 Comparison of Channel Stream Power along Little Sandy Creek for a 1:2 AEP Event



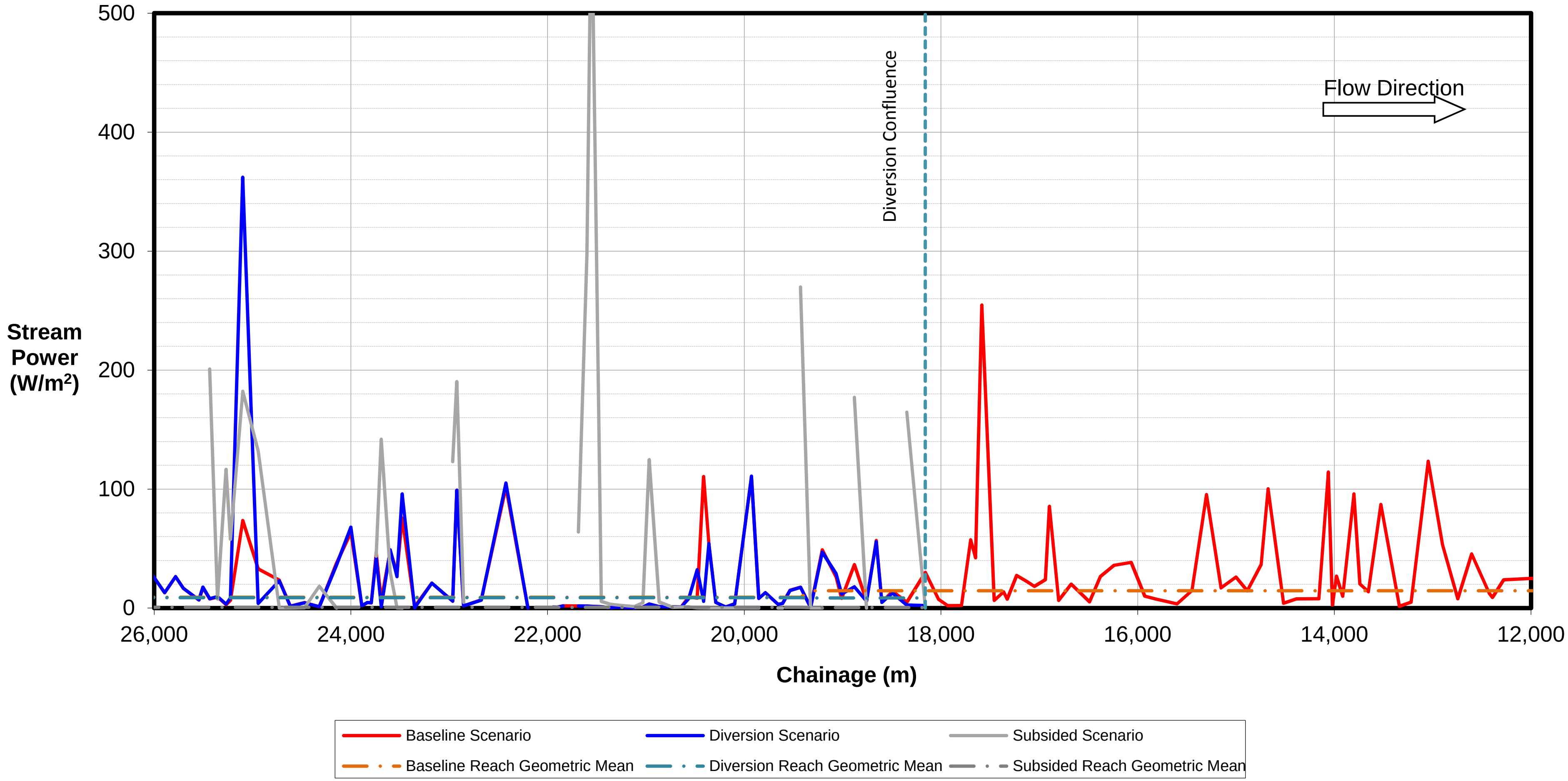
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-77 Comparison of Channel Stream Power along Little Sandy Creek for a 1:5 AEP Event



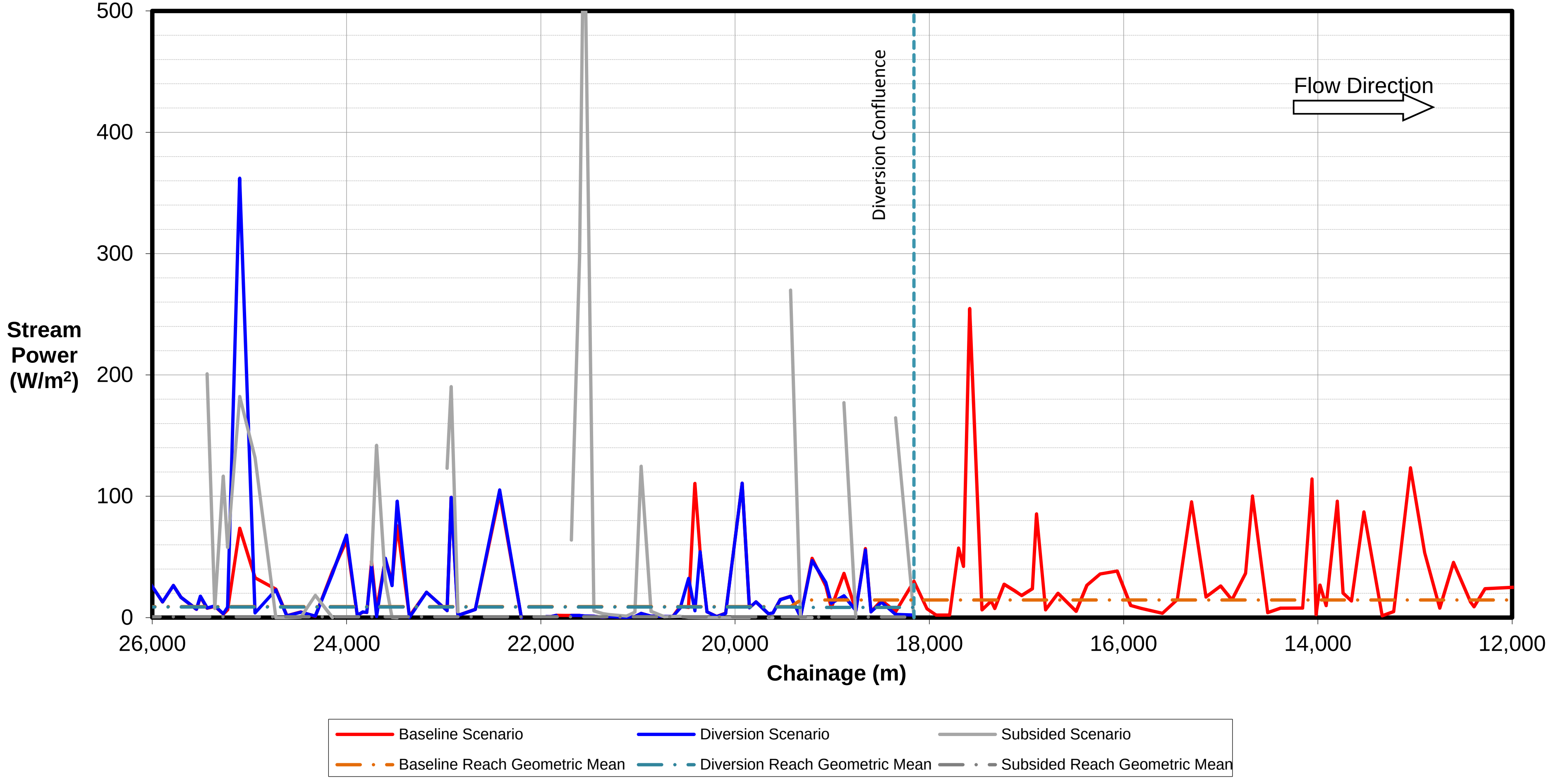
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-78 Comparison of Channel Stream Power along Little Sandy Creek for a 1:10 AEP Event



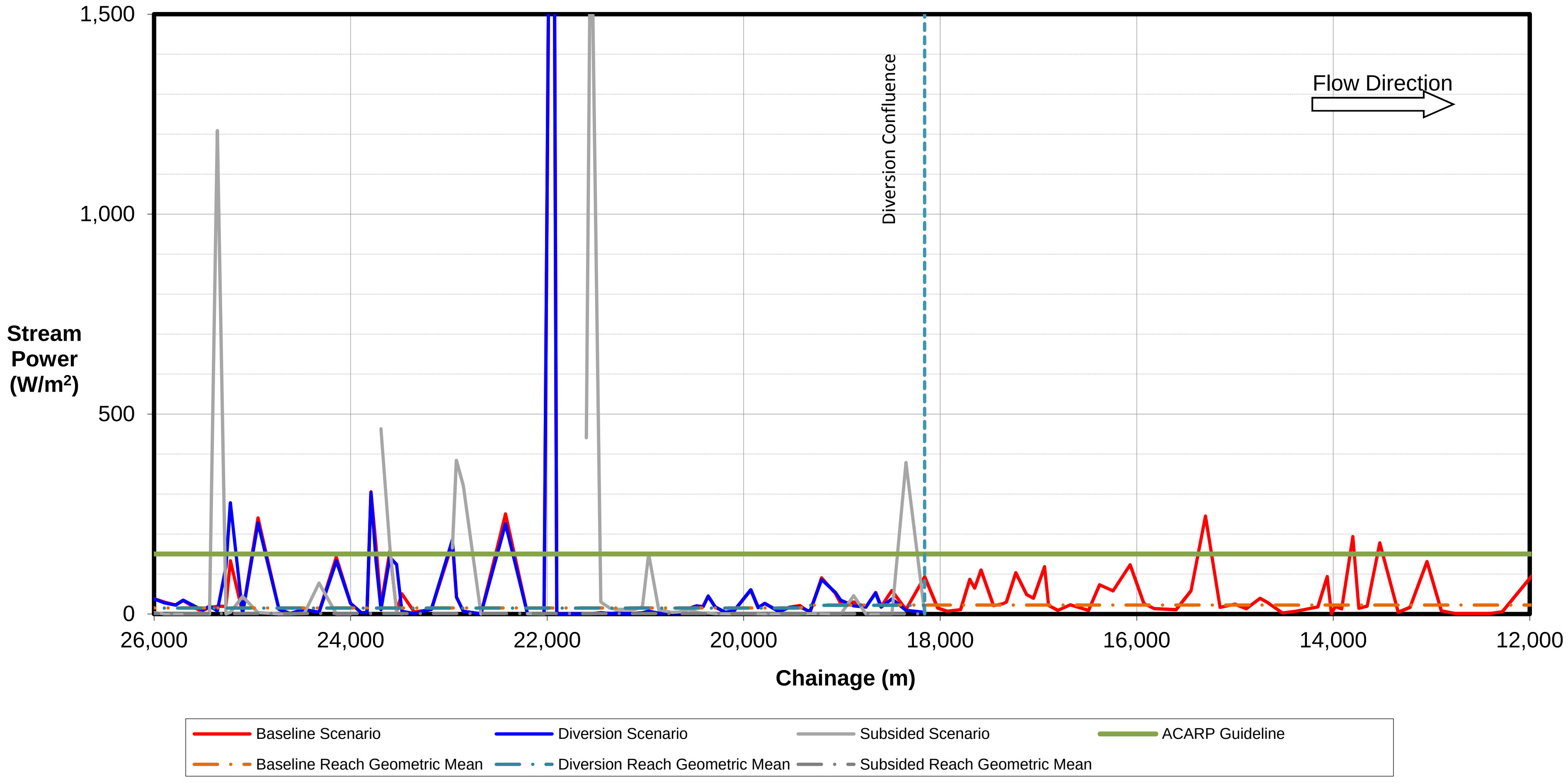
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-79 Comparison of Channel Stream Power along Little Sandy Creek for a 1:20 AEP Event



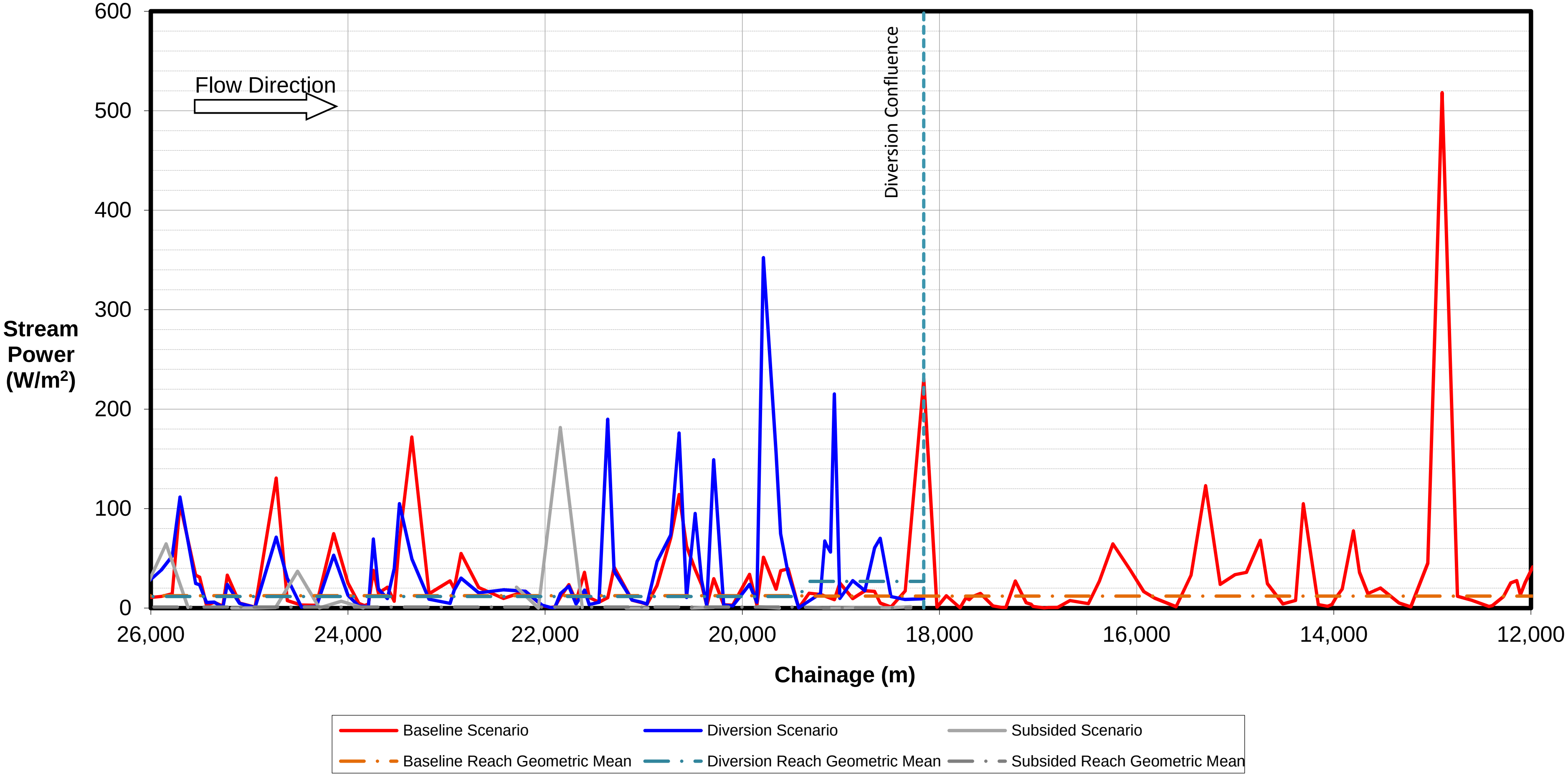
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-80 Comparison of Channel Stream Power along Little Sandy Creek for a 1:50 AEP Event



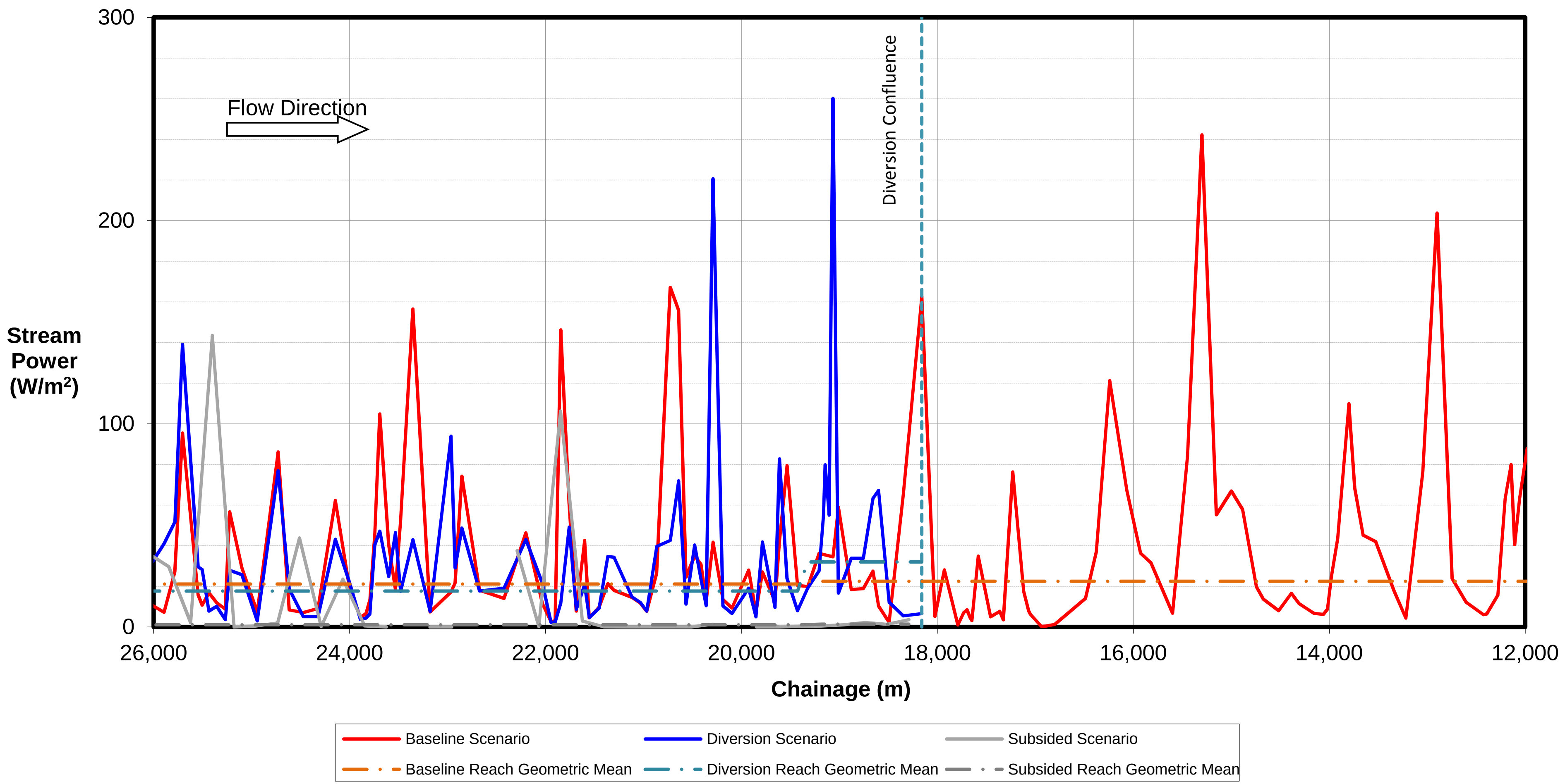
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-81 Comparison of Channel Stream Power along Little Sandy Creek for a 1:100 AEP Event



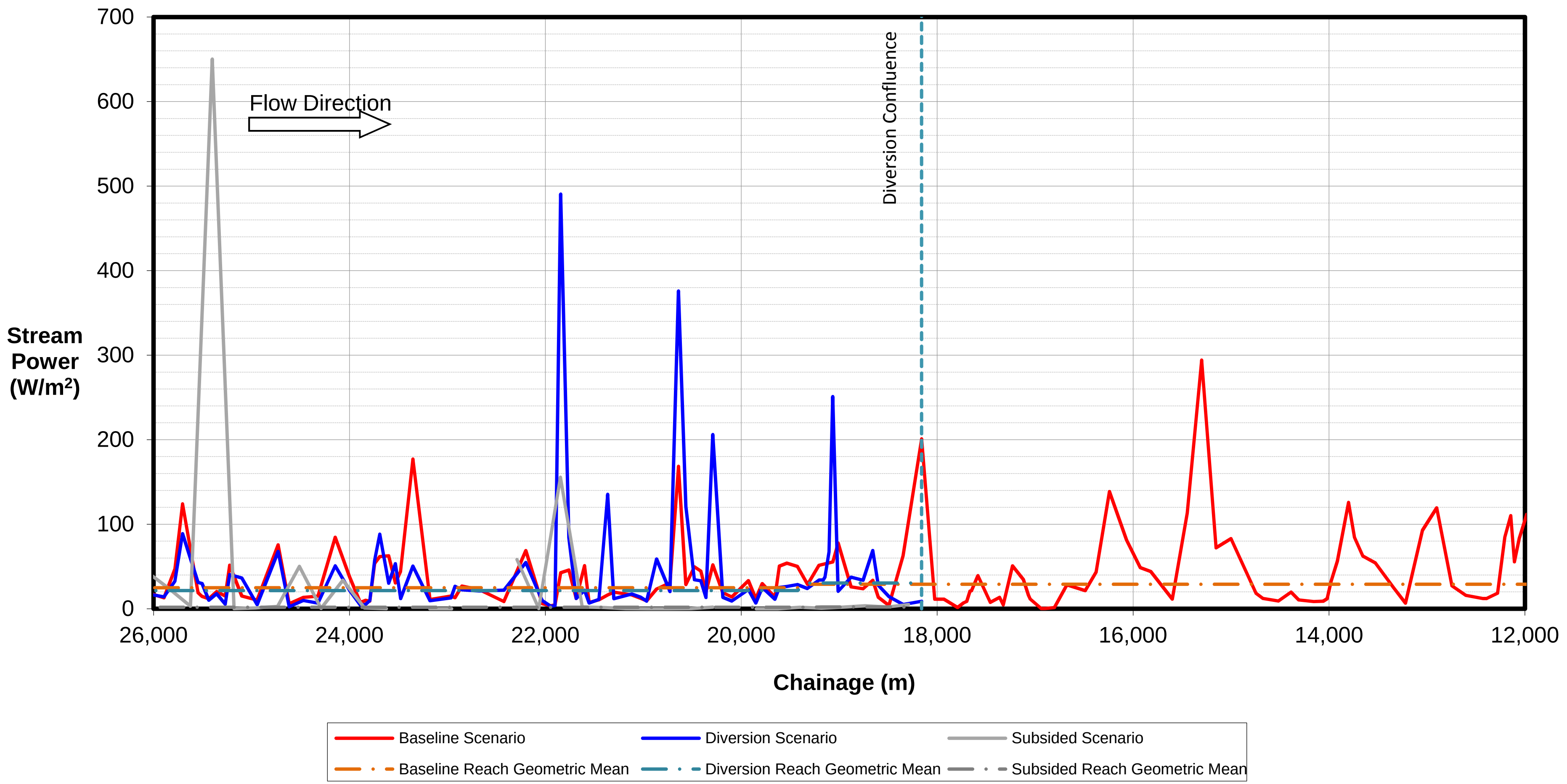
Appendix C - **Modelling Results – Profile Comparison Plots**

Figure Appendix C-82 Comparison of Channel Stream Power along Little Sandy Creek for a 1:1000 AEP Event



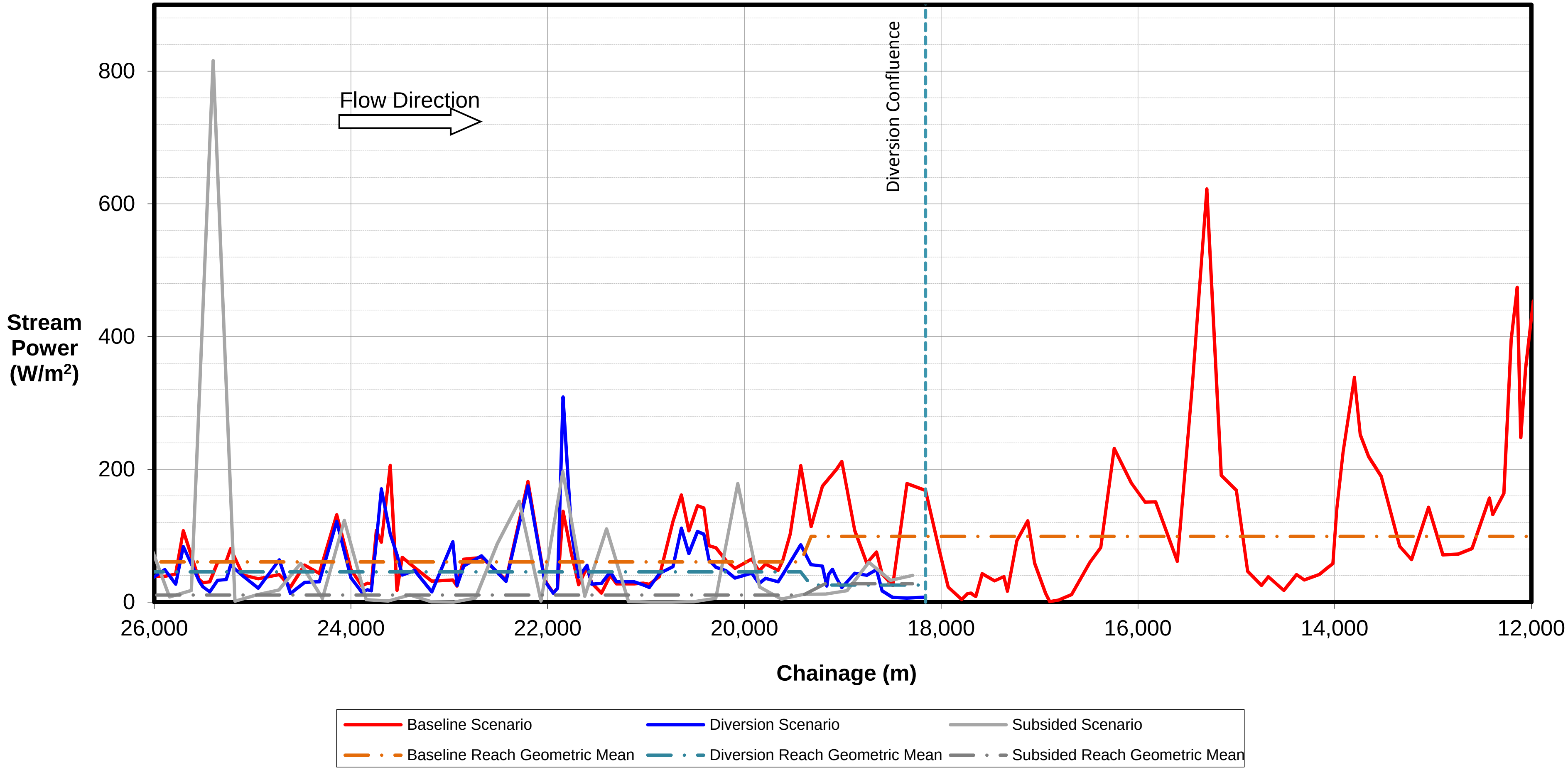
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-83 Comparison of Channel Stream Power along Little Sandy Creek for a 1:2000 AEP Event



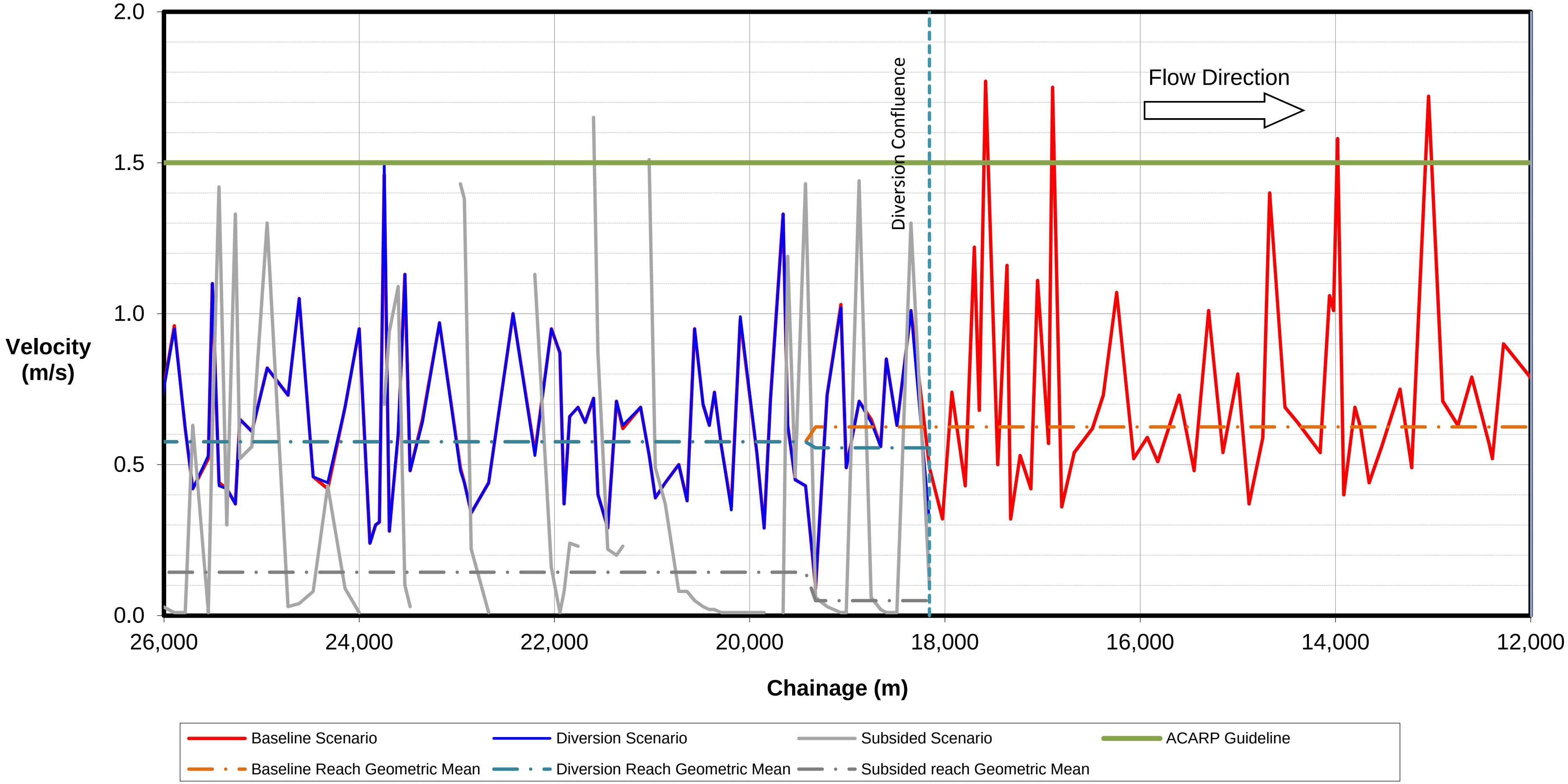
Appendix C - **Modelling Results – Profile Comparison Plots**

Figure Appendix C-84 Comparison of Channel Stream Power along Little Sandy Creek for a PMF Event



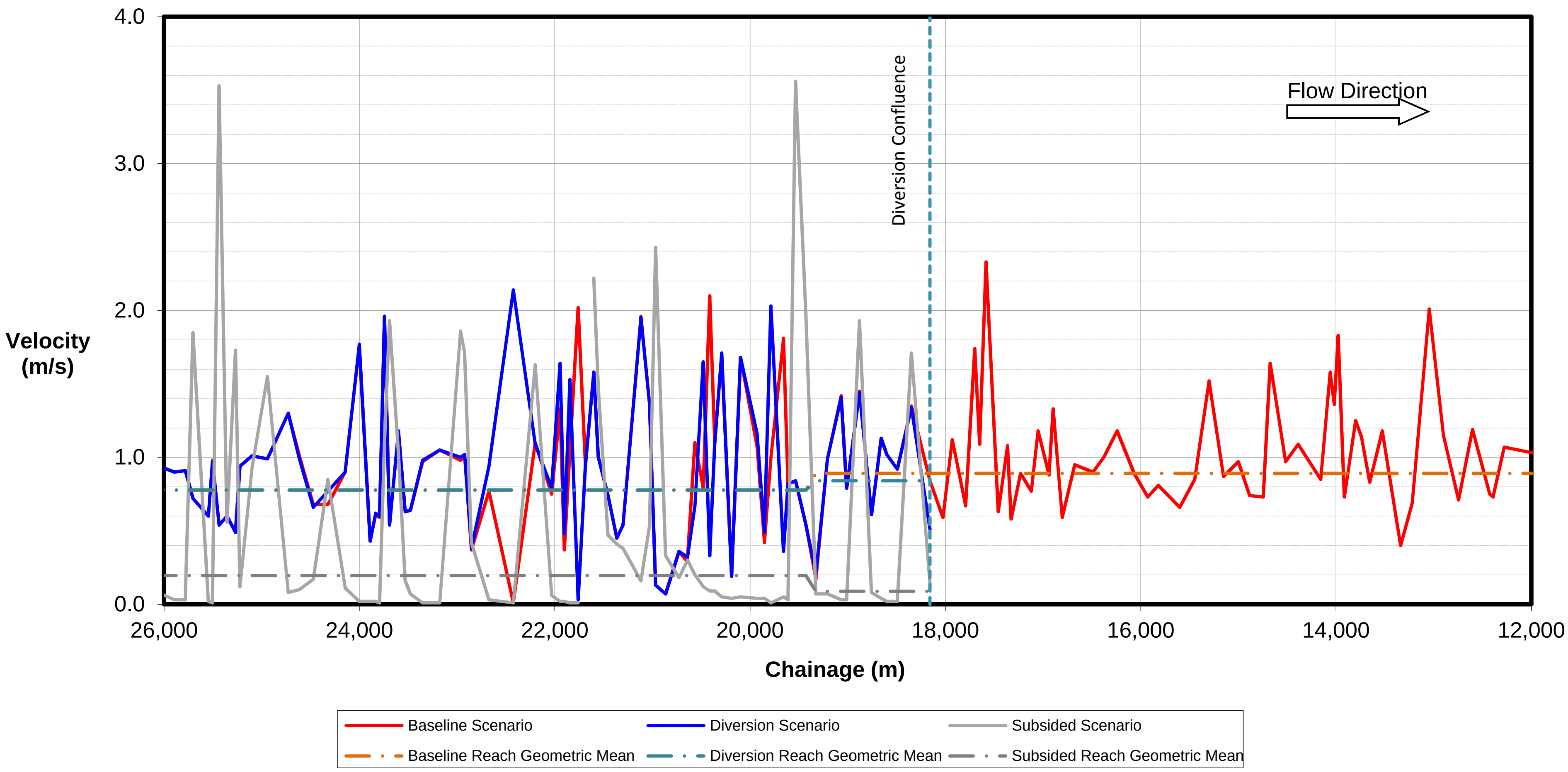
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-85 Comparison of Channel Velocity along Little Sandy Creek for a 1:2 AEP Event



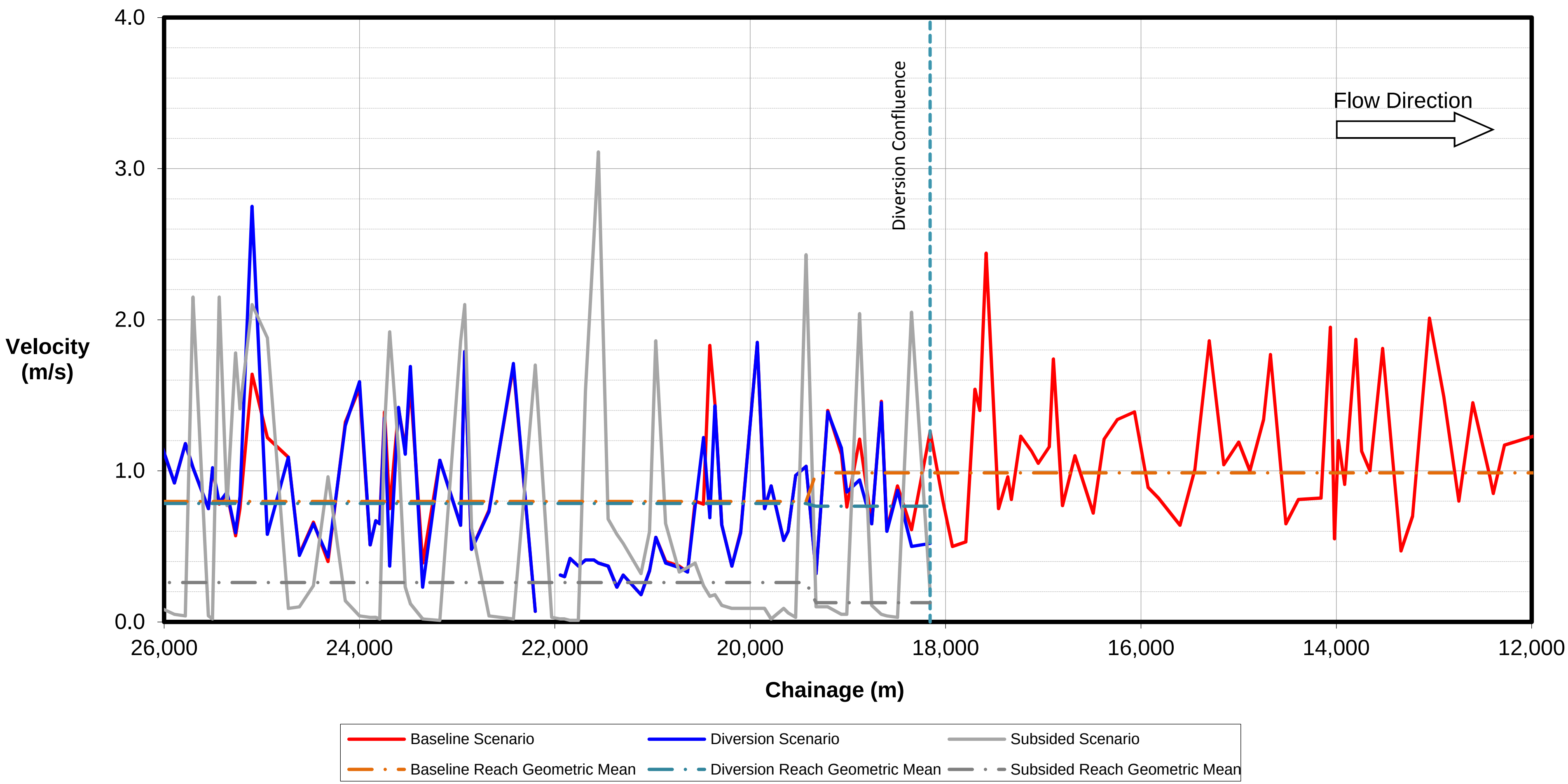
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-86 Comparison of Channel Velocity along Little Sandy Creek for a 1:5 AEP Event



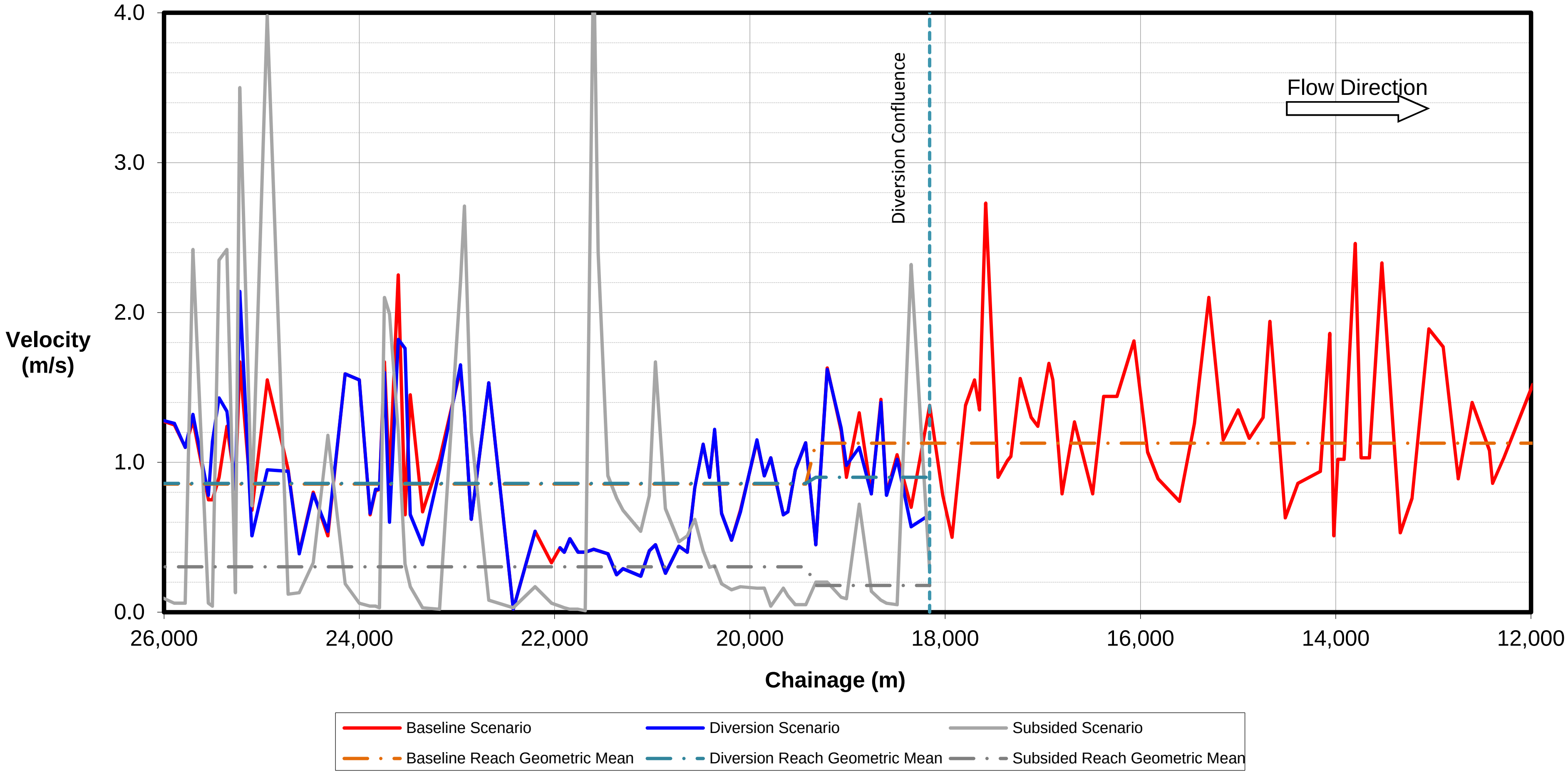
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-87 Comparison of Channel Velocity along Little Sandy Creek for a 1:10 AEP Event



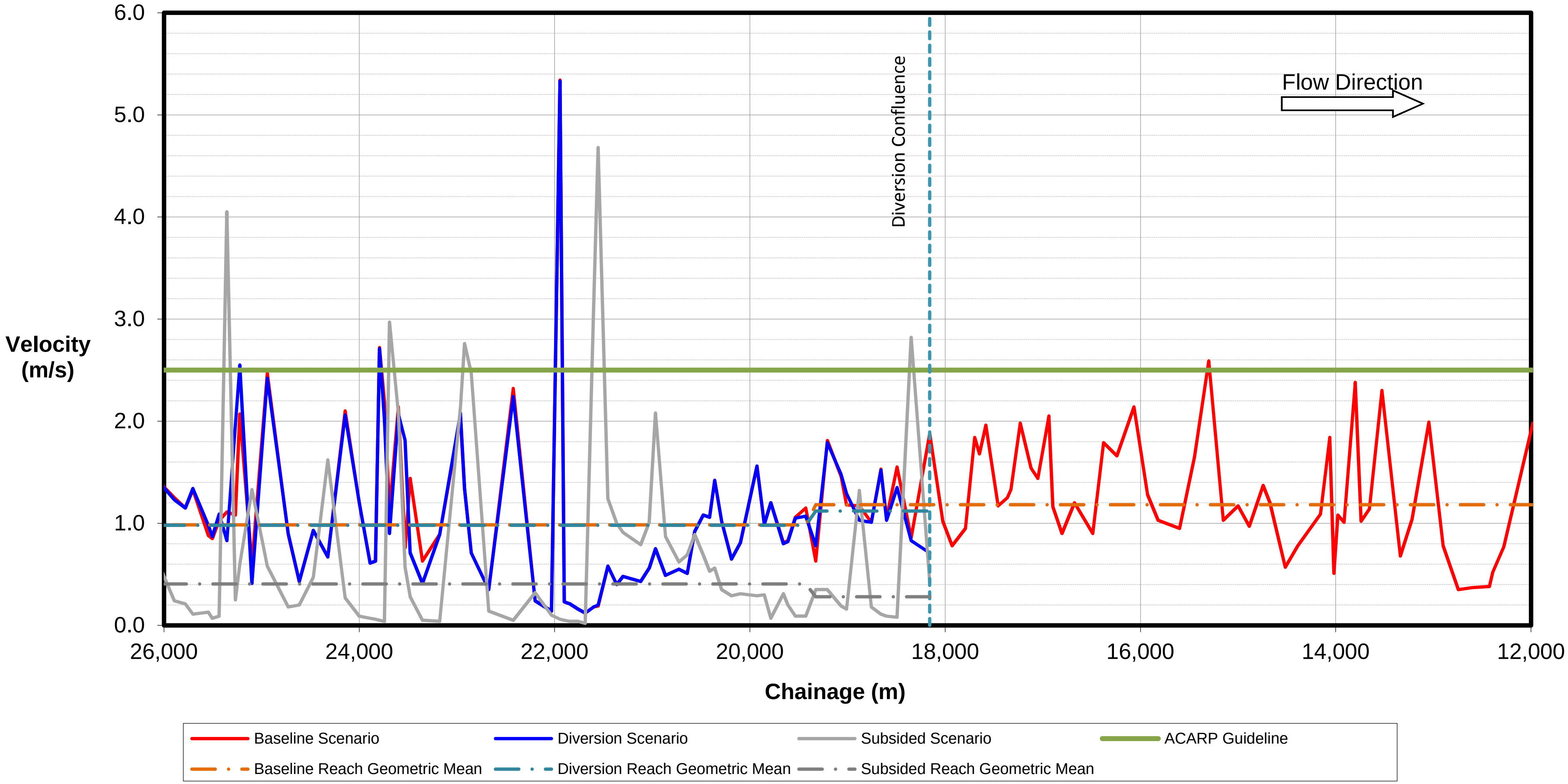
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-88 Comparison of Channel Velocity along Little Sandy Creek for a 1:20 AEP Event



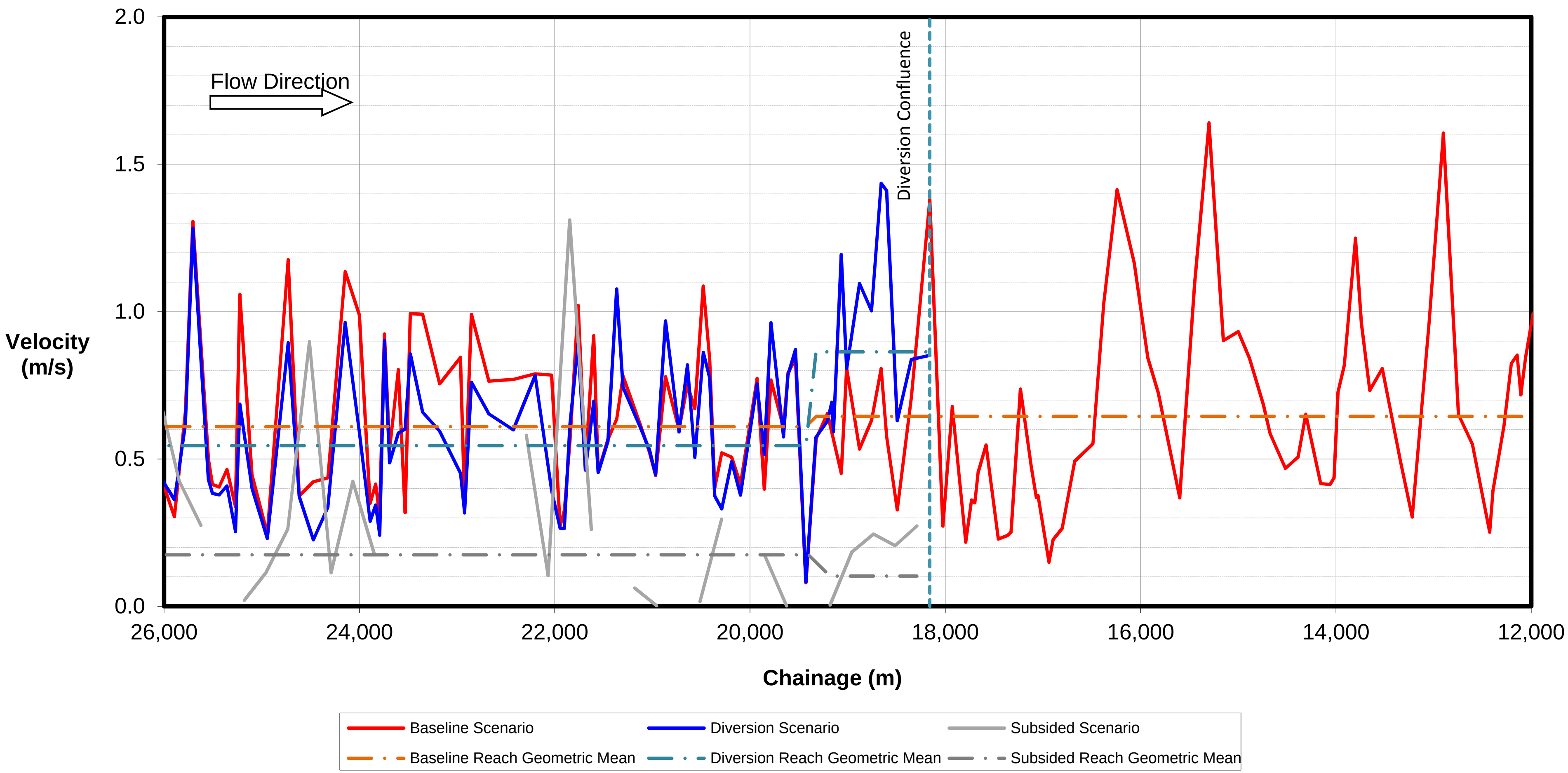
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-89 Comparison of Channel Velocity along Little Sandy Creek for a 1:50 AEP Event



