Photo 57- Culvert and support for sewer pipe accross open channel drain in lot 1 DP825808

Photo 58-Open channel drain in Lot 1 DP 825808

Photo 59- Sewer man hole in open drain along north boundary of Lot1 DP 825808

Photo 60- North boundary of Lot1 DP825808

Photo 61-Proposed gas main route in Shoalhaven Starches property lot 1 DP 825808

Photo 62- Looking toward Shoalhaven Starches Factory (Manildra), along existing sewer rising main alignment

Photo 63- Proposed gas main route through Shoalhaven Starches paddock, looking toward interim packing plant

Photo 64- Sewer pump station on Shoalhaven Starches land, with location of proposed gas main route and pressure reduction station in background

Photo 65- Civil works at most likely position of proposed gas main crossing of Bolong Road

Photo 66 - Bolong Road showing infrastructure in vicinity of proposed gas main crossing

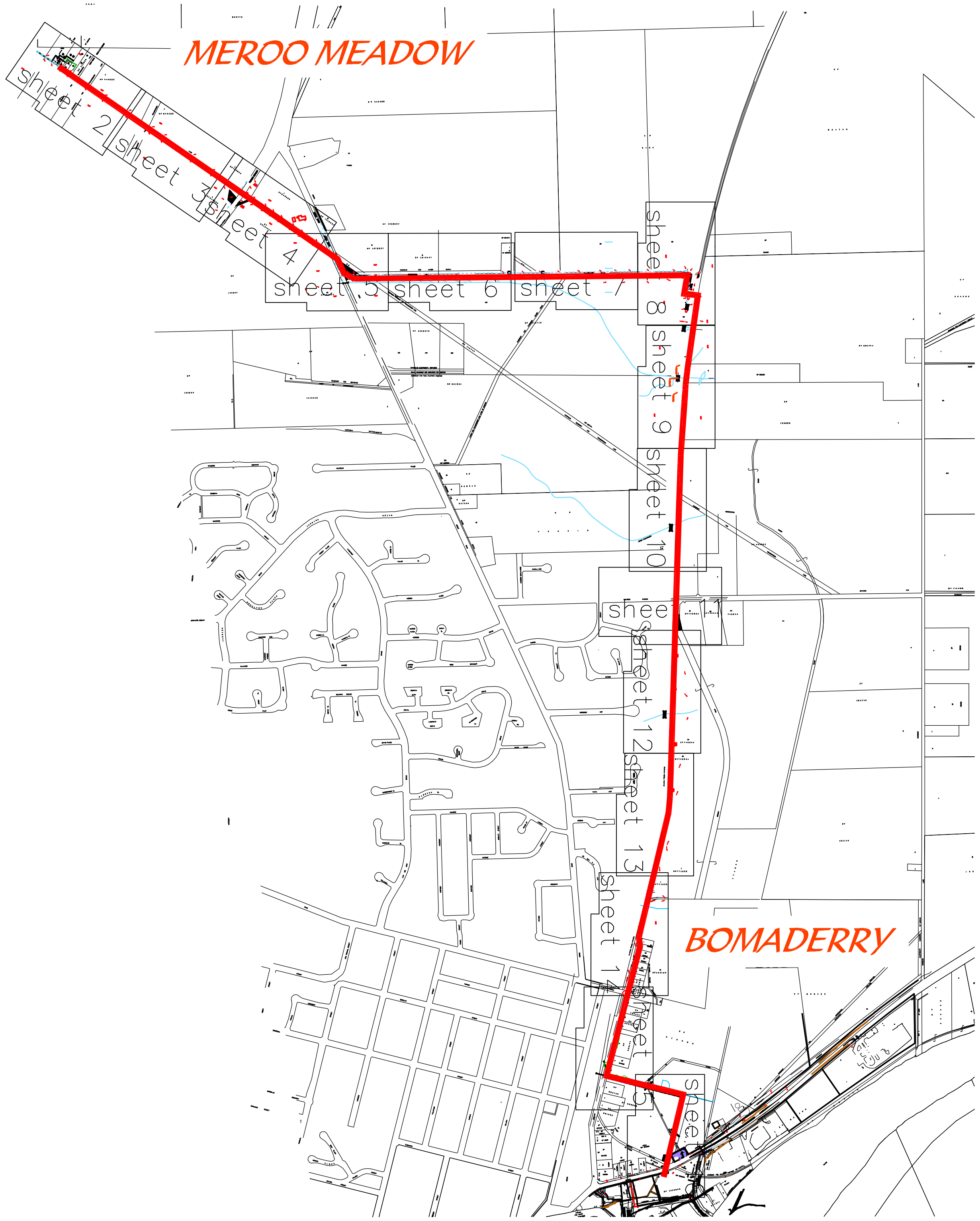
Photo 67-Bolong Road showing infrastructure in vicinity of proposed gas main crossing