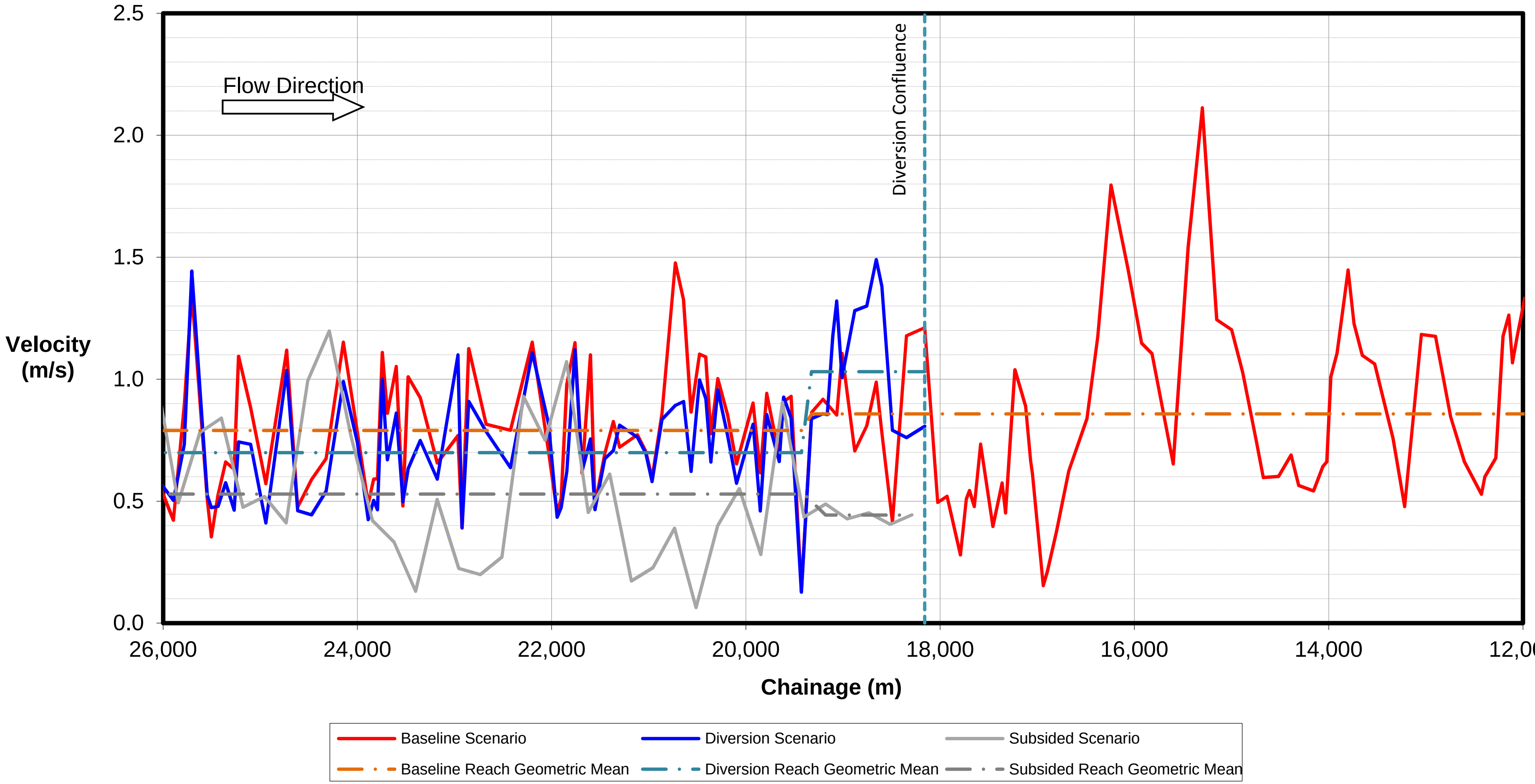
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-90 Comparison of Channel Velocity along Little Sandy Creek for a 1:100 AEP Event



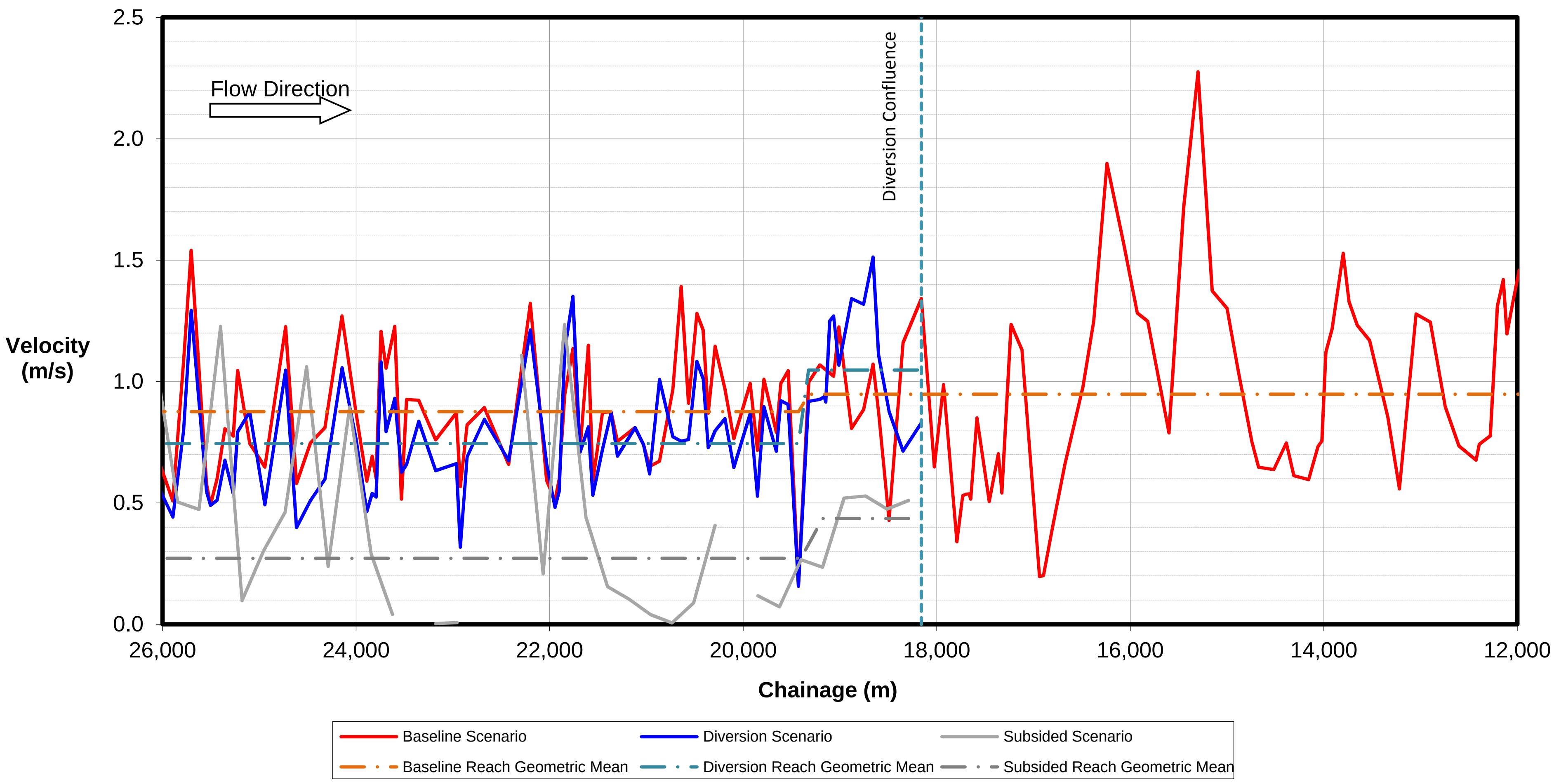
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-91 Comparison of Channel Velocity along Little Sandy Creek for a 1:1000 AEP Event



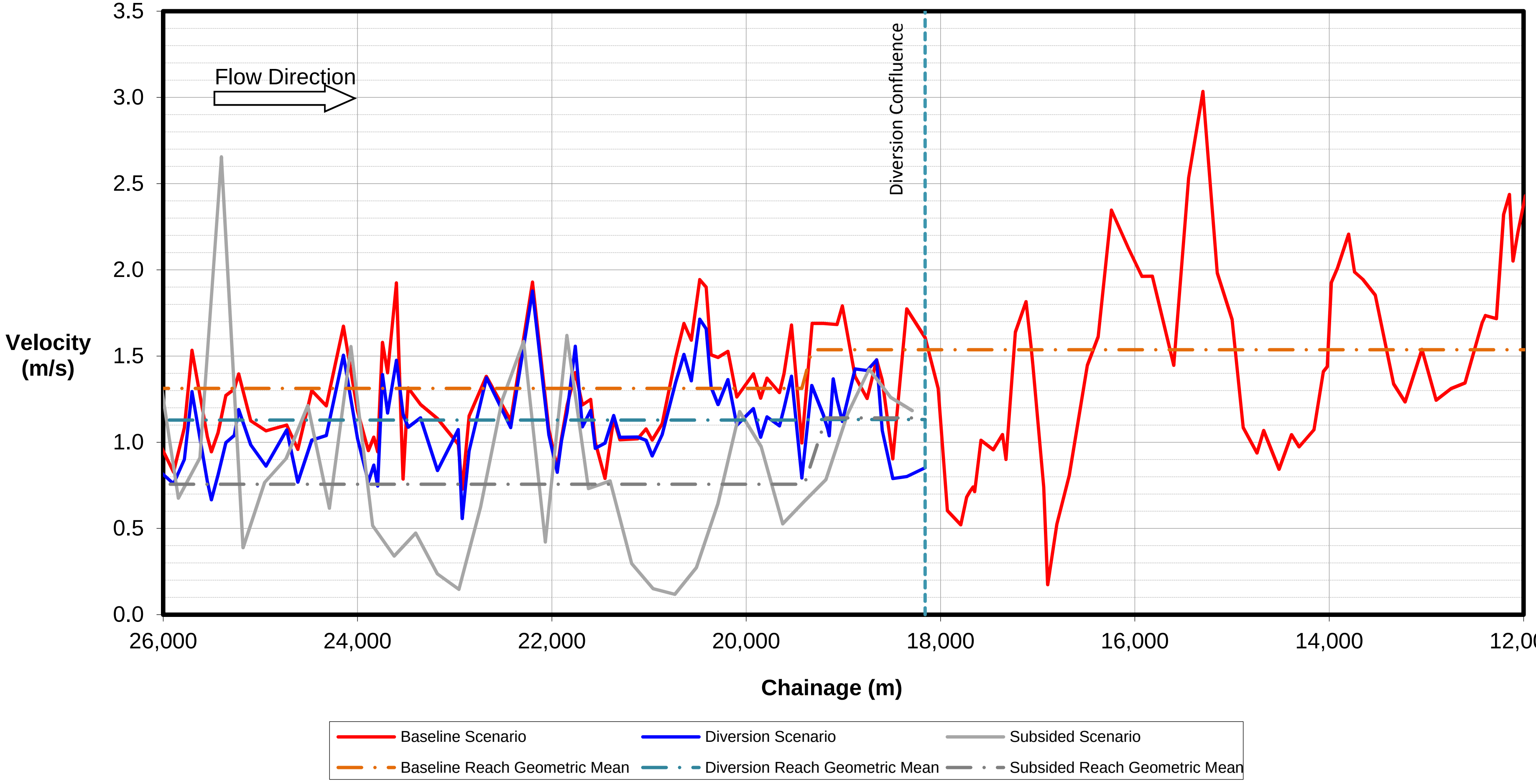
Appendix C - **Modelling Results – Profile Comparison Plots**

Figure Appendix C-92 Comparison of Channel Velocity along Little Sandy Creek for a 1:2000 AEP Event



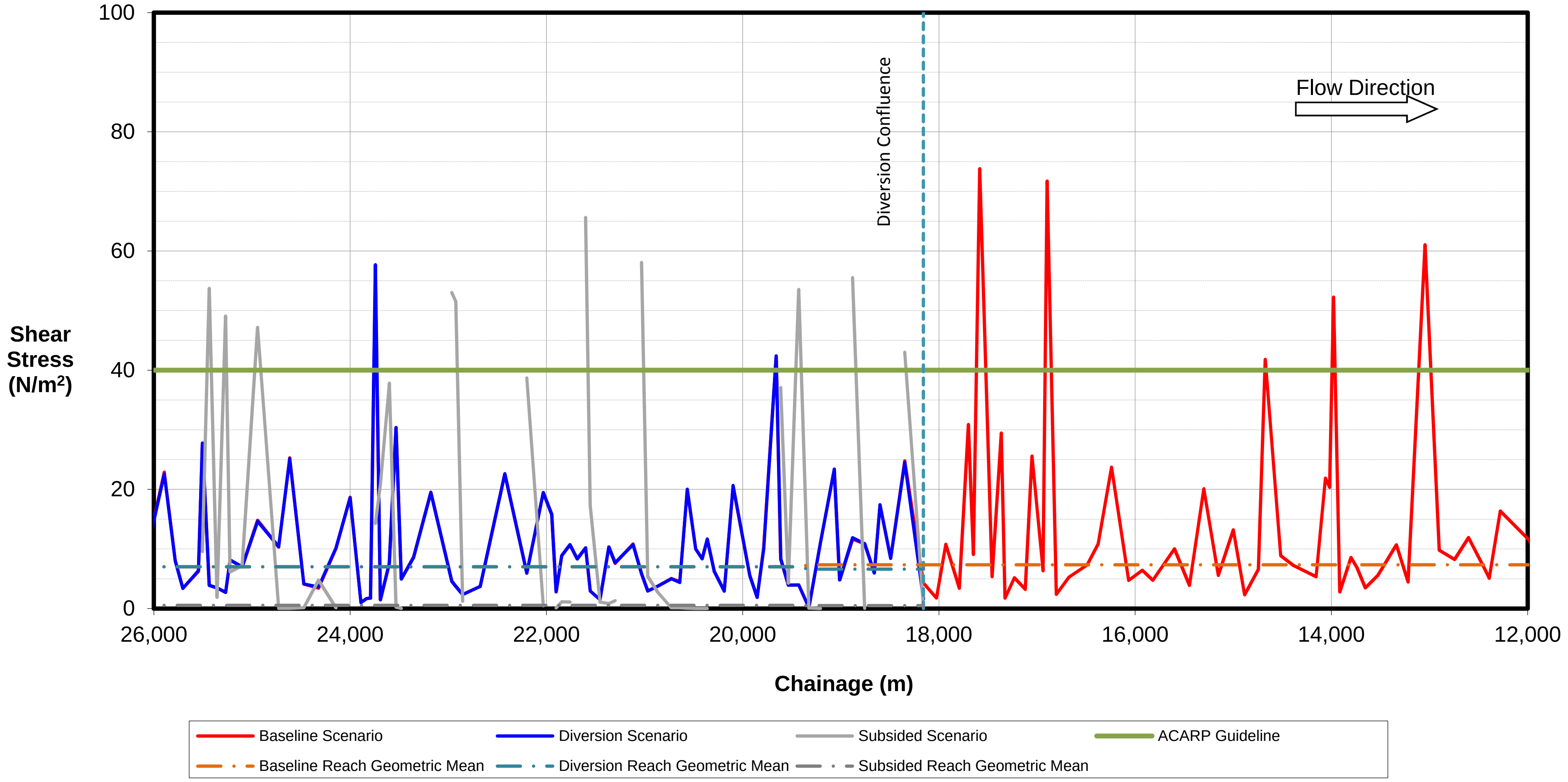
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-93 Comparison of Channel Velocity along Little Sandy Creek for a PMF Event



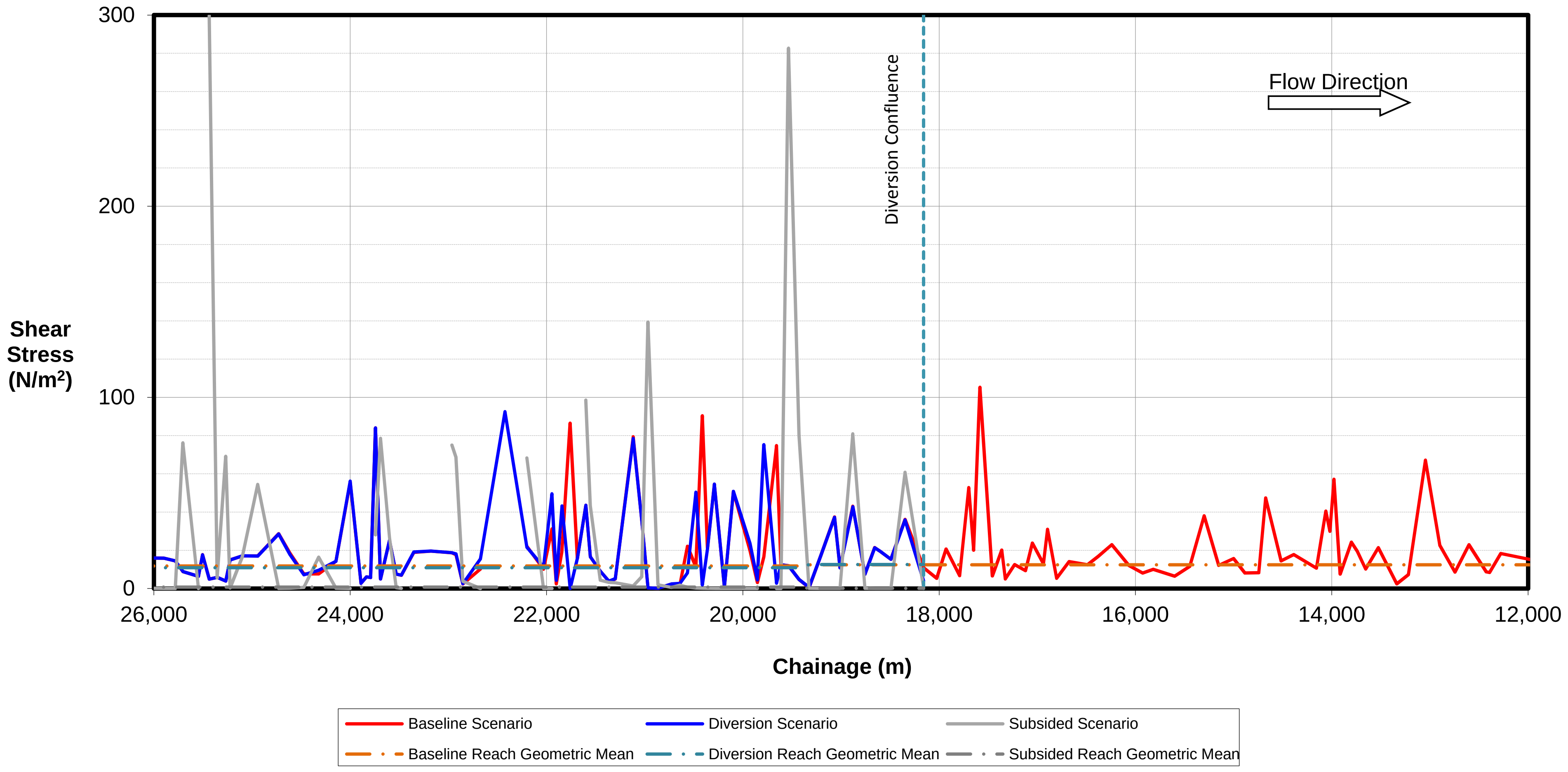
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-94 Comparison of Bed Shear Stress along Little Sandy Creek for a 1:2 AEP Event



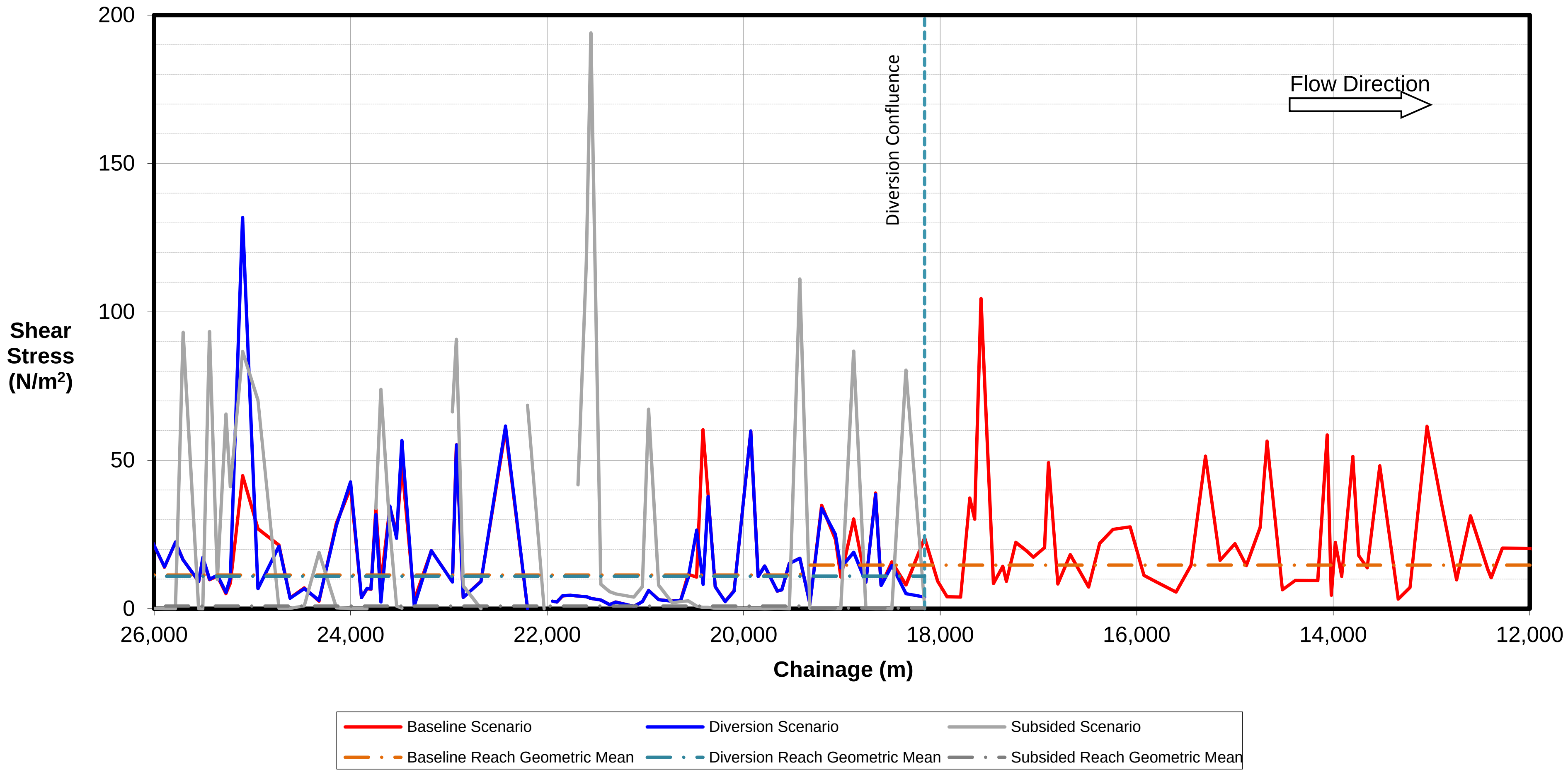
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-95 Comparison of Bed Shear Stress along Little Sandy Creek for a 1:5 AEP Event



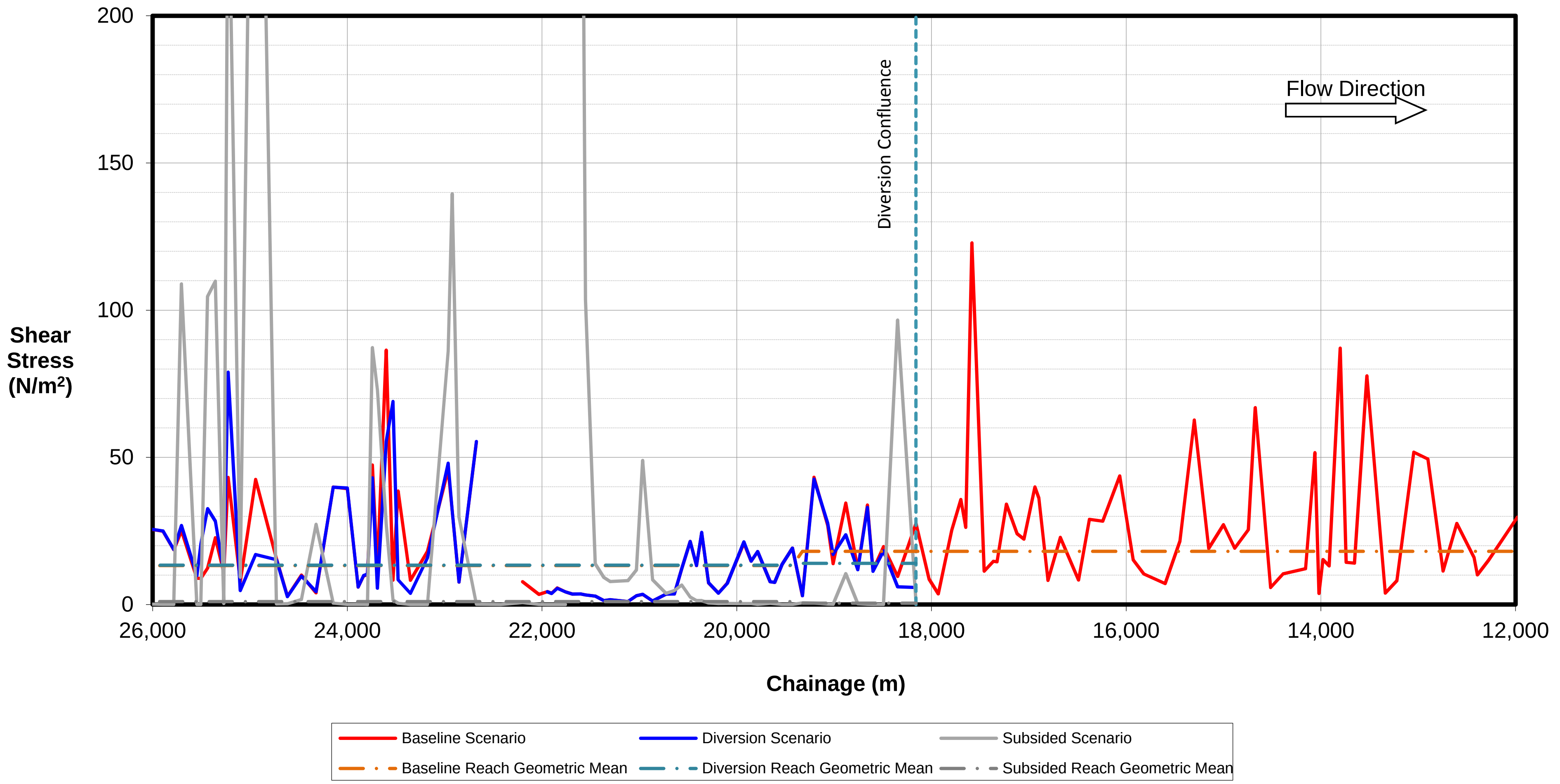
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-96 Comparison of Bed Shear Stress along Little Sandy Creek for a 1:10 AEP Event



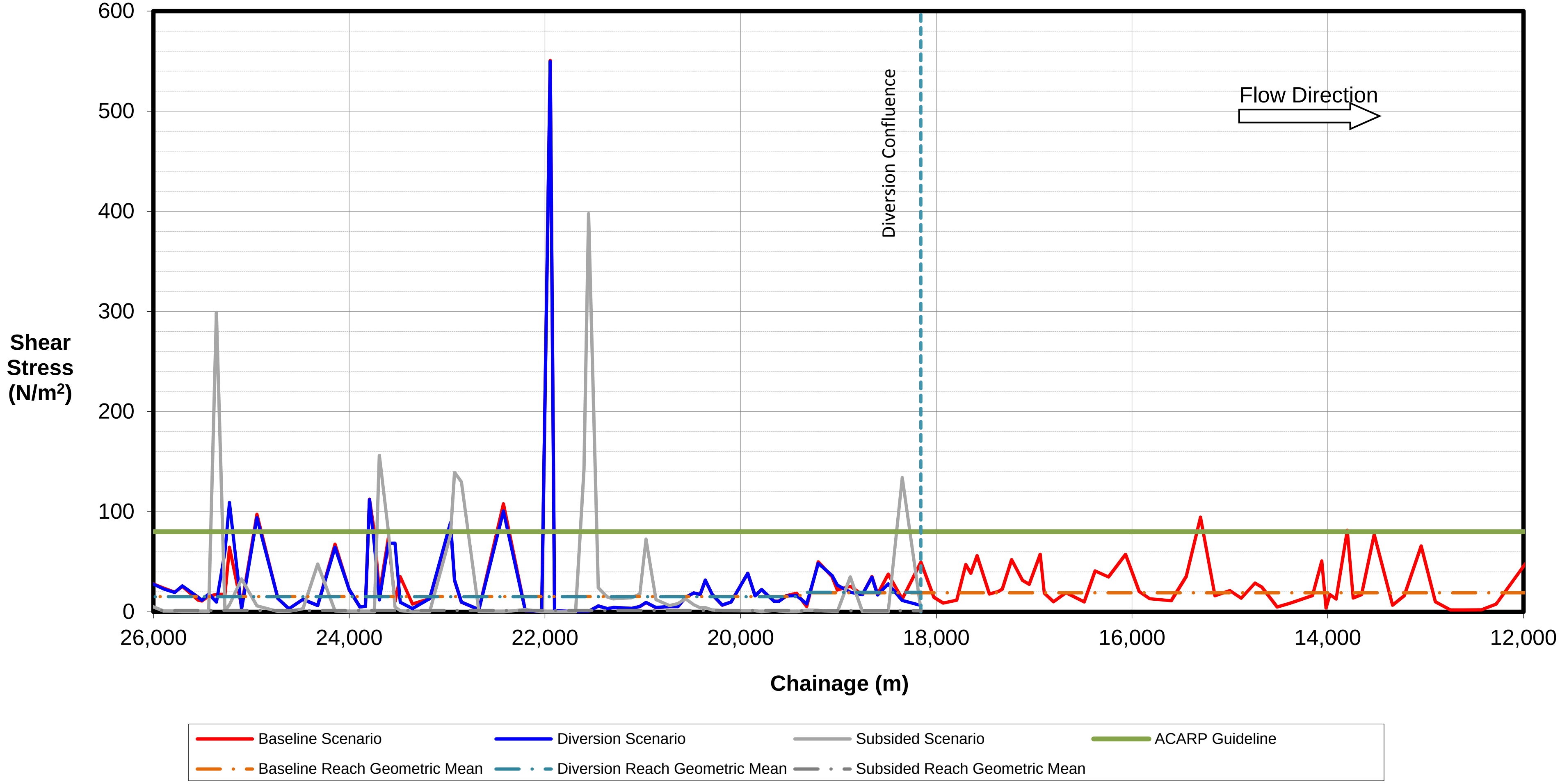
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-97 Comparison of Bed Shear Stress along Little Sandy Creek for a 1:20 AEP Event



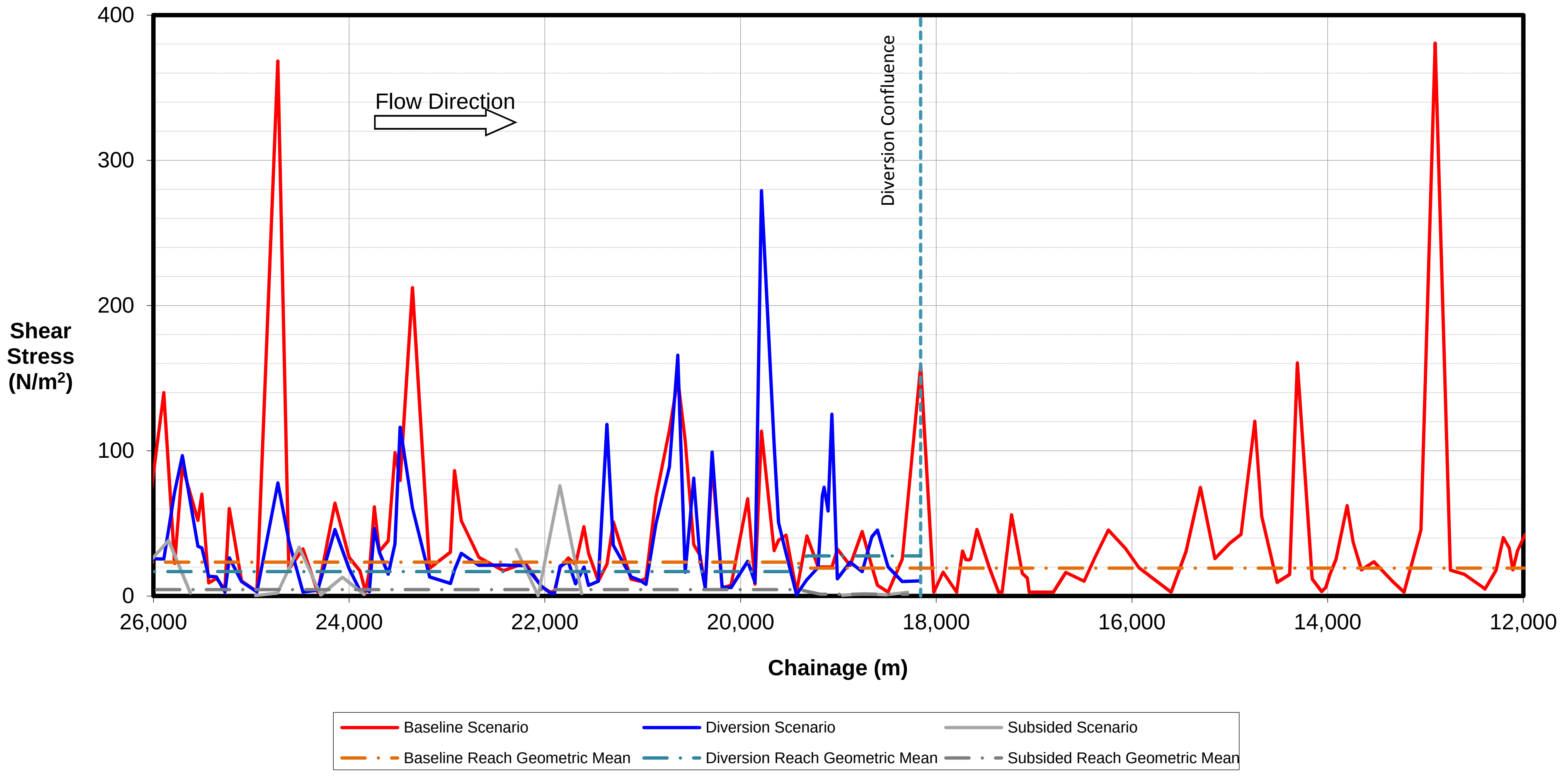
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-98 Comparison of Bed Shear Stress along Little Sandy Creek for a 1:50 AEP Event



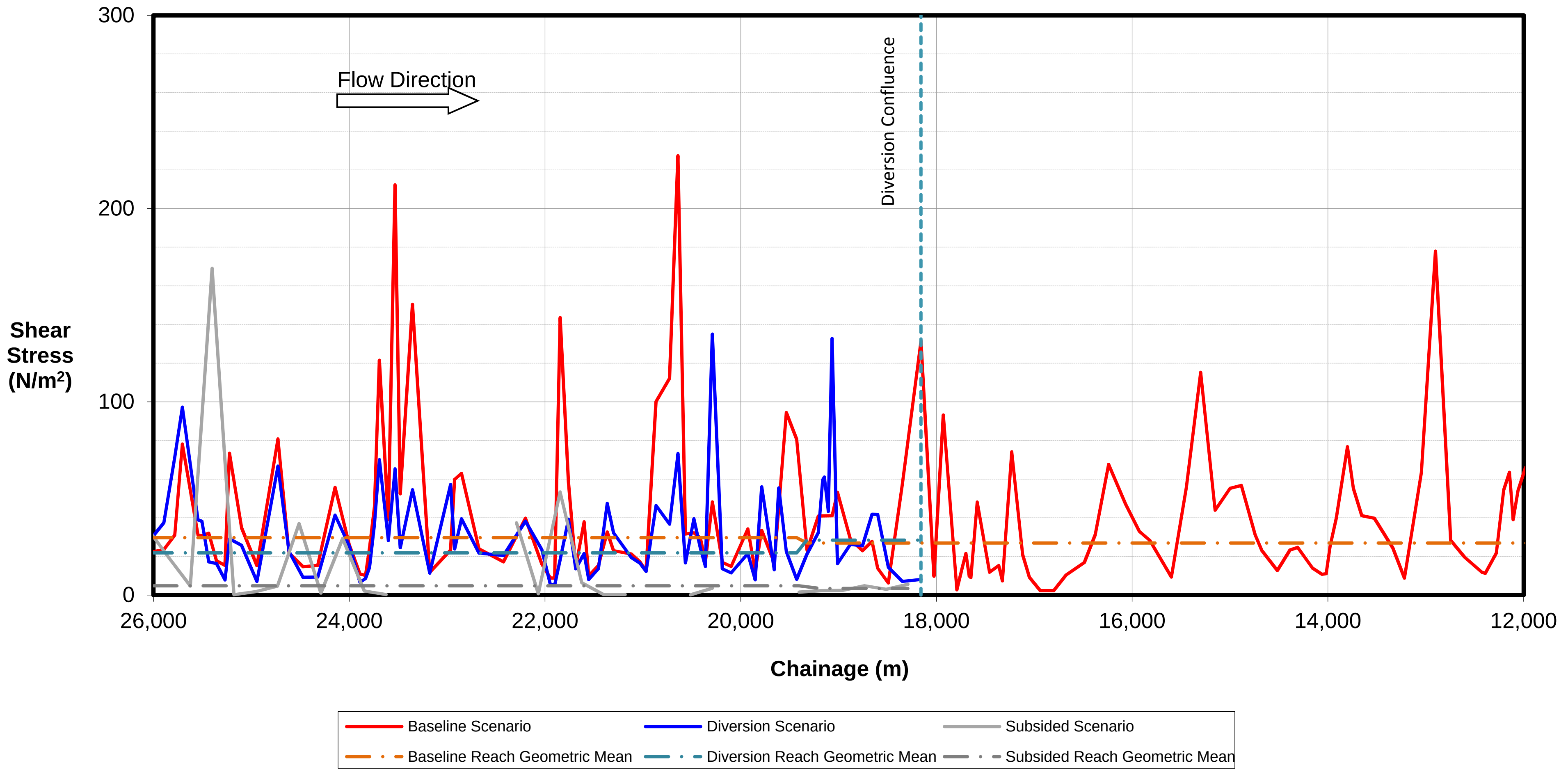
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-99 Comparison of Bed Shear Stress along Little Sandy Creek for a 1:100 AEP Event



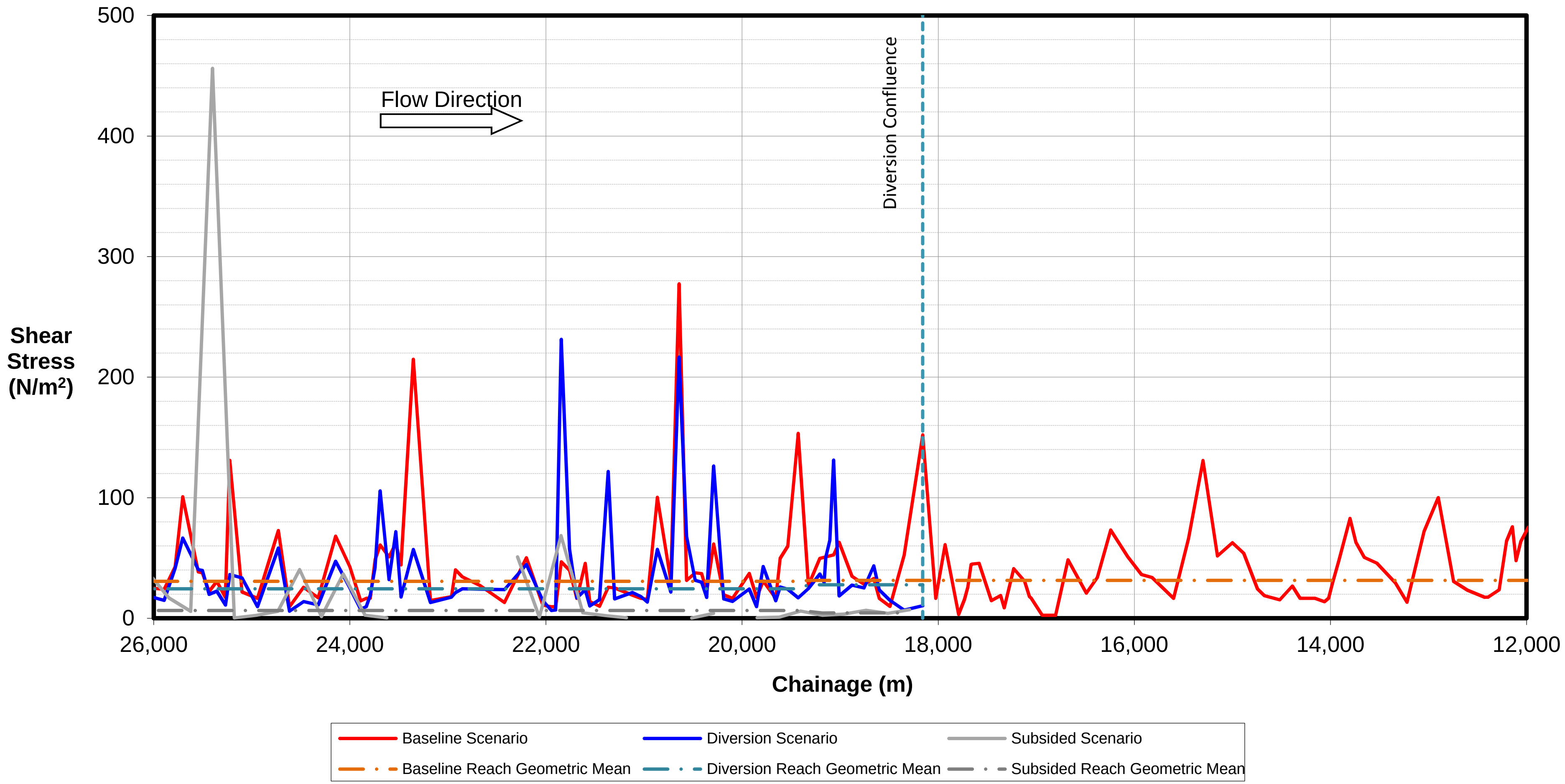
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-100 Comparison of Bed Shear Stress along Little Sandy Creek for a 1:1000 AEP Event



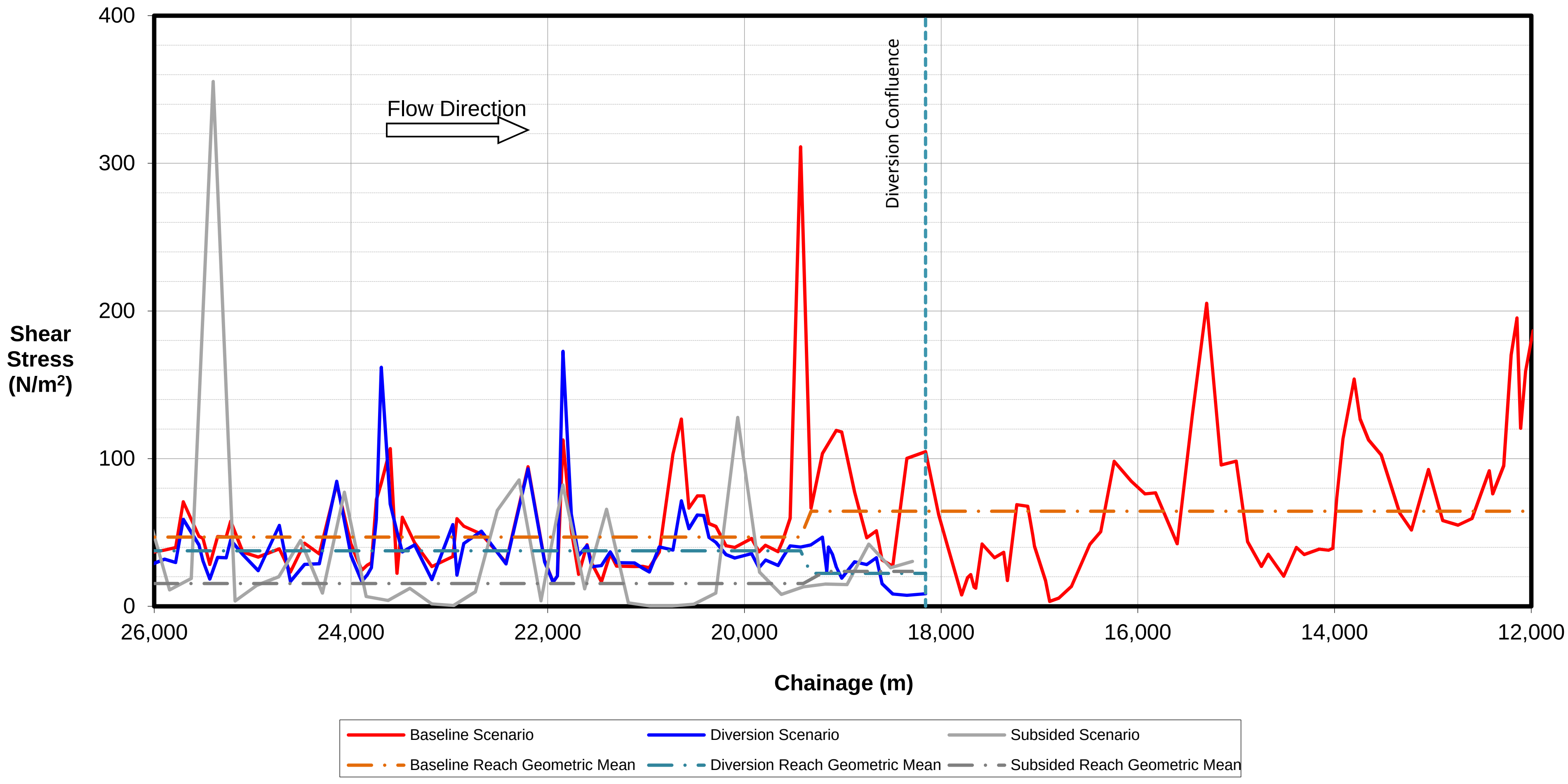
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-101 Comparison of Bed Shear Stress along Little Sandy Creek for a 1:2000 AEP Event



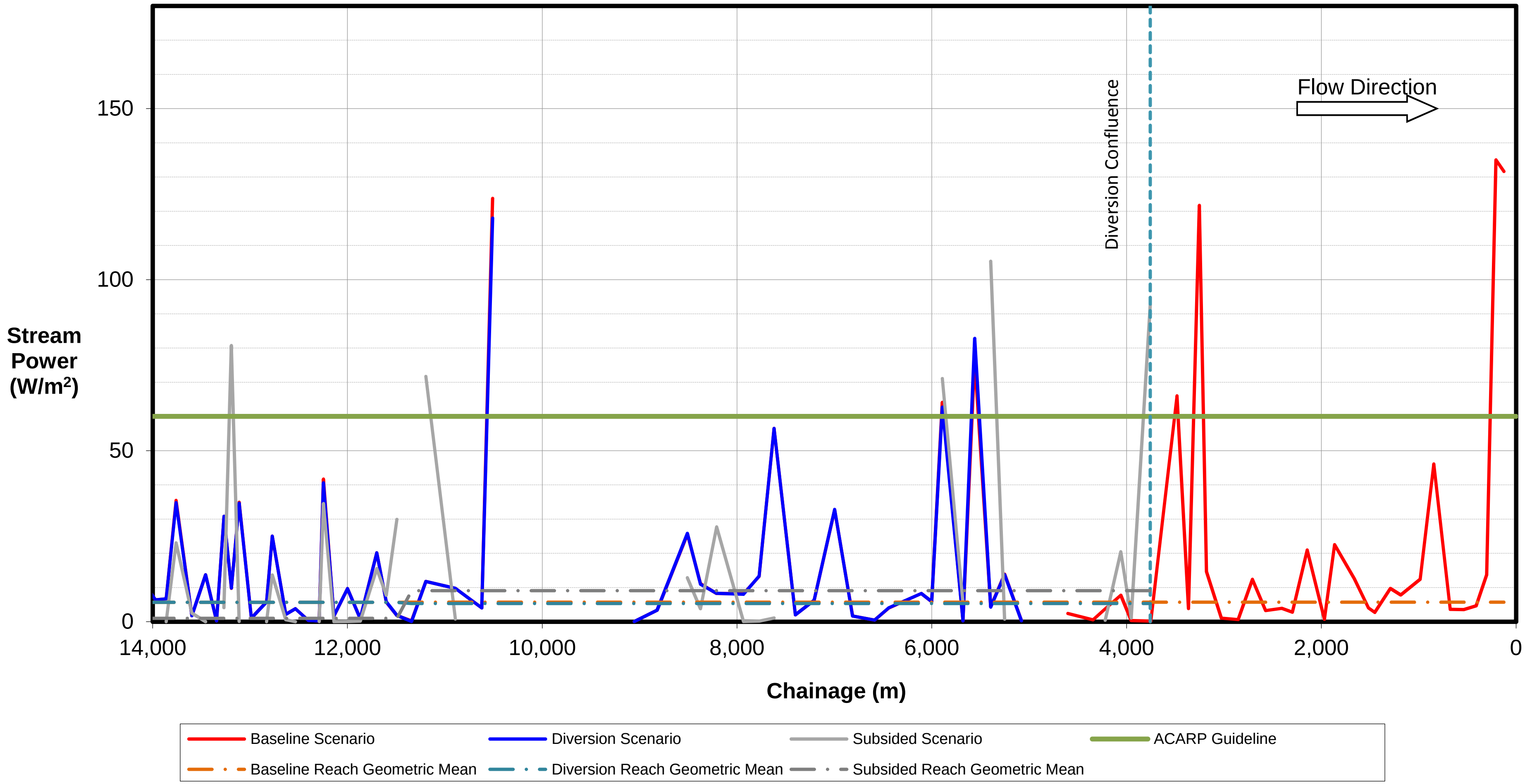
Appendix C - **Modelling Results – Profile Comparison Plots**

Figure Appendix C-102 Comparison of Bed Shear Stress along Little Sandy Creek for a PMF Event



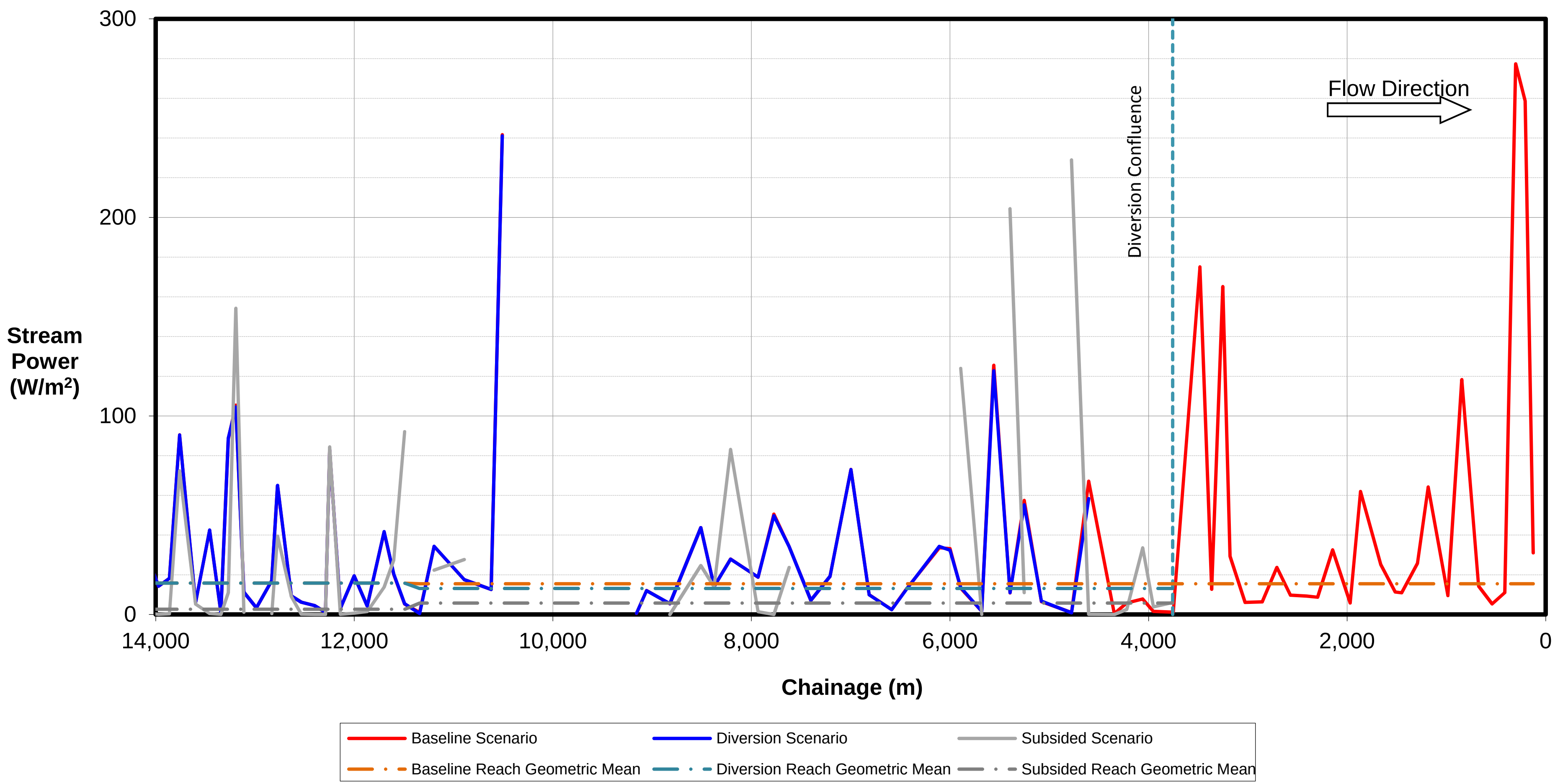
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-103 Comparison of Channel Stream Power along Rocky Creek for a 1:2 AEP Event



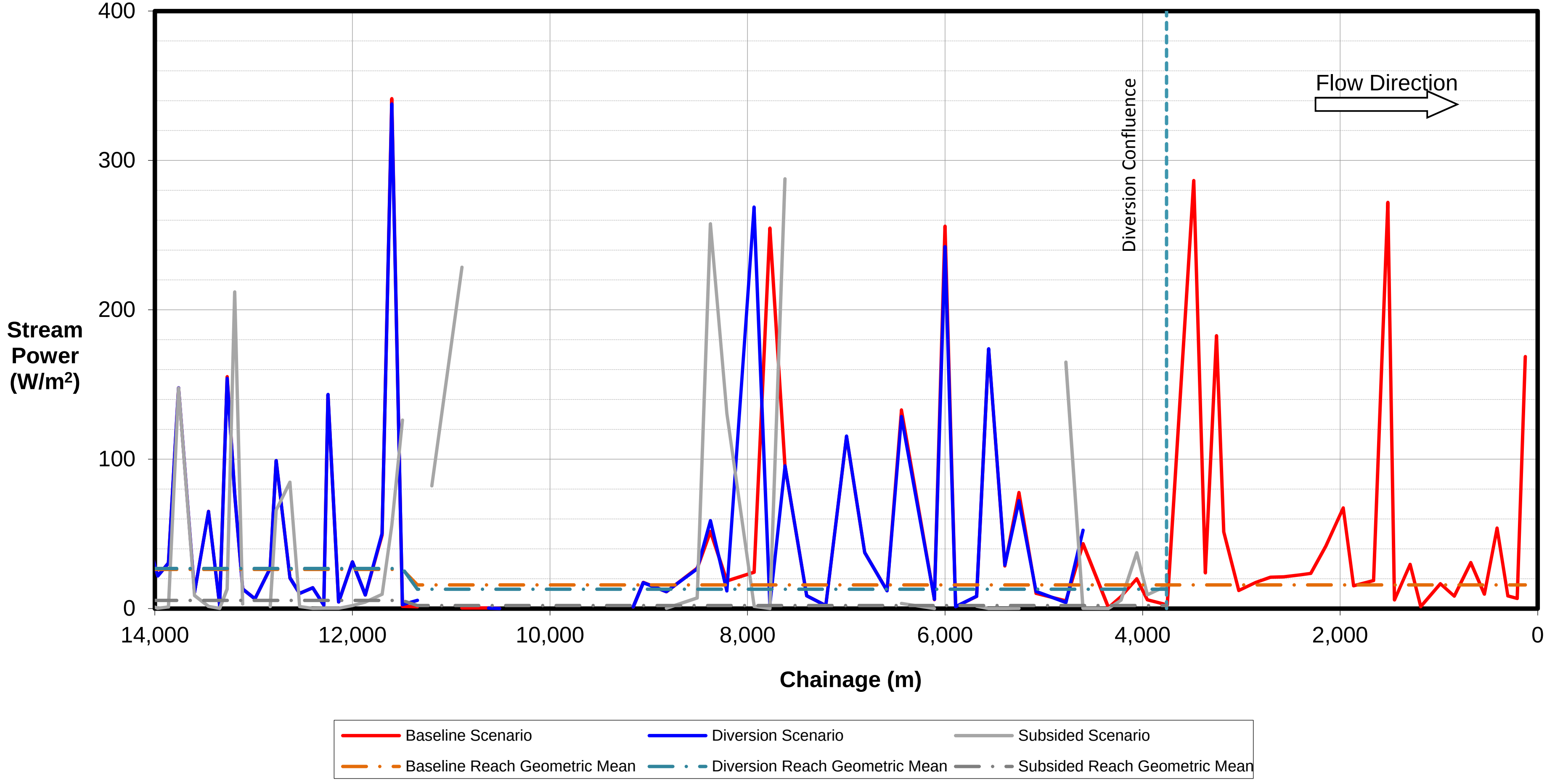
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-104 Comparison of Channel Stream Power along Rocky Creek for a 1:5 AEP Event



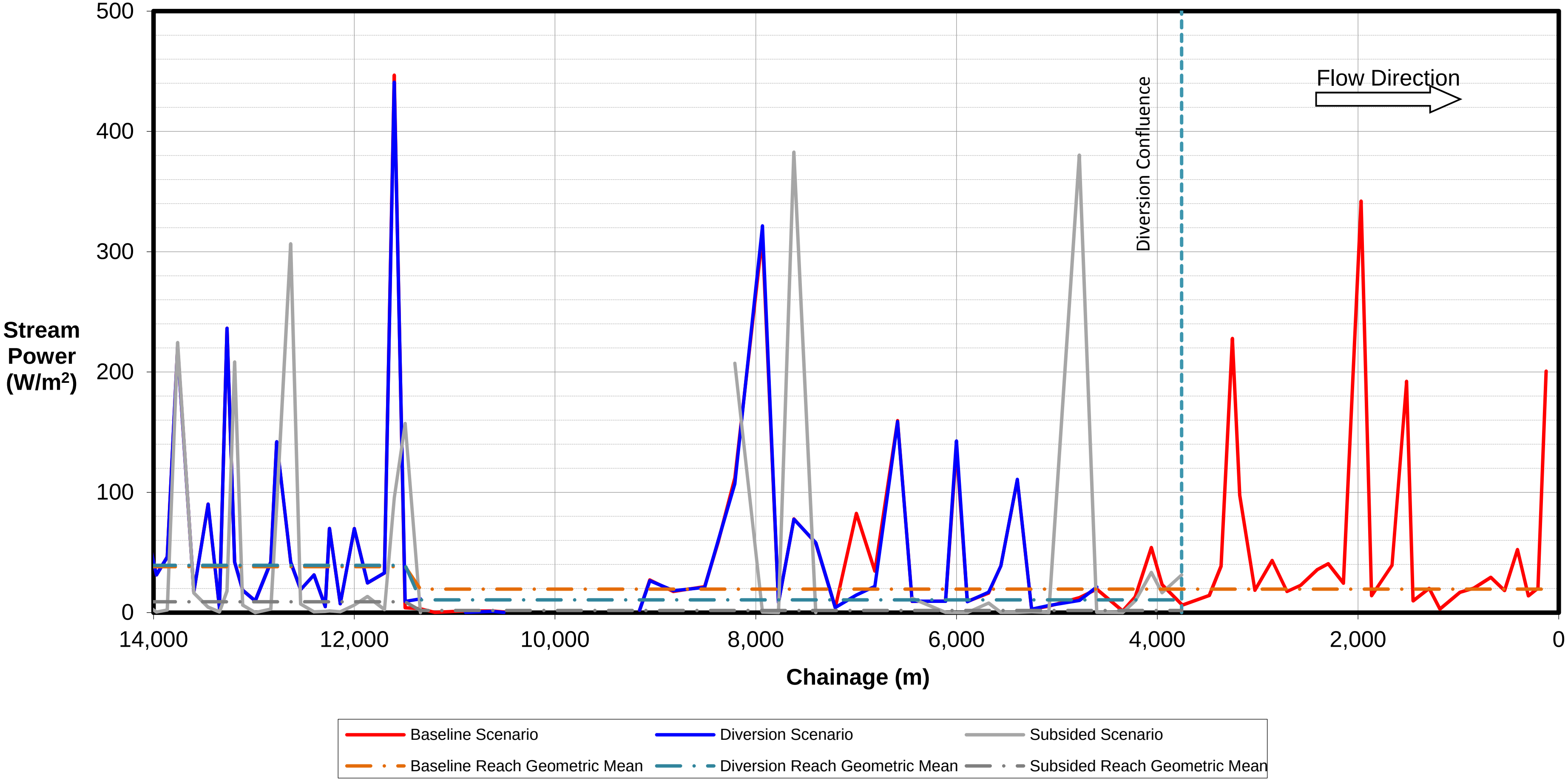
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-105 Comparison of Channel Stream Power along Rocky Creek for a 1:10 AEP Event



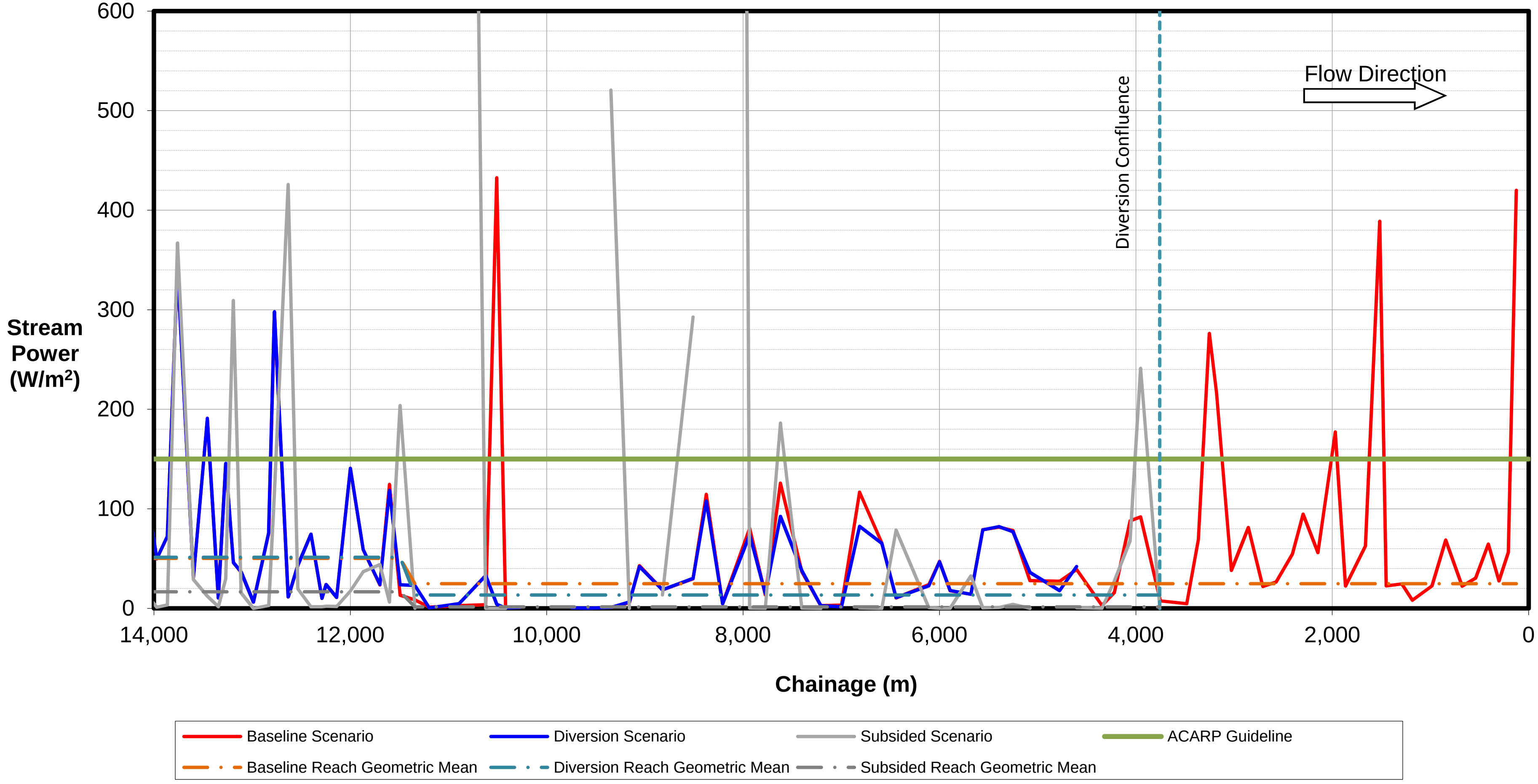
Appendix C - **Modelling Results – Profile Comparison Plots**

Figure Appendix C-106 Comparison of Channel Stream Power along Rocky Creek for a 1:20 AEP Event



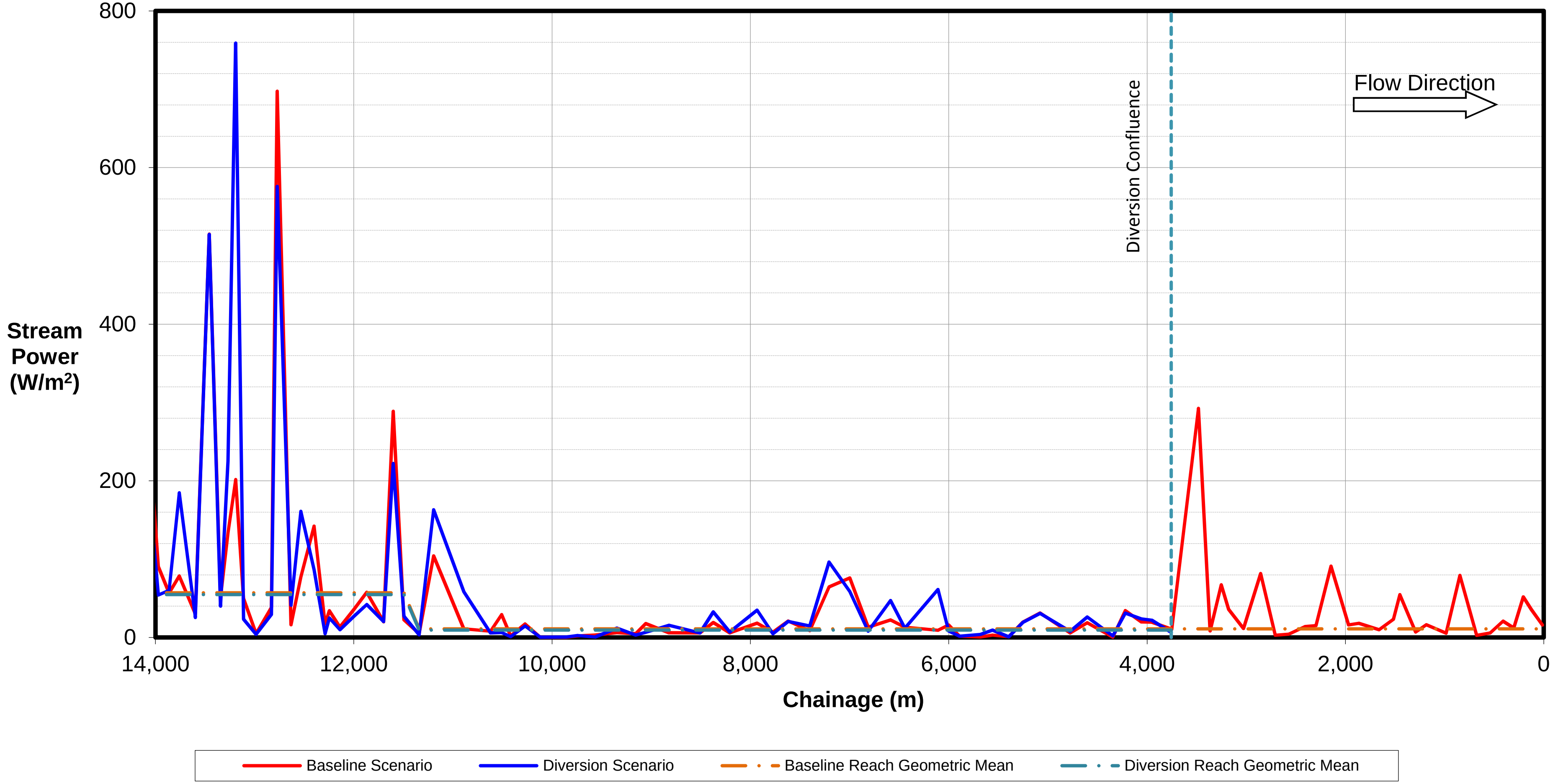
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-107 Comparison of Channel Stream Power along Rocky Creek for a 1:50 AEP Event



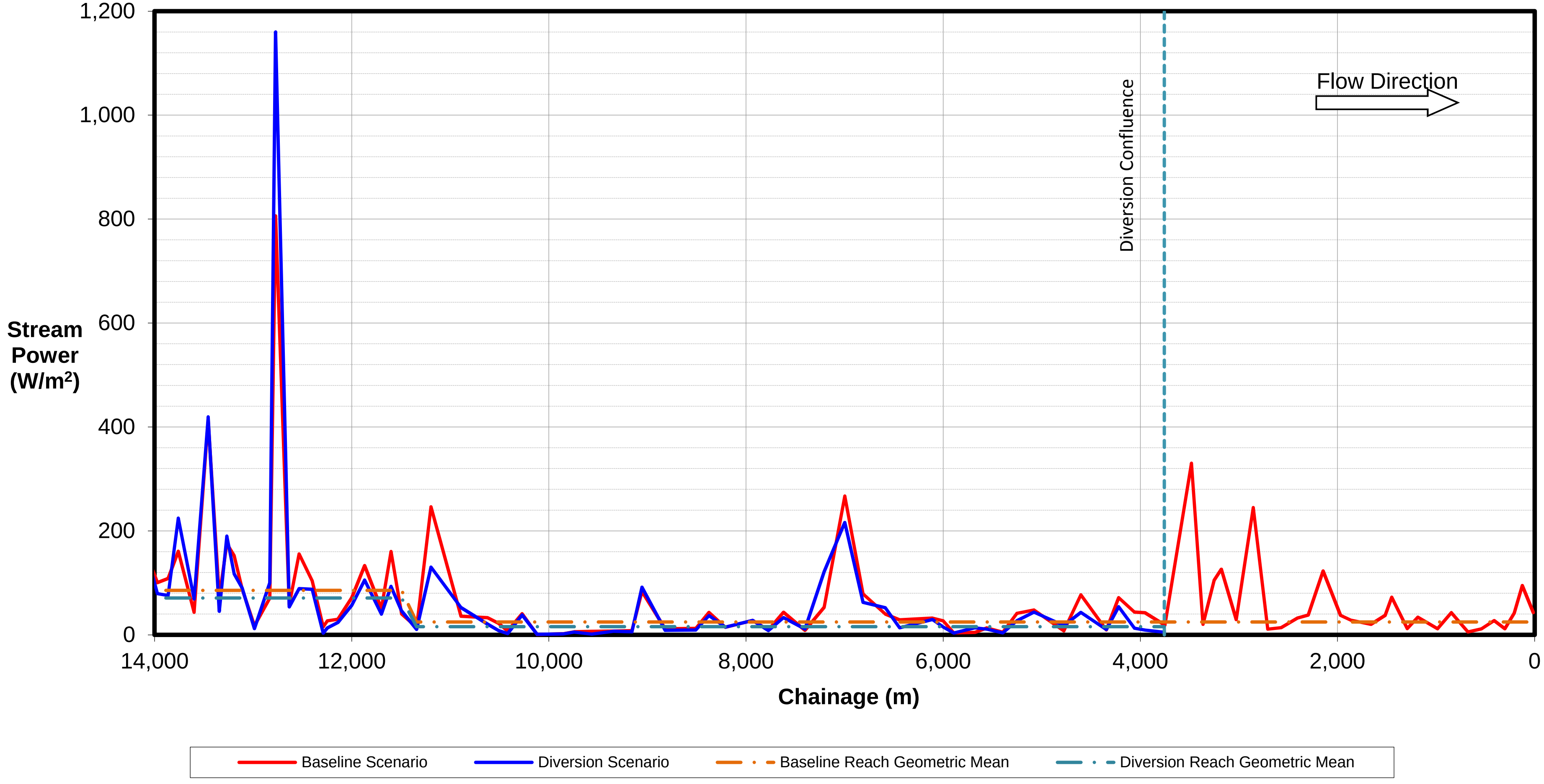
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-108 Comparison of Channel Stream Power along Rocky Creek for a 1:100 AEP Event



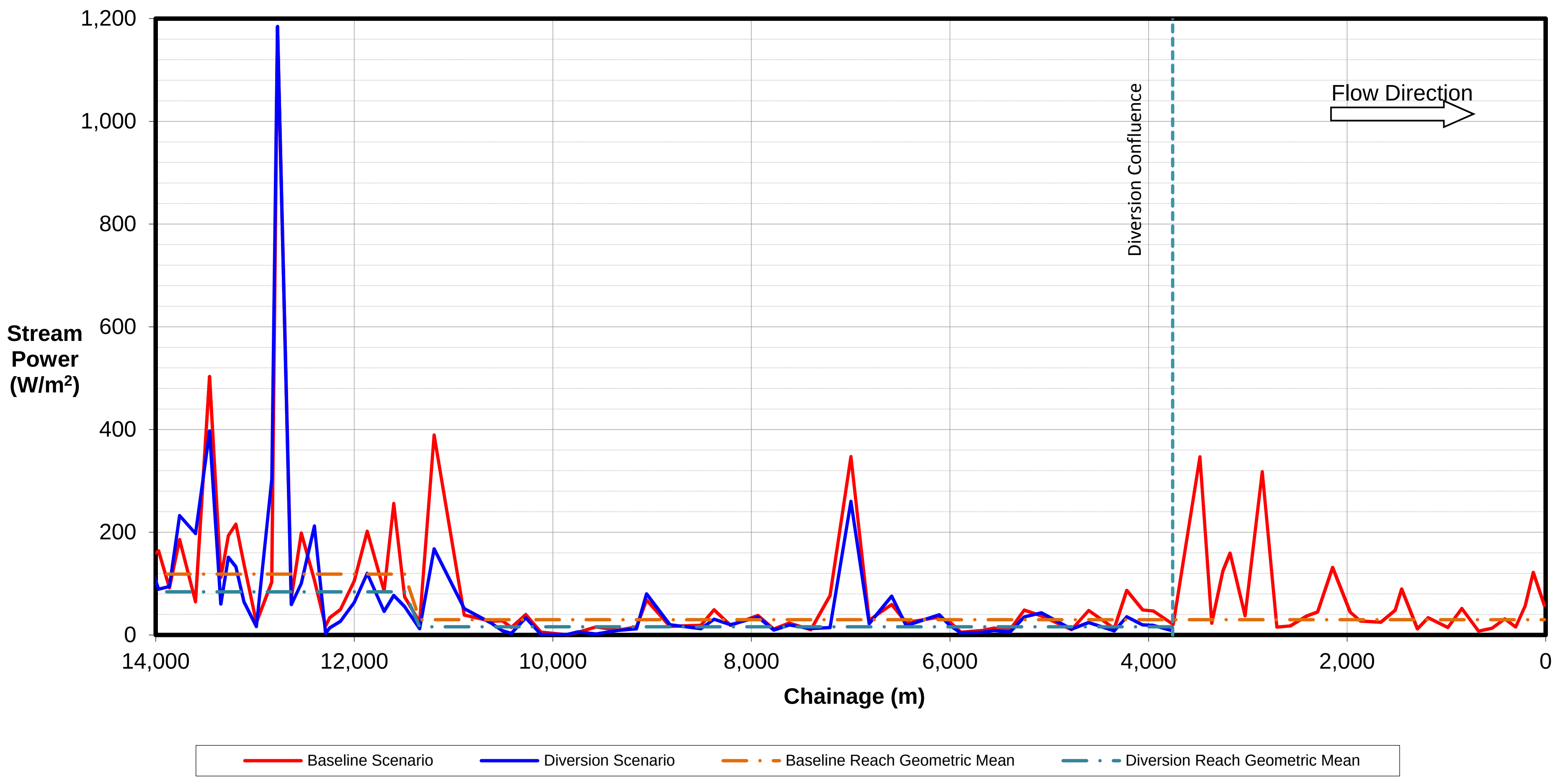
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-109 Comparison of Channel Stream Power along Rocky Creek for a 1:1000 AEP Event



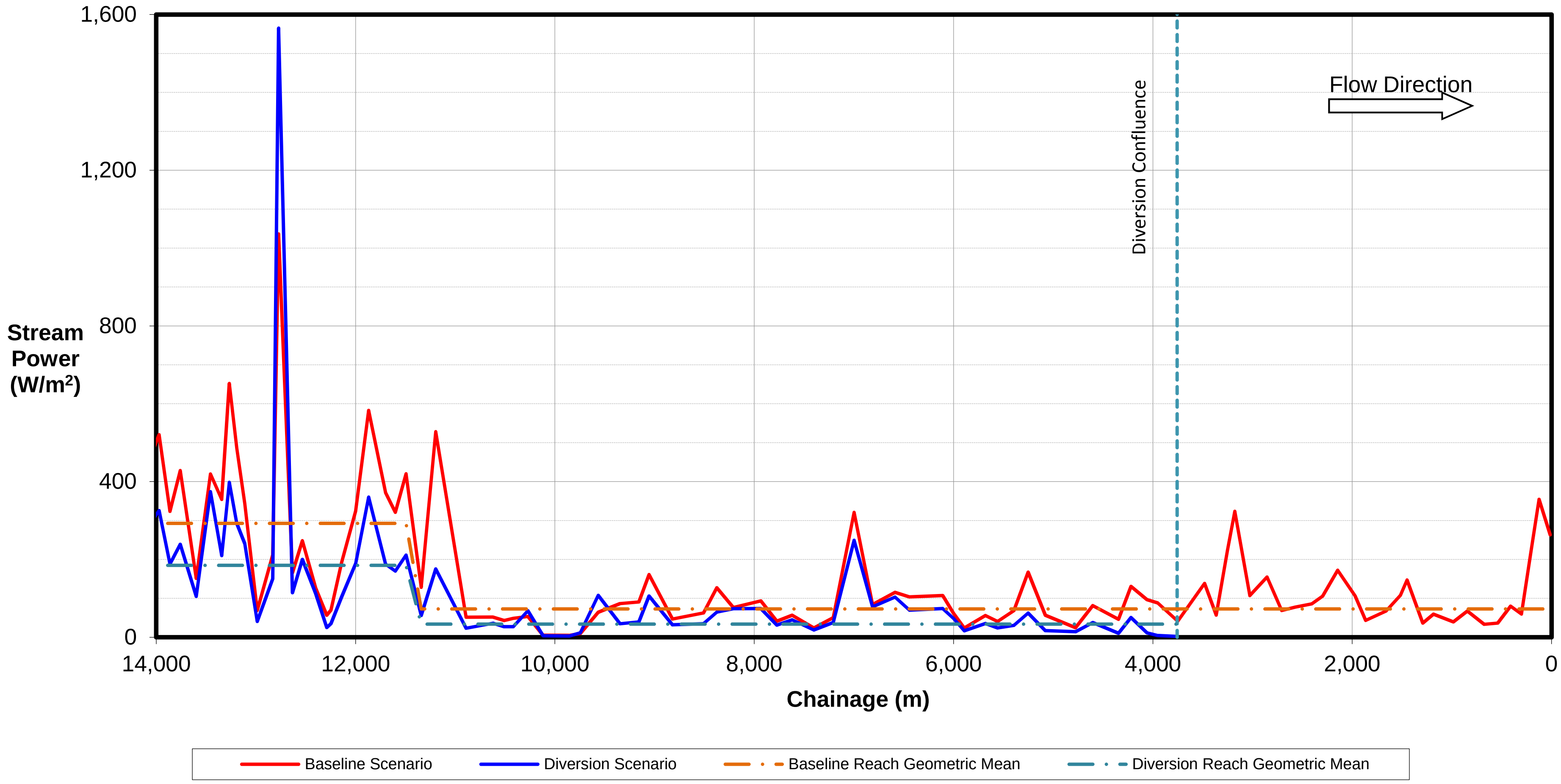
Appendix C - **Modelling Results – Profile Comparison Plots**

Figure Appendix C-110 Comparison of Channel Stream Power along Rocky Creek for a 1:2000 AEP Event



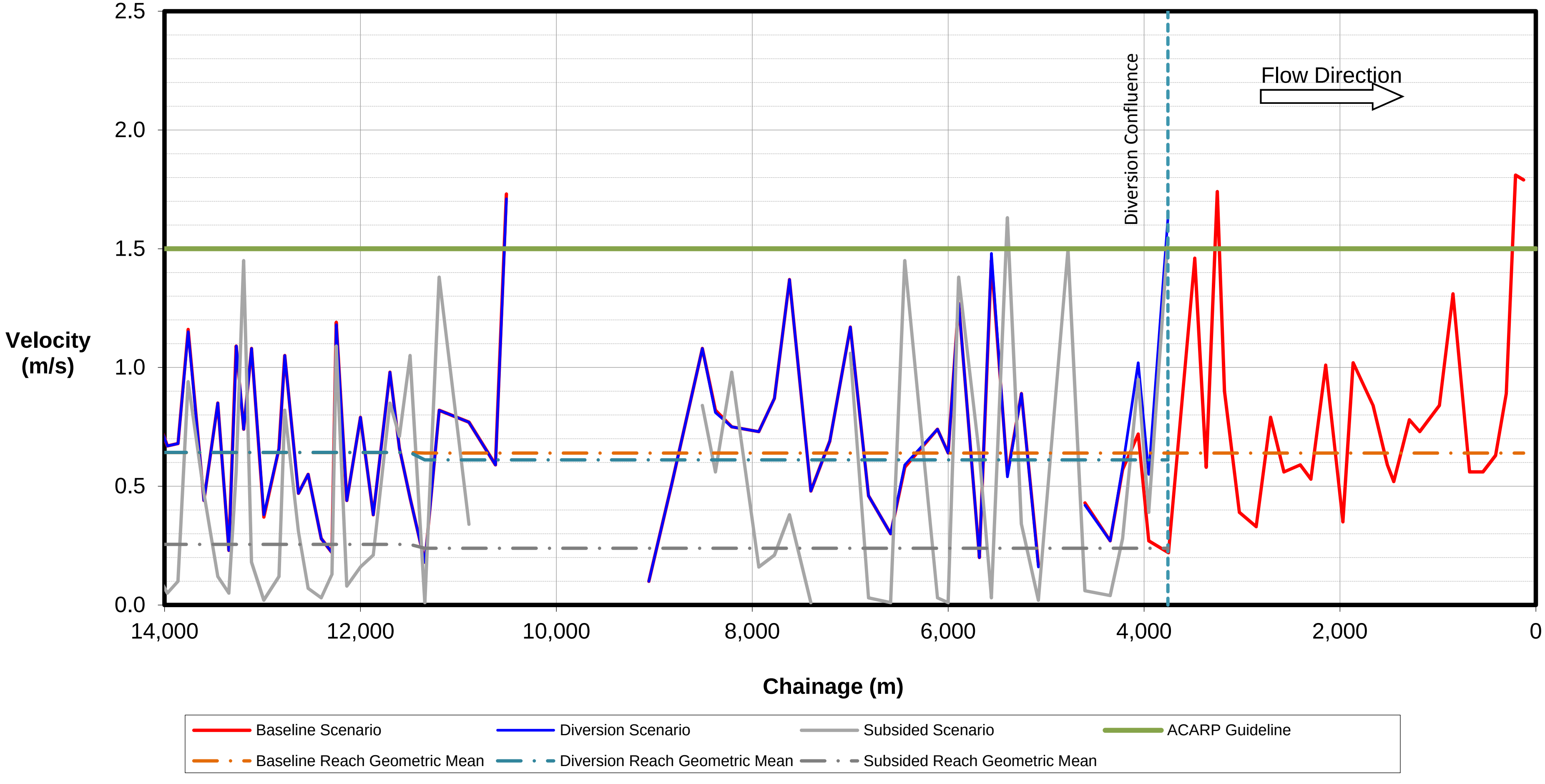
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-111 Comparison of Channel Stream Power along Rocky Creek for a PMF Event



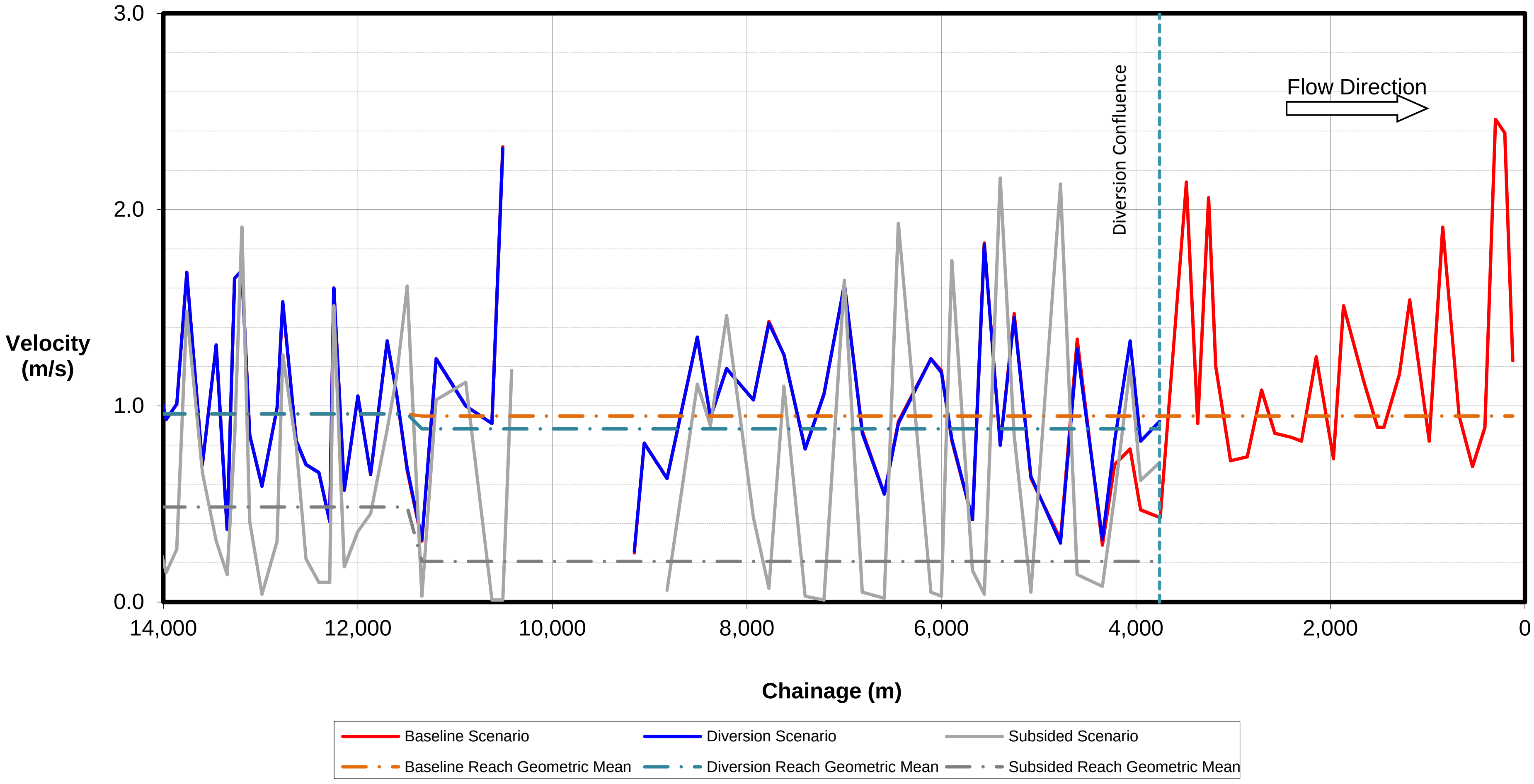
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-112 Comparison of Channel Velocity along Rocky Creek for a 1:2 AEP Event



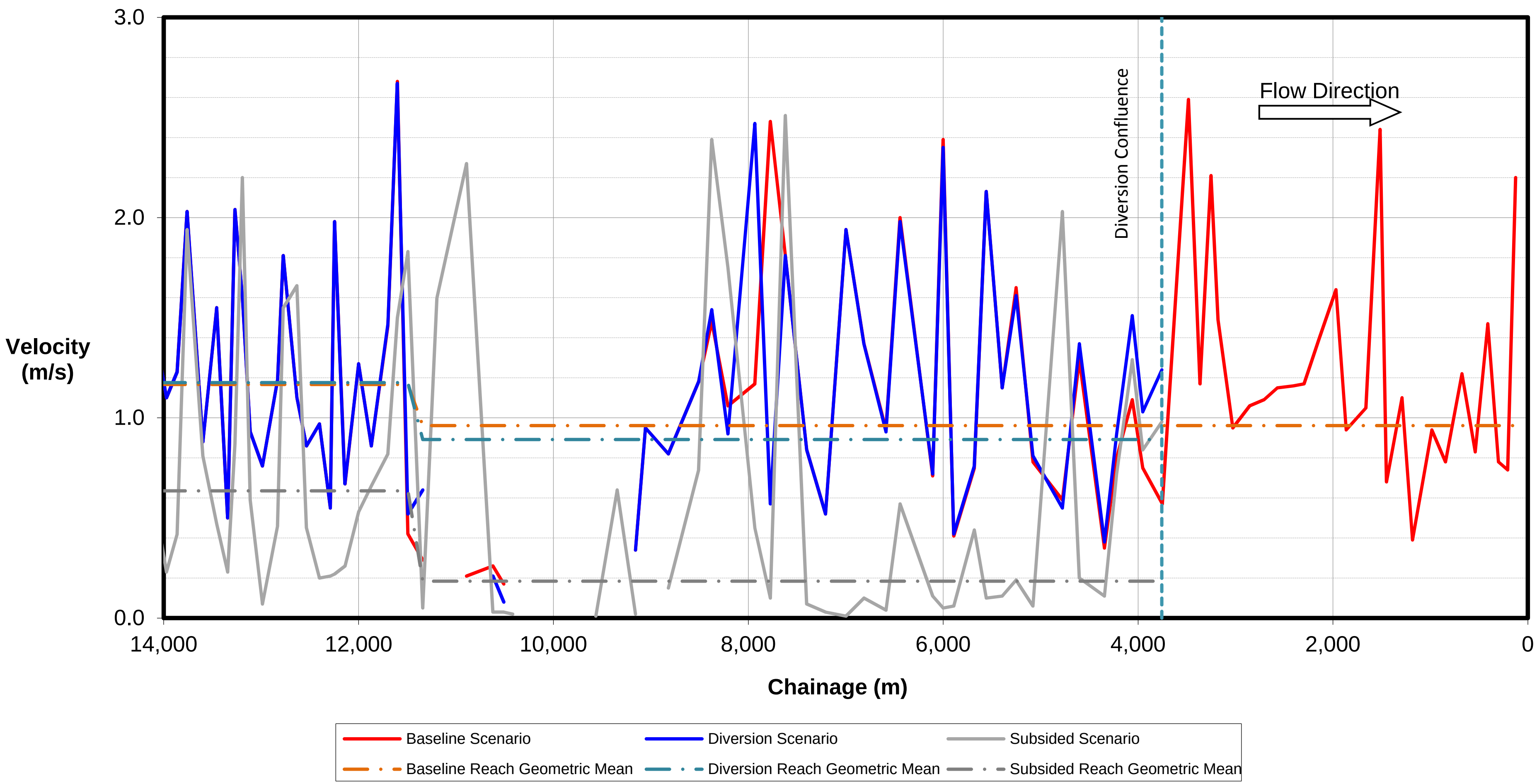
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-113 Comparison of Channel Velocity along Rocky Creek for a 1:5 AEP Event



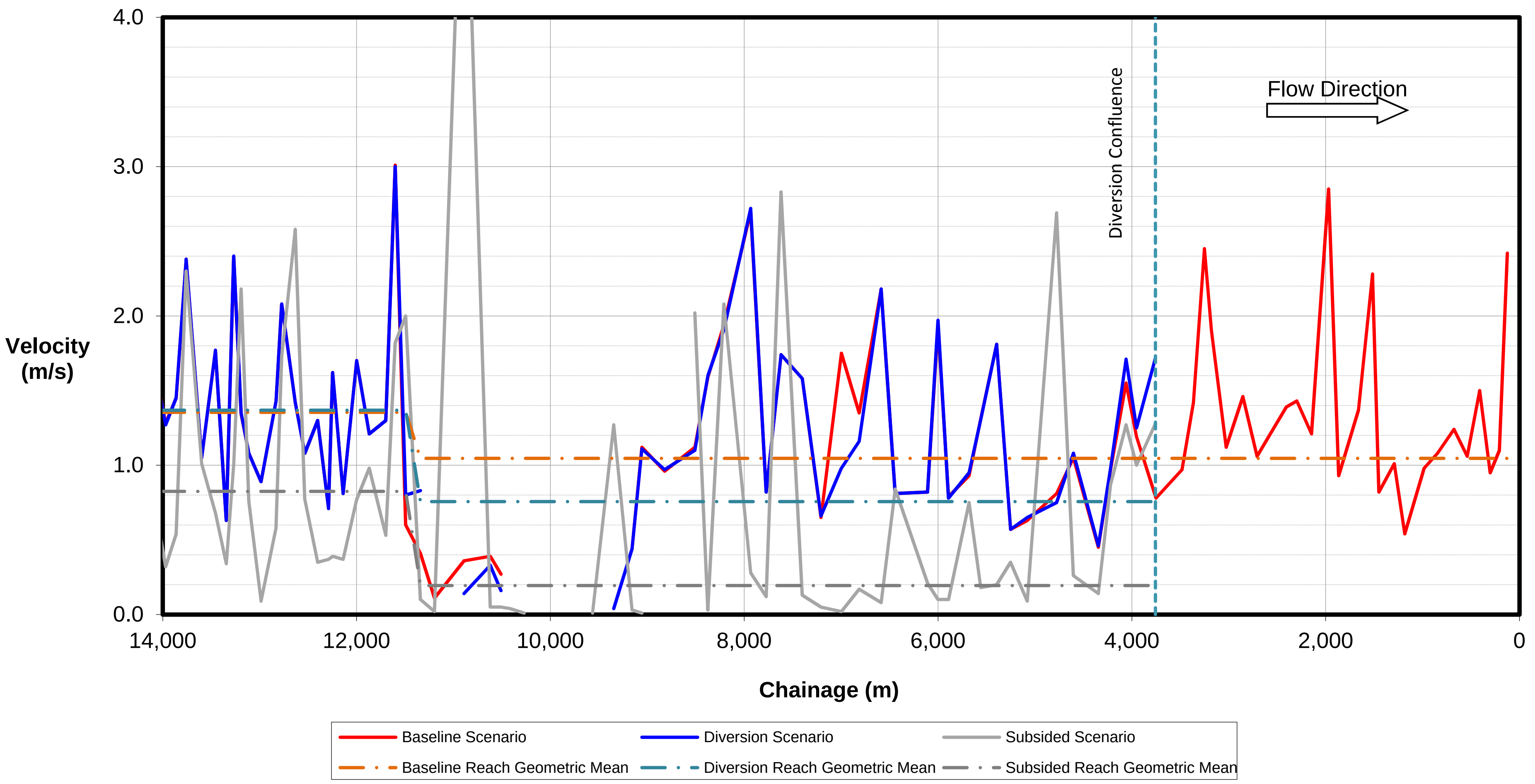
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-114 Comparison of Channel Velocity along Rocky Creek for a 1:10 AEP Event



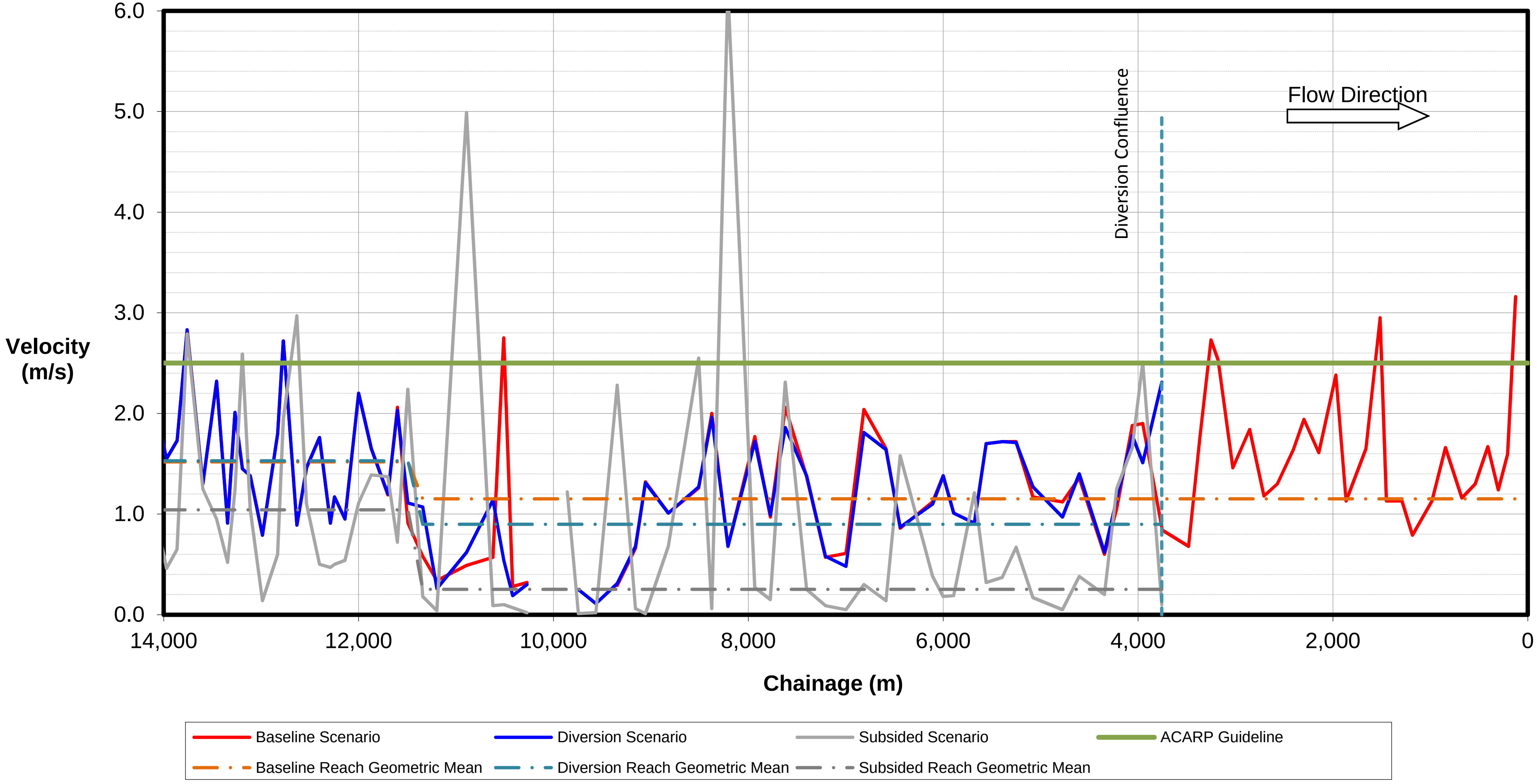
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-115 Comparison of Channel Velocity along Rocky Creek for a 1:20 AEP Event



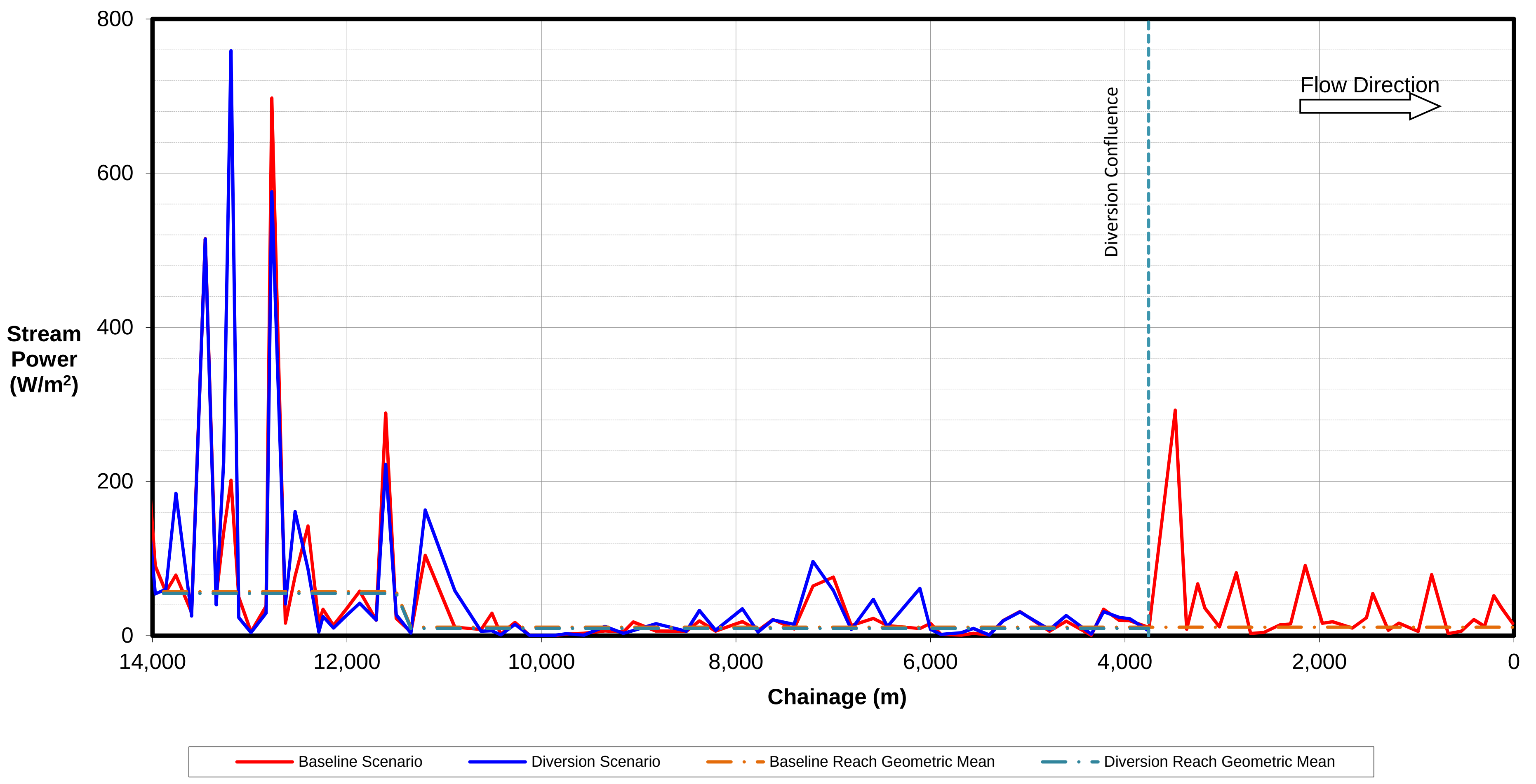
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-116 Comparison of Channel Velocity along Rocky Creek for a 1:50 AEP Event