Photo 68- Shoalhaven Starches interim packing plant on south side of Bolong Road

Appendix C – APA Drawing 24710-04 Sheets 1 to 16

SHOALHAVEN STARCHES PROPOSED GAS PIPELINE

AT MEROO MEADOW AND BOMADERRY, NSW



APPENDIX C

This drawing complements two reports written by Allen, Price and Associates for the proposed Shoalhaven Starches gas pipeline project. To better understand the content of this drawing, the reports titled, 'Impacts on Infrastructure Report' and 'Erosion and Sediment Control Management Plan' should be read prior. This drawing is located in Appendix C of both reports.

Items shown on these sheets have not been located by detailed survey. They are indicatively shown based on field observation and measurement, and information given by service and infrastructure owners and operators.

LEGEND

1 2 DP 595402	EXISTING BOUNDARY FENCE (SCC CADASTRE)
	EXISTING RURAL FENCE
	EXISTING GAS MAIN
	PROPOSED GAS MAIN
GAS	EASTERN GAS LINE
E E	EXISTING OVERHEAD ELECTRICAL POWER SERVICE
W W	EXISTING WATER MAIN
S S	EXISTING SEWER MAIN
SRM	EXISTING SEWER RISING MAIN
T T	EXISTING UNDERGROUND TELSTRA LINE
	EXISTING TAIL-OUT OR TABLE DRAIN
	EXISTING CREEK OR SWALE DRAIN LESS THAN 5m WIDE
	EXISTING TREE SHOWING APPROX. DRIP LINE
PP	POWER POLE (SCC INFRASTRUCTURE)
TP	TELEGRAPH POLE (RAIL INFRASTRUCTURE)
	EXISTING BRIDGE
	EXISTING CULVERT
AV	EXISTING AIR VALVE FOR WATER MAIN
SV	EXISTING STOP VALVE FOR WATER MAIN
SCV	SCOUR VALVE
	RAILWAY TRACK
	LAND SLOPE
	TEMPORARY STABILISED SITE AND ACCESS FOR MACHINERY STORAGE AND UNDERBORE OPERATIONS

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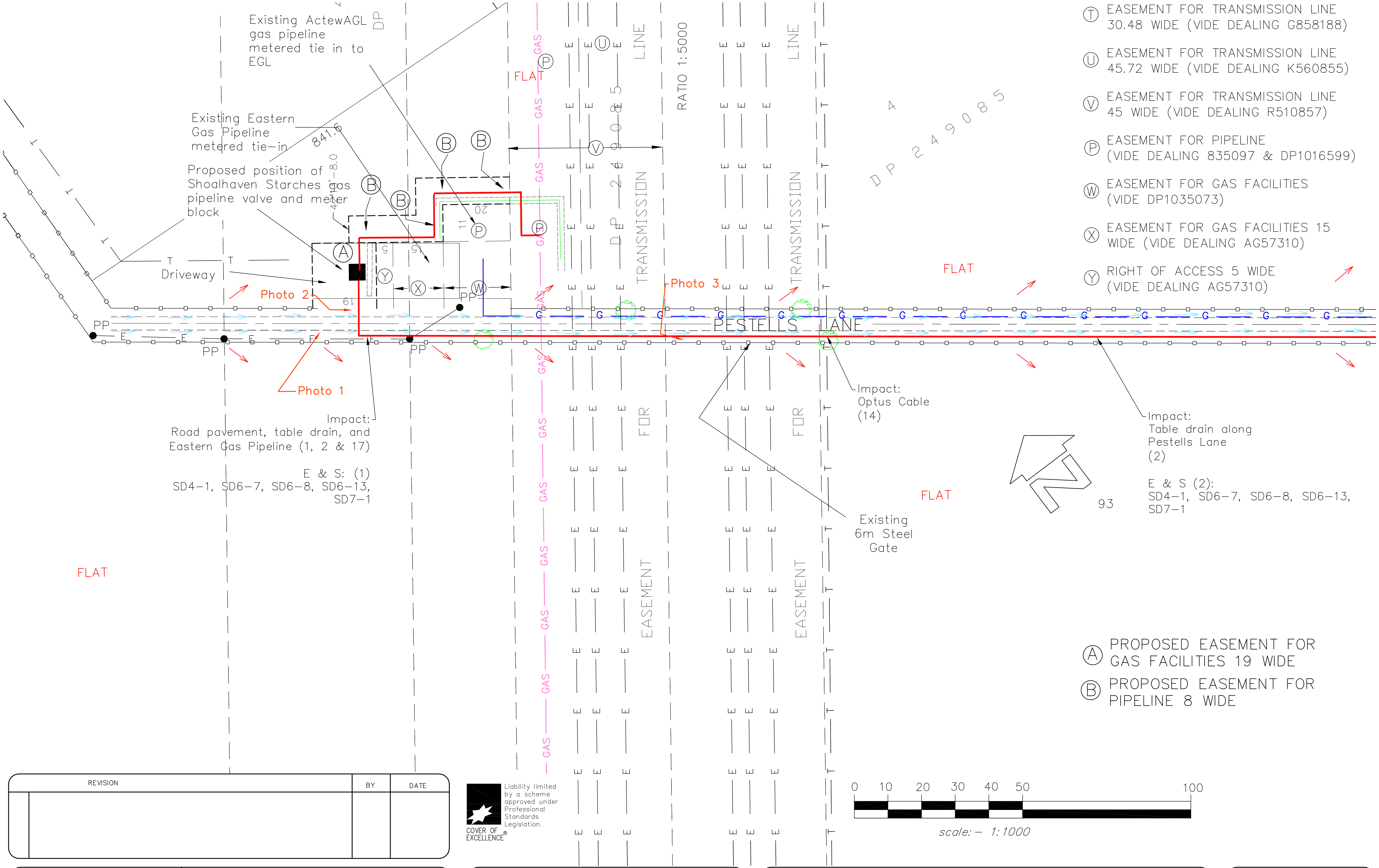