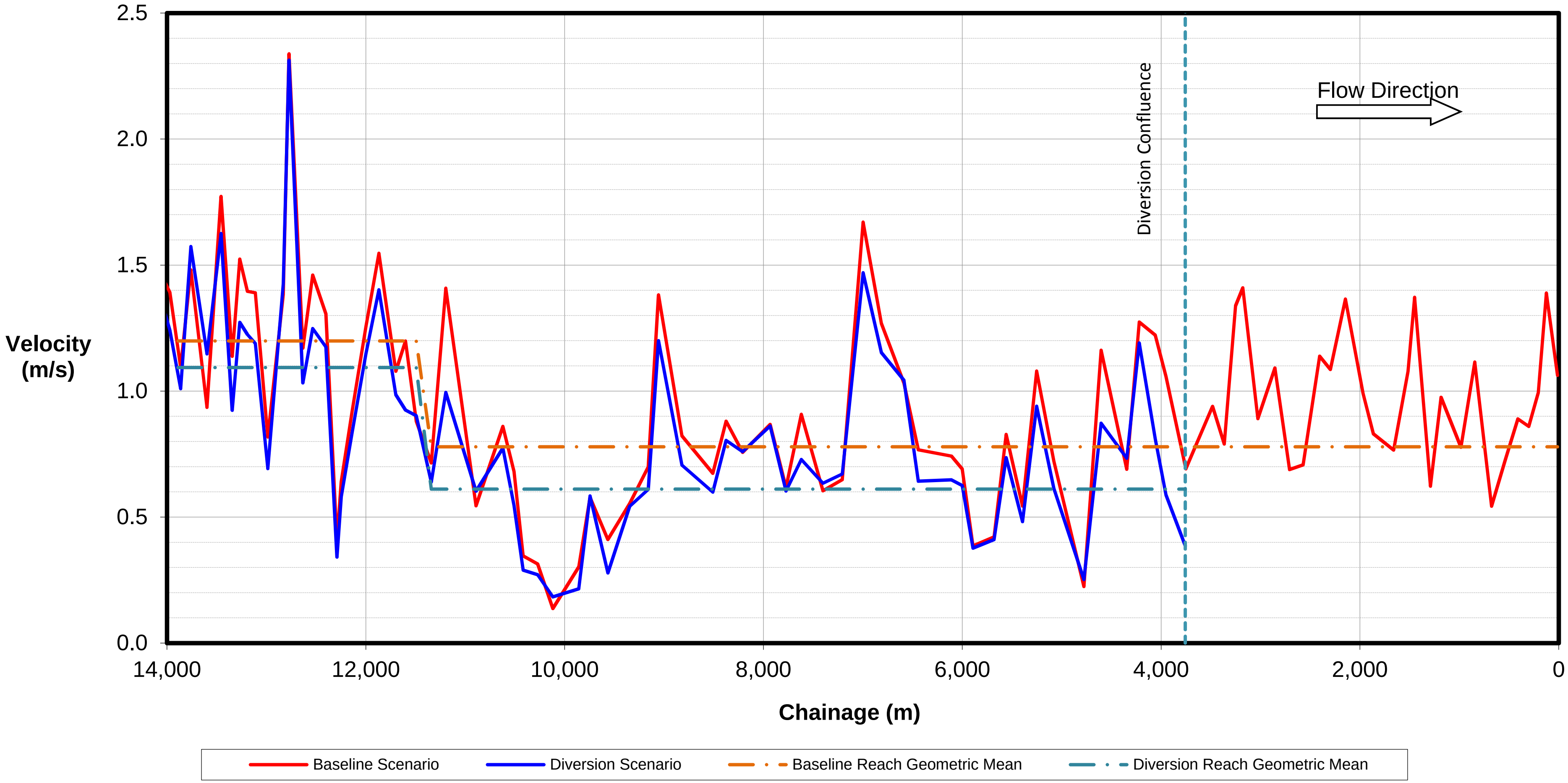
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-117 Comparison of Channel Velocity along Rocky Creek for a 1:100 AEP Event



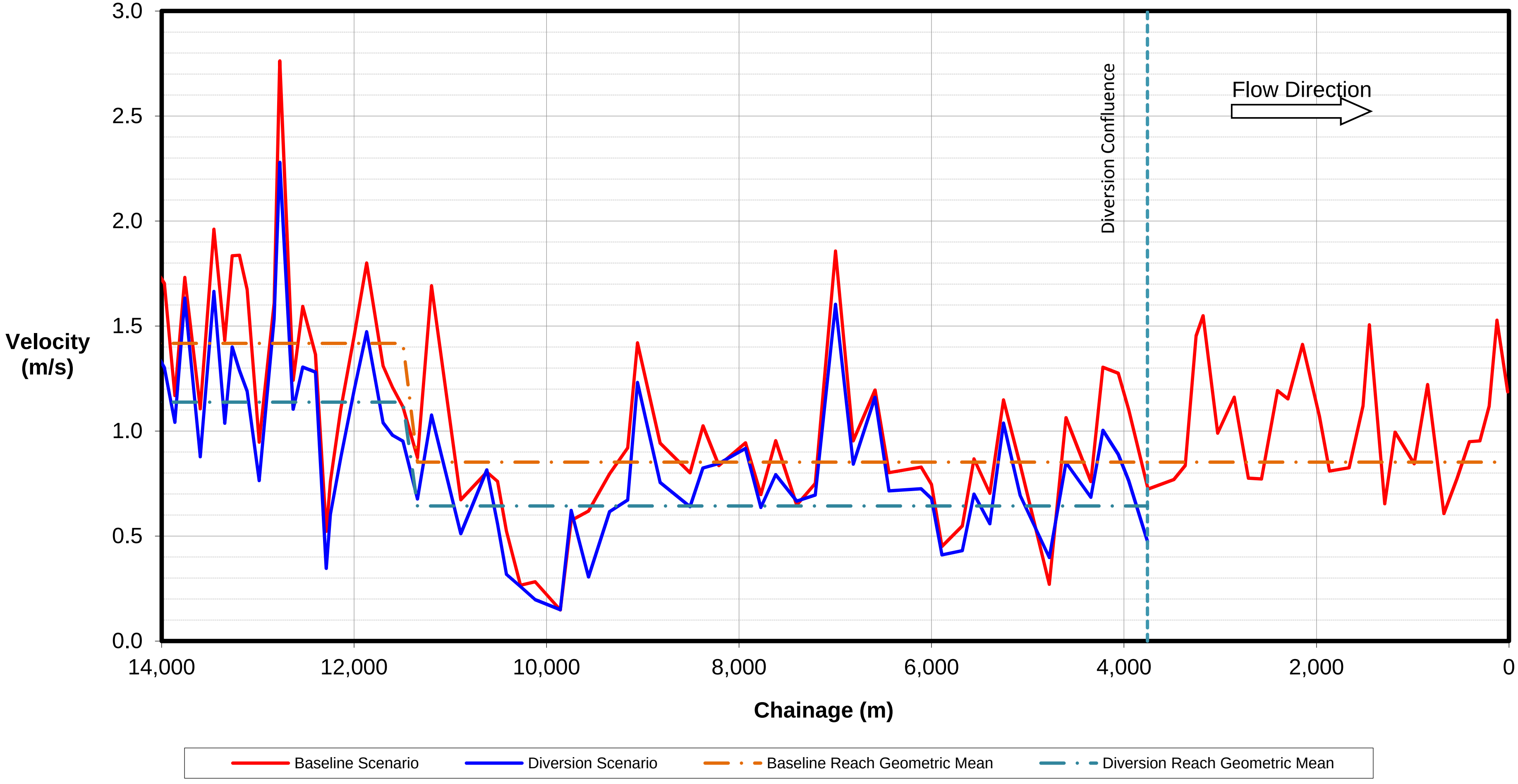
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-118 Comparison of Channel Velocity along Rocky Creek for a 1:1000 AEP Event



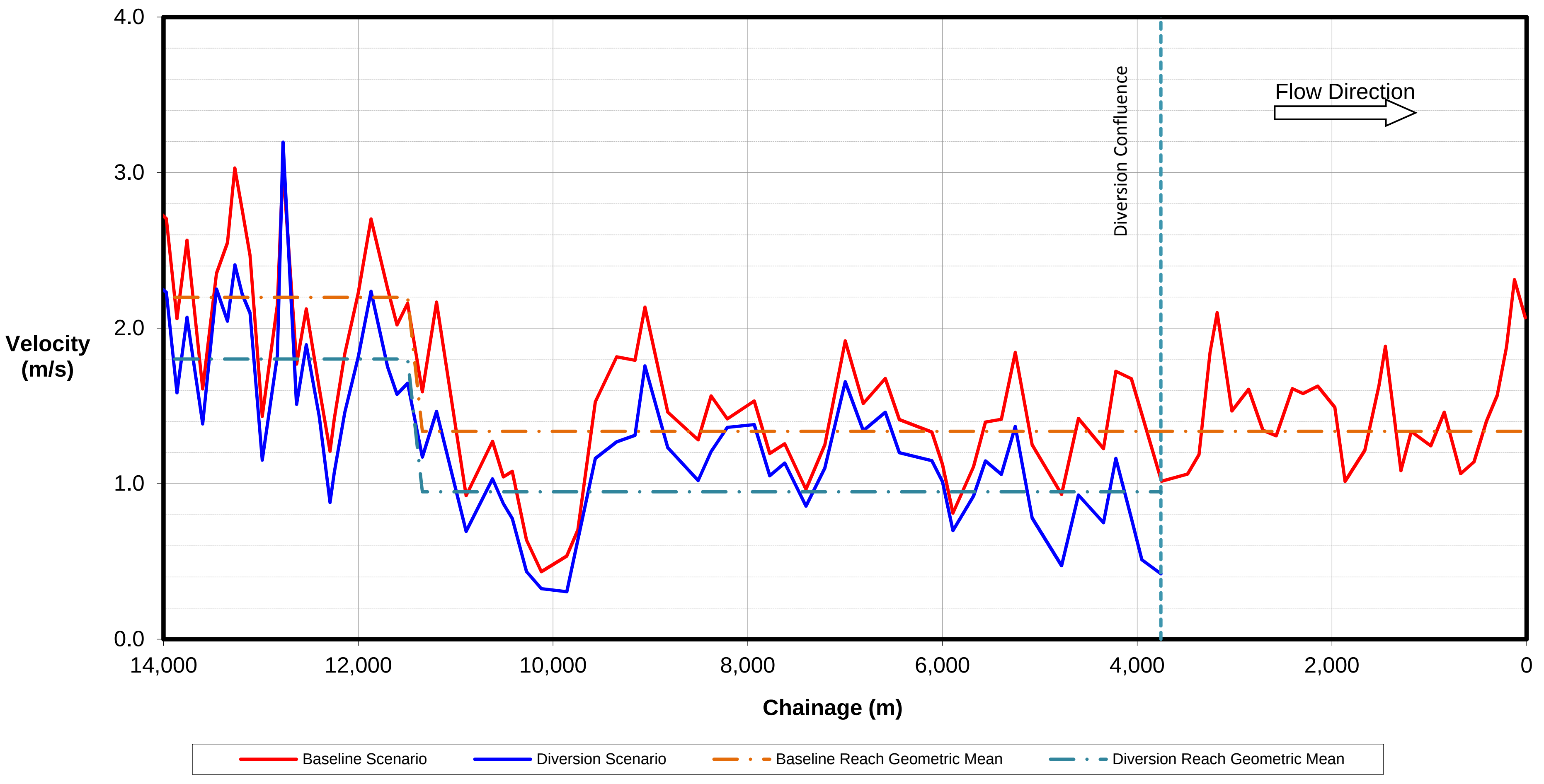
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-119 Comparison of Channel Velocity along Rocky Creek for a 1:2000 AEP Event



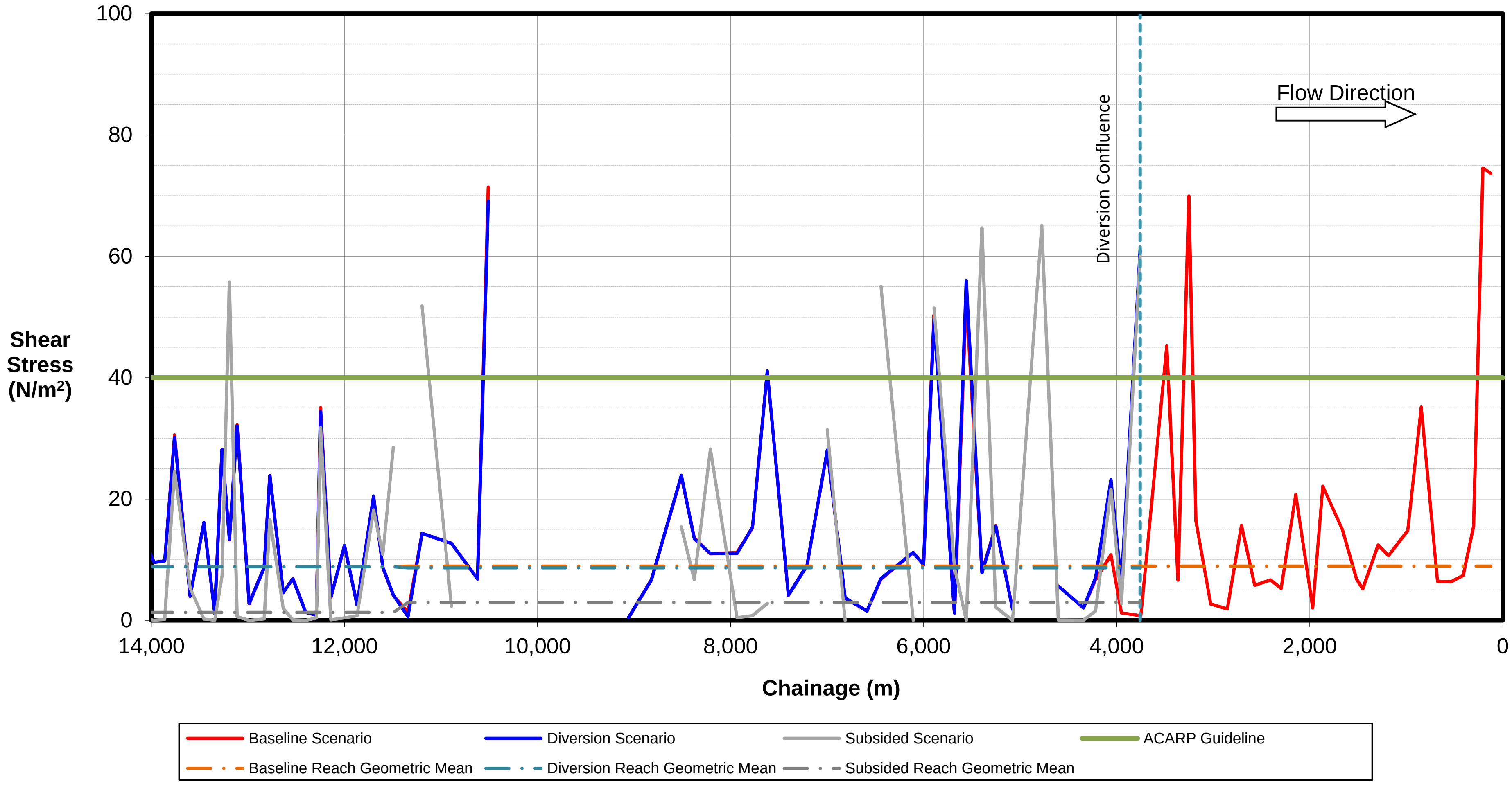
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-120 Comparison of Channel Velocity along Rocky Creek for a PMF Event



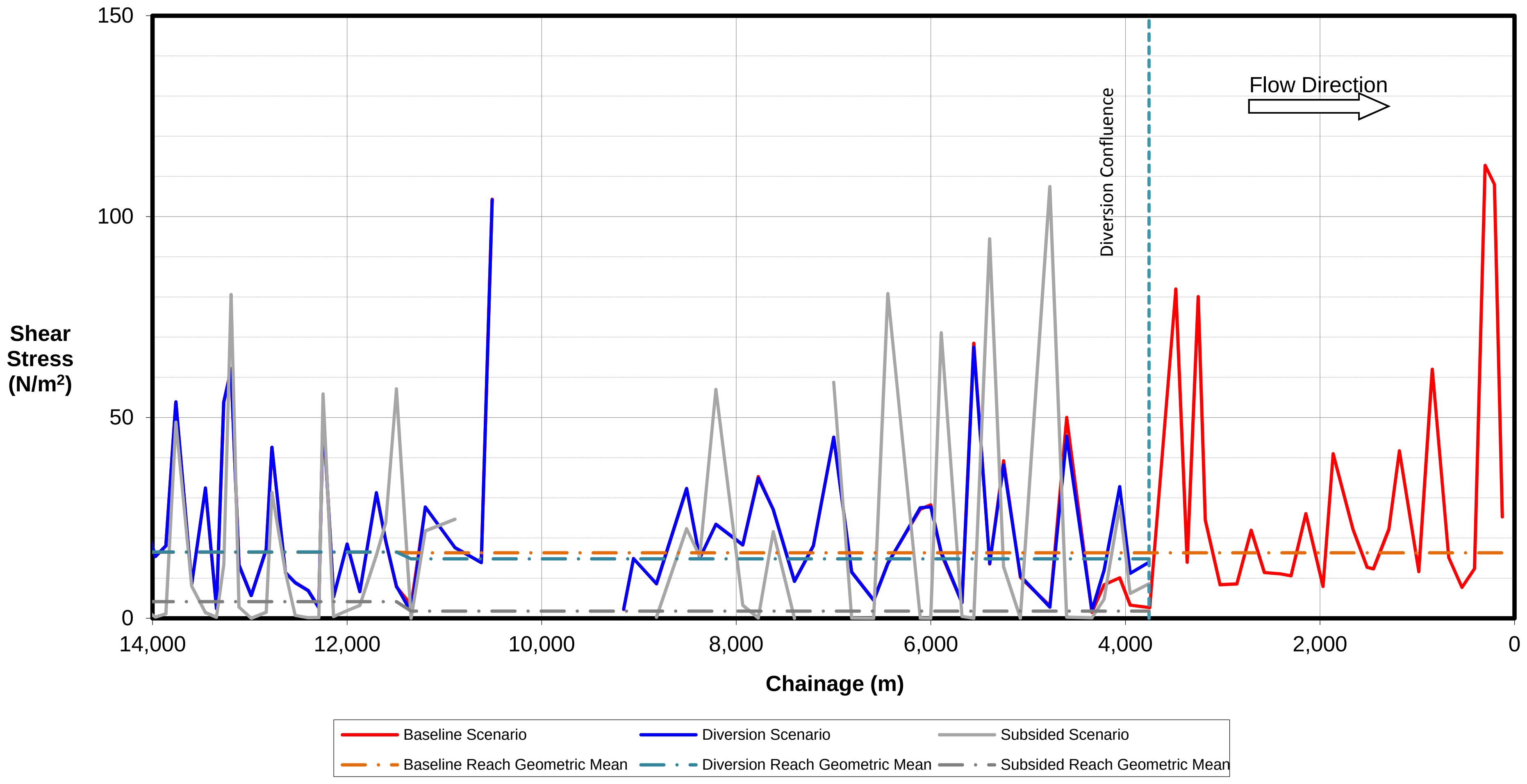
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-121 Comparison of Bed Shear Stress along Rocky Creek for a 1:2 AEP Event



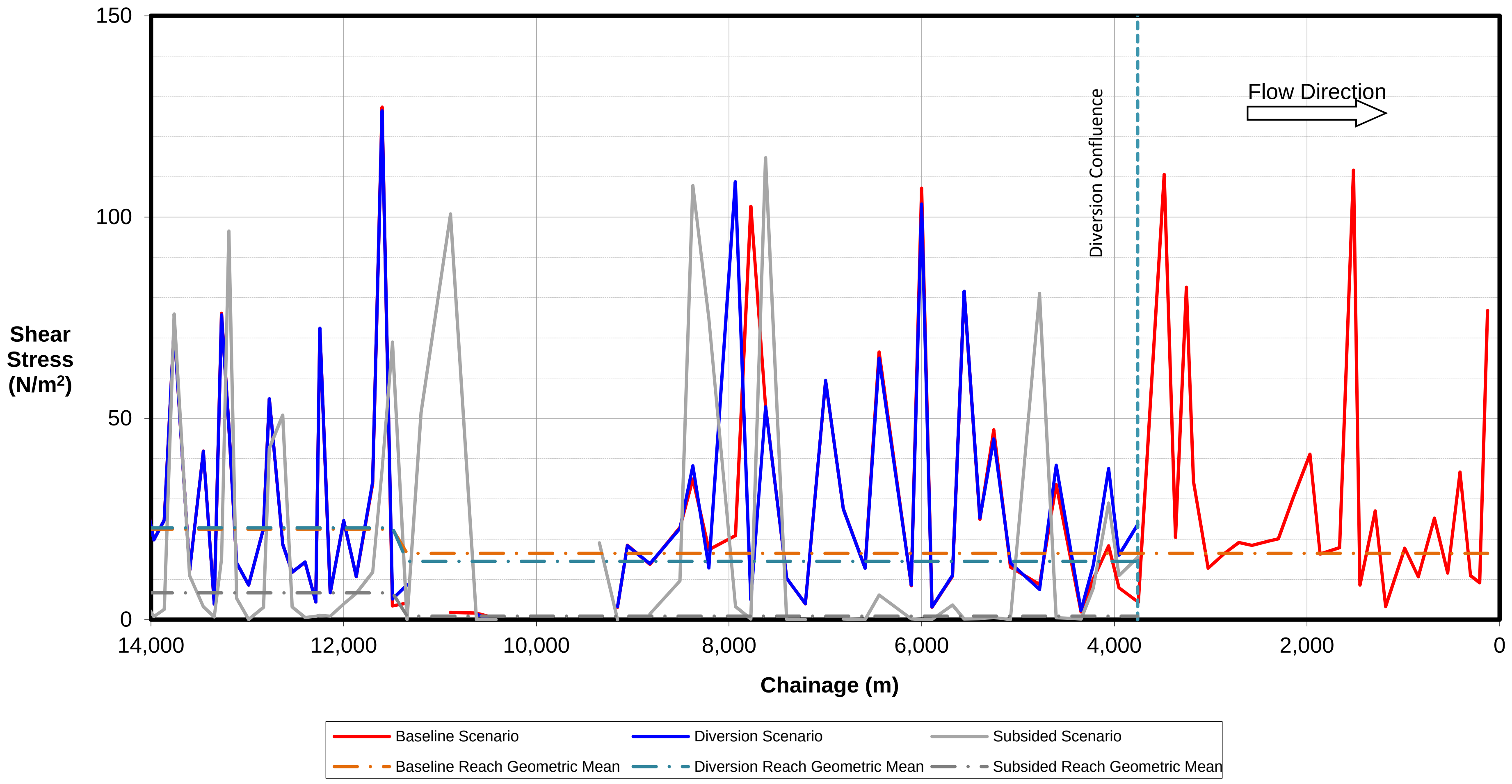
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-122 Comparison of Bed Shear Stress along Rocky Creek for a 1:5 AEP Event



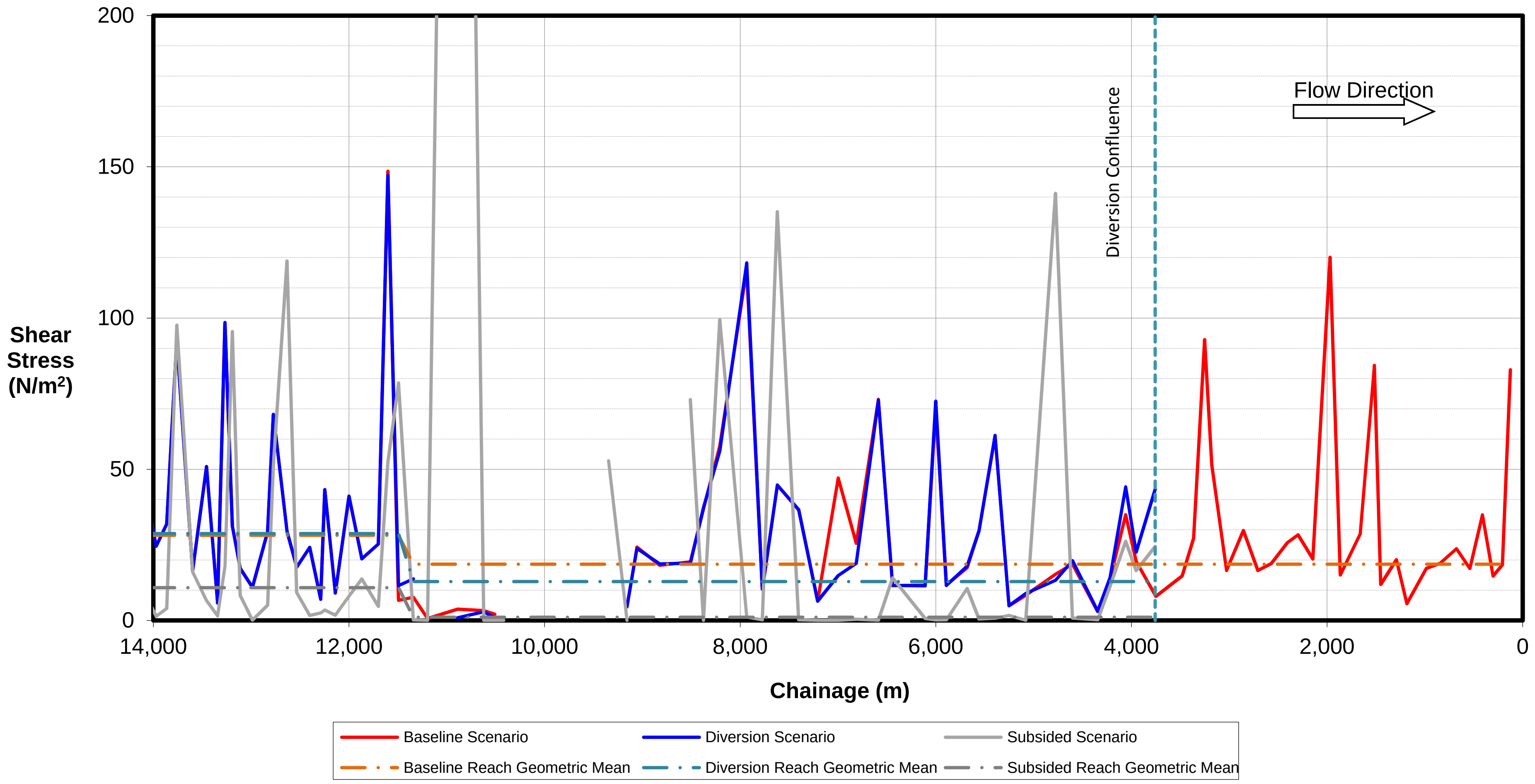
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-123 Comparison of Bed Shear Stress along Rocky Creek for a 1:10 AEP Event



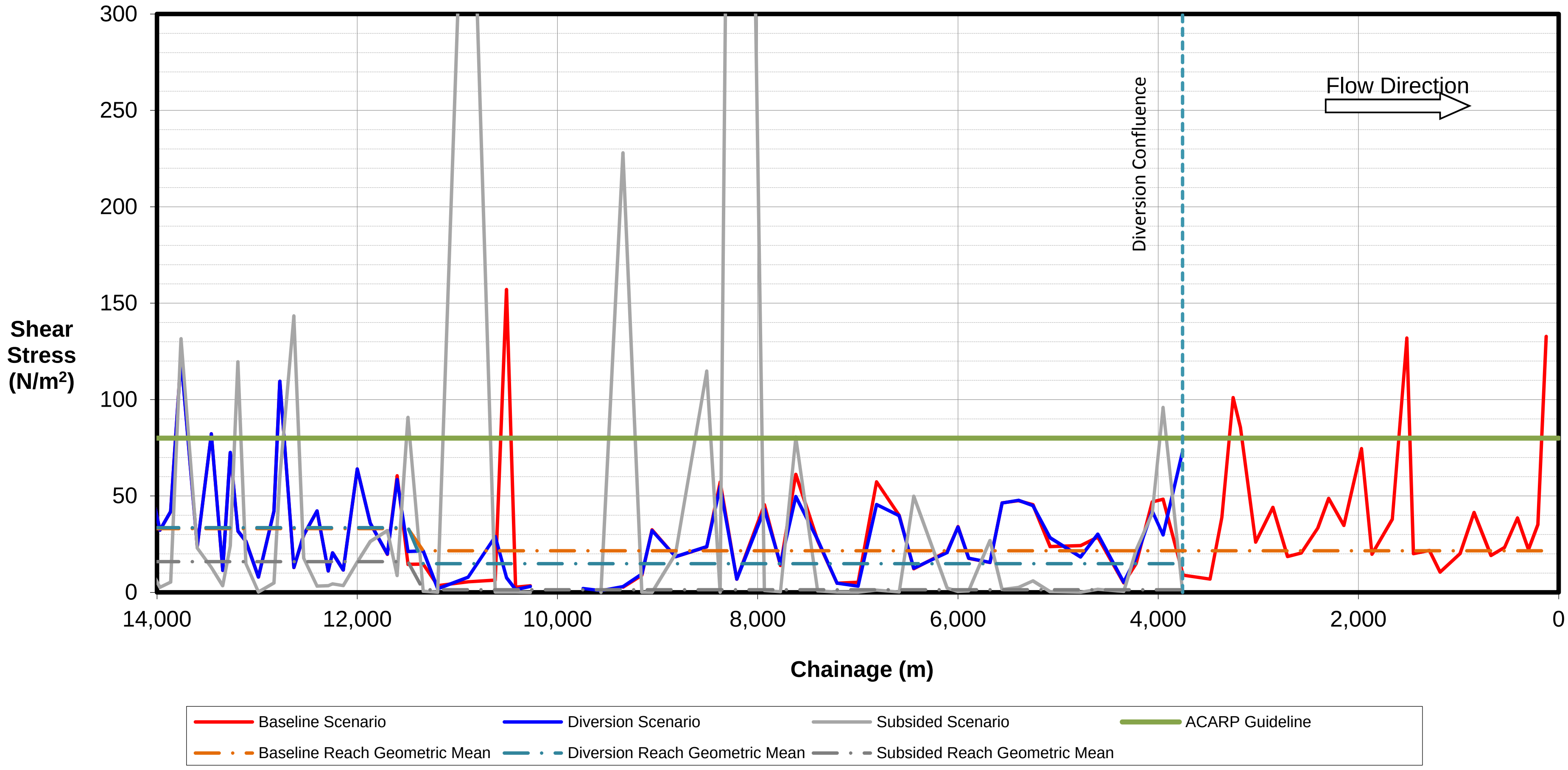
Appendix C - **Modelling Results – Profile Comparison Plots**

Figure Appendix C-124 Comparison of Bed Shear Stress along Rocky Creek for a 1:20 AEP Event



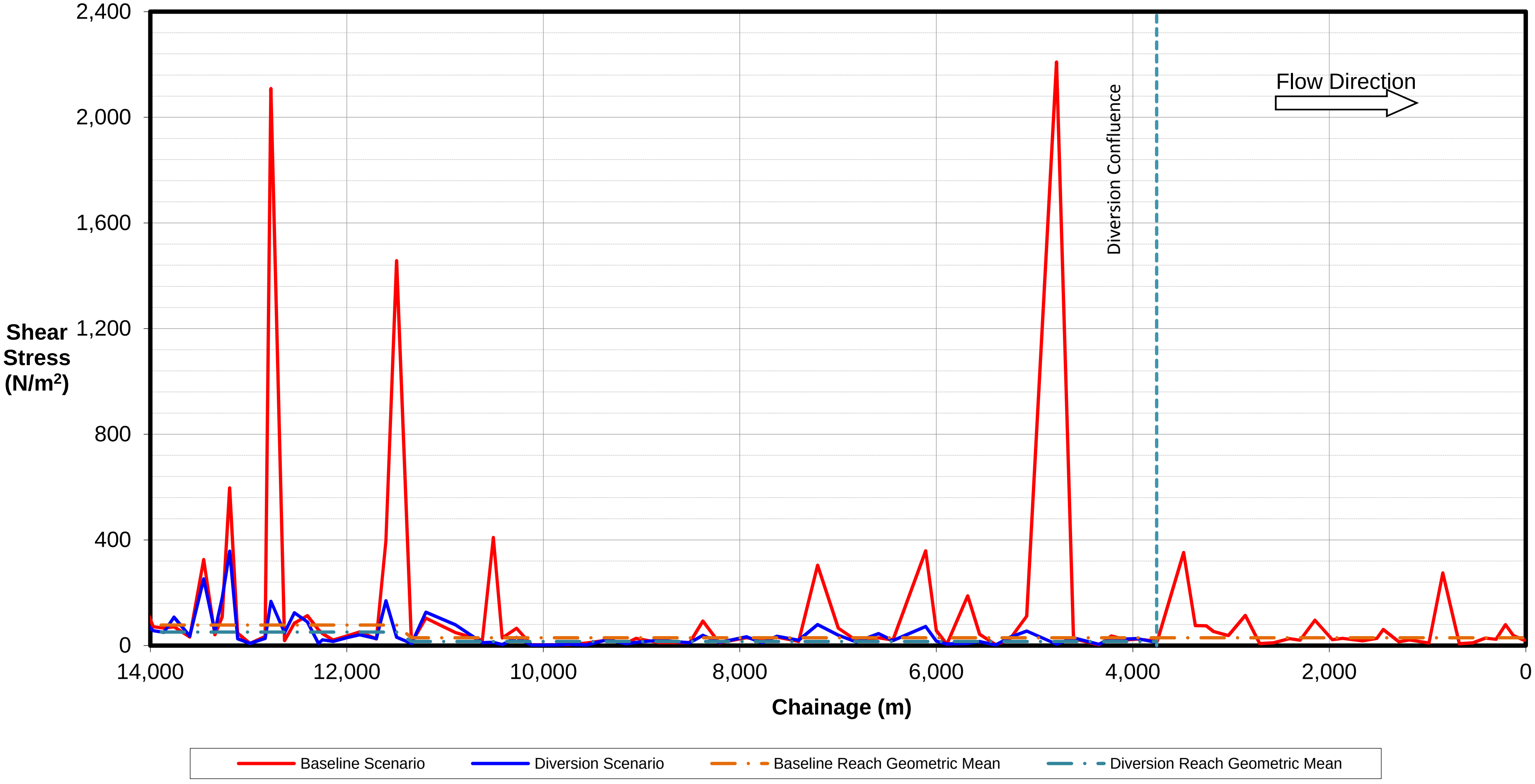
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-125 Comparison of Bed Shear Stress along Rocky Creek for a 1:50 AEP Event



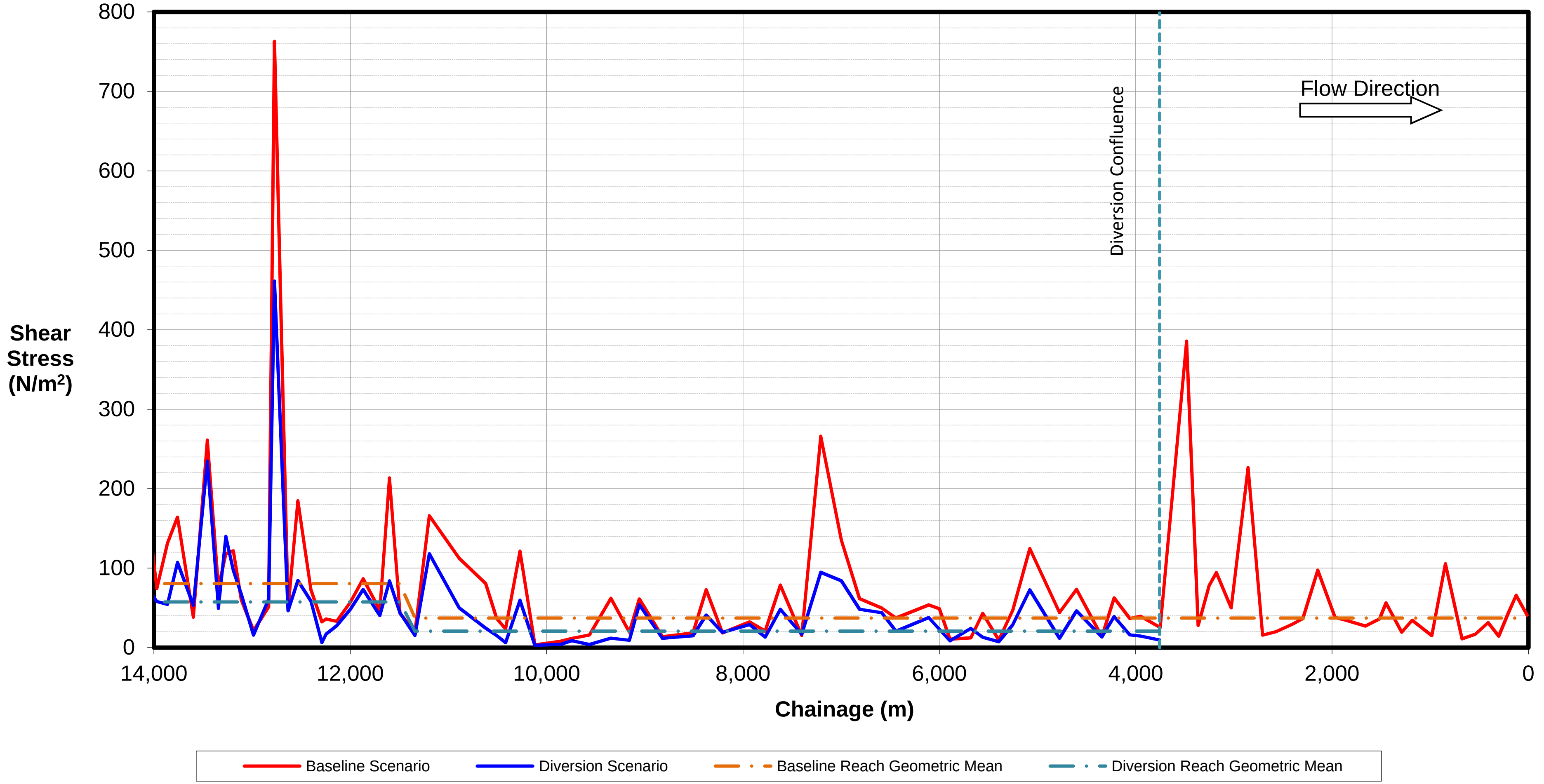
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-126 Comparison of Bed Shear Stress along Rocky Creek for a 1:100 AEP Event



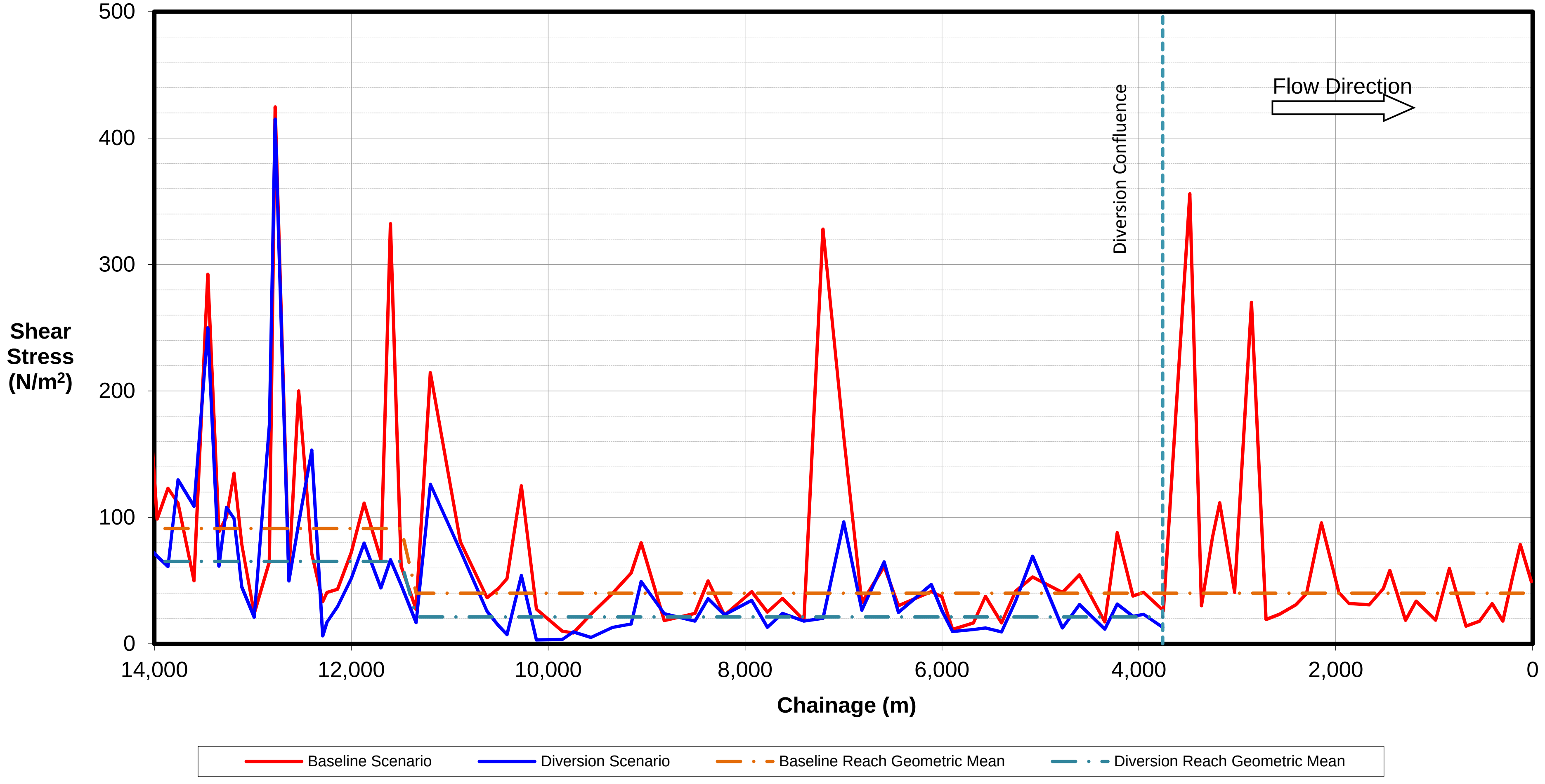
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-127 Comparison of Bed Shear Stress along Rocky Creek for a 1:1000 AEP Event



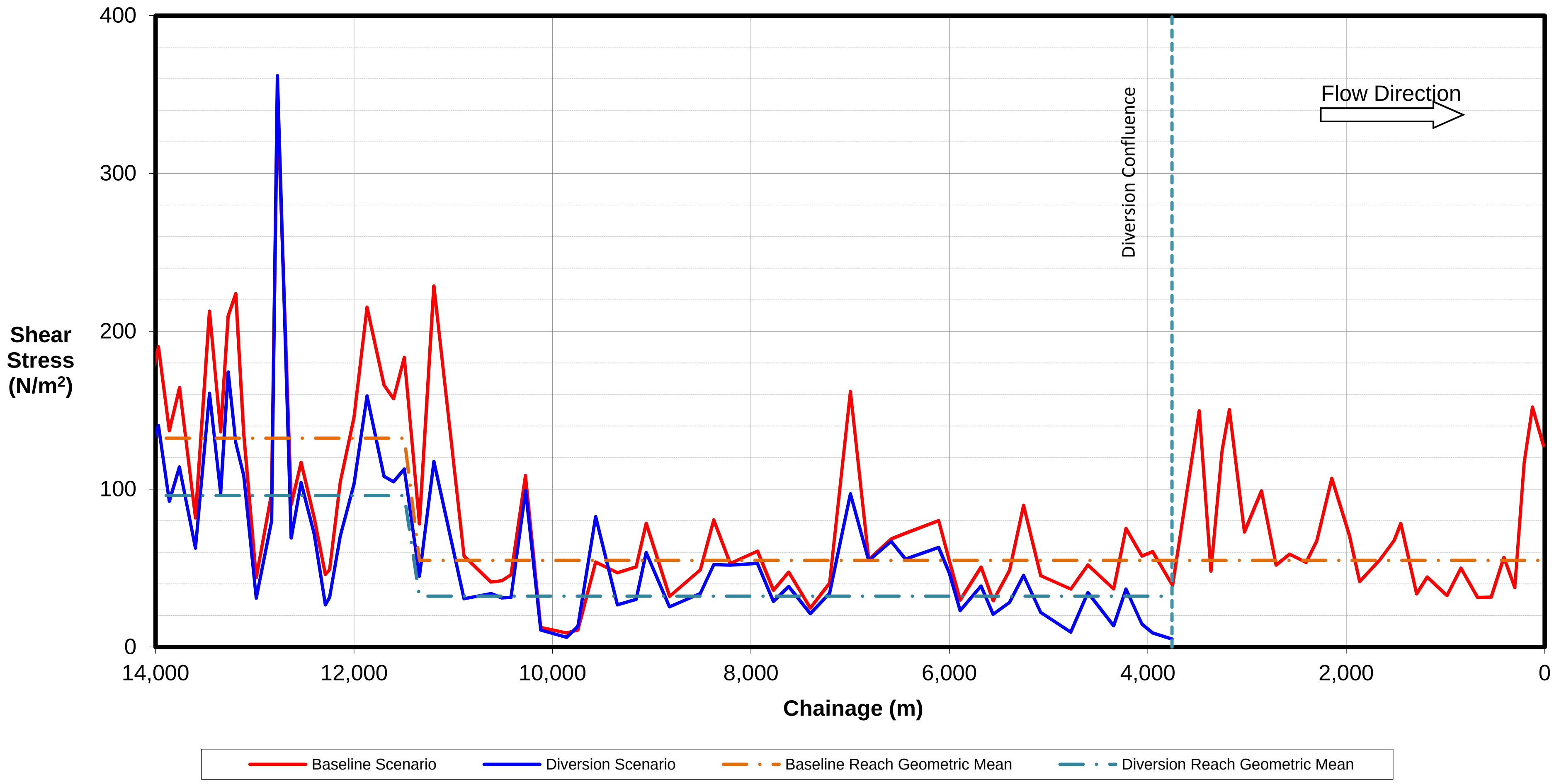
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-128 Comparison of Bed Shear Stress along Rocky Creek for a 1:2000 AEP Event



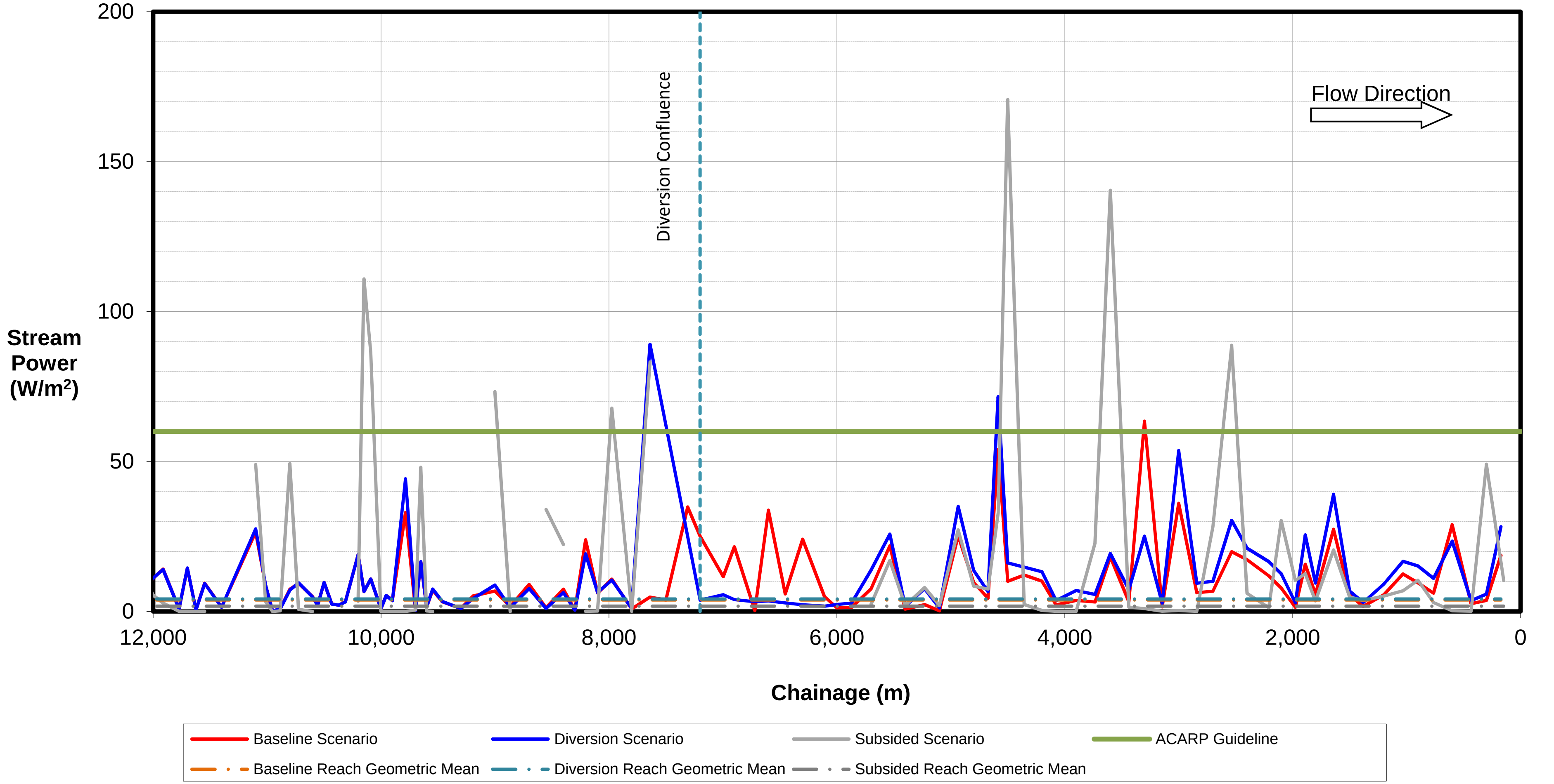
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-129 Comparison of Bed Shear Stress along Rocky Creek for a PMF Event



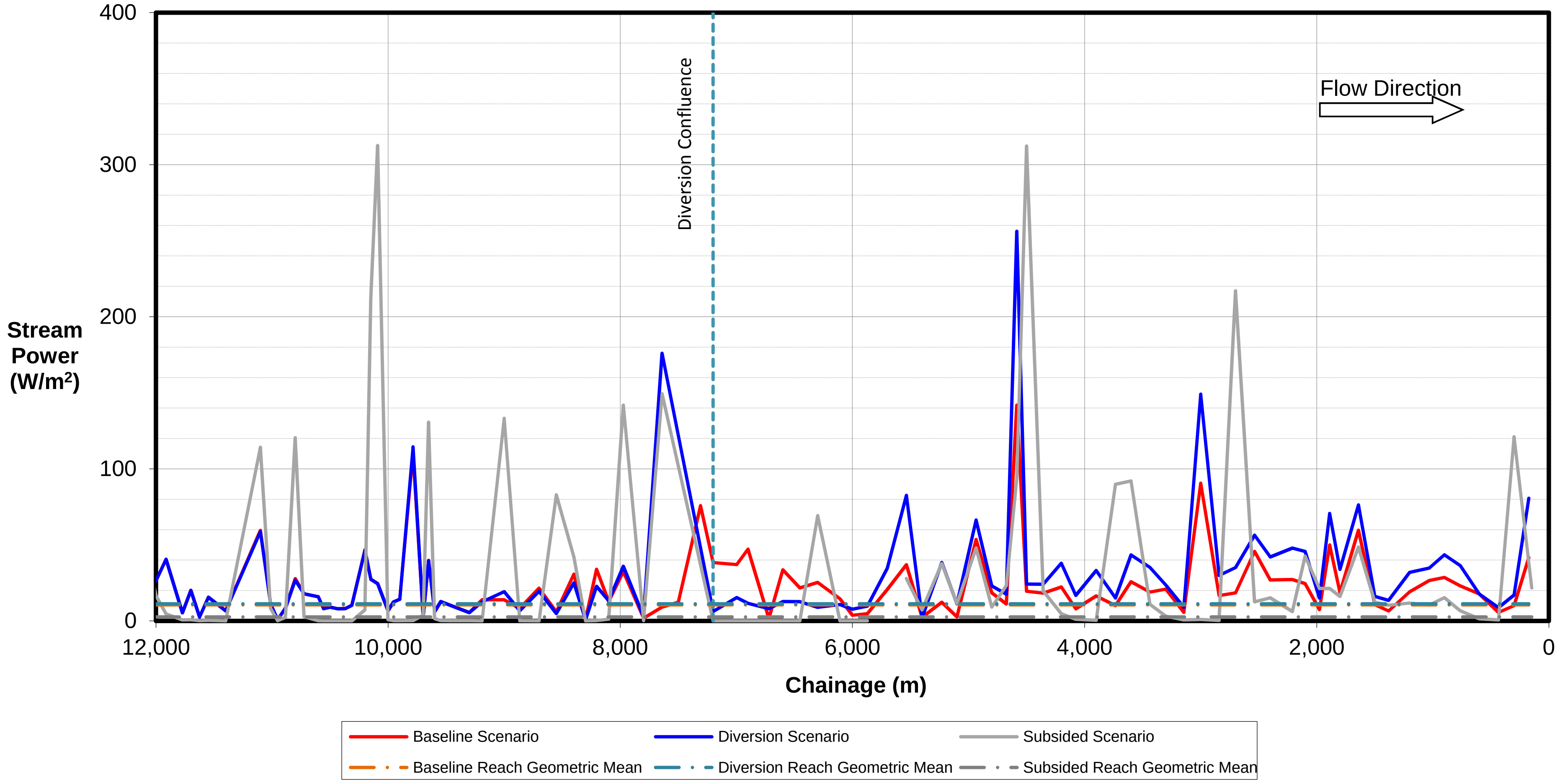
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-130 Comparison of Channel Stream Power along Middle Creek for a 1:2 AEP Event



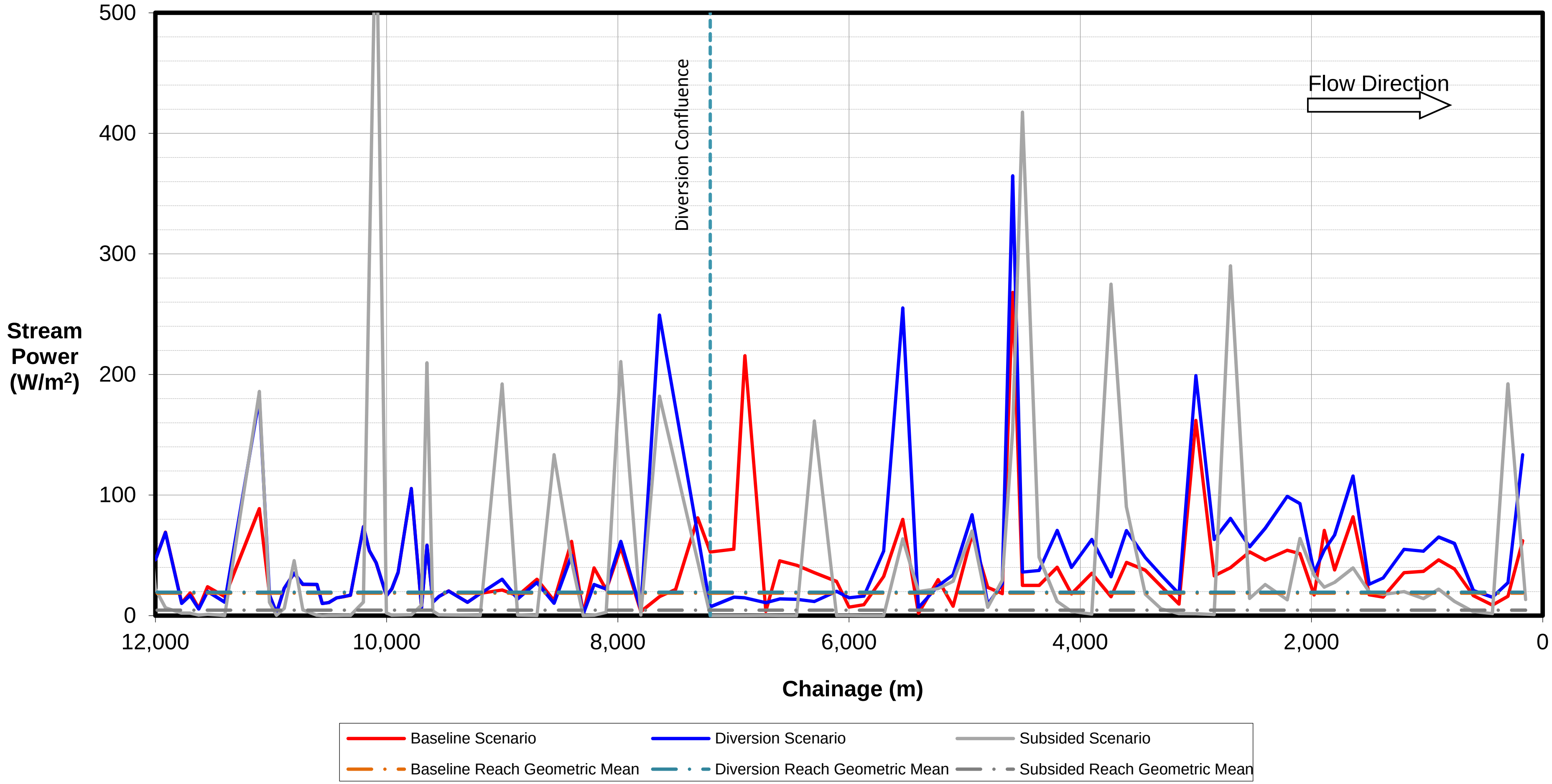
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-131 Comparison of Channel Stream Power along Middle Creek for a 1:5 AEP Event



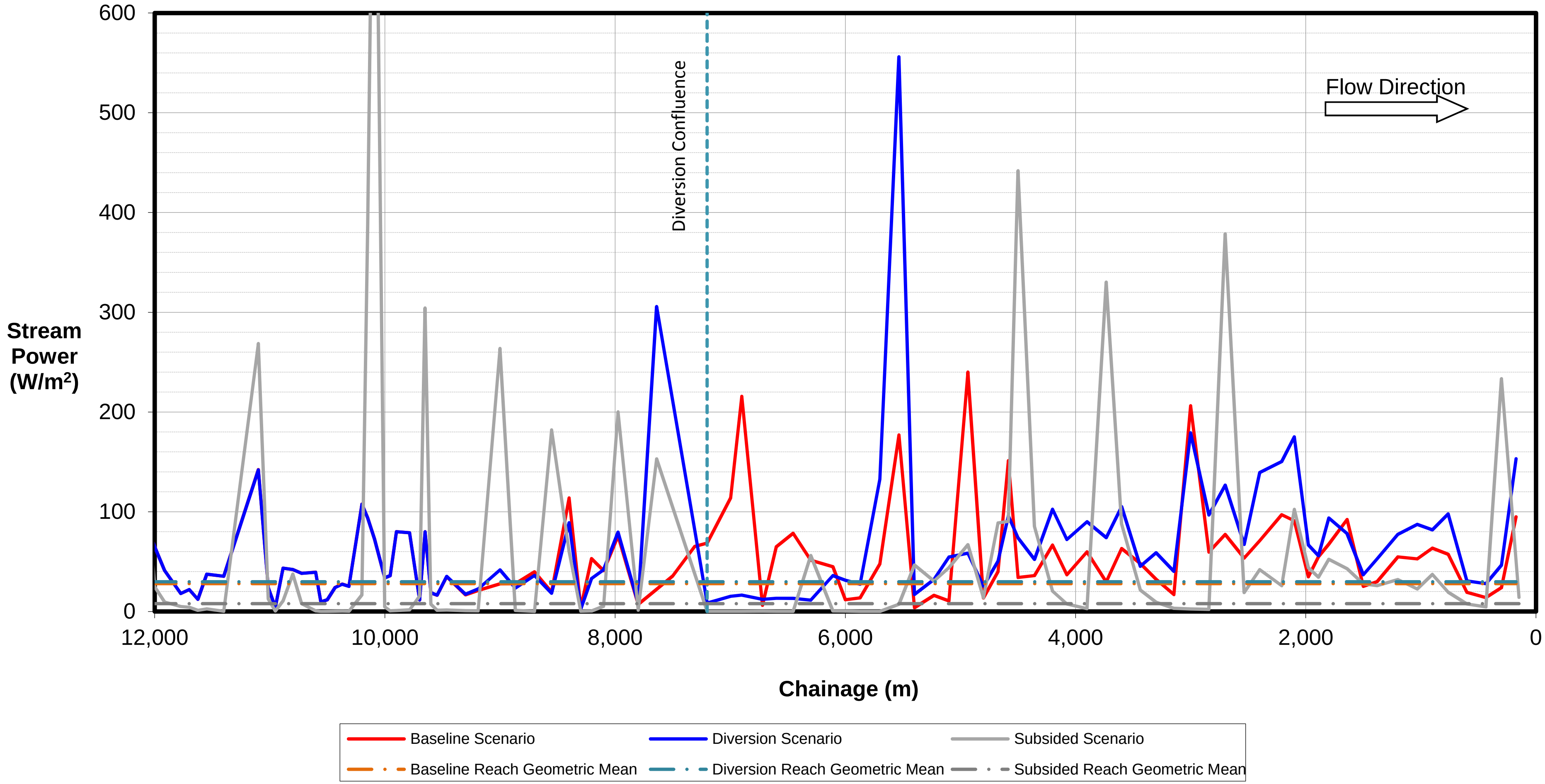
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-132 Comparison of Channel Stream Power along Middle Creek for a 1:10 AEP Event



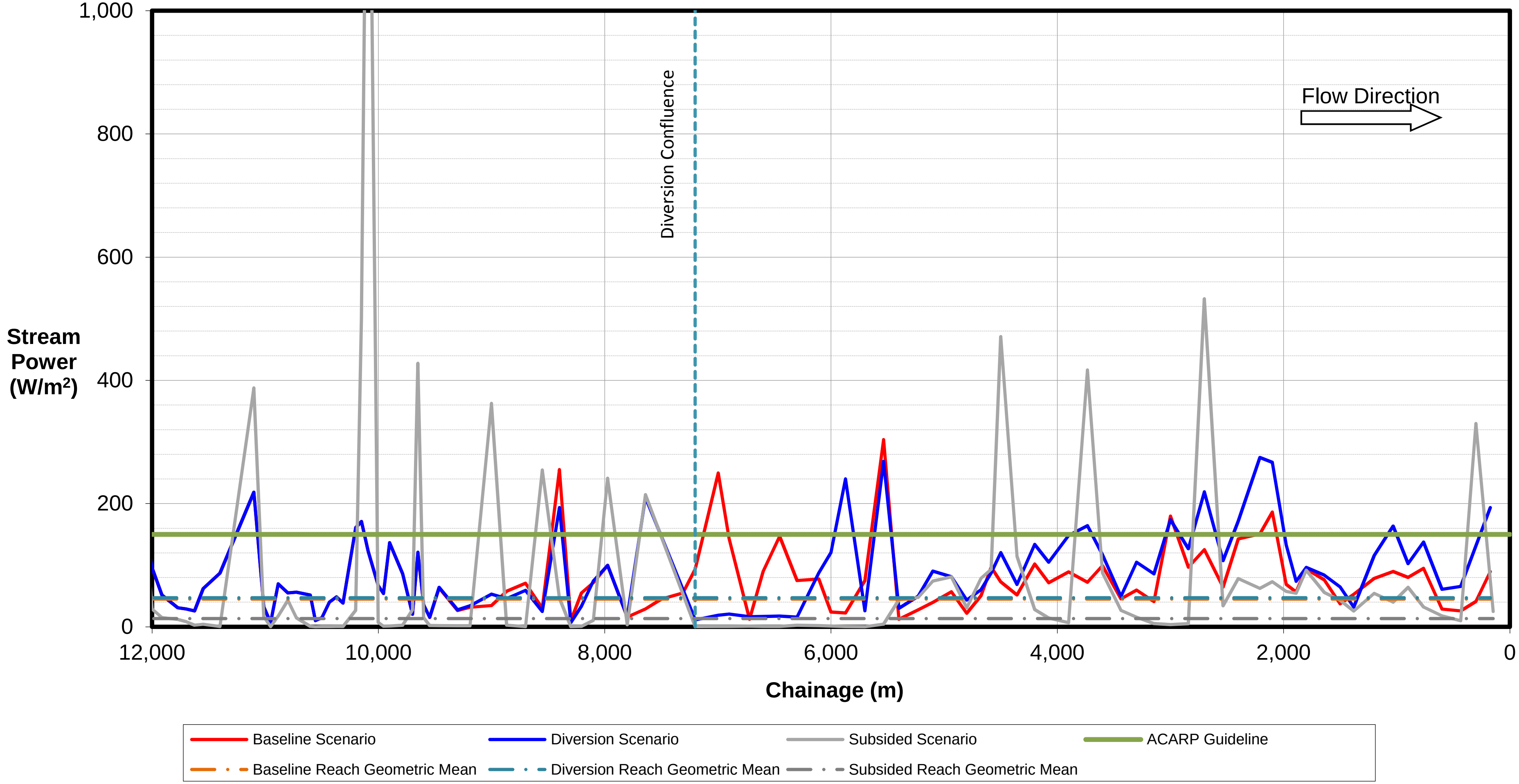
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-133 Comparison of Channel Stream Power along Middle Creek for a 1:20 AEP Event



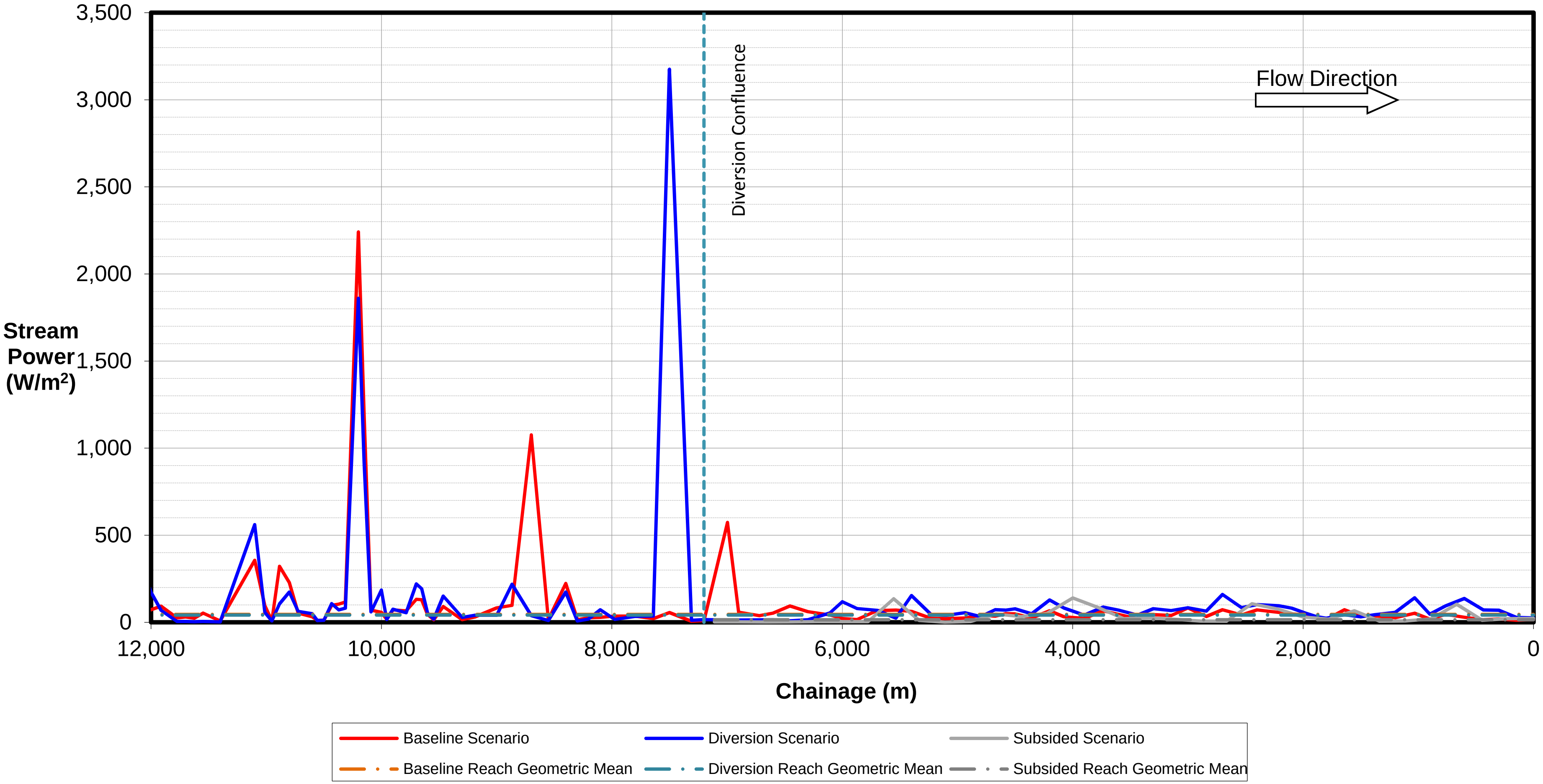
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-134 Comparison of Channel Stream Power along Middle Creek for a 1:50 AEP Event



Appendix C - Modelling Results – Profile Comparison Plots

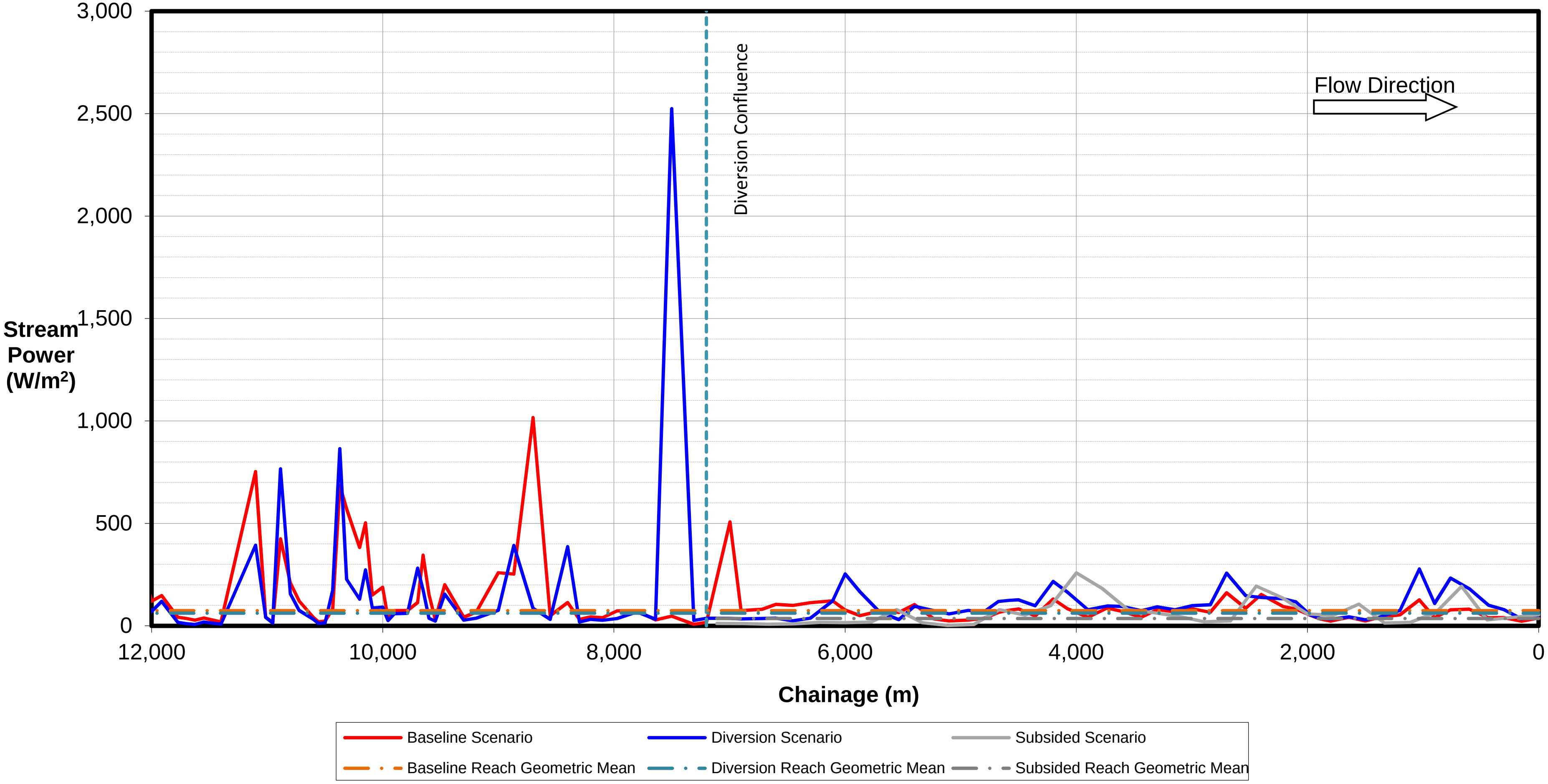
Figure Appendix C-135 Comparison of Channel Stream Power along Middle Creek for a 1:100 AEP Event



URS

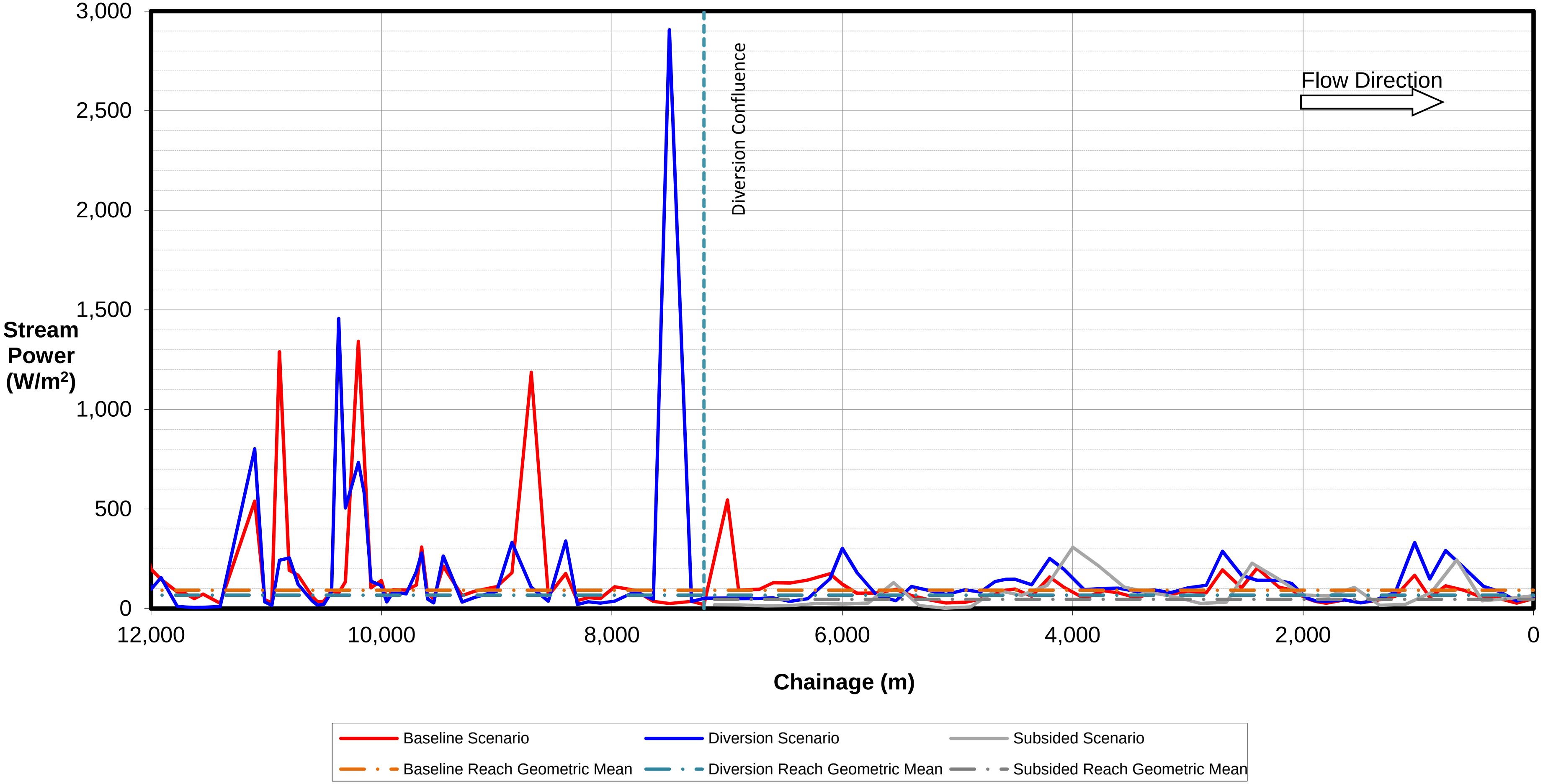
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-136 Comparison of Channel Stream Power along Middle Creek for a 1:1000 AEP Event



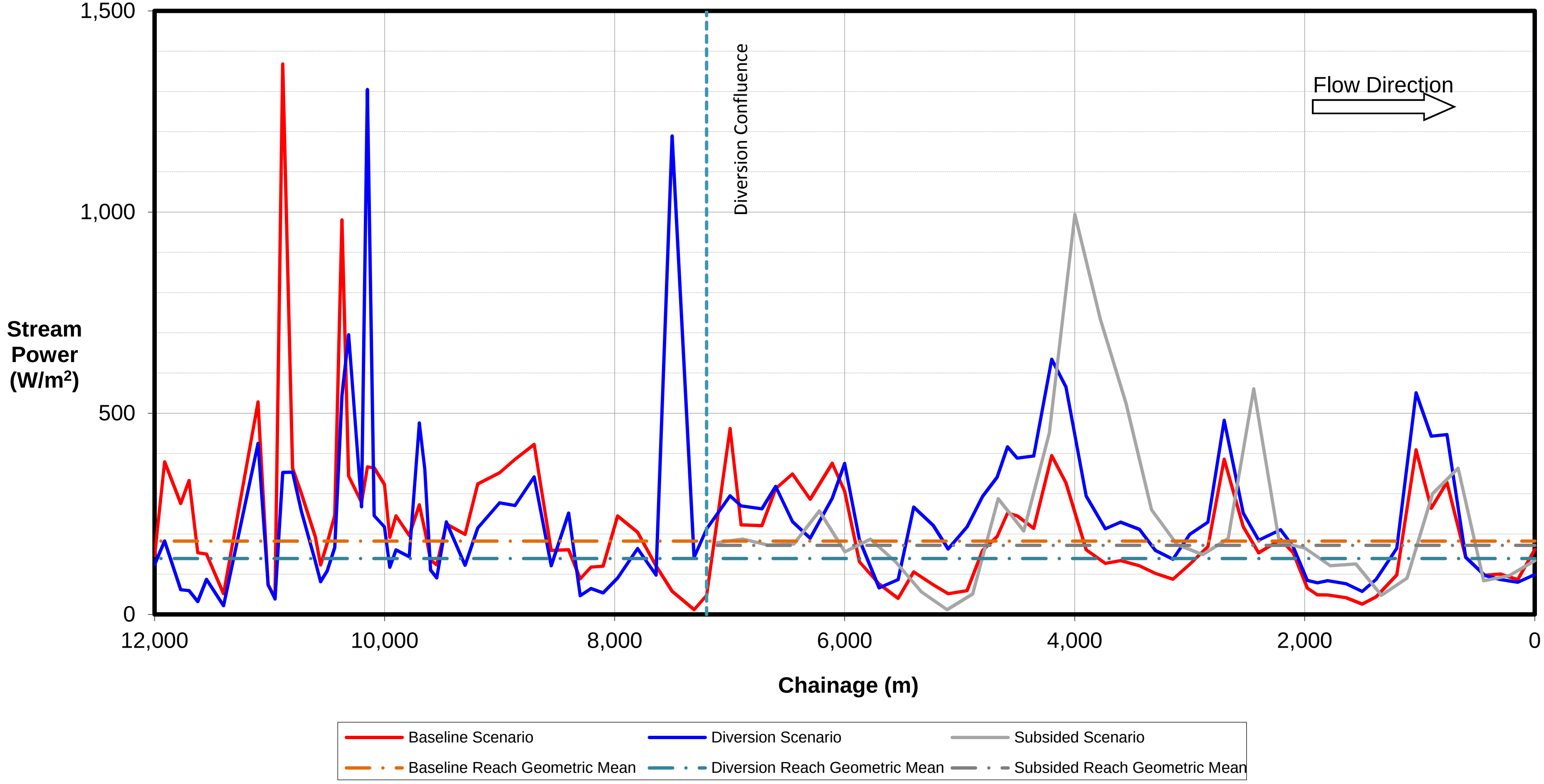
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-137 Comparison of Channel Stream Power along Middle Creek for a 1:2000 AEP Event



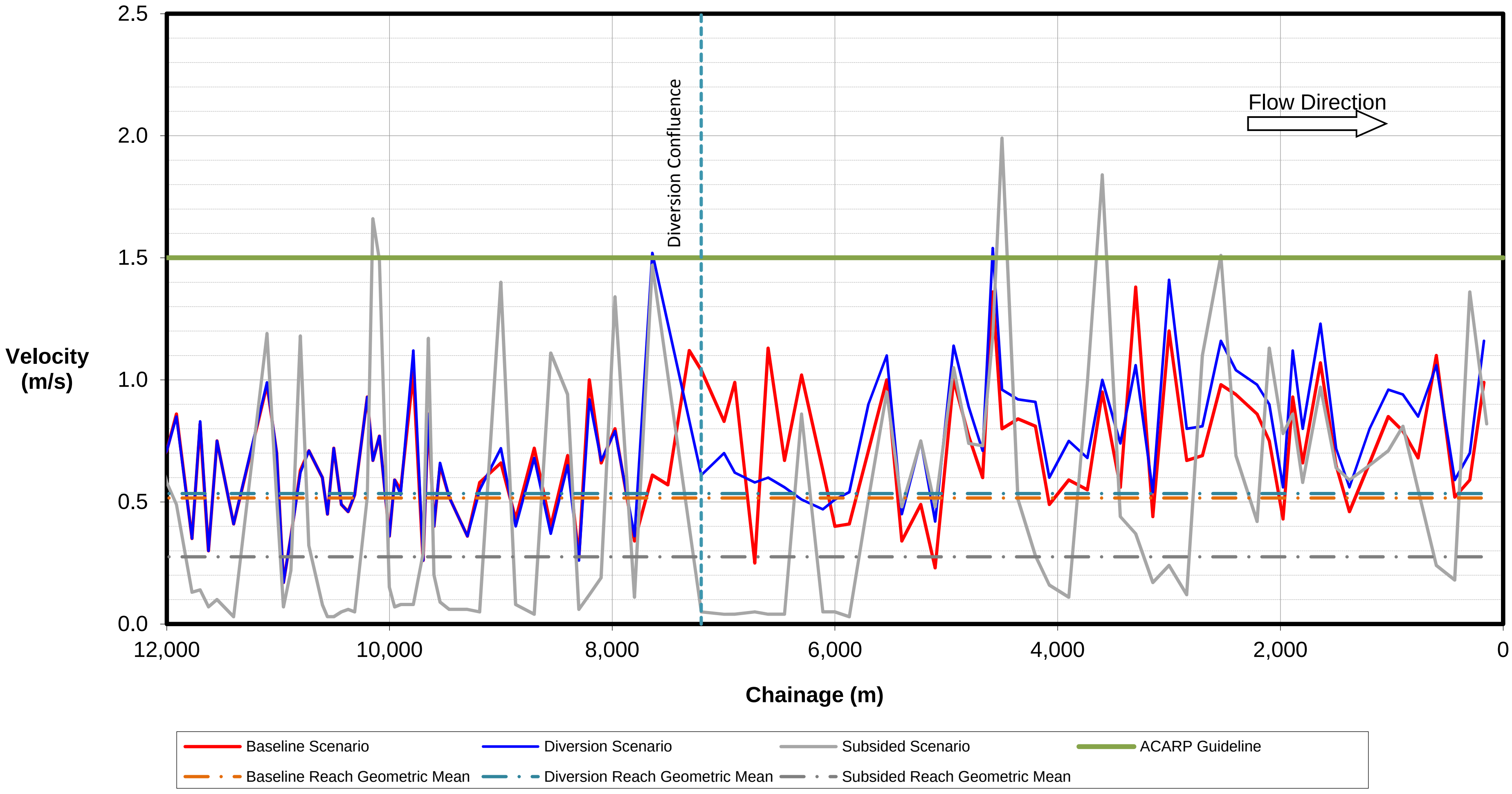
Appendix C - **Modelling Results – Profile Comparison Plots**

Figure Appendix C-138 Comparison of Channel Stream Power along Middle Creek for a PMF Event



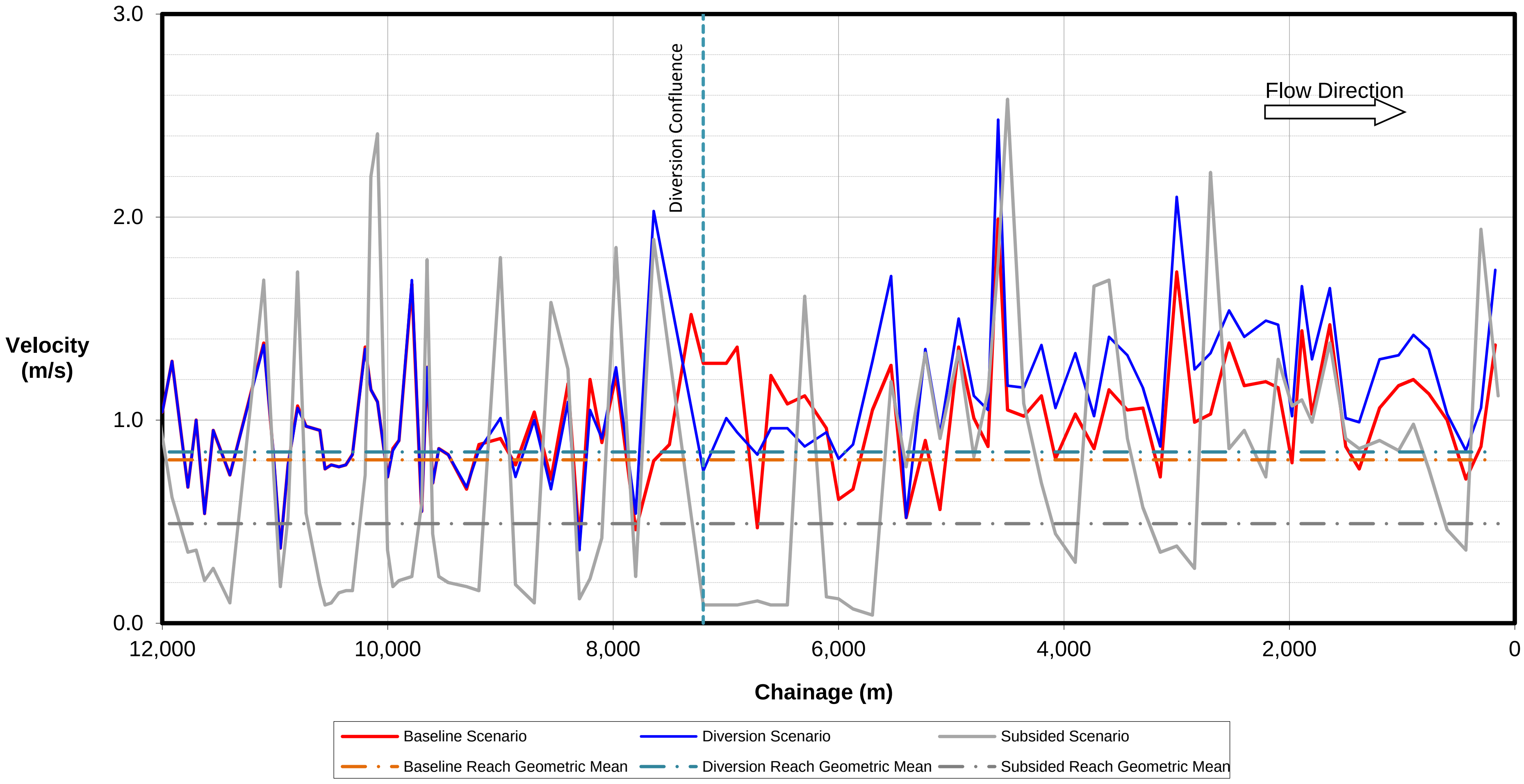
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-139 Comparison of Channel Velocity along Middle Creek for a 1:2 AEP Event



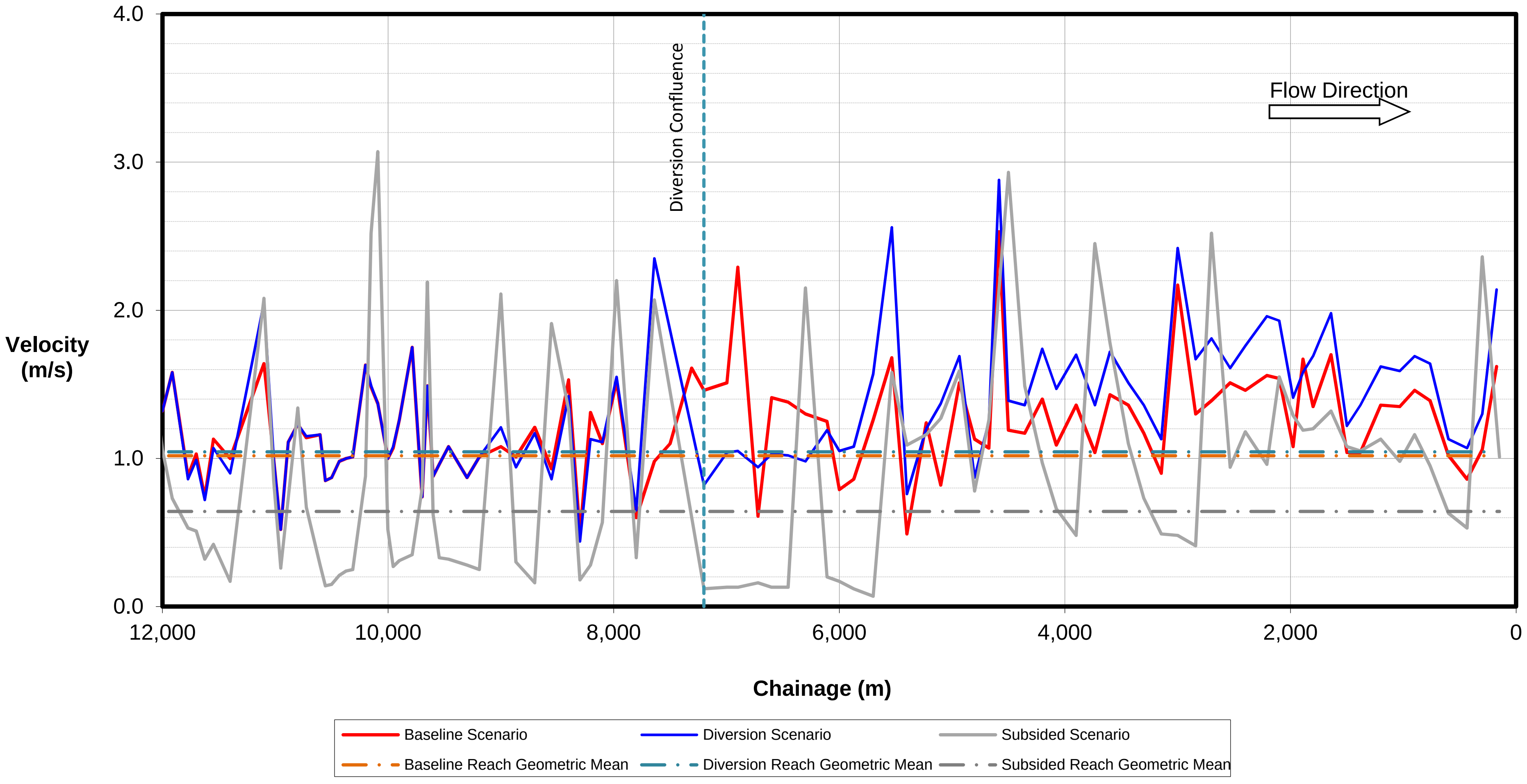
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-140 Comparison of Channel Velocity along Middle Creek for a 1:5 AEP Event



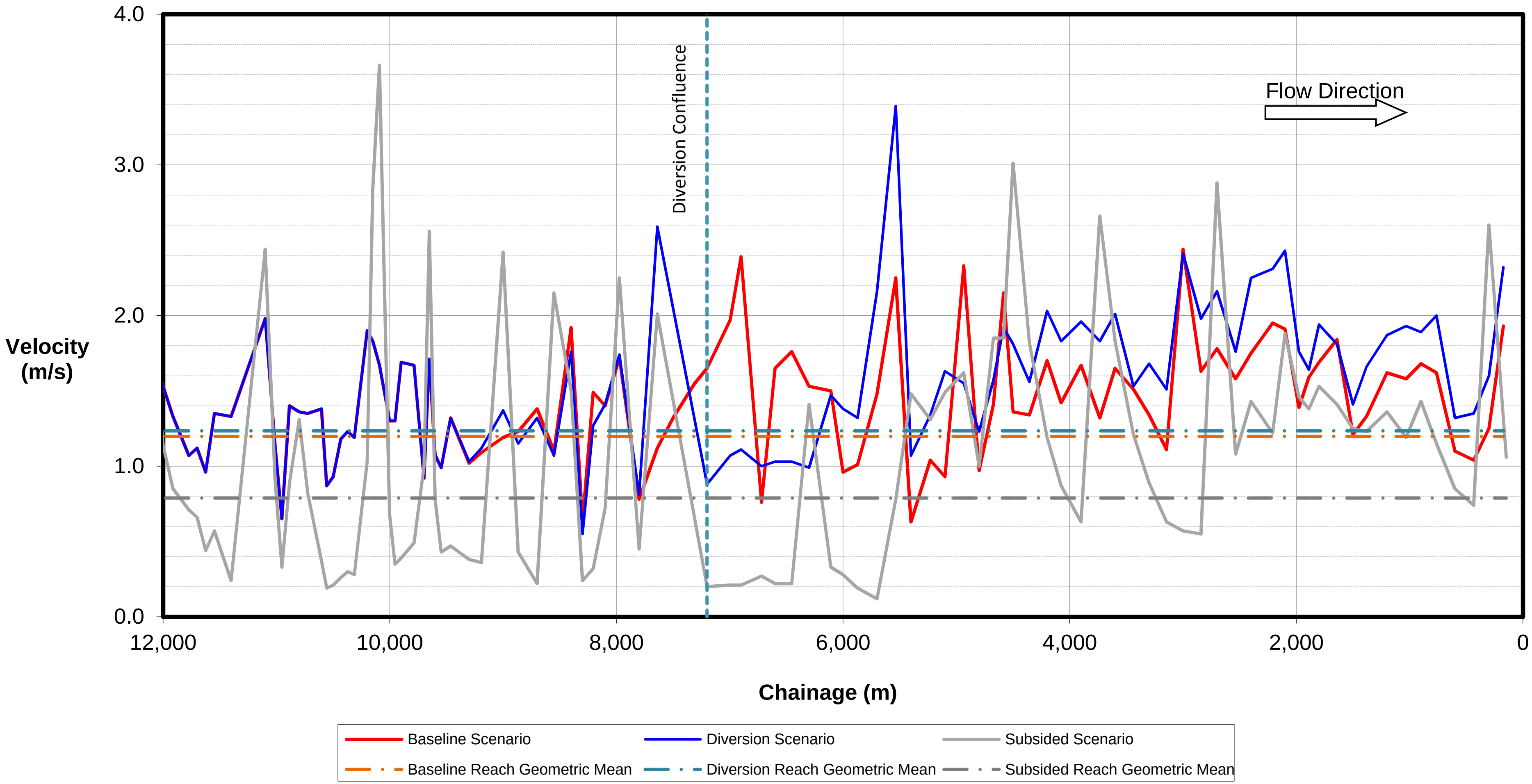
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-141 Comparison of Channel Velocity along Middle Creek for a 1:10 AEP Event



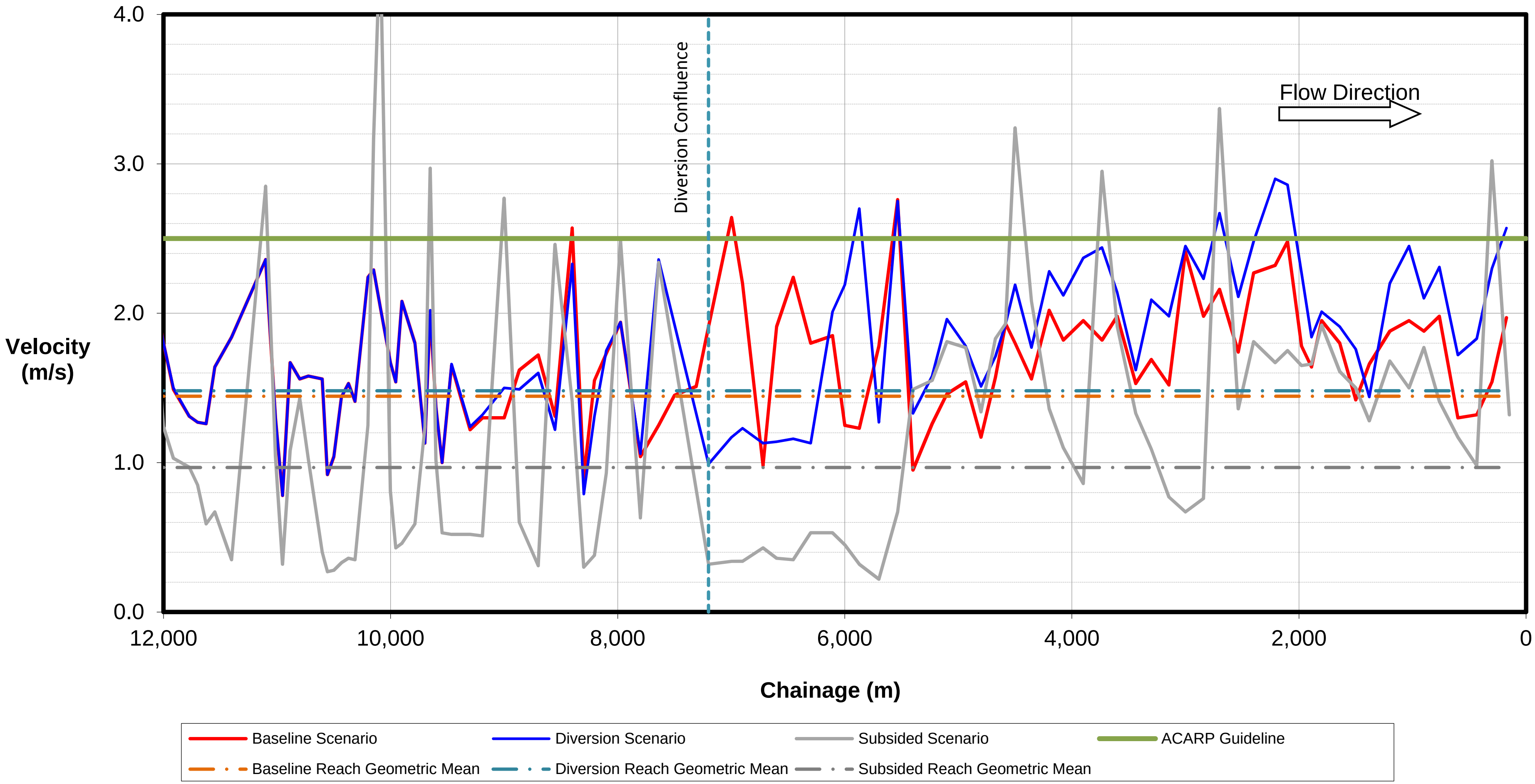
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-142 Comparison of Channel Velocity along Middle Creek for a 1:20 AEP Event



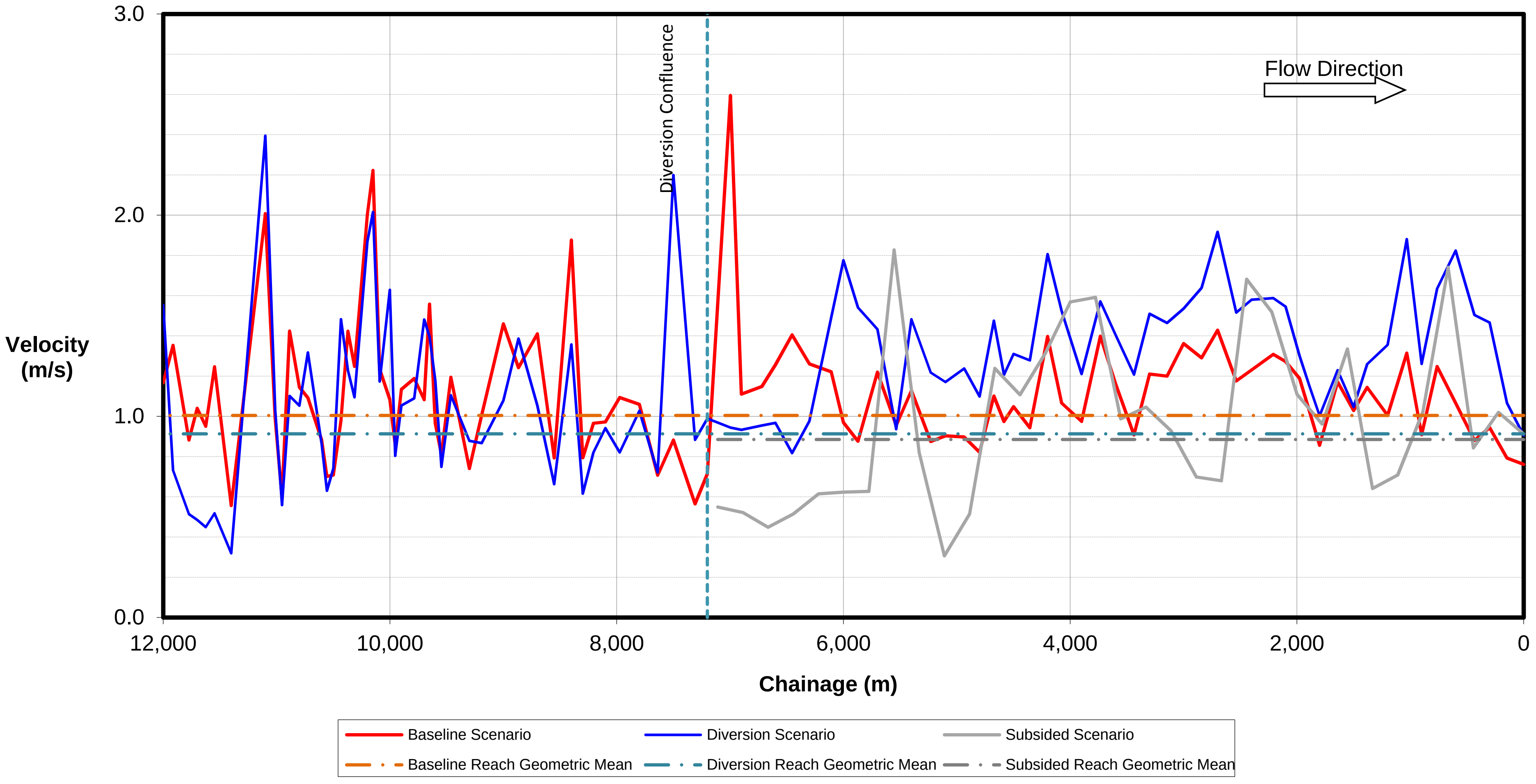
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-143 Comparison of Channel Velocity along Middle Creek for a 1:50 AEP Event