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sheet 2 of 16
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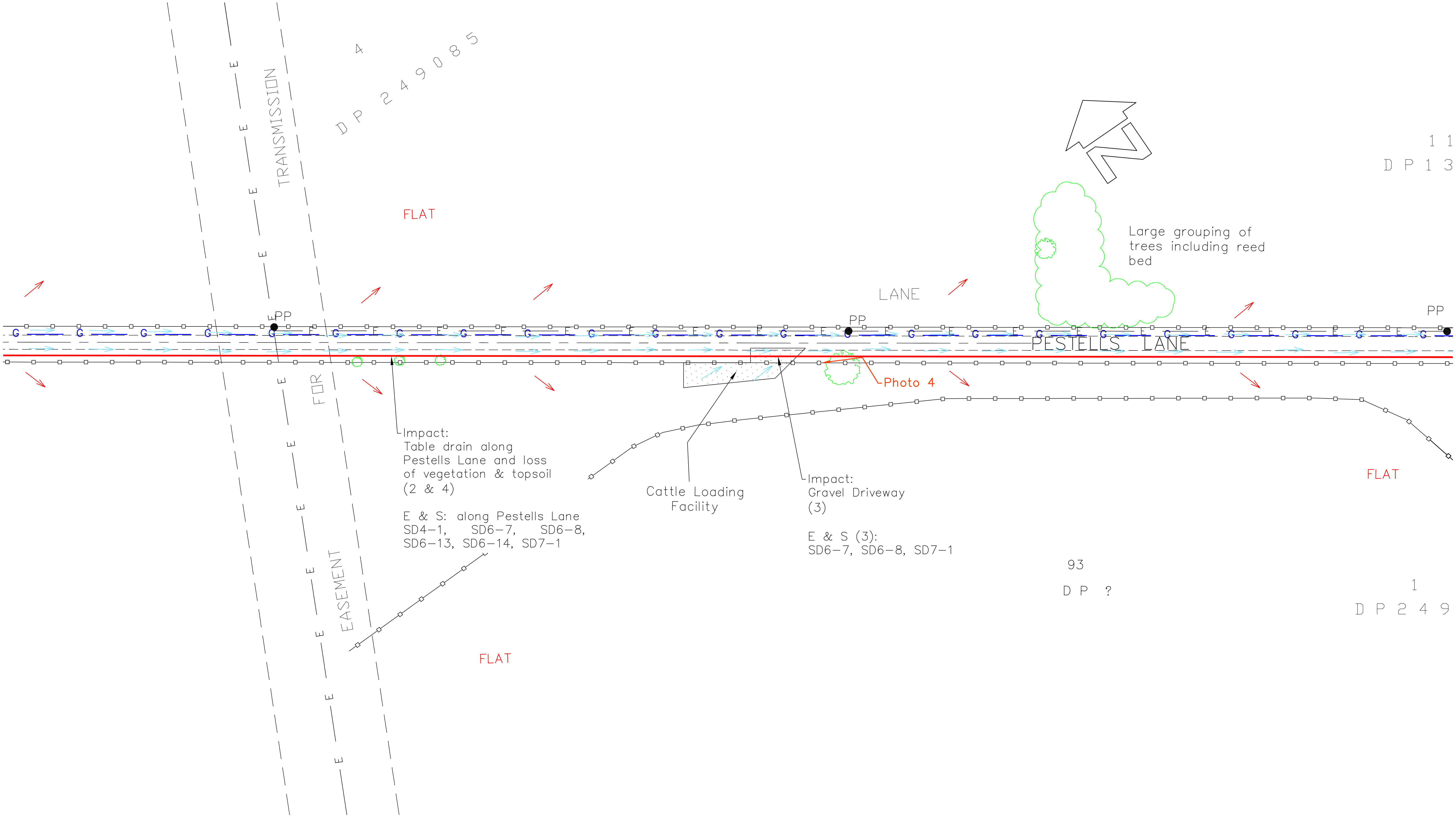