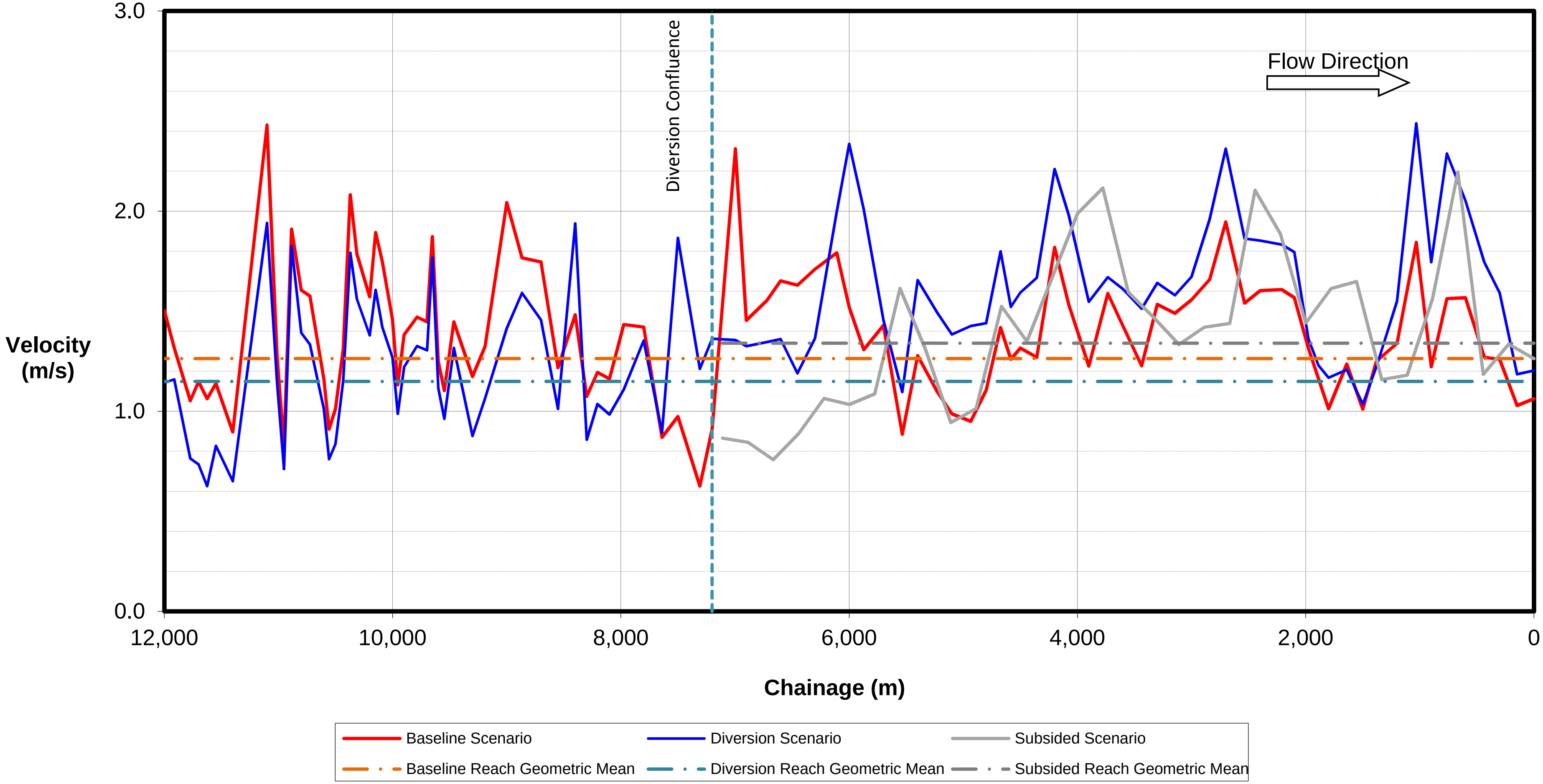
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-144 Comparison of Channel Velocity along Middle Creek for a 1:100 AEP Event



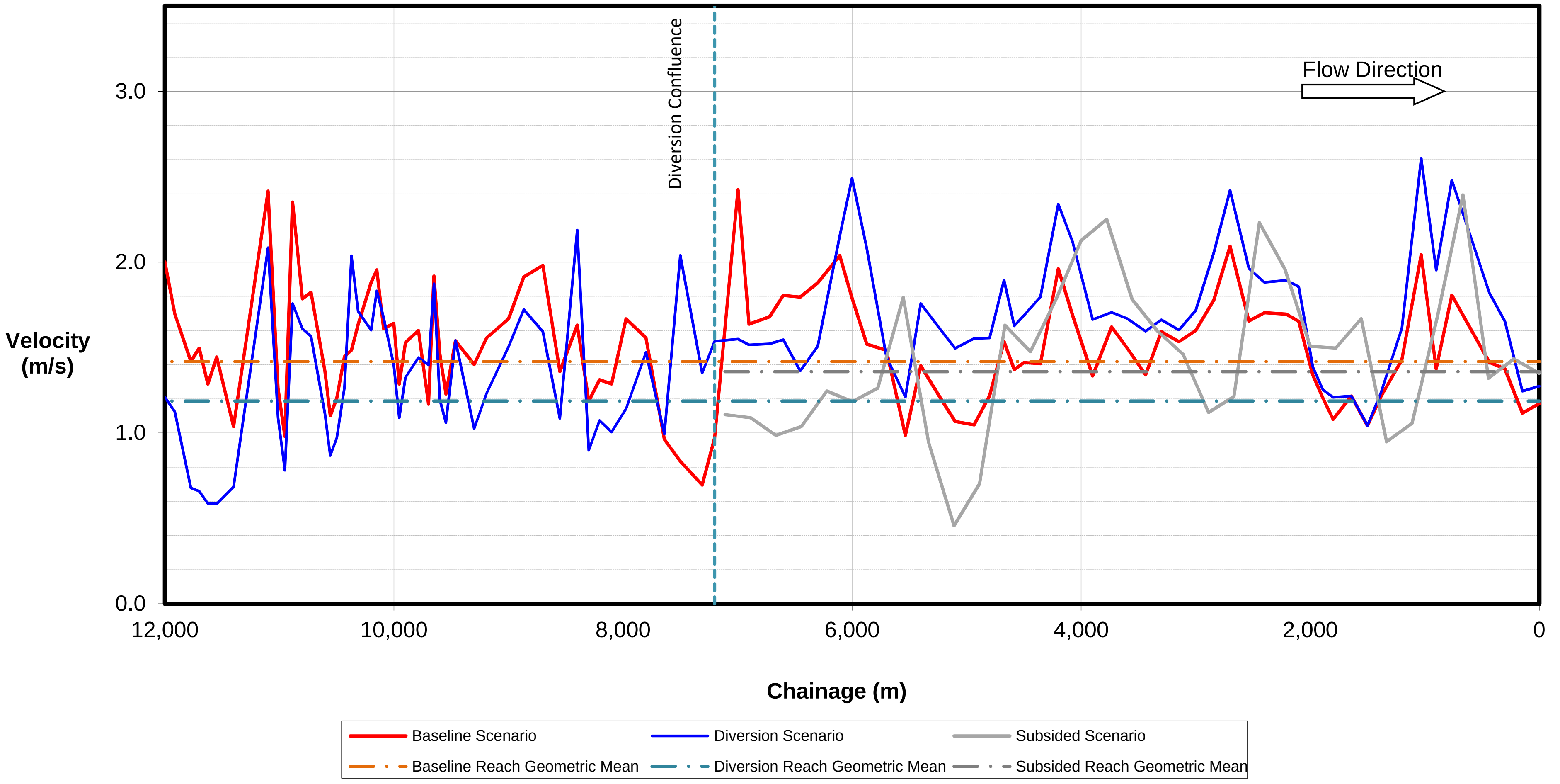
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-145 Comparison of Channel Velocity along Middle Creek for a 1:1000 AEP Event



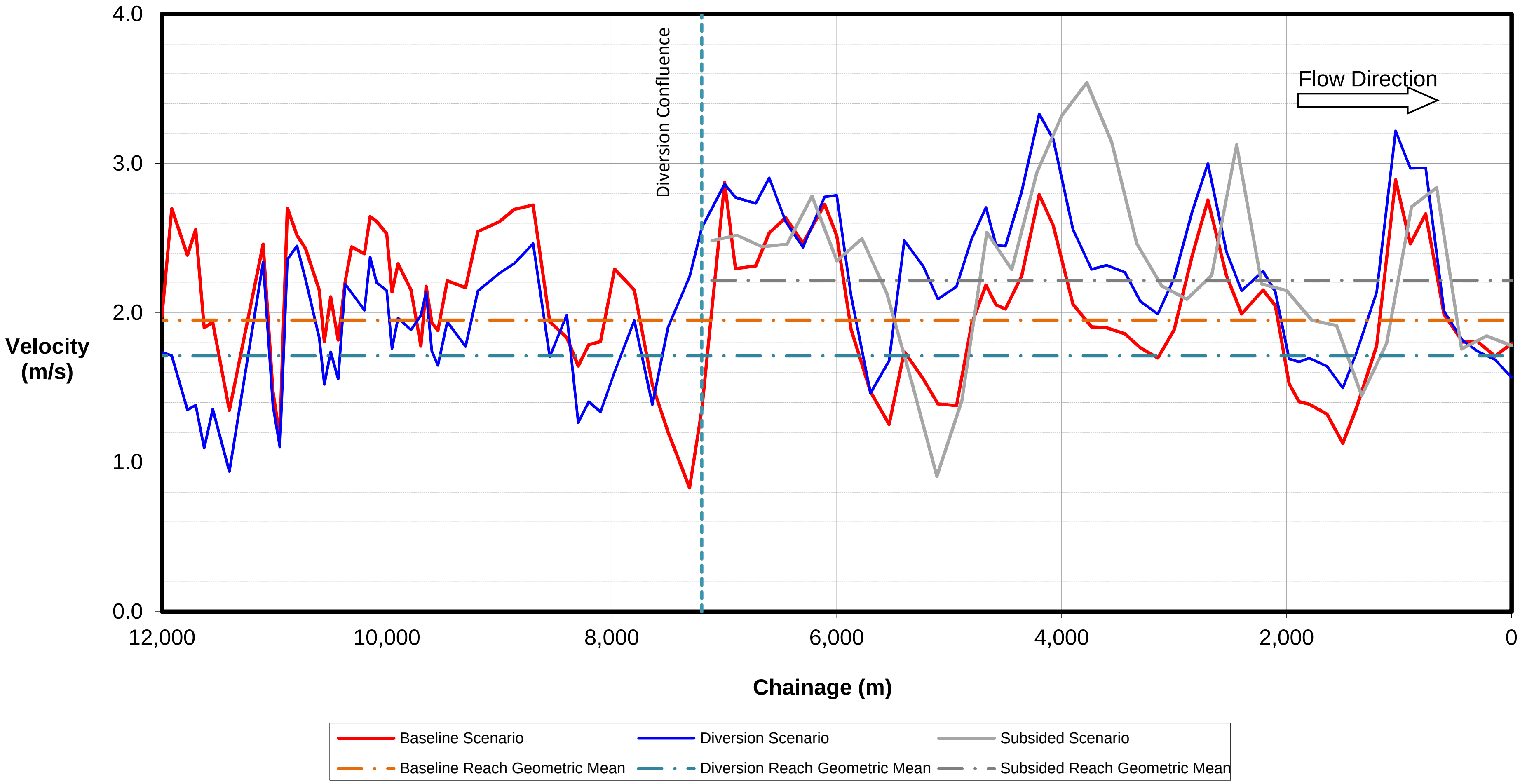
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-146 Comparison of Channel Velocity along Middle Creek for a 1:2000 AEP Event



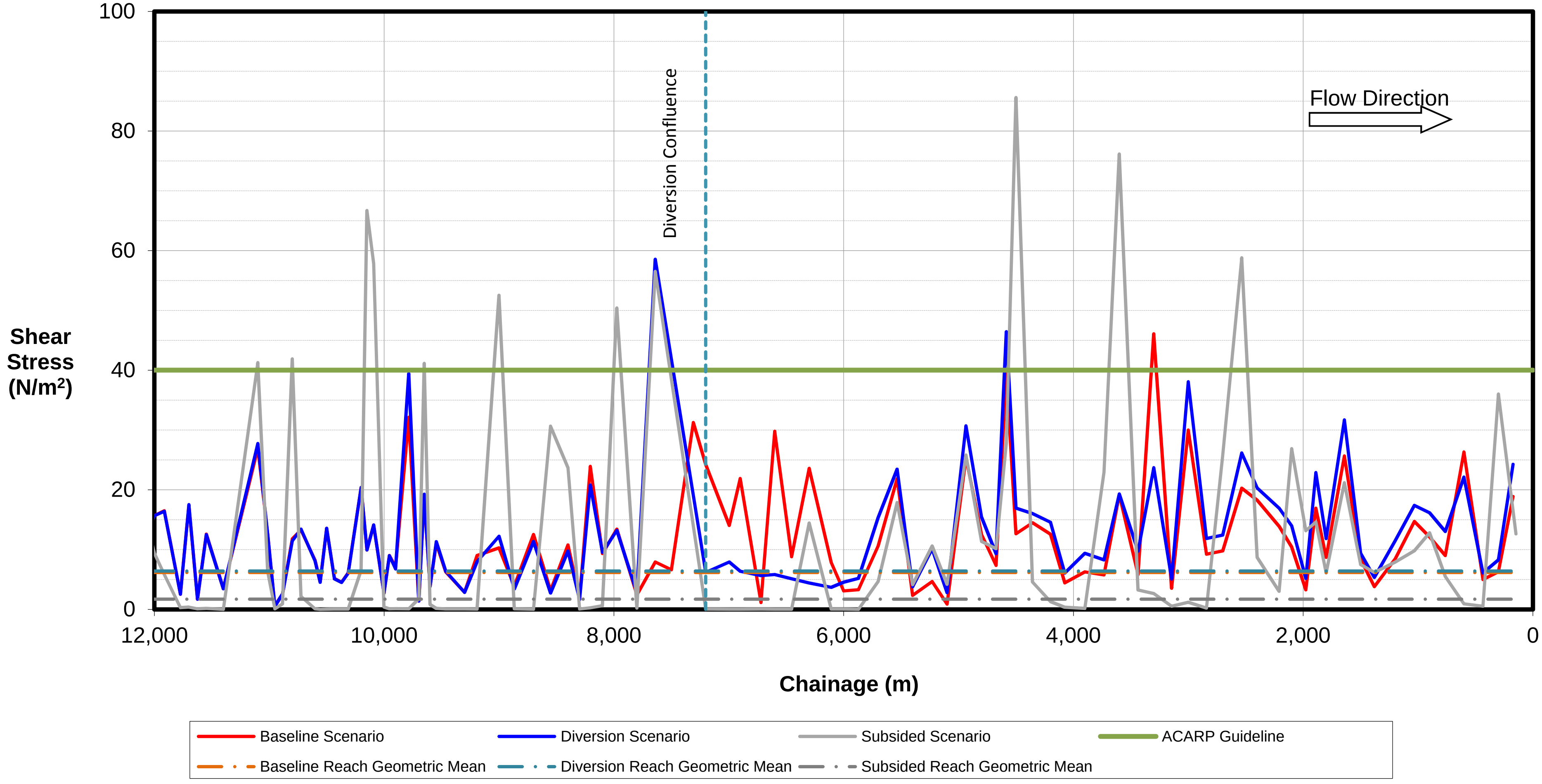
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-147 Comparison of Channel Velocity along Middle Creek for a PMF Event



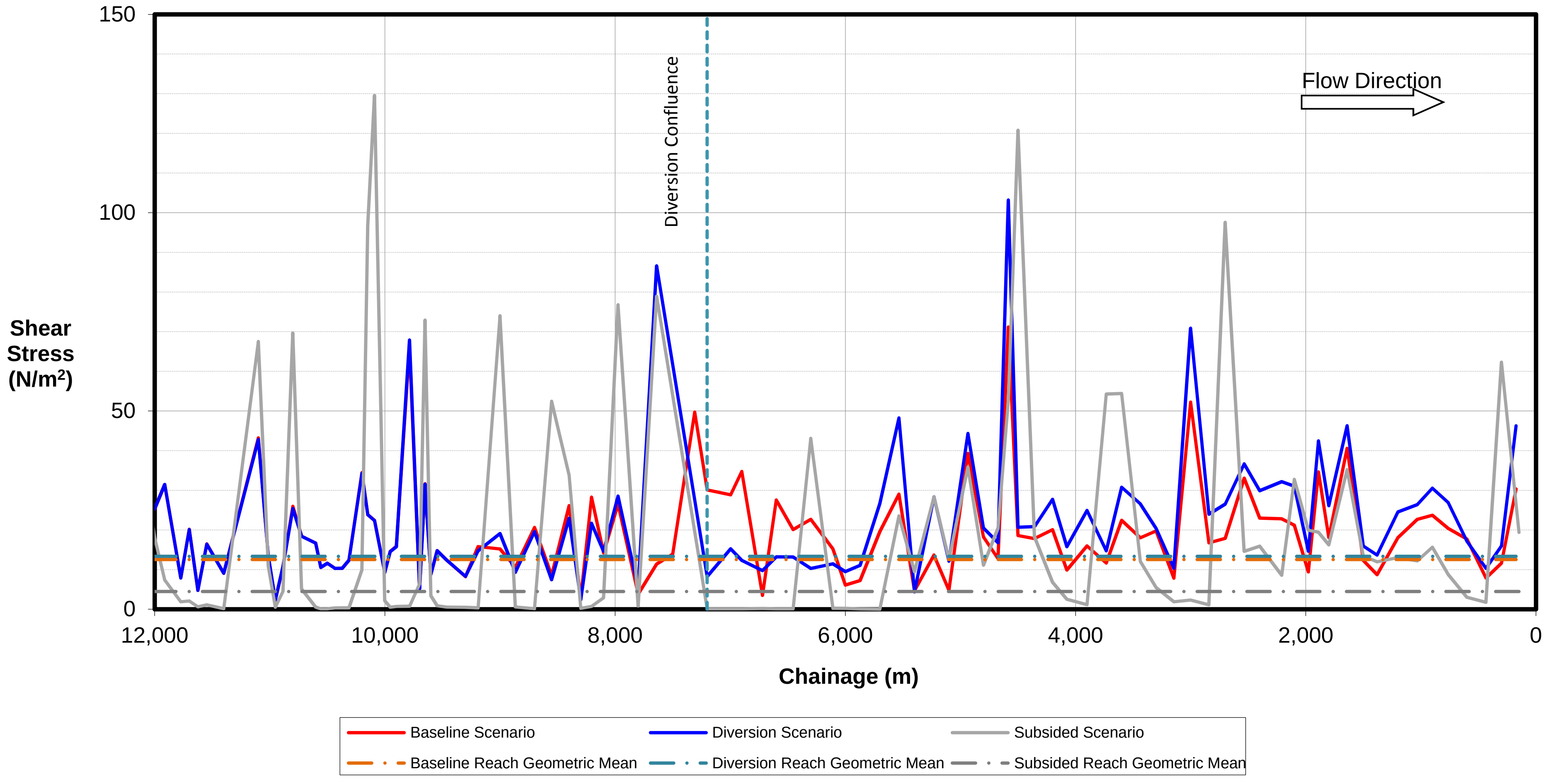
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-148 Comparison of Bed Shear Stress along Middle Creek for a 1:2 AEP Event



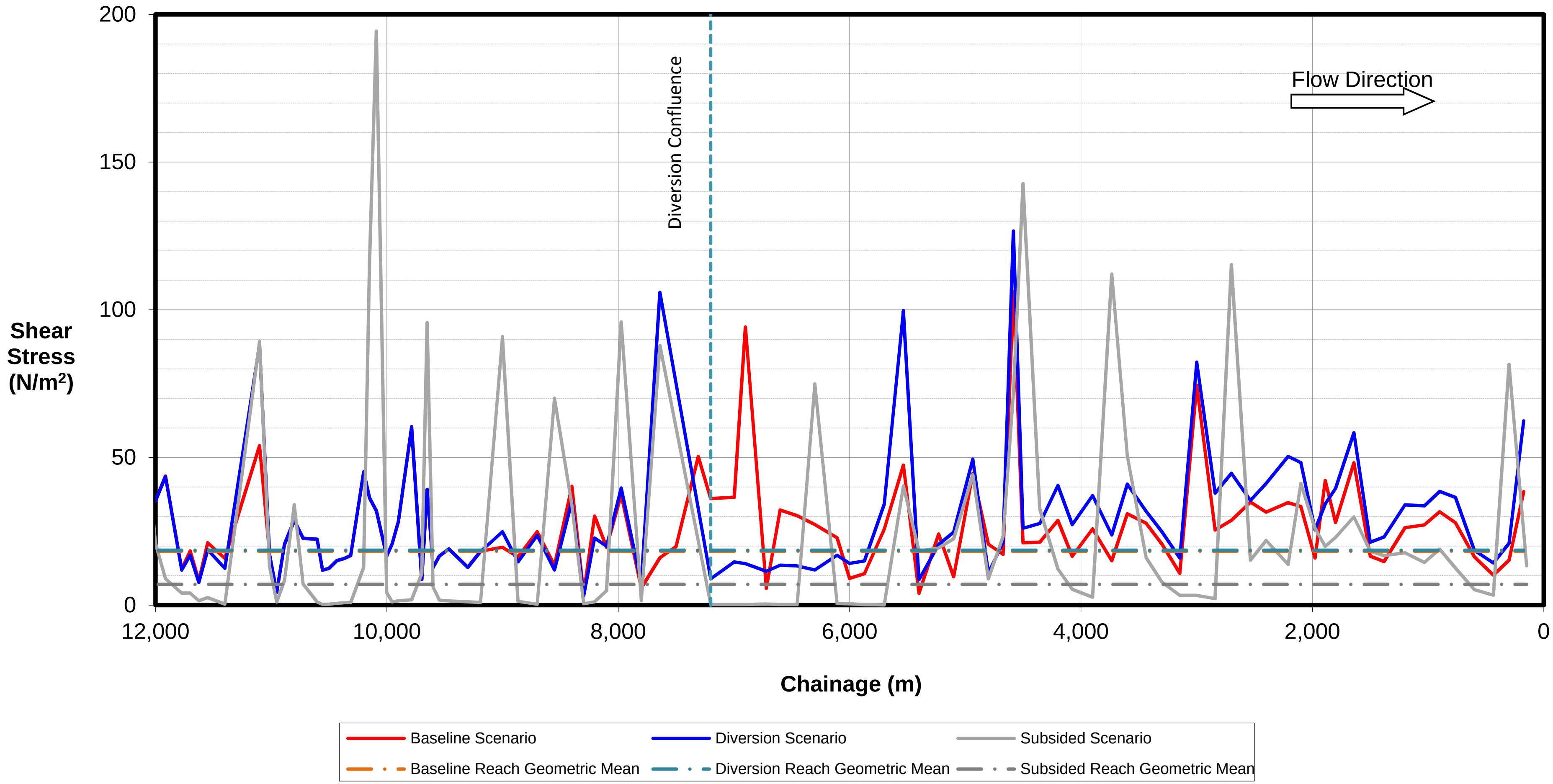
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-149 Comparison of Bed Shear Stress along Middle Creek for a 1:5 AEP Event



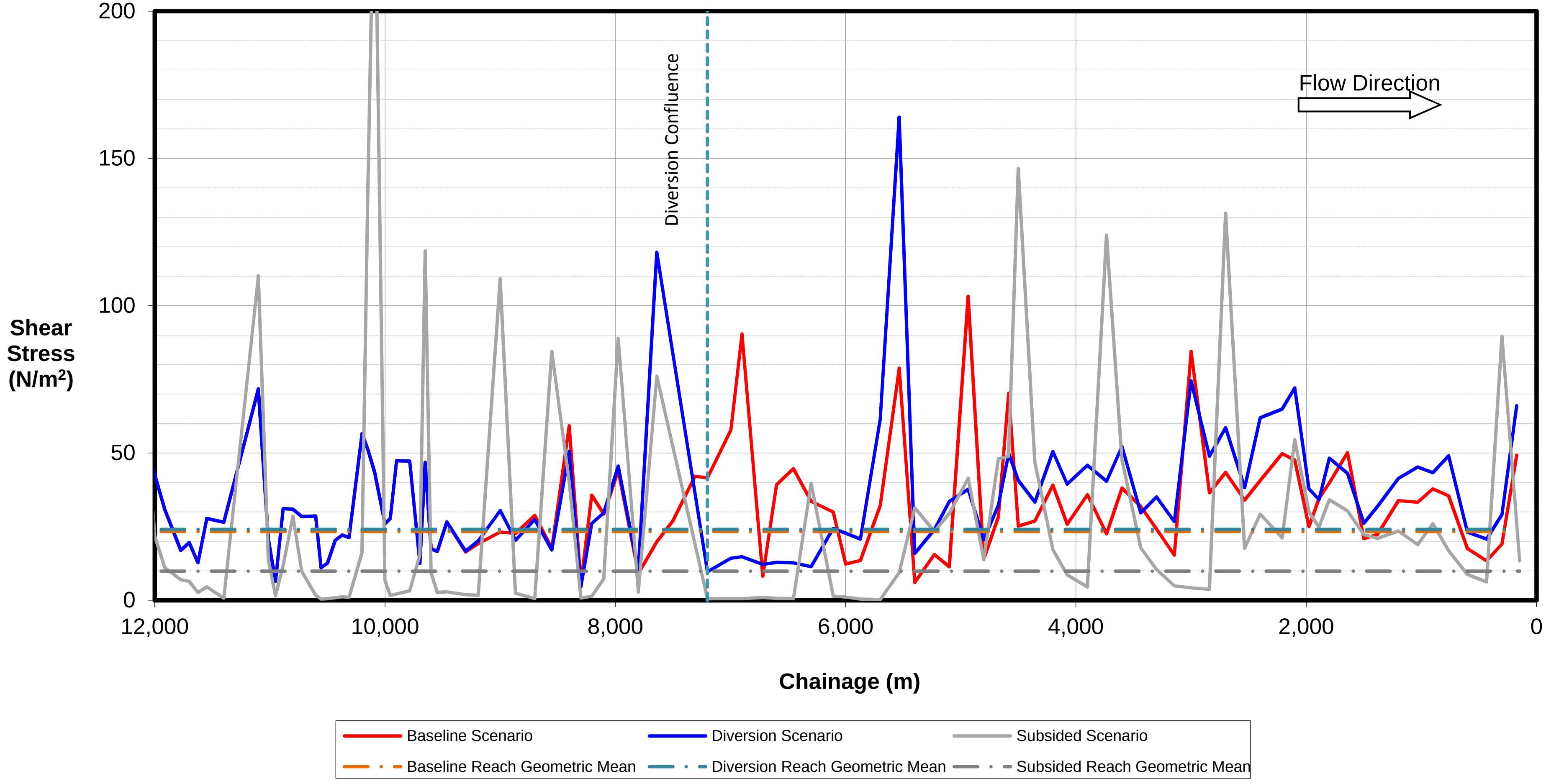
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-150 Comparison of Bed Shear Stress along Middle Creek for a 1:10 AEP Event



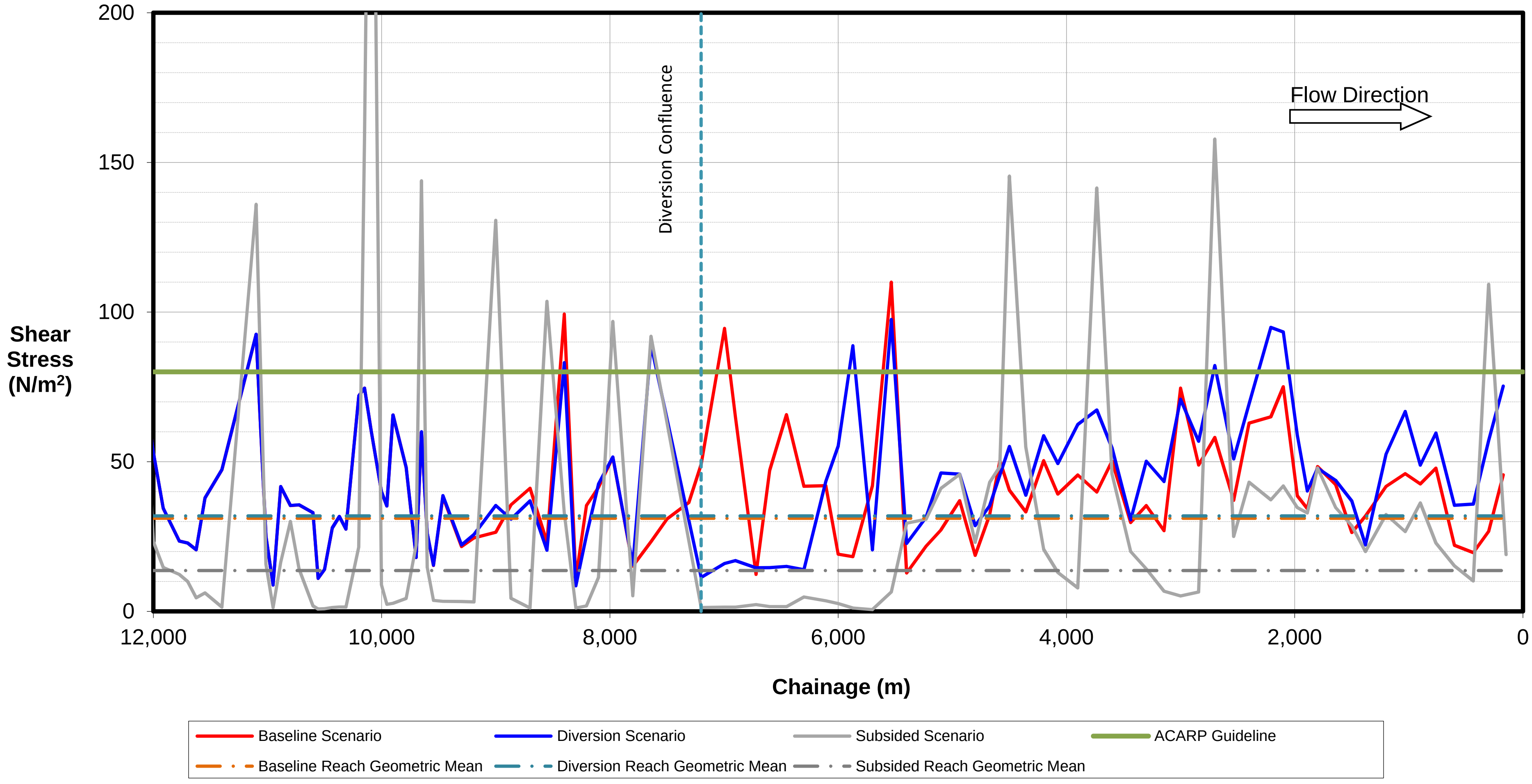
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-151 Comparison of Bed Shear Stress along Middle Creek for a 1:20 AEP Event



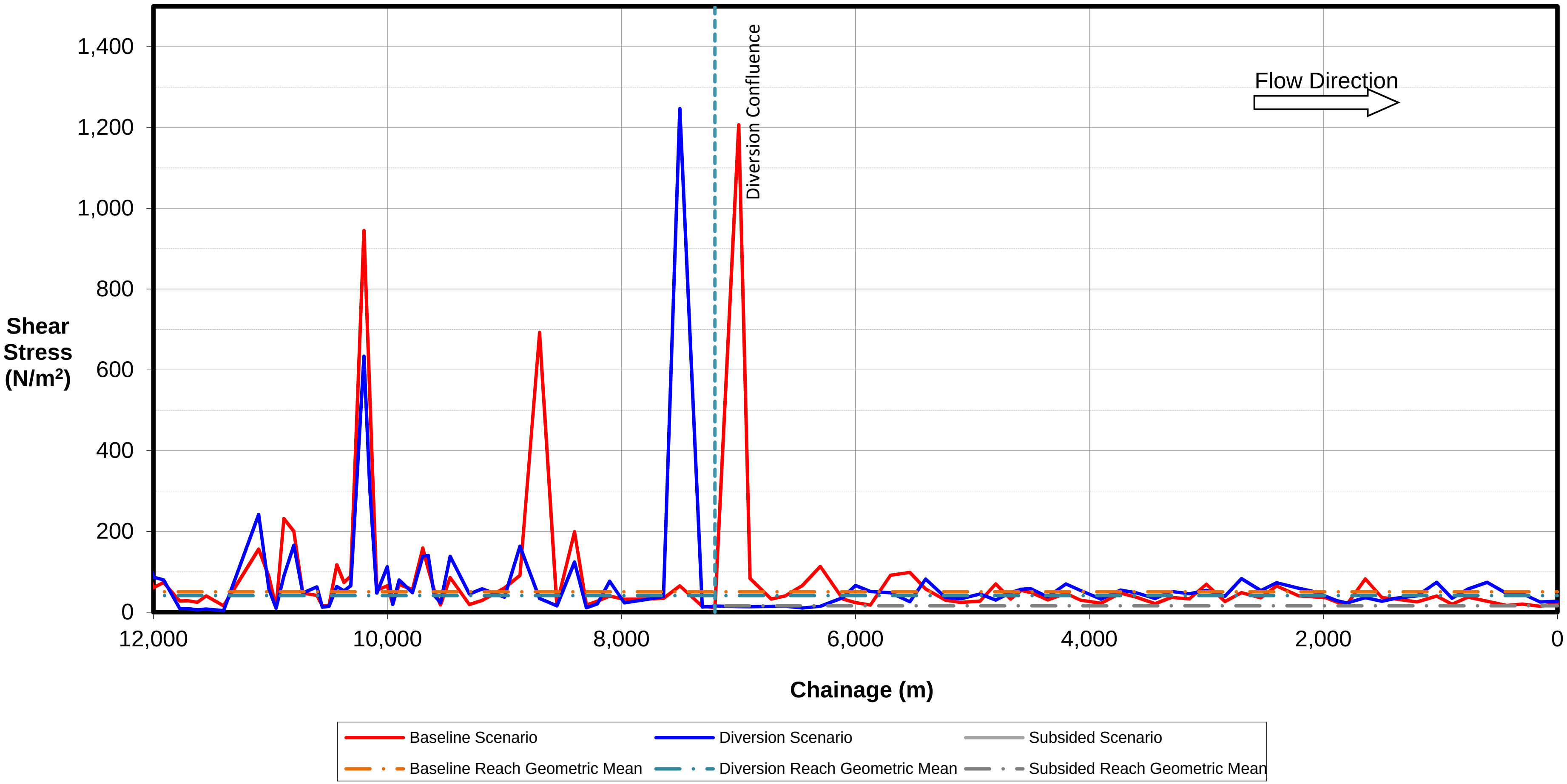
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-152 Comparison of Bed Shear Stress along Middle Creek for a 1:50 AEP Event



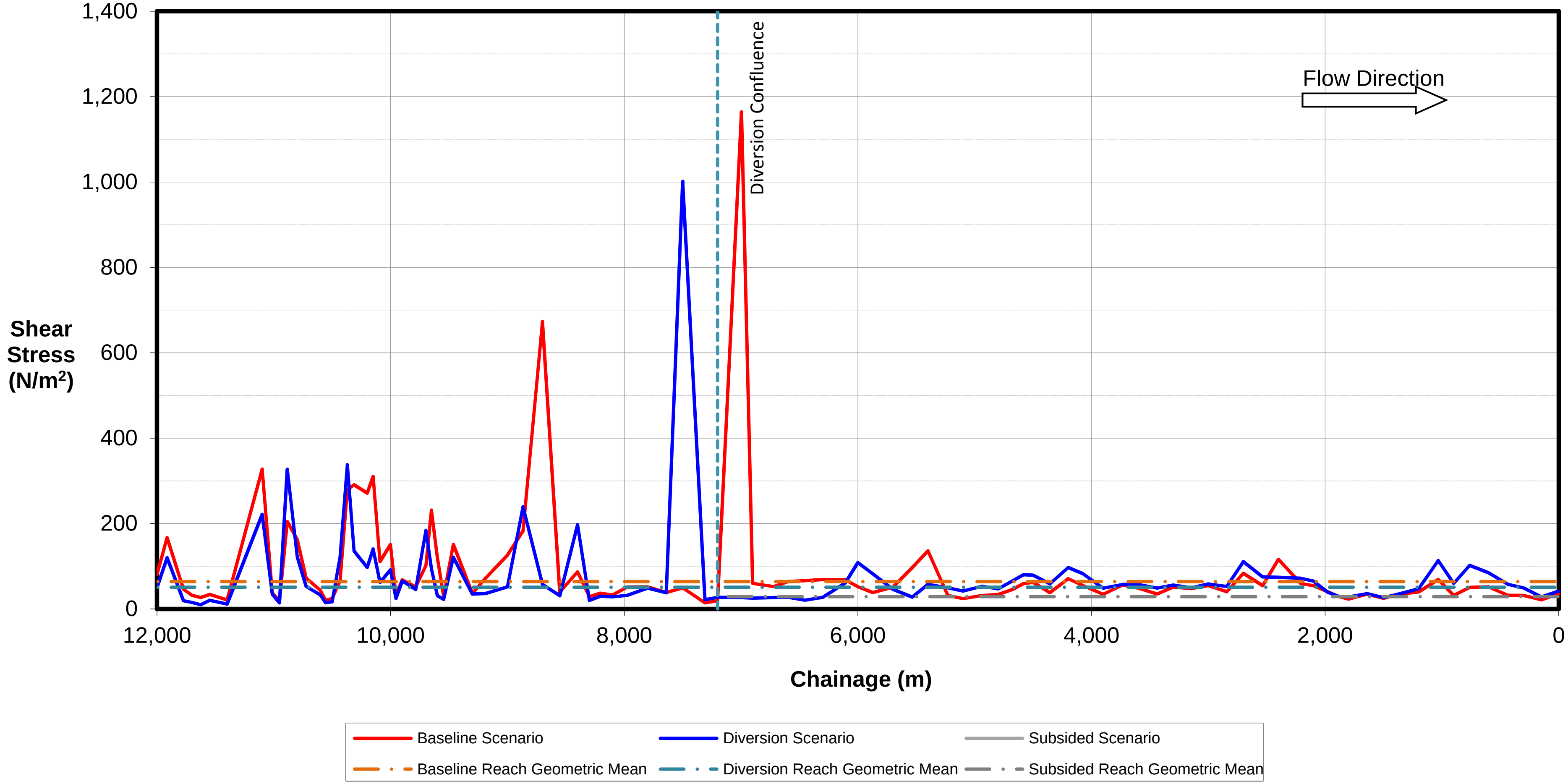
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-153 Comparison of Bed Shear Stress along Middle Creek for a 1:100 AEP Event



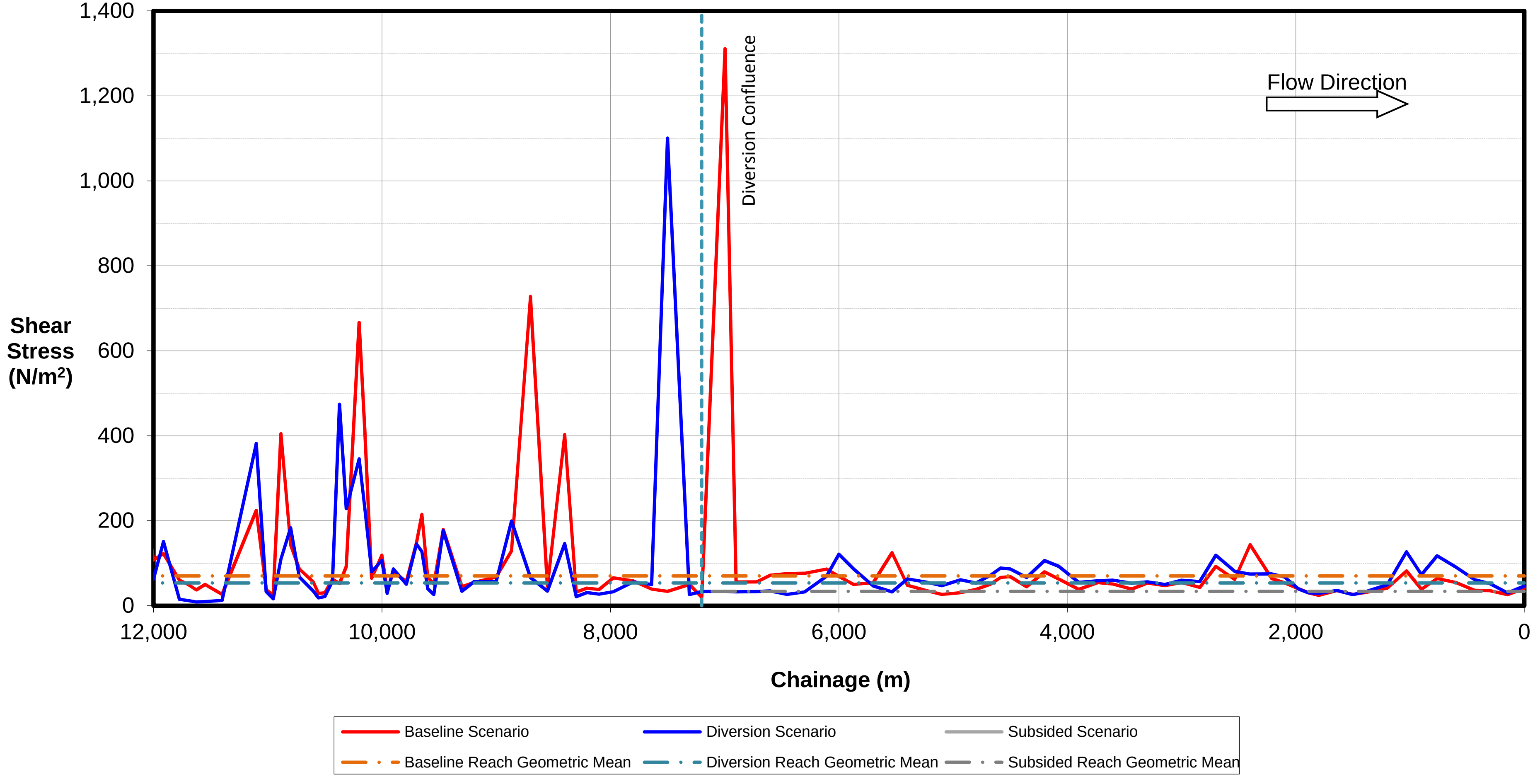
Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-154 Comparison of Bed Shear Stress along Middle Creek for a 1:1000 AEP Event



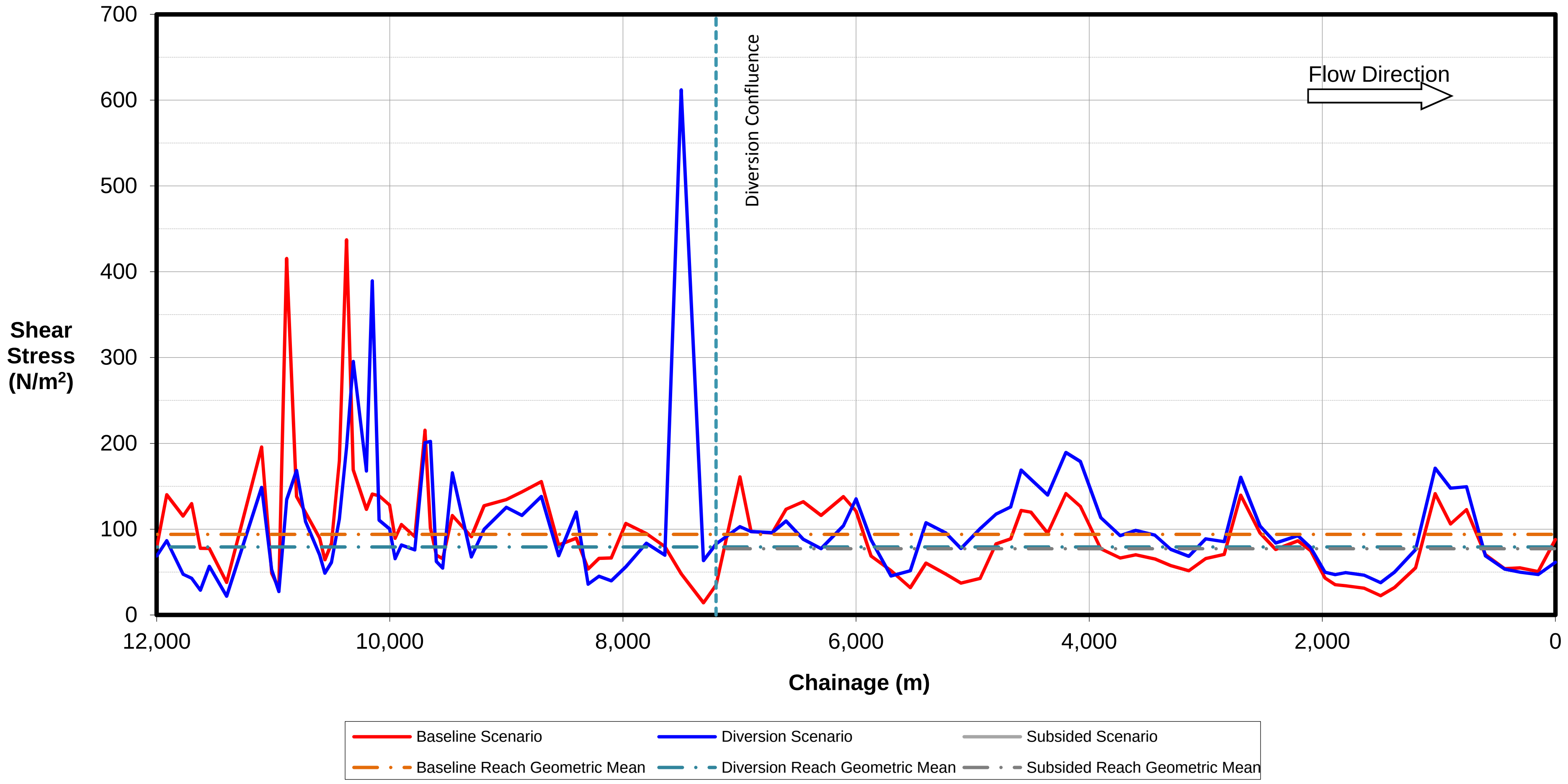
Appendix C - Modelling Results – Profile Comparison Plots

Figure Appendix C-155 Comparison of Bed Shear Stress along Middle Creek for a 1:2000 AEP Event



Appendix C **- Modelling Results – Profile Comparison Plots**

Figure Appendix C-156 Comparison of Bed Shear Stress along Middle Creek for a PMF Event

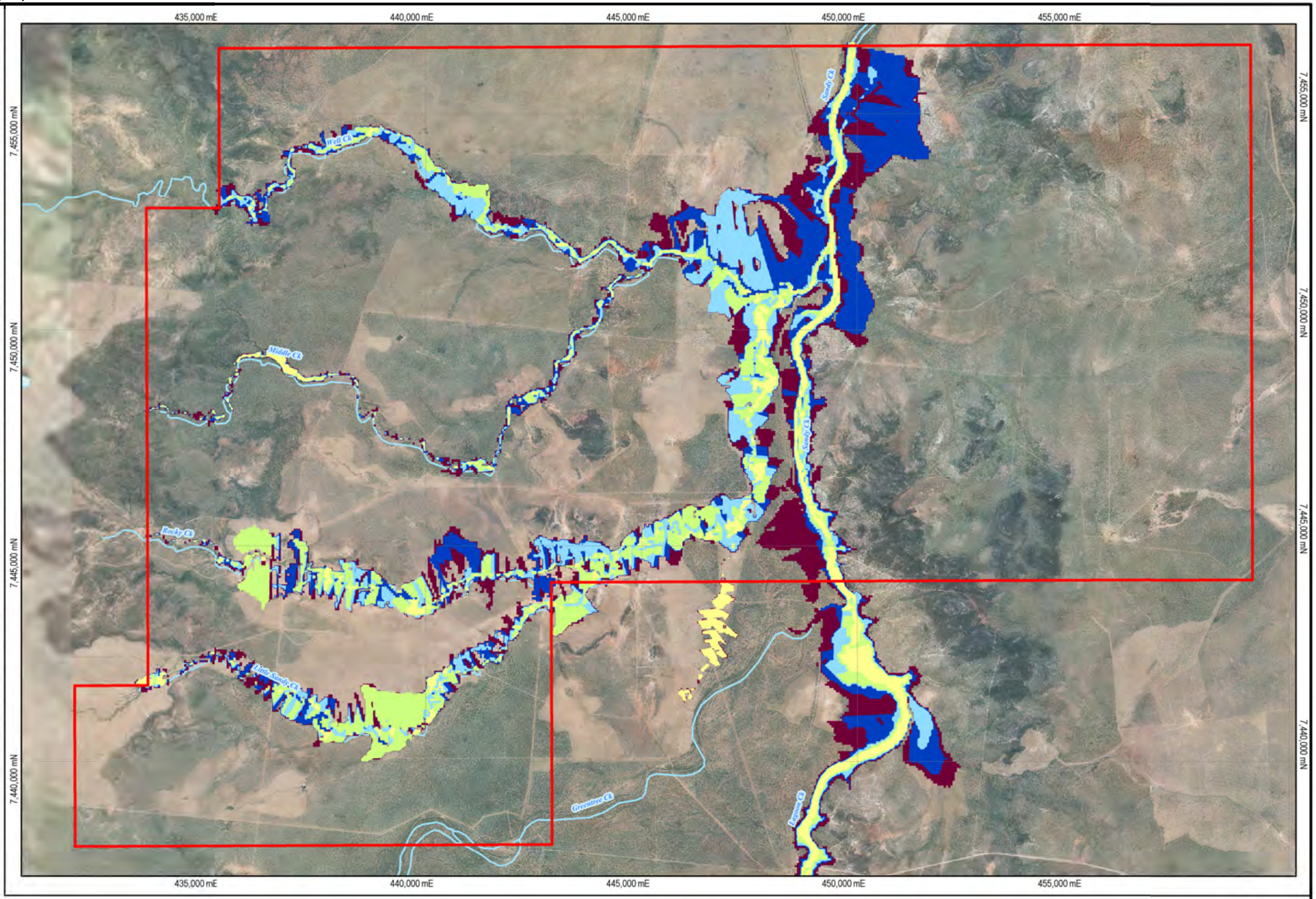


D

Appendix D Modelling Results – Flood Extent and Velocity Maps

Appendix D - Modelling Results – Flood Extent and Velocity Maps

D.1 Index of Figures



0 1.25 2.5km
Scale: 1:125,000 (A4)

Inundation

2-Year	20-Year
5-Year	50-Year
10-Year	

Mining Lease Application (MLA70425) Boundary
Existing Watercourse

URS

N W E S

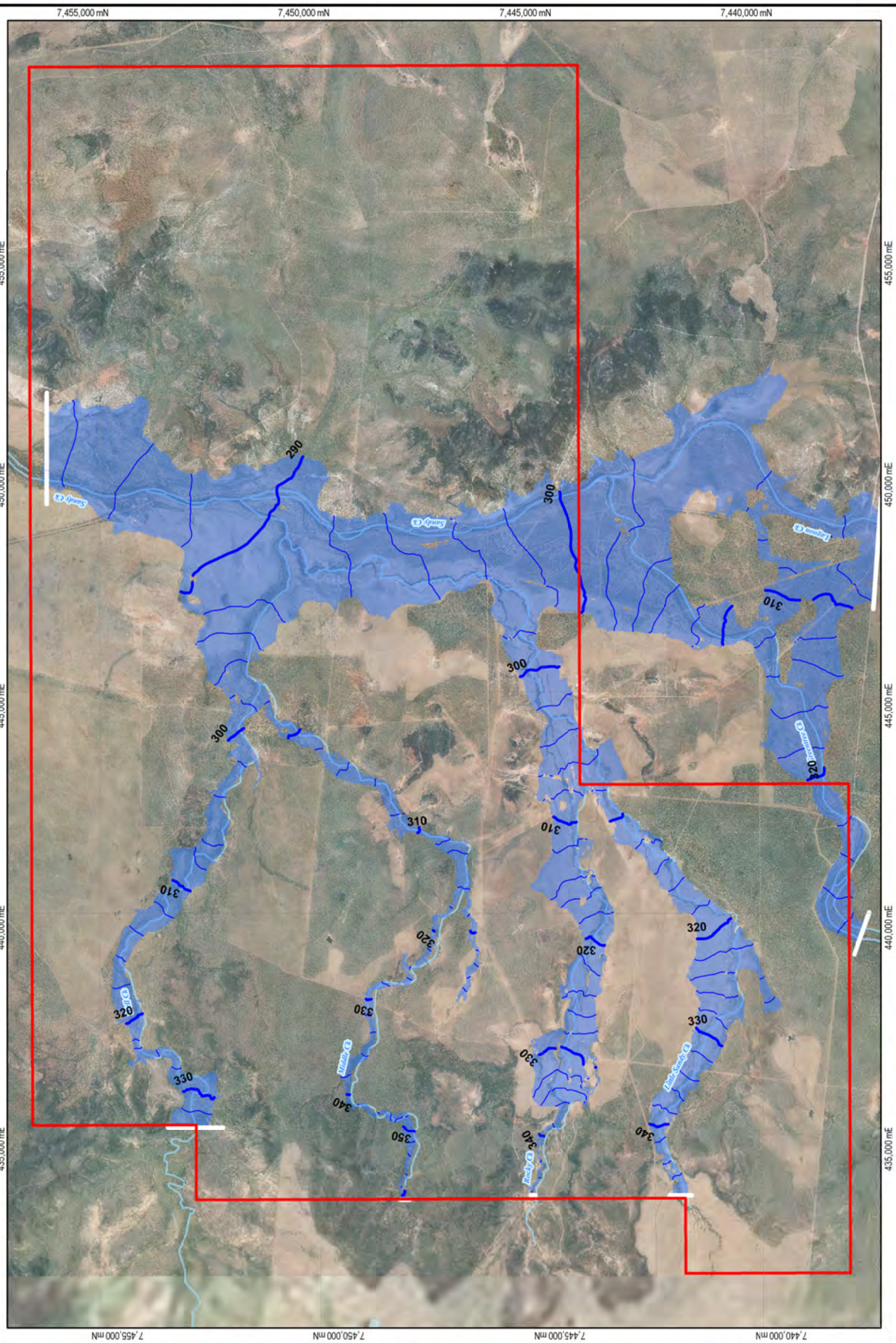
HANCOCK GALILEE PTY LTD
Kevin's Corner Project
Supplementary Environmental Impact Statement

1:2 TO 1:50 AEP EVENT MODELLED INUNDATION EXTENTS - BASELINE CONDITIONS

REVISED HYDRAULIC TECHNICAL REPORT

Figure: D-1

File No: 42626920-g-2120.wor | Drawn: XL | Approved: PV | Date: 15-06-2012 | Rev: A | A4



Mining Lease Application (MLA70425) Boundary

Existing Watercourse

0 1.25 2.5km

Scale: 1:125,000 (A4)

N E S W

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Kevin's Corner Project
Supplementary Environmental Impact Statement

SUMMARY OF 1:100 AEP EVENT INUNDATION RESULTS

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REVISED HYDRAULIC TECHNICAL REPORT

Figure: D-2

File No: 42626920-g-2073.wor | Drawn: XL | Approved: JS | Date: 15-06-2012 | Rev: A | A4

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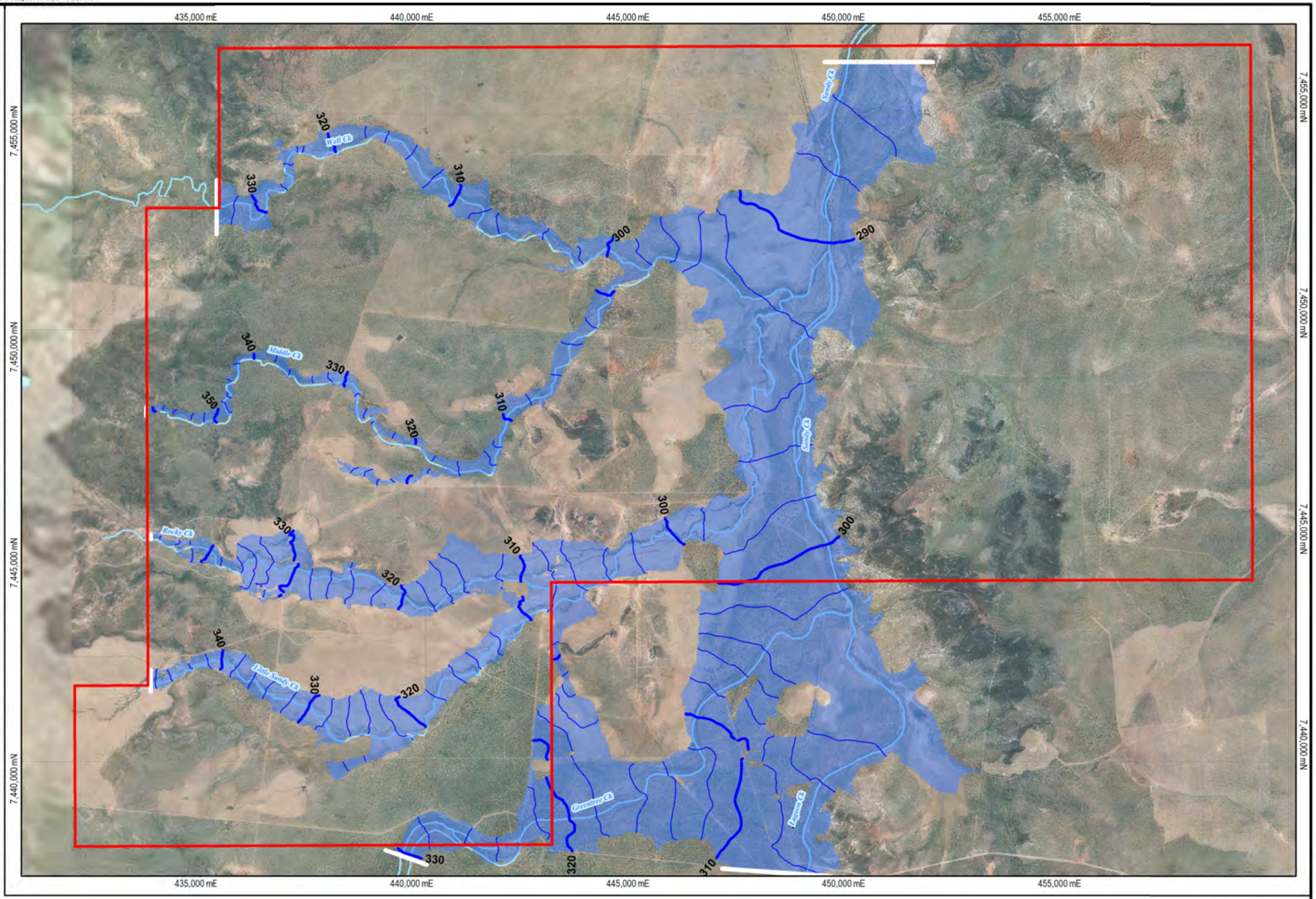

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0 1.25 2.5km
Scale: 1:125,000 (A4)

Mining Lease Application (MLA70425) Boundary
Existing Watercourse

URS

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Supplementary Environmental Impact Statement

SUMMARY OF 1:1000 AEP EVENT INUNDATION RESULTS

REVISED HYDRAULIC TECHNICAL REPORT

Figure: D-3

File No: 42626920-g-2074.wor
Drawn: XL
Approved: JS
Date: 15-06-2012
Rev: A
A4

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File No: 42626920-g-2075.wor Drawn: XL Approved: JS Date: 15-06-2012 Rev: A A4

Figure: D-4

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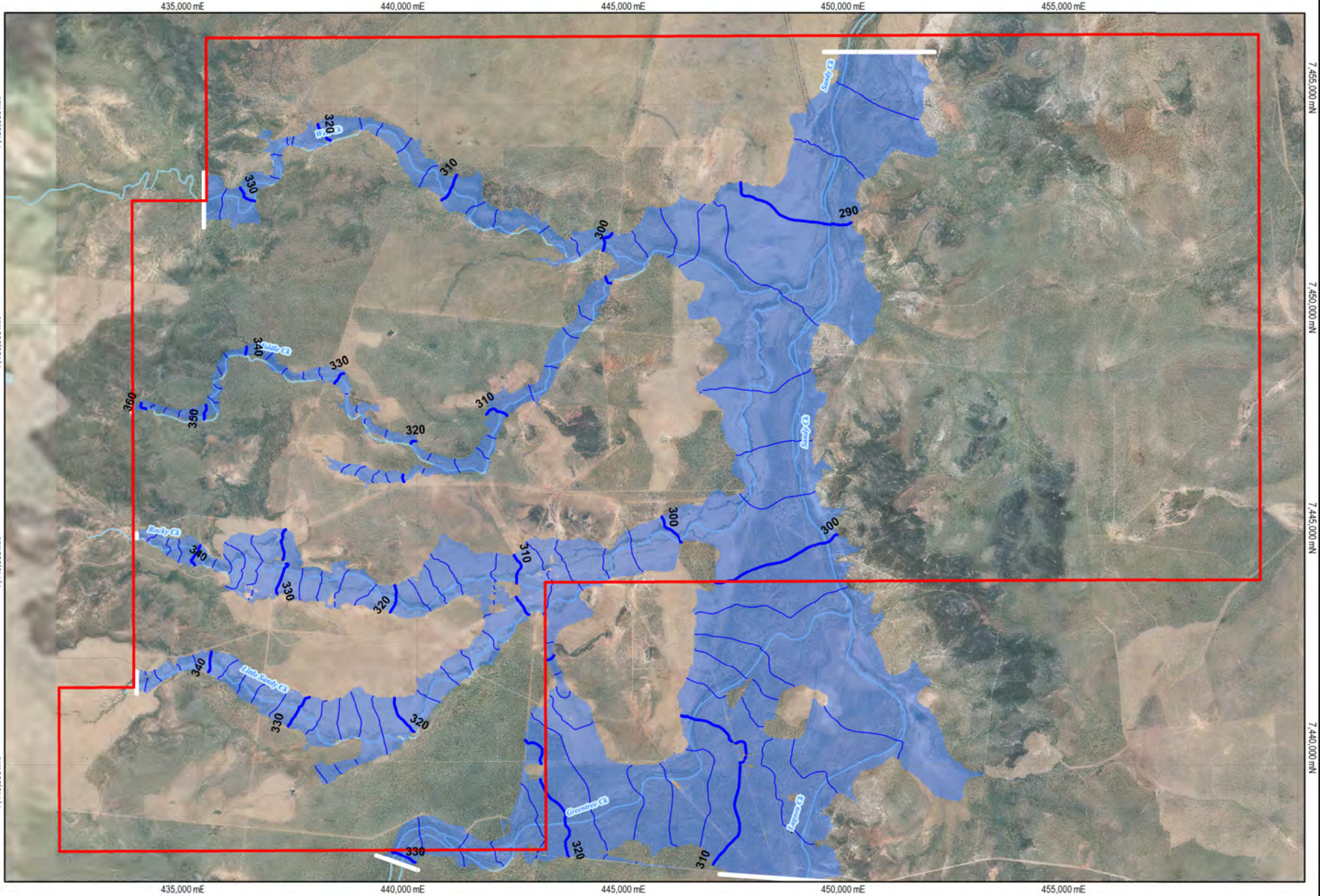
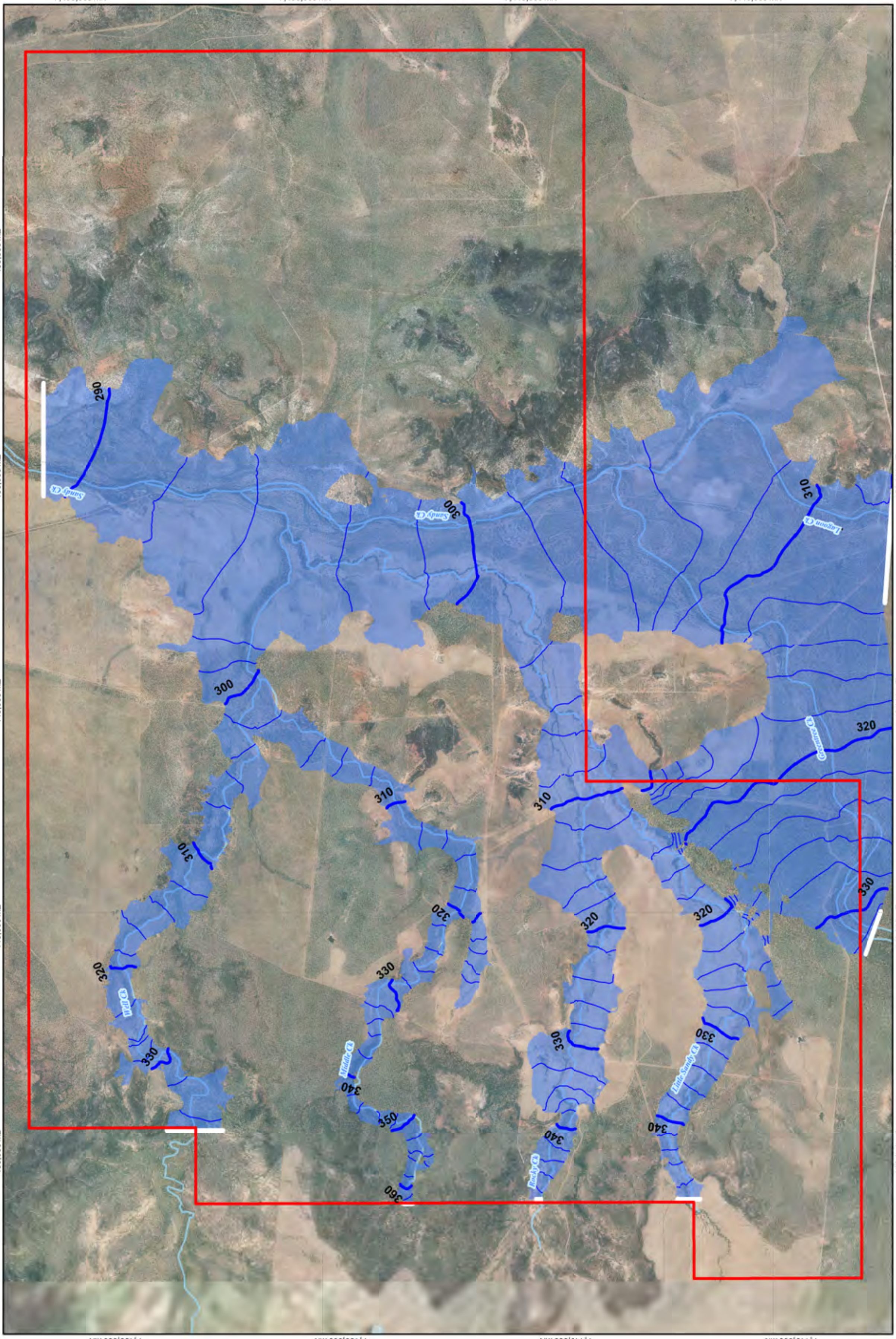
SUMMARY OF 1:2000 AEP EVENT INUNDATION RESULTS



0 1.25 2.5km
Scale: 1:125,000 (A4)

Mining Lease Application (MLA70425) Boundary
Existing Watercourse



Mining Lease Application (MLA70425) Boundary
Existing Watercourse

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Scale: 1:125,000 (A4)

N E S W

HANCOCK GALILEE PTY LTD
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SUMMARY OF PMF EVENT INUNDATION RESULTS

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REVISED HYDRAULIC TECHNICAL REPORT

Figure: D-5

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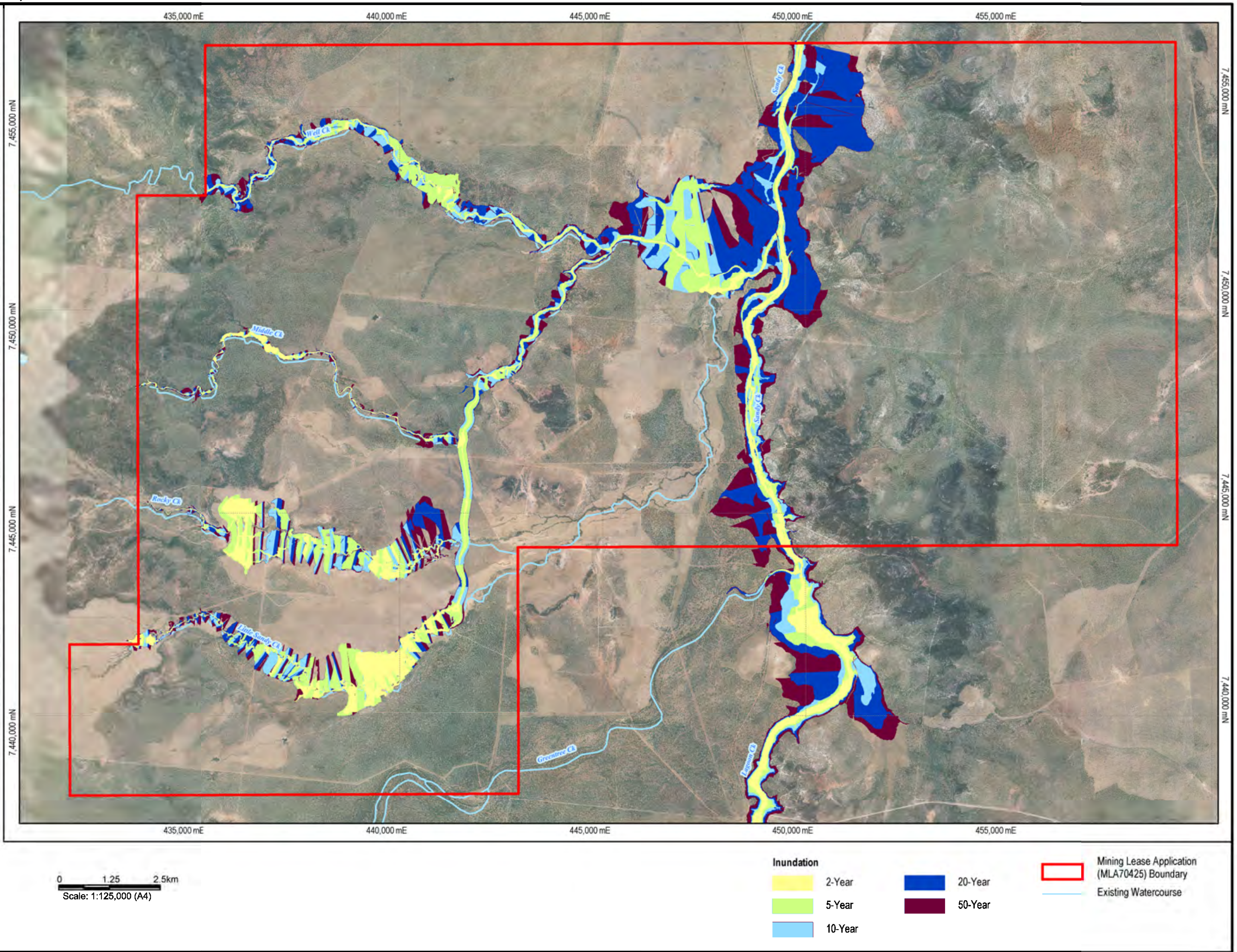

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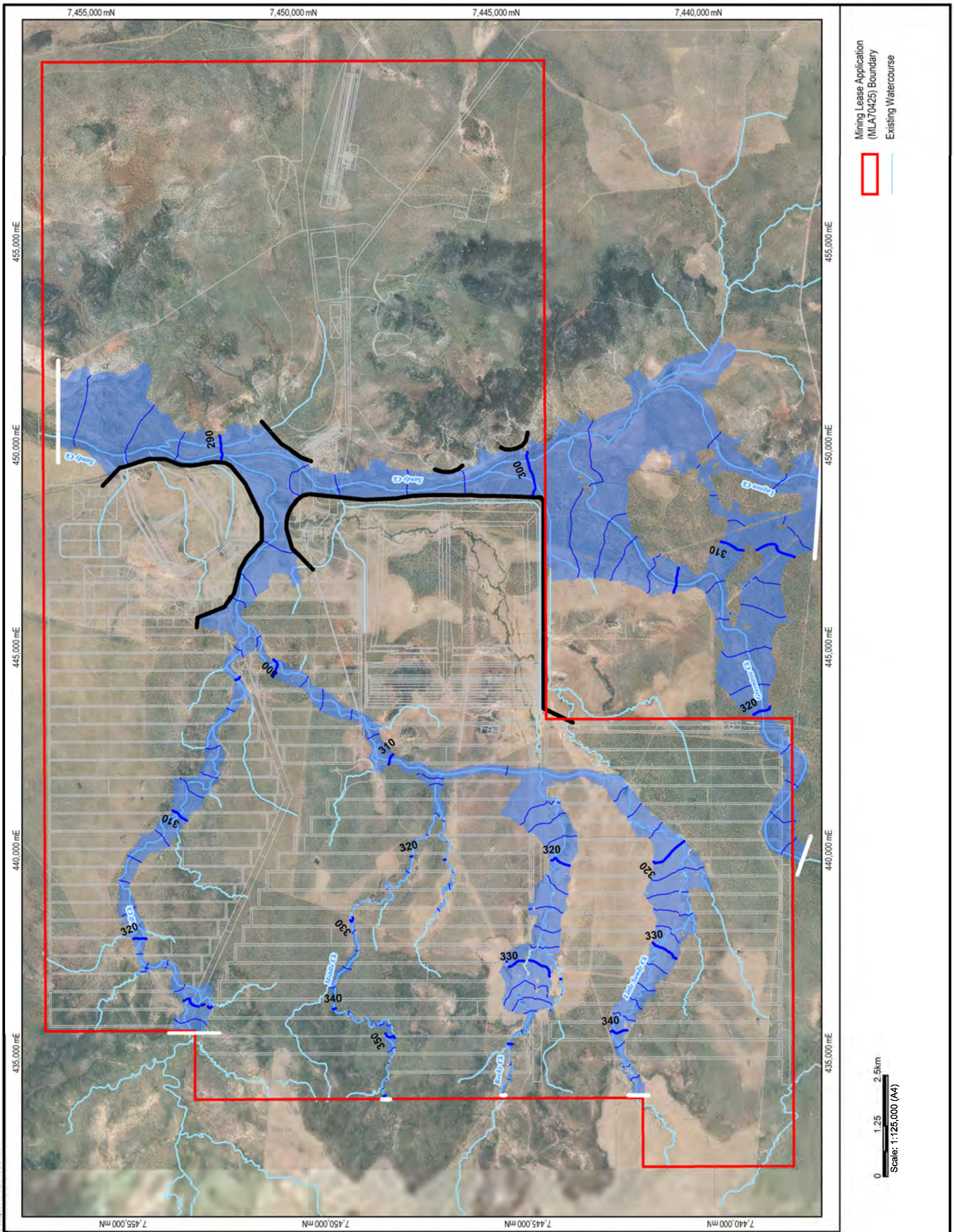
Kevin's Corner Project
Supplementary Environmental Impact Statement

1:2 TO 1:50 AEP EVENT MODELLED INUNDATION EXTENTS - DIVERSION CONDITIONS

REVISED HYDRAULIC TECHNICAL REPORT

Figure: D-6

File No: 42626920-g-2121.wor | Drawn: XL | Approved: PV | Date: 15-06-2012 | Rev: A | A4



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HANCOCK GALILEE PTY LTD

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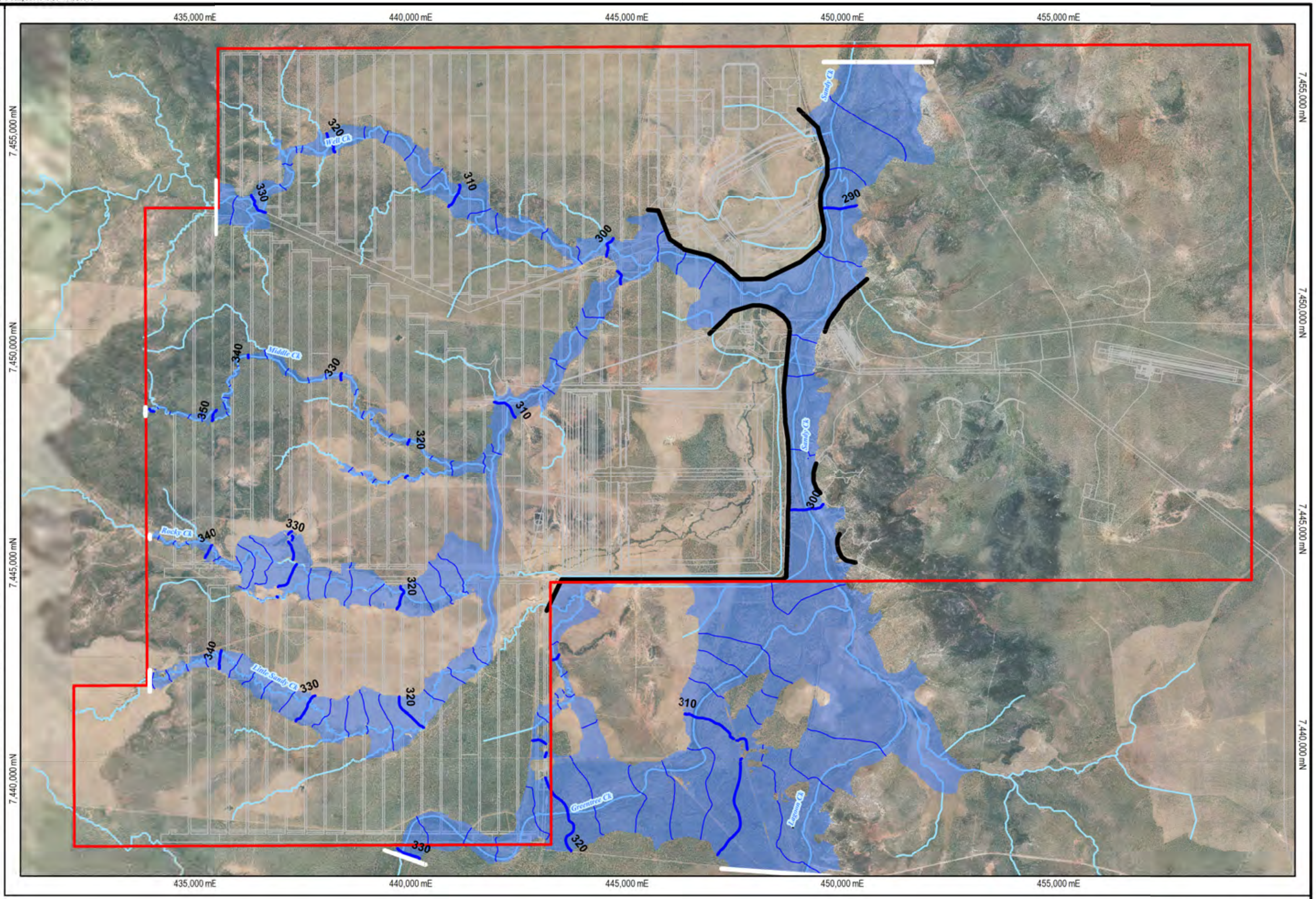
URS

REVISED HYDRAULIC TECHNICAL REPORT

Figure: D-7

File No: 42626920-g-2077.wor | Drawn: XL | Approved: JS | Date: 15-06-2012 | Rev: A | A4



Mining Lease Application (MLA70425) Boundary

Existing Watercourse

0 1.25 2.5km

Scale: 1:125,000 (A4)

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SUMMARY OF 1:1000 AEP EVENT INUNDATION RESULTS - DIVERTED

File No: 42626920-g-2078.wor

Drawn: XL

Approved: JS

Date: 15-06-2012

Rev: A

Figure: D-8

A4

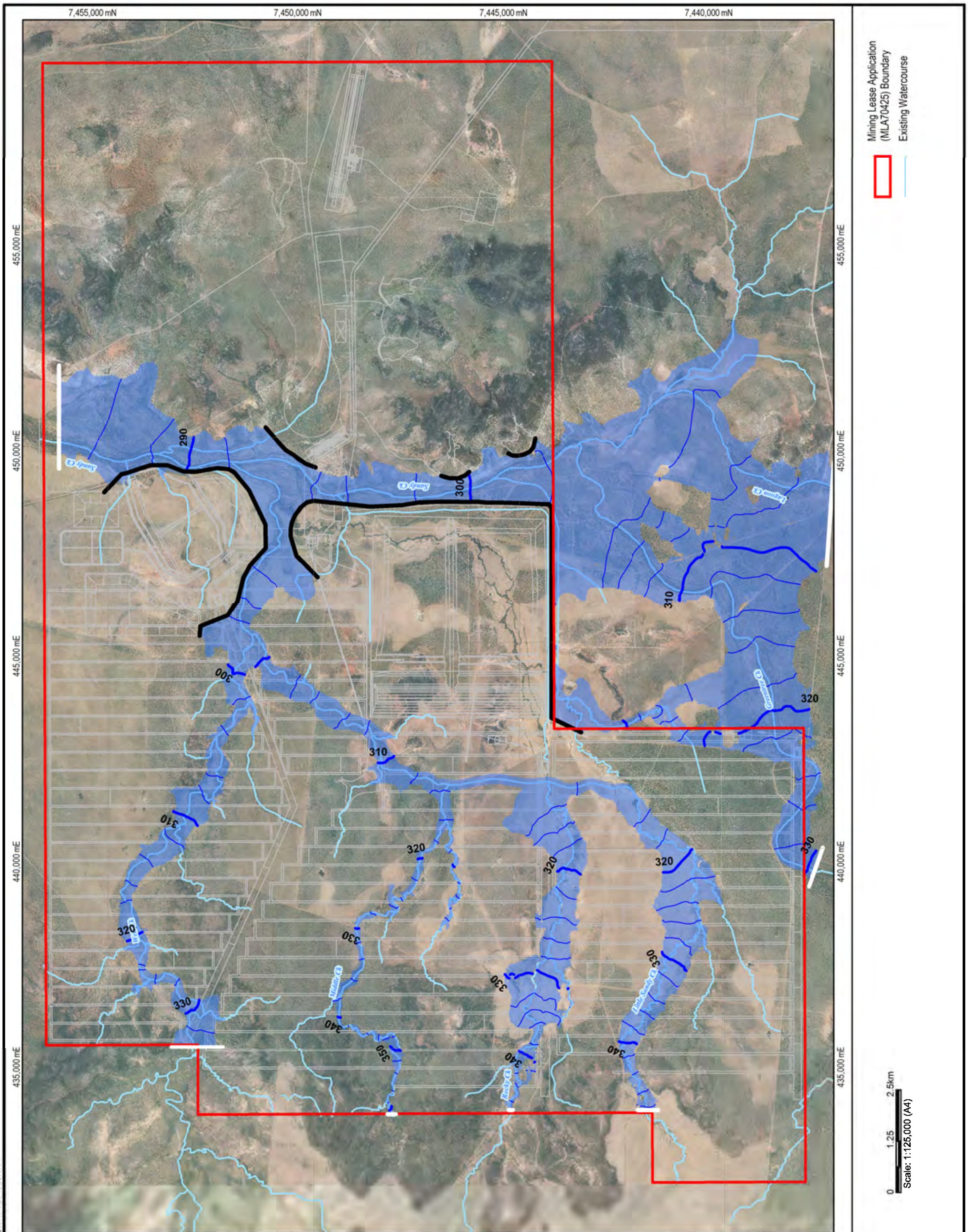

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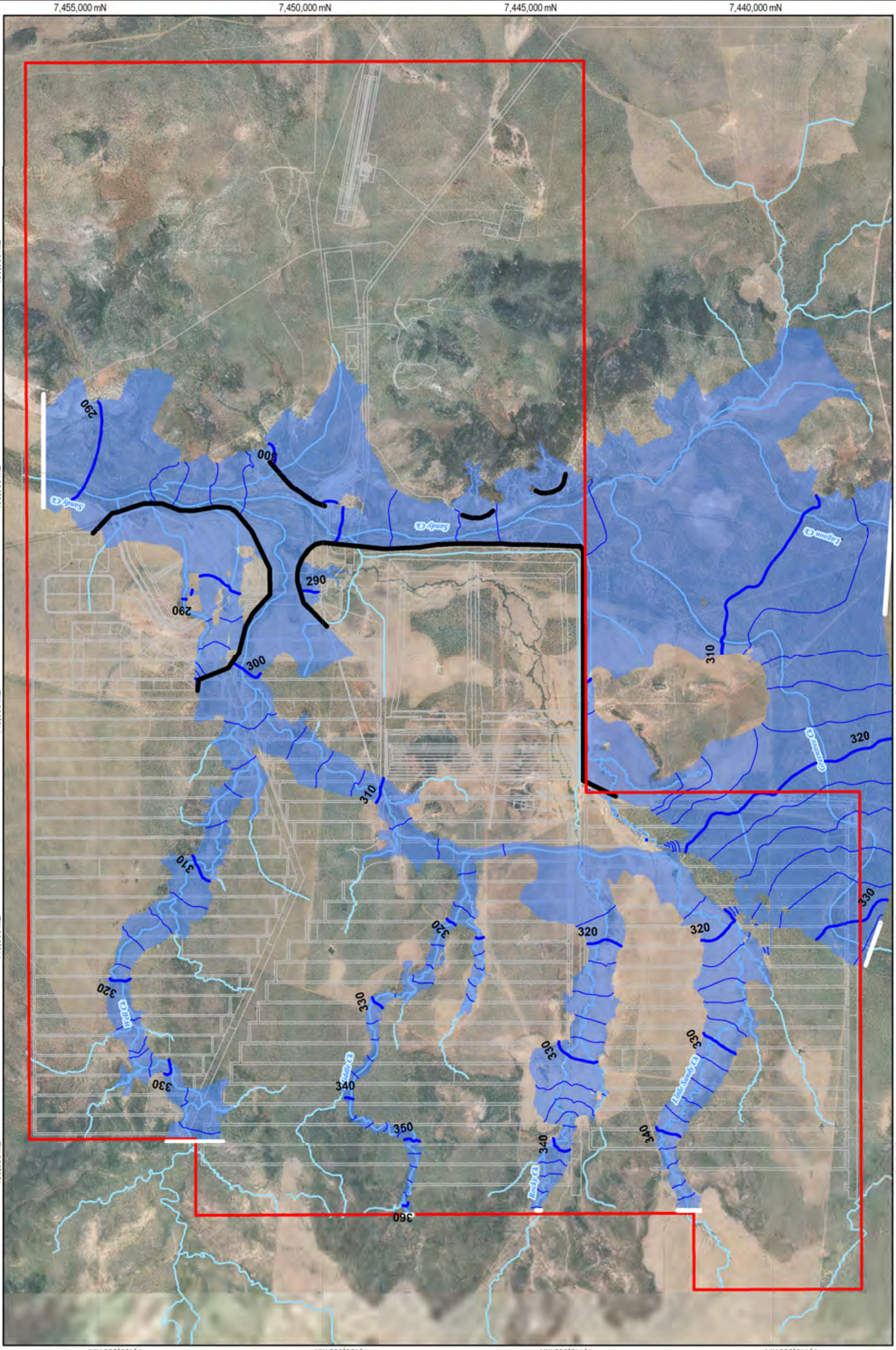
Figure: D-9

File No: 42626920-g-2079.wor | Drawn: XL | Approved: JS | Date: 15-06-2012 | Rev: A | A4



Mining Lease Application (MLA70425) Boundary

Existing Watercourse

0 1.25 2.5km
Scale: 1:125,000 (A4)

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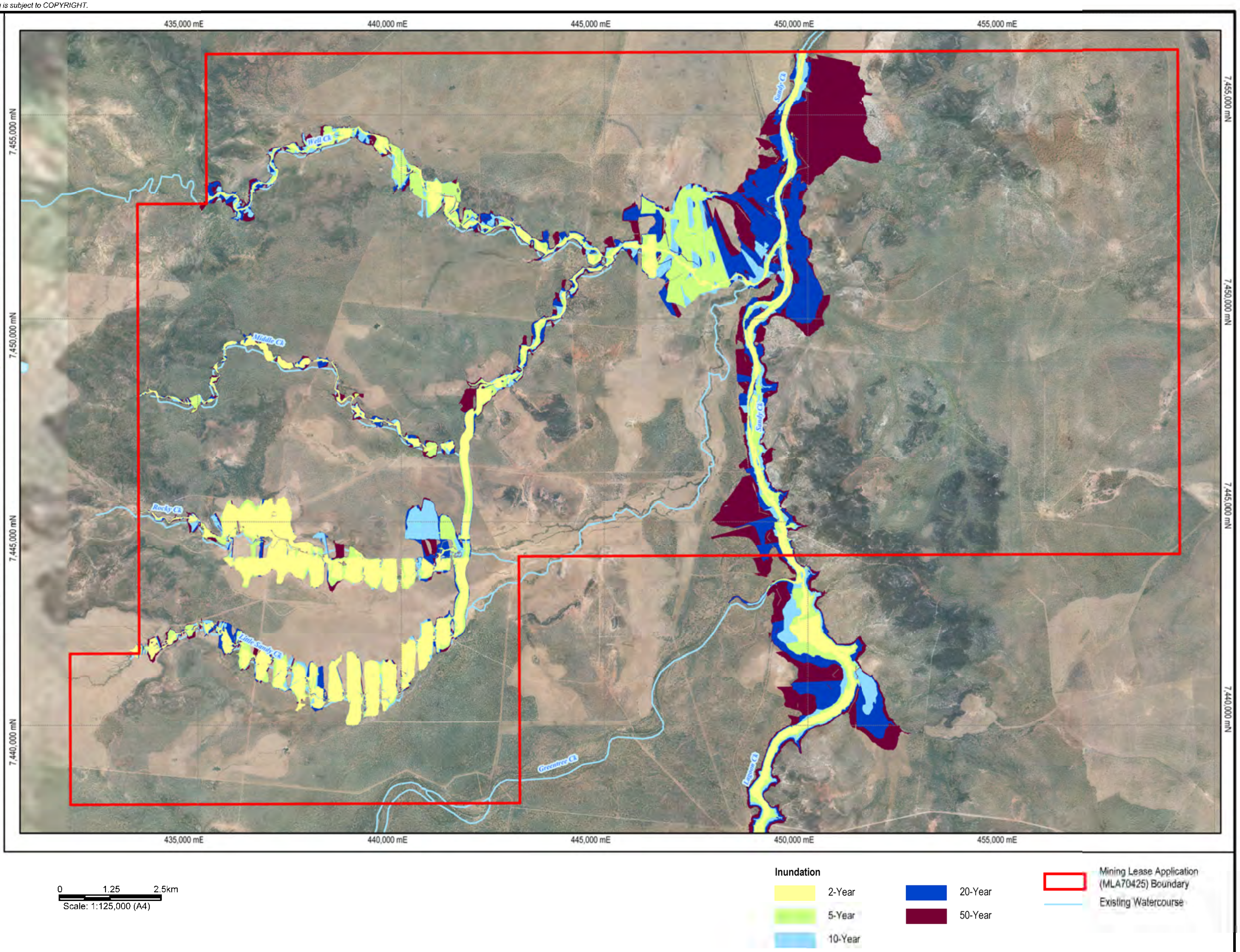
Figure: D-10

File No: 42626920-g-2080.wor | Drawn: XL | Approved: JS | Date: 15-06-2012 | Rev: A | A4



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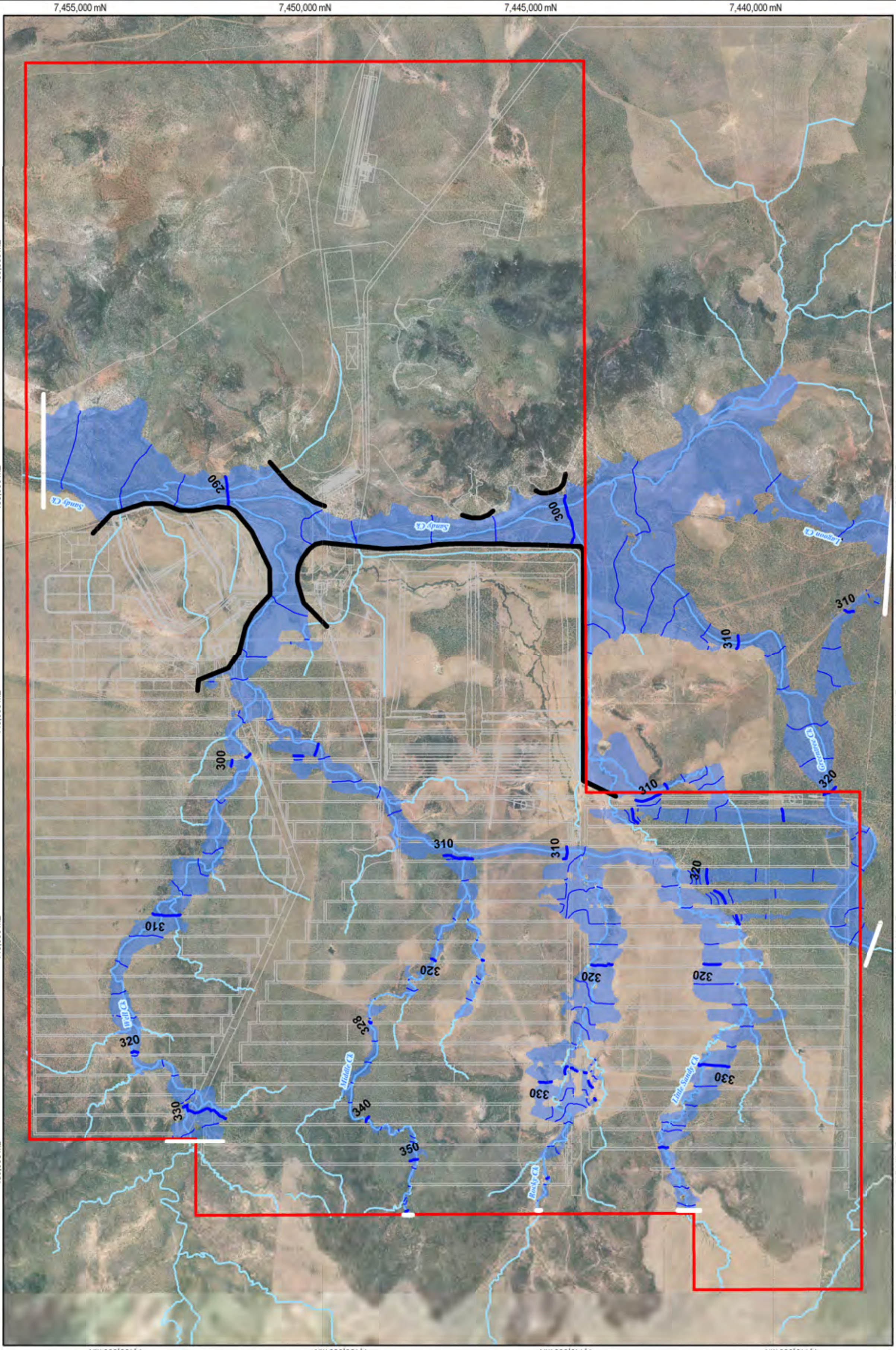
1:2 TO 1:50 AEP EVENT MODELLED INUNDATION EXTENTS - SUBSIDED CONDITIONS

REVISED HYDRAULIC TECHNICAL REPORT

Figure: D-11

File No: 4262920-g-2122.wor | Drawn: XL | Approved: PV | Date: 15-06-2012 | Rev. A | A4



Mining Lease Application (MLA70425) Boundary

Existing Watercourse

0 1.25 2.5km

Scale: 1:125,000 (A4)

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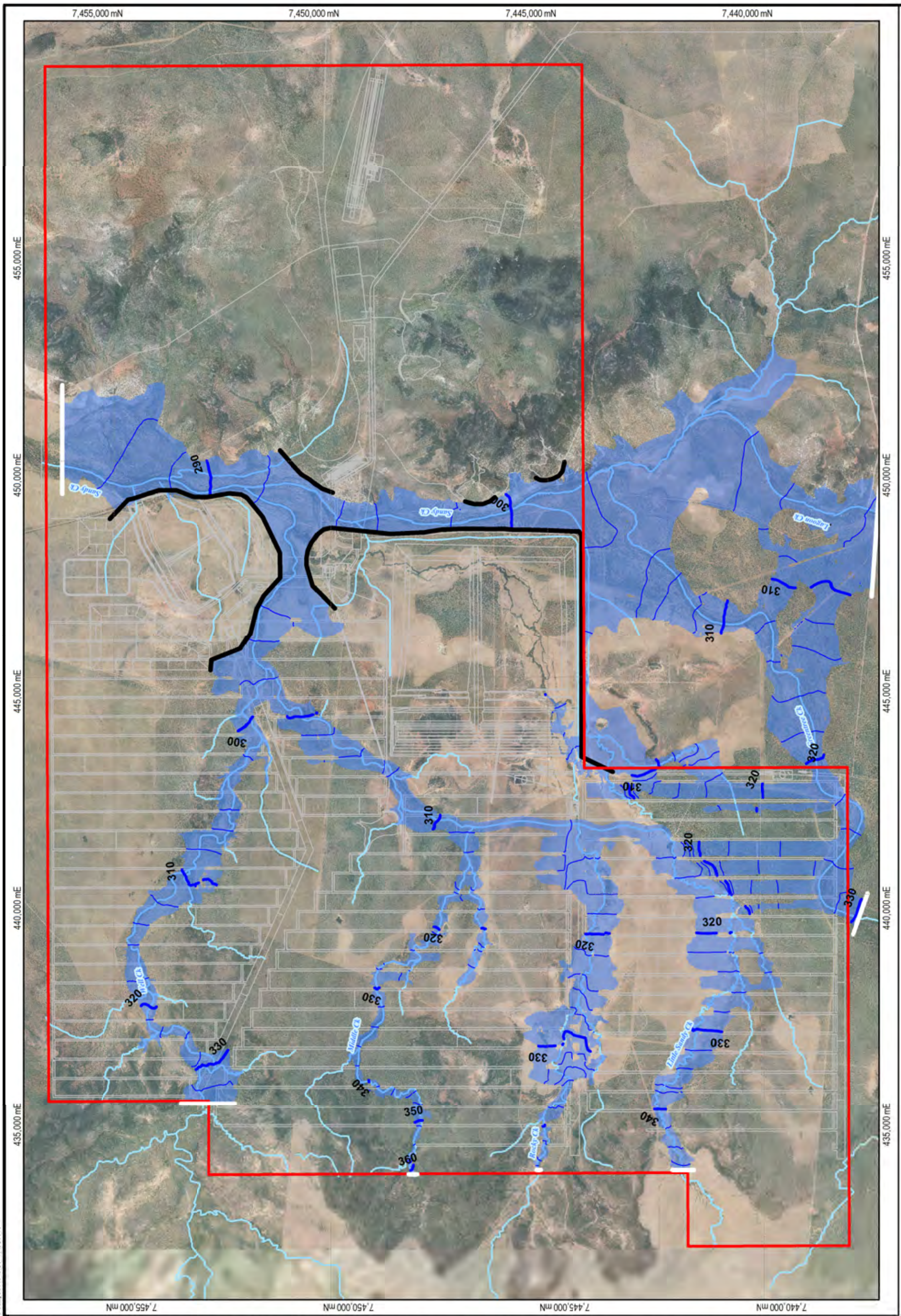
Figure: D-12

File No: 42626920-g-2081.wor Drawn: XL Approved: JS Date: 15-06-2012 Rev: A A4



Mining Lease Application (MLA70425) Boundary
Existing Watercourse

0 1.25 2.5km
Scale: 1:125,000 (A4)

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Figure: D-13

File No: 42626920-g-2082.wor | Drawn: XL | Approved: JS | Date: 15-06-2012 | Rev: A | A4

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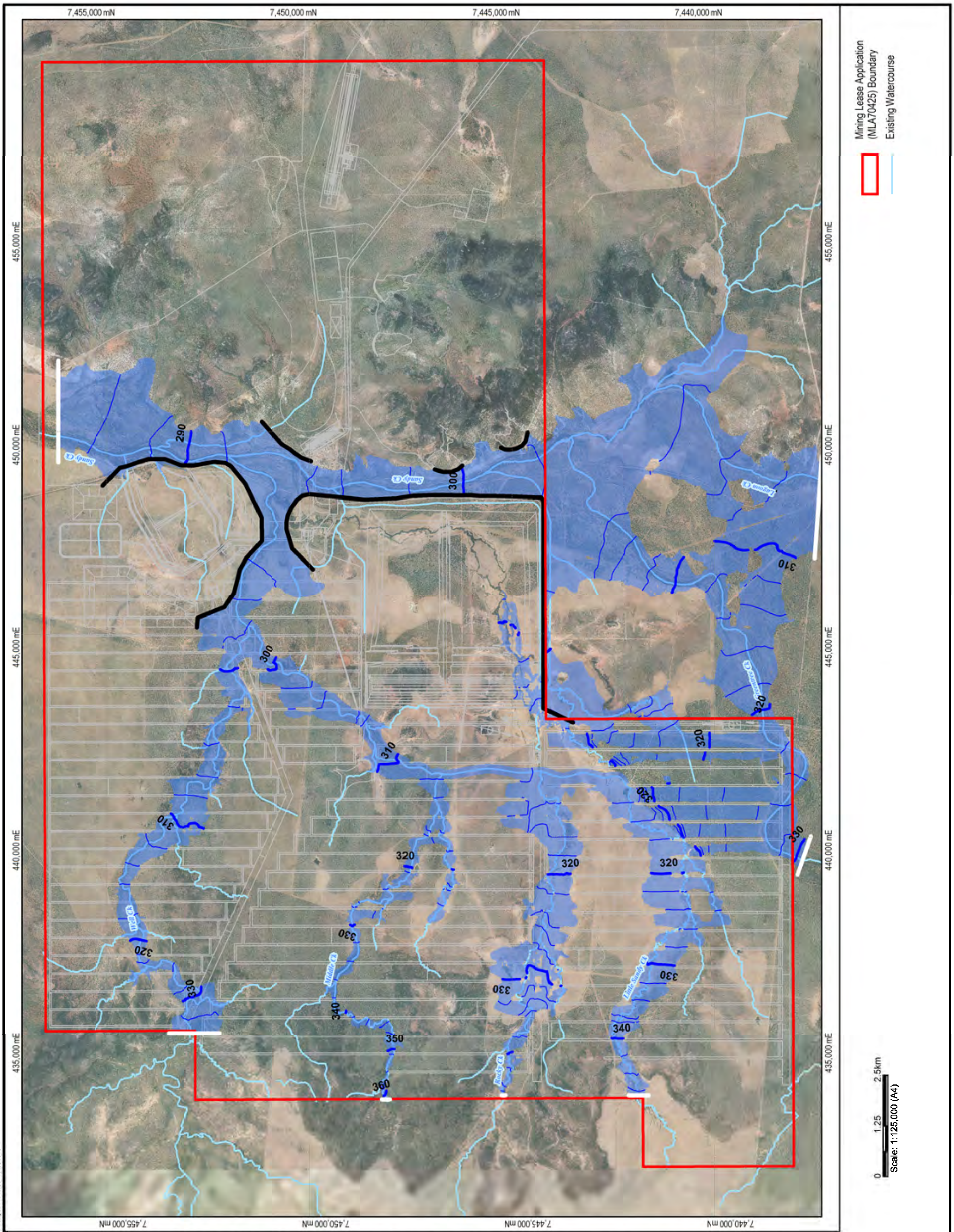

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Figure: D-14

File No: 42626920-g-2083.wor | Drawn: XL | Approved: JS | Date: 15-06-2012 | Rev: A | A4

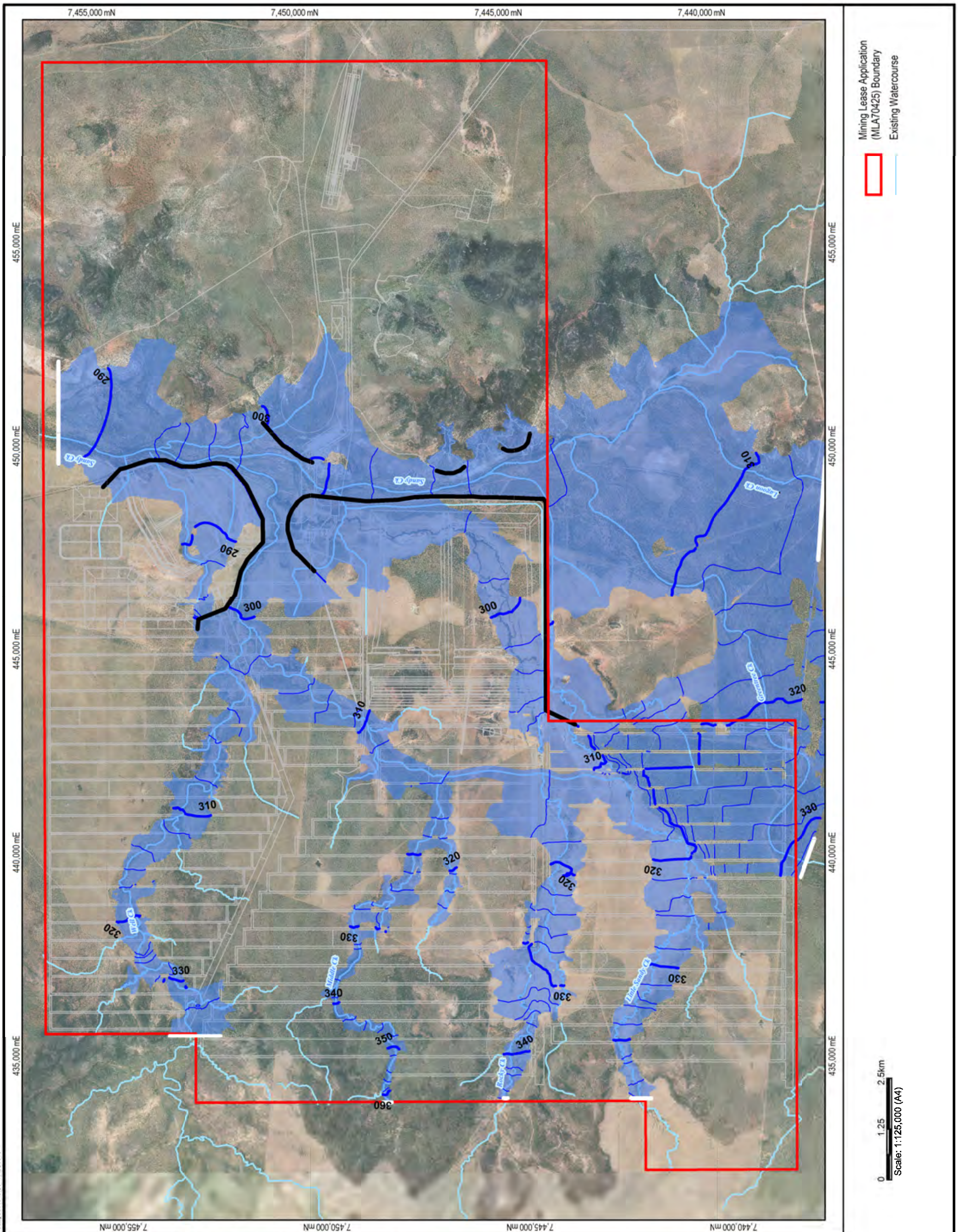

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Figure: D-15

File No: 42626920-g-2084.wor | Drawn: XL | Approved: JS | Date: 15-06-2012 | Rev: A | A4

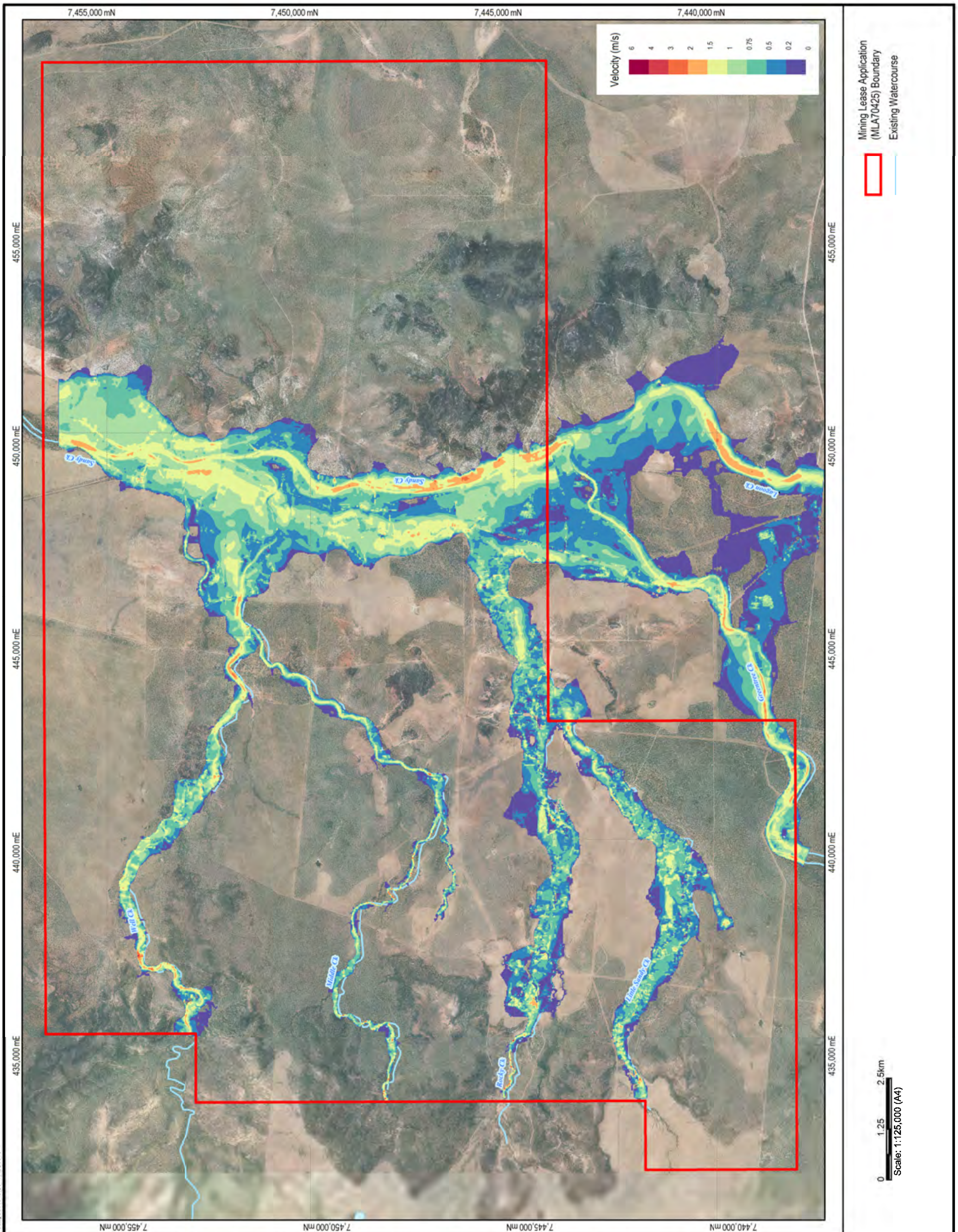

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Figure: D-16

File No: 42626920-g-2085.wor | Drawn: RG | Approved: CP | Date: 15-06-2012 | Rev: A | A4

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File No: 42626920-g-2086.wor | Drawn: RG | Approved: CP | Date: 15-06-2012 | Rev: A | A4

Figure: D-17

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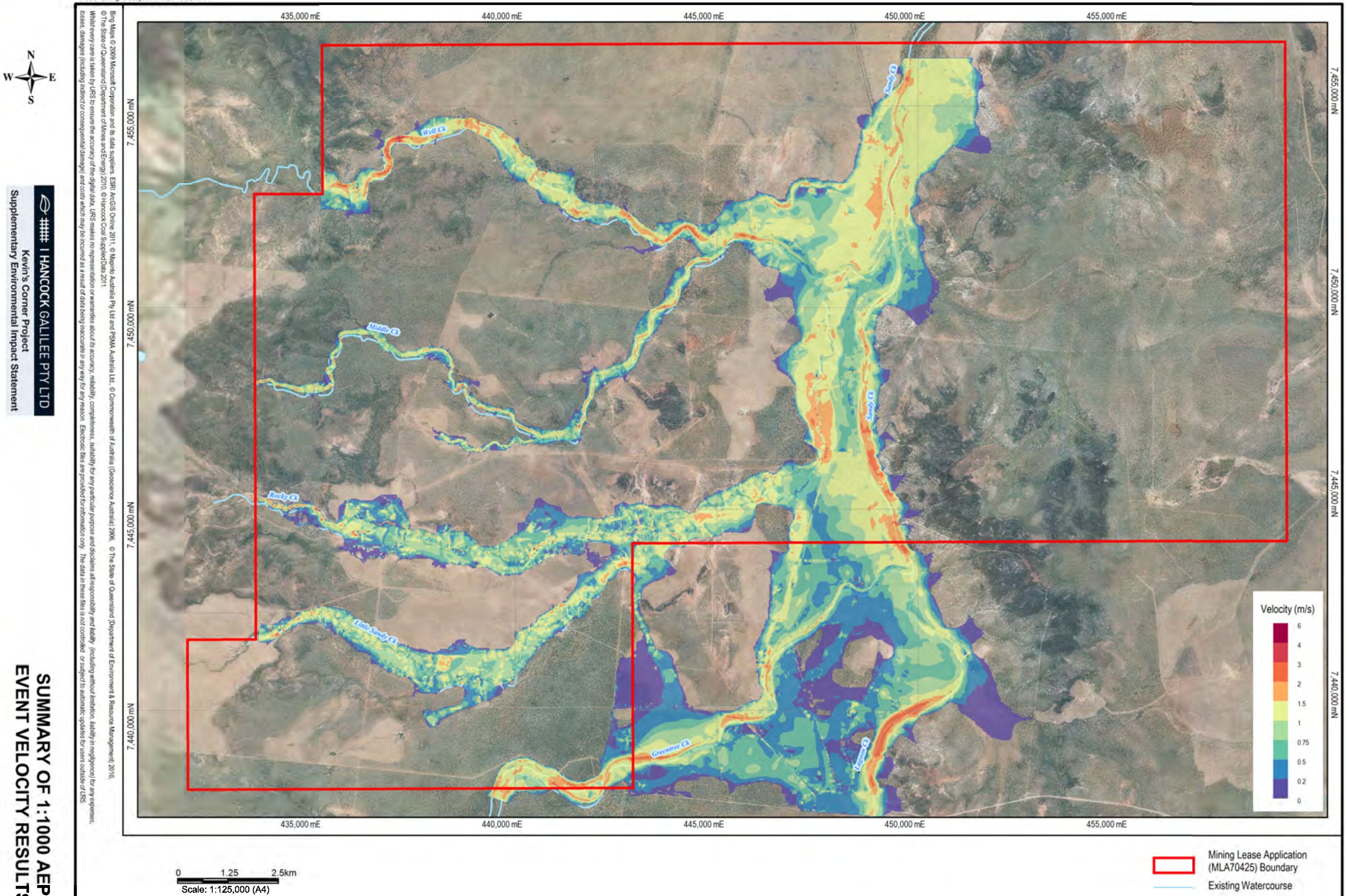

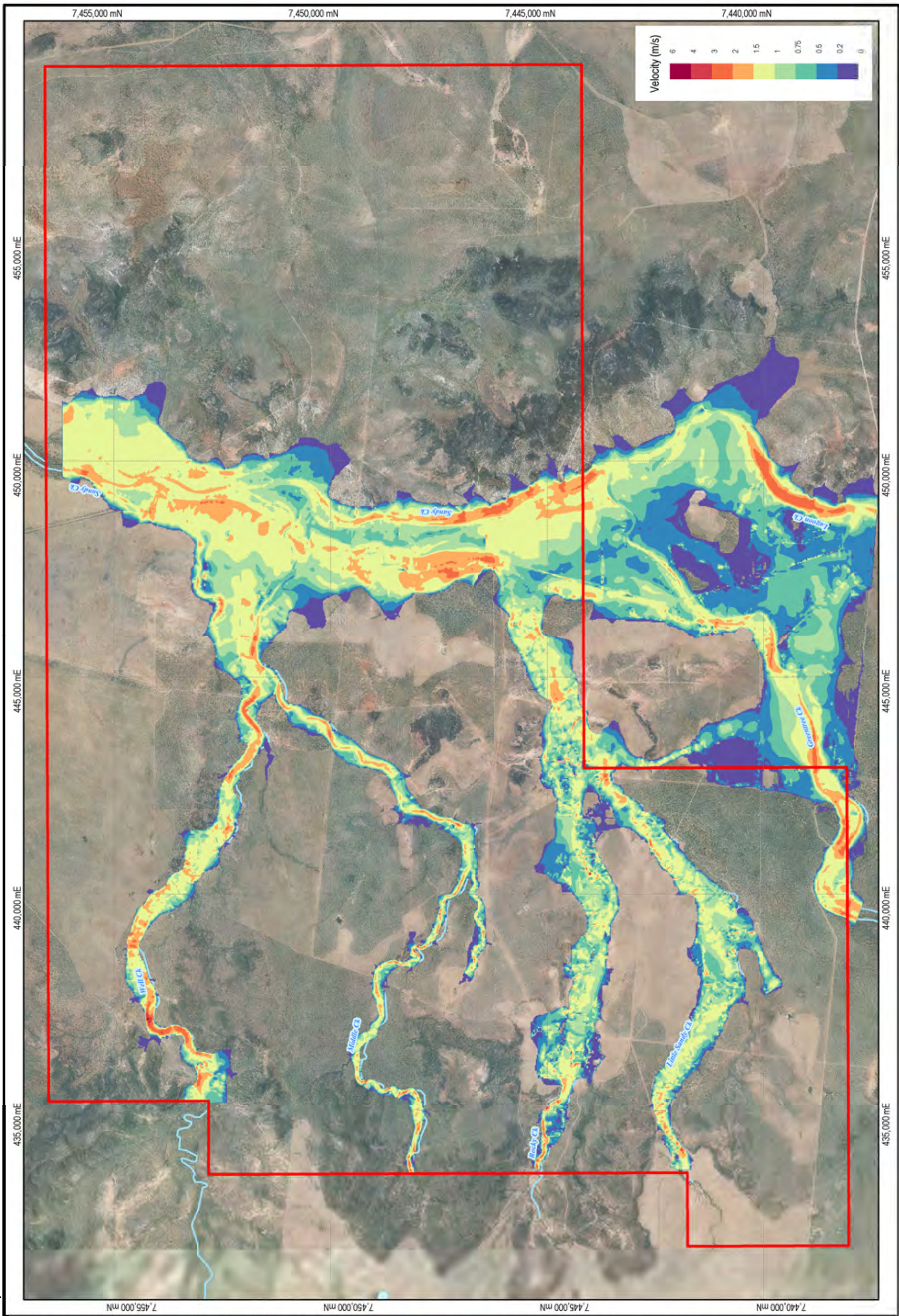

Mining Lease Application (MLA70425) Boundary
Existing Watercourse

0 1.25 2.5km
Scale: 1:125,000 (A4)

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Figure: D-18

File No: 42626920-g-2087.wor Drawn: RG Approved: CP Date: 15-06-2012 Rev: A A4

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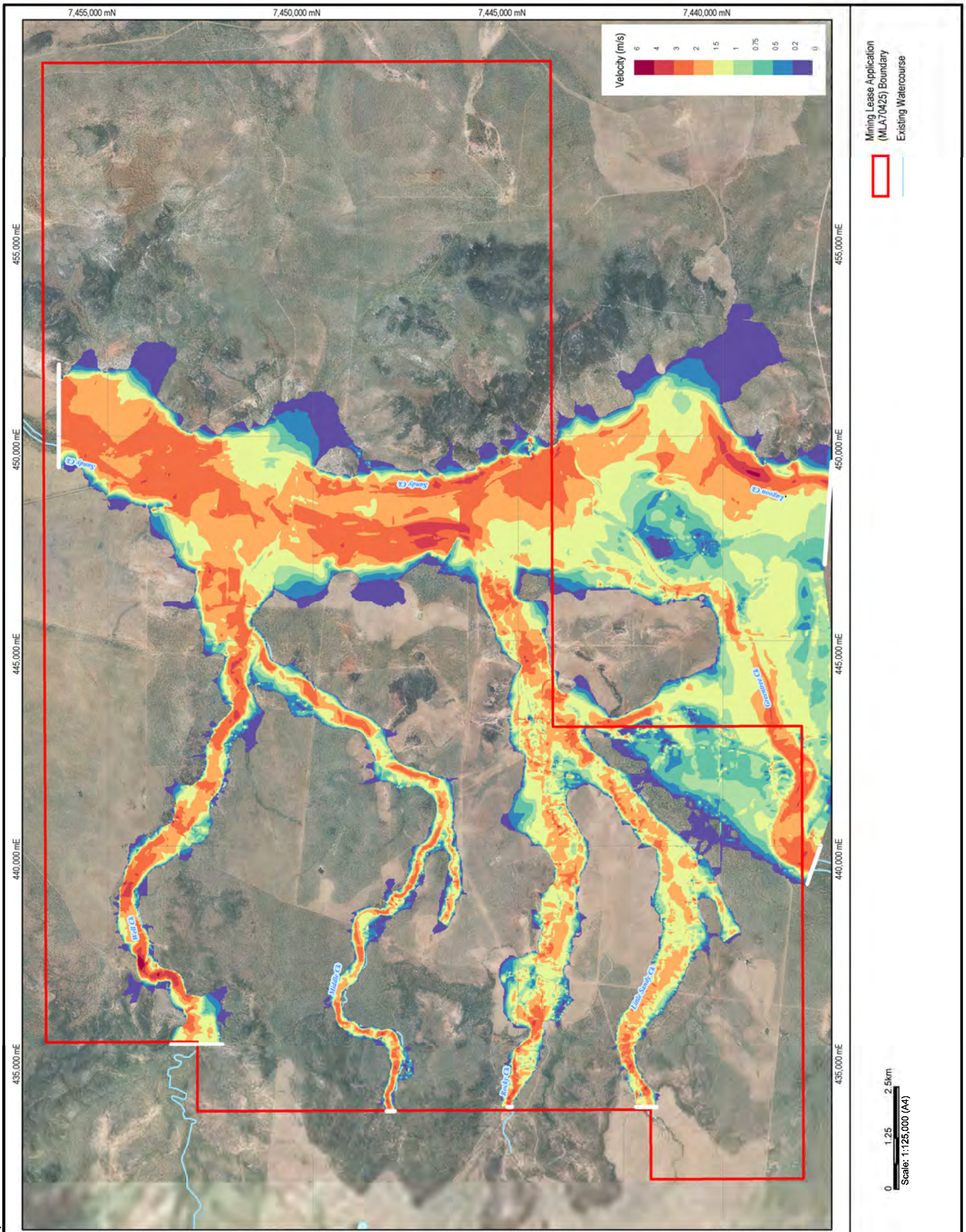

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Figure: D-19

File No: 42626920-g-2088.wor | Drawn: RG | Approved: CP | Date: 17-05-2012 | Rev: A | A4

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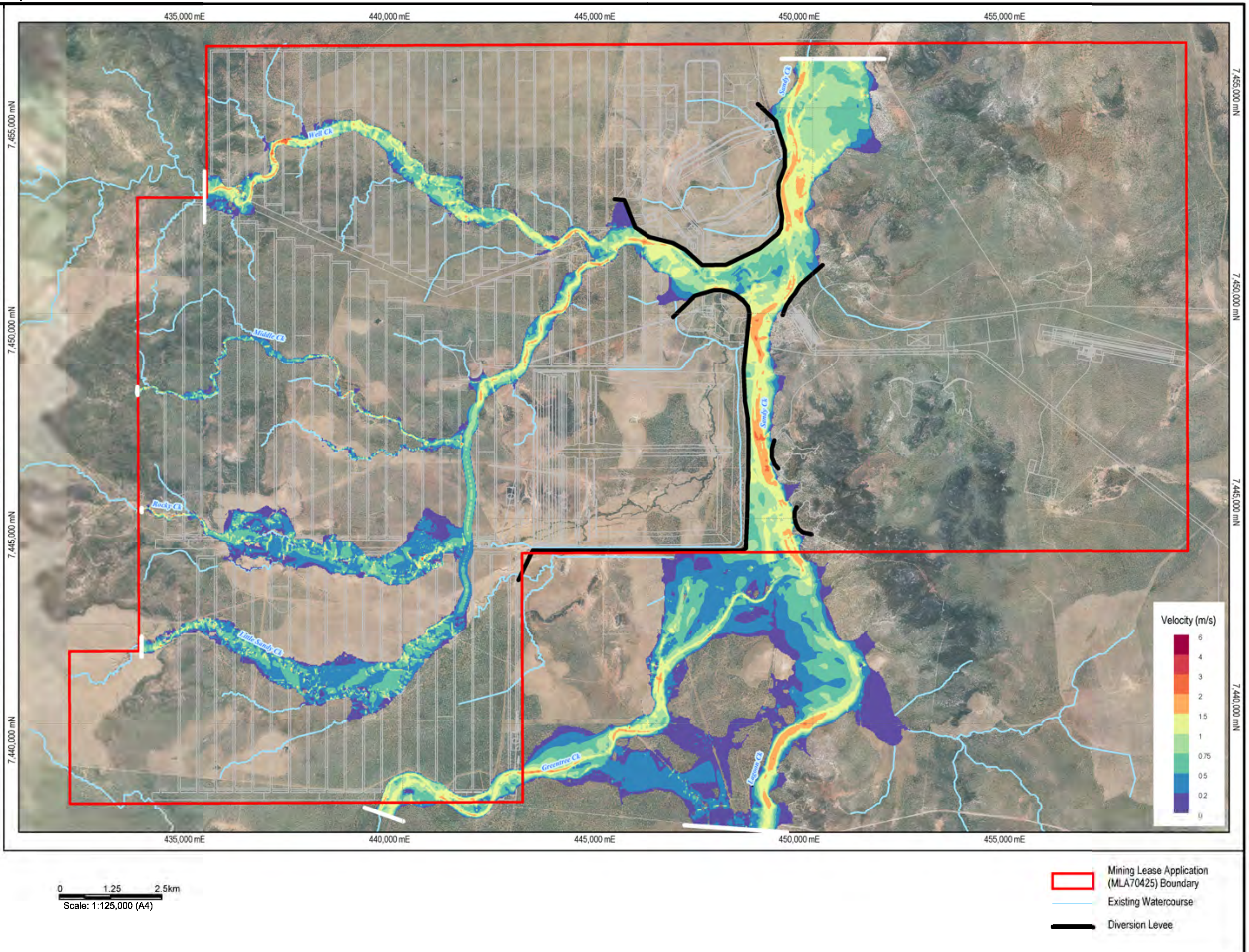

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Figure: D-20

File No: 42626920-g-2089.wor

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File No: 42626920-g-2090.wor

Drawn: RG

Approved: CP

Date: 15-06-2012

Figure: D-21

Rev: A

A4

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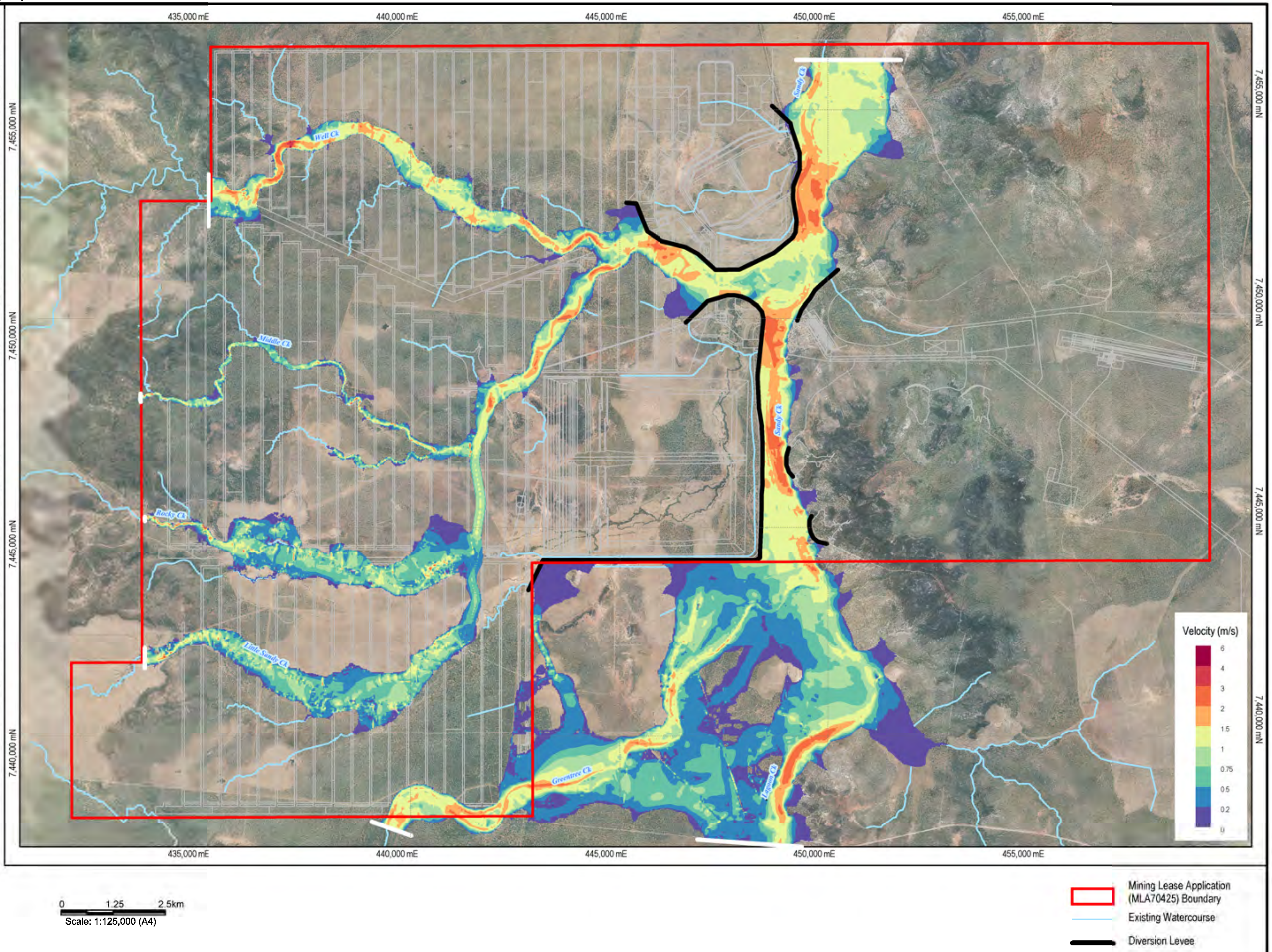

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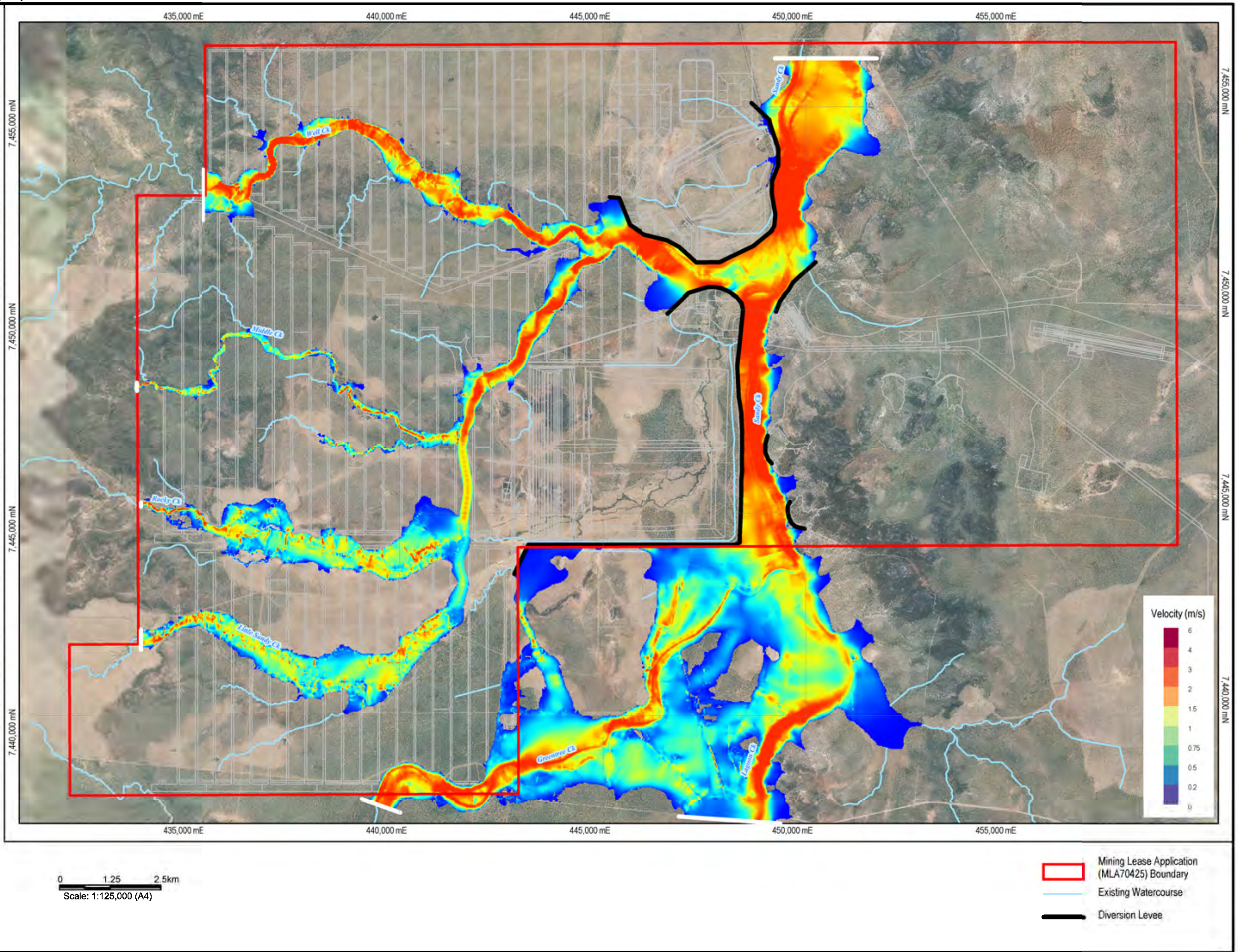

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Figure: D-22

File No: 42626920-g-2091.wor Drawn: RG Approved: CP Date: 15-06-2012 Rev. A A4

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File No: 4262692O-g-2092.wor   Drawn: RG   Approved: CP   Date: 15-06-2012   Rev.A   A4

Figure: D-23

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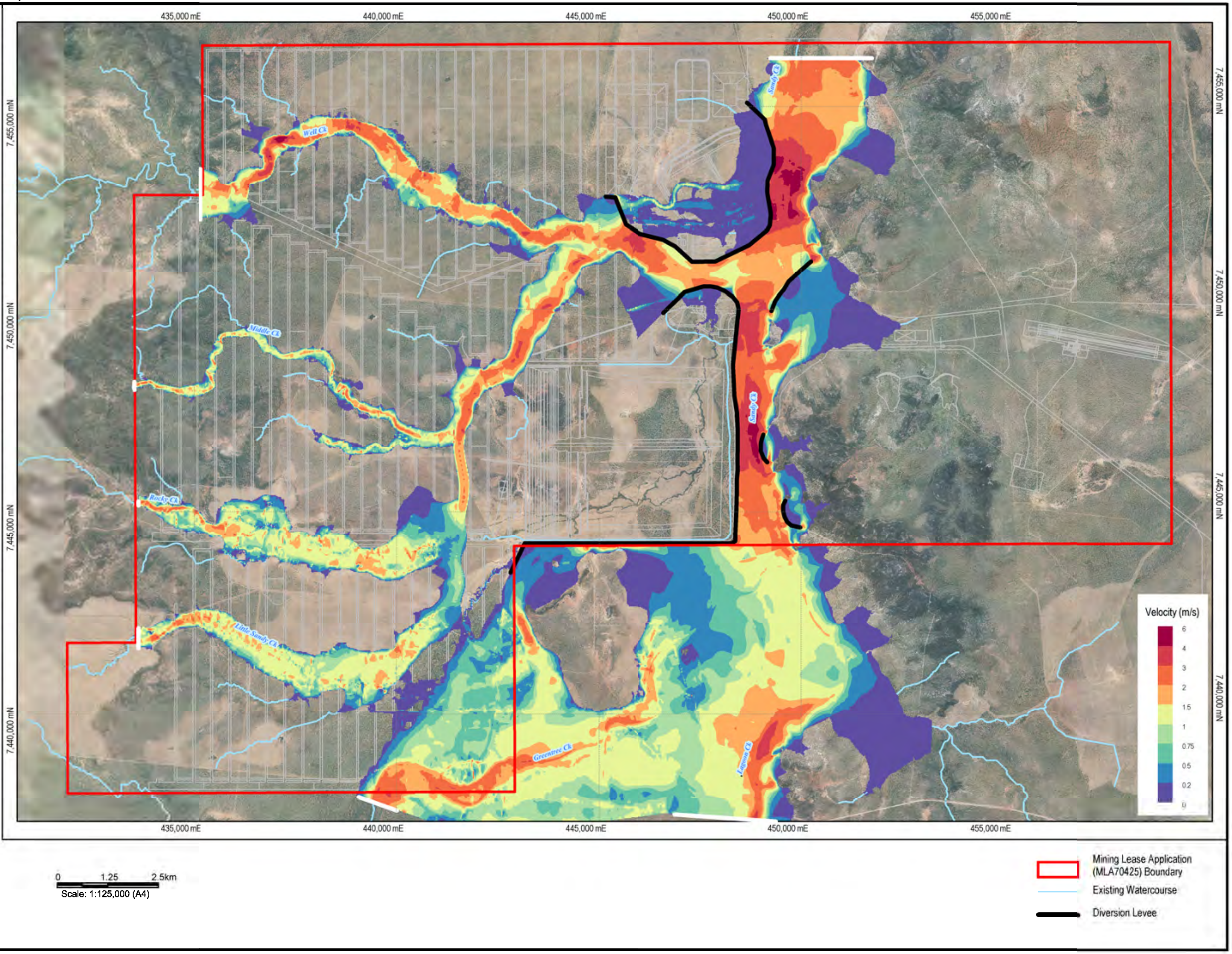

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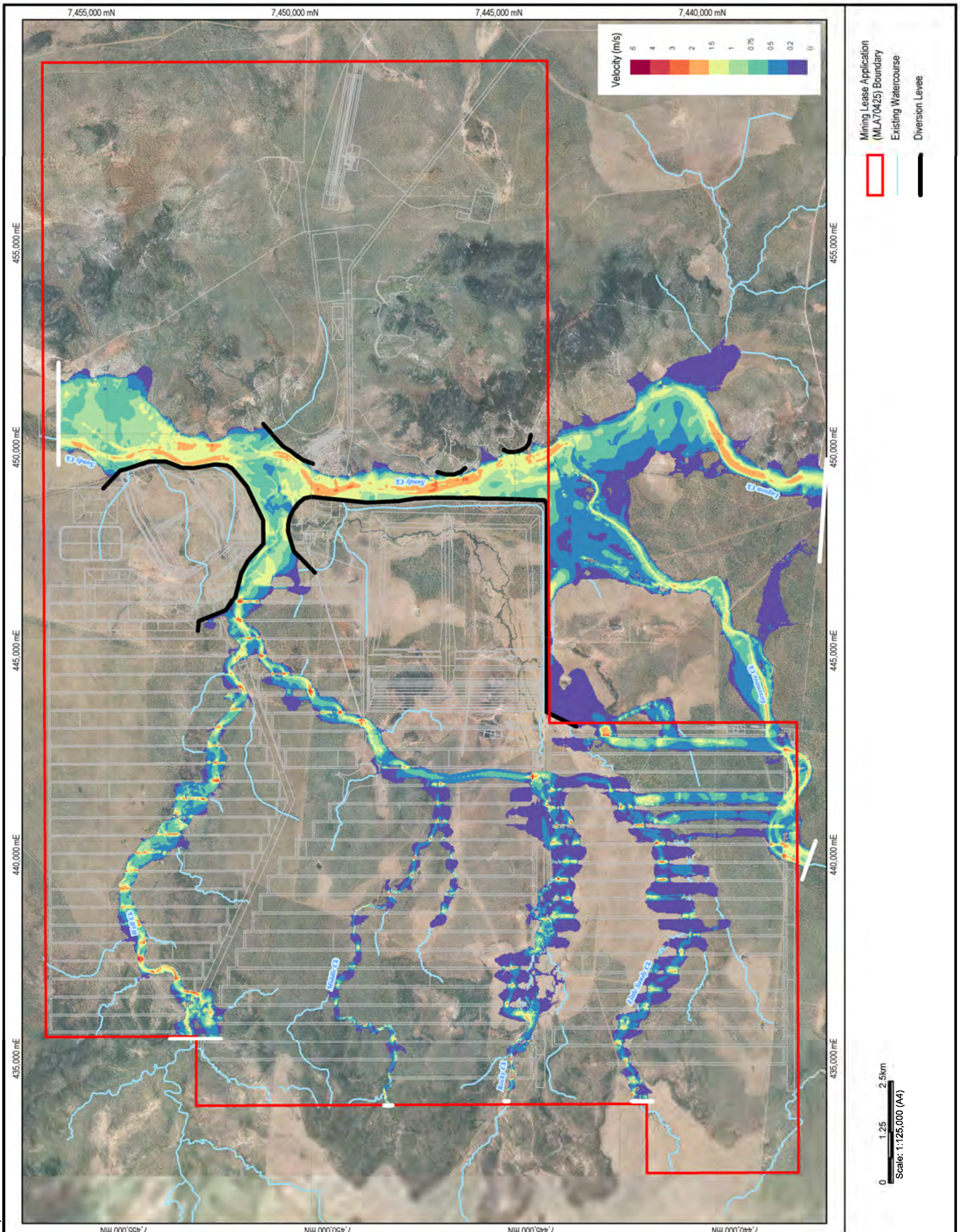

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Figure: D-24

File No: 42626920-g-2093.wor | Drawn: RG | Approved: CP | Date: 15-06-2012 | Rev: A | A4

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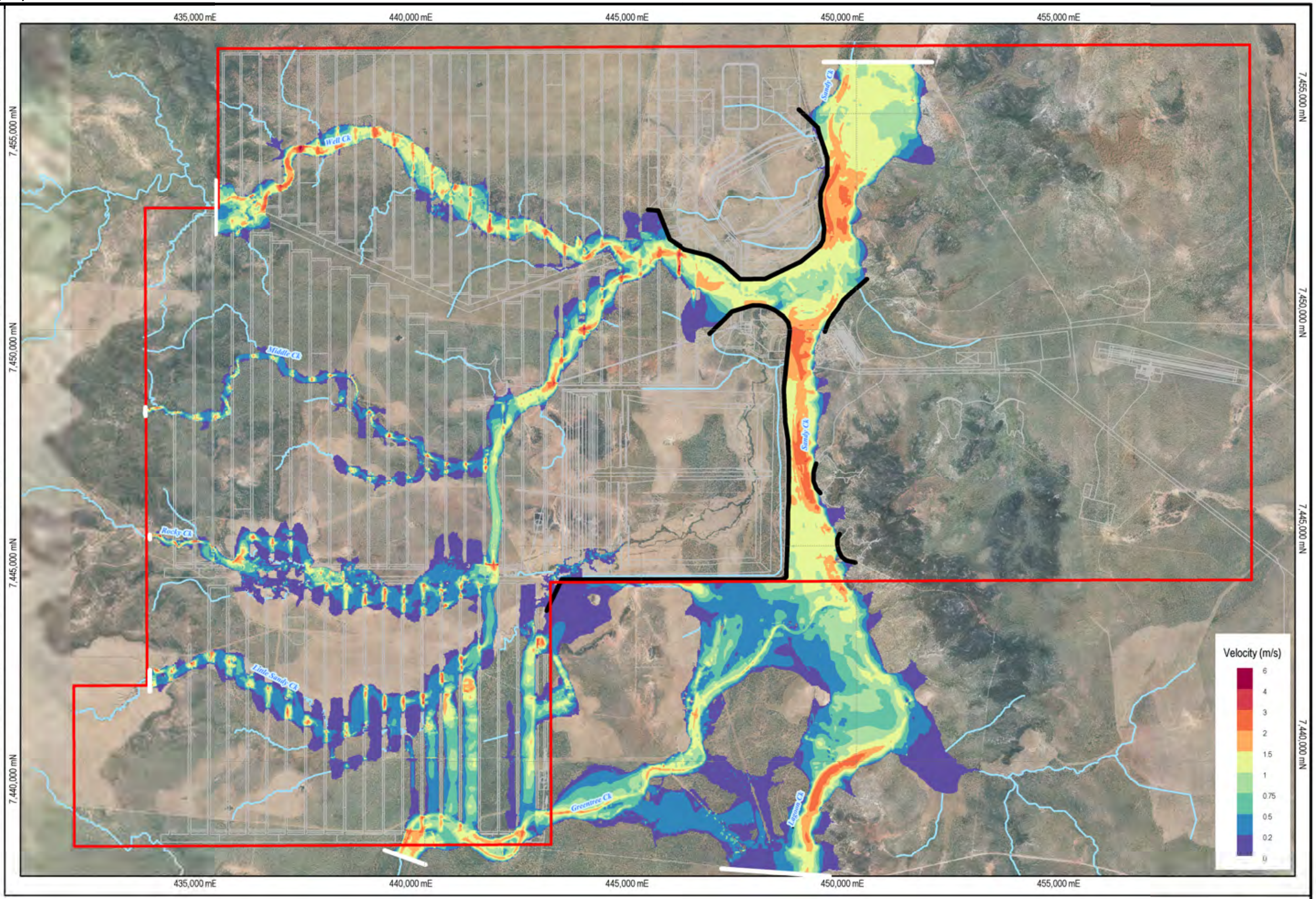

0 1.25 2.5km
Scale: 1:125,000 (A4)

Mining Lease Application (MLA70425) Boundary
Existing Watercourse
Diversion Levee

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Figure: D-25

File No: 42626920-g-2094.wor | Drawn: RG | Approved: CP | Date: 15-06-2012 | Rev: A | A4

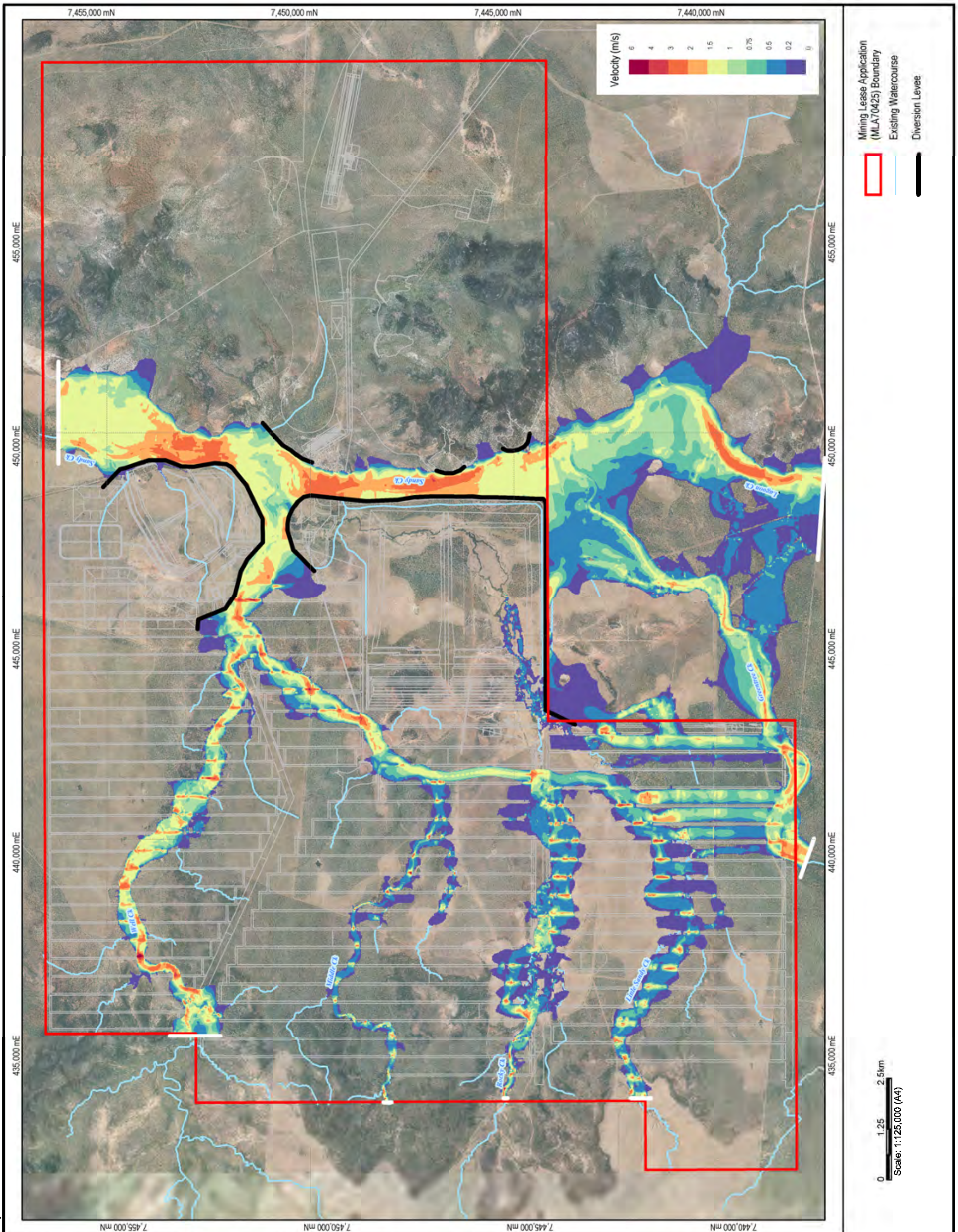

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Figure: D-26

File No: 42626920-g-2095.wor | Drawn: RG | Approved: CP | Date: 15-06-2012 | Rev: A | A4

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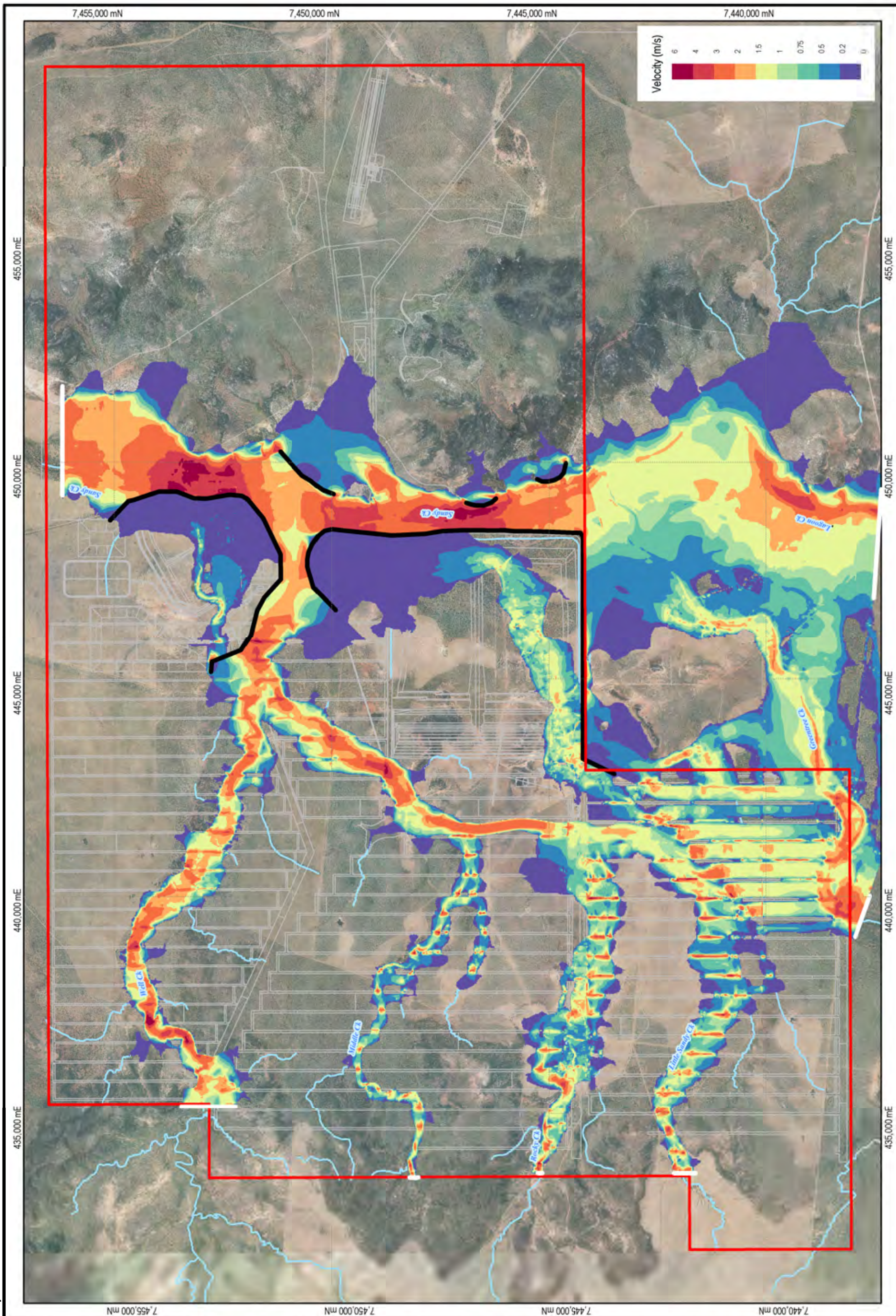

Mining Lease Application (MLA70425) Boundary

Existing Watercourse

Diversion Levee

0 1.25 2.5km

Scale: 1:125,000 (A4)

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Figure: D-27

File No: 42626920-g-2096.wor | Drawn: RG | Approved: CP | Date: 15-06-2012 | Rev: A | A4

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