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sheet 3 of 16

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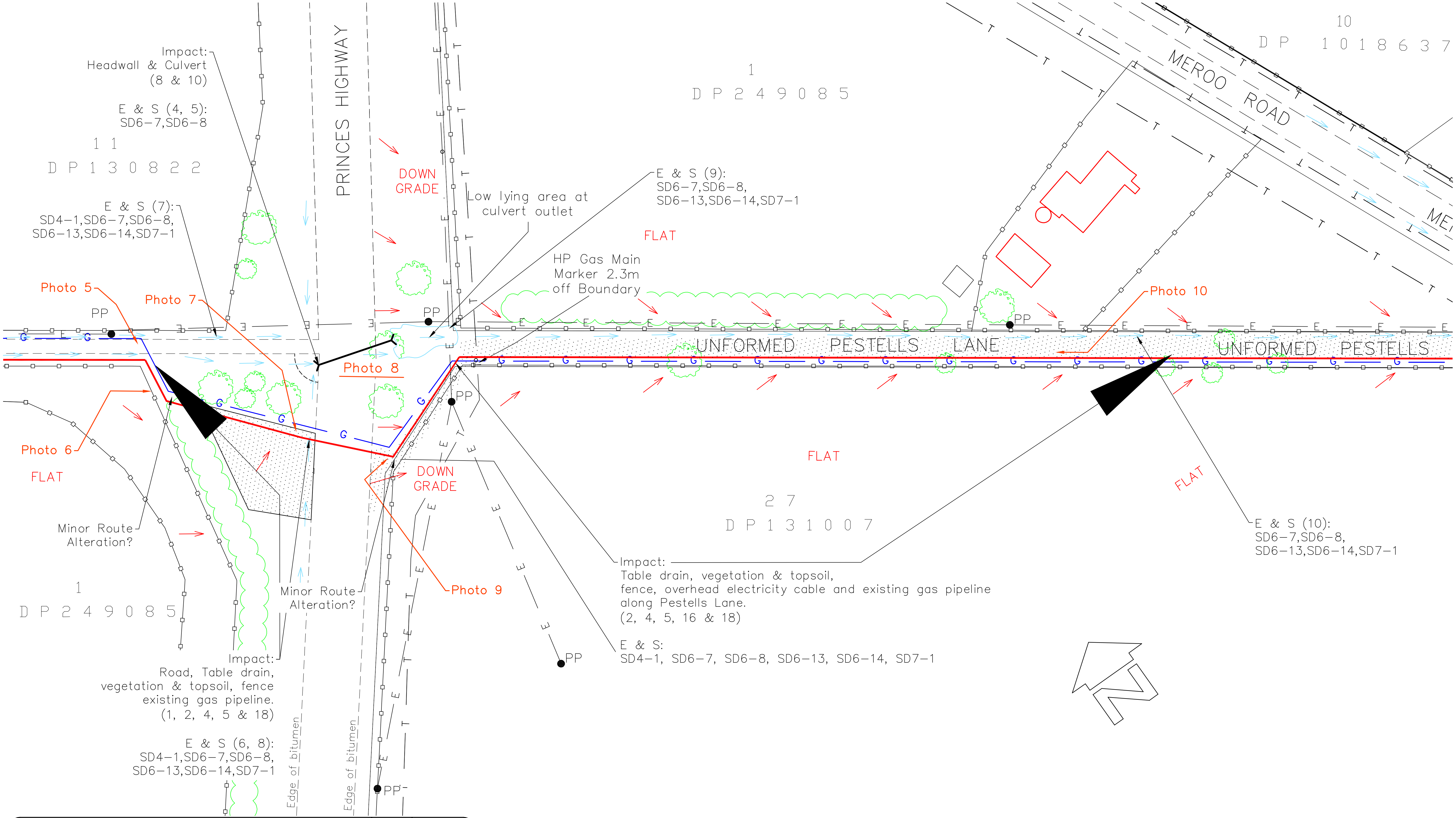

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sheet 4 of 16
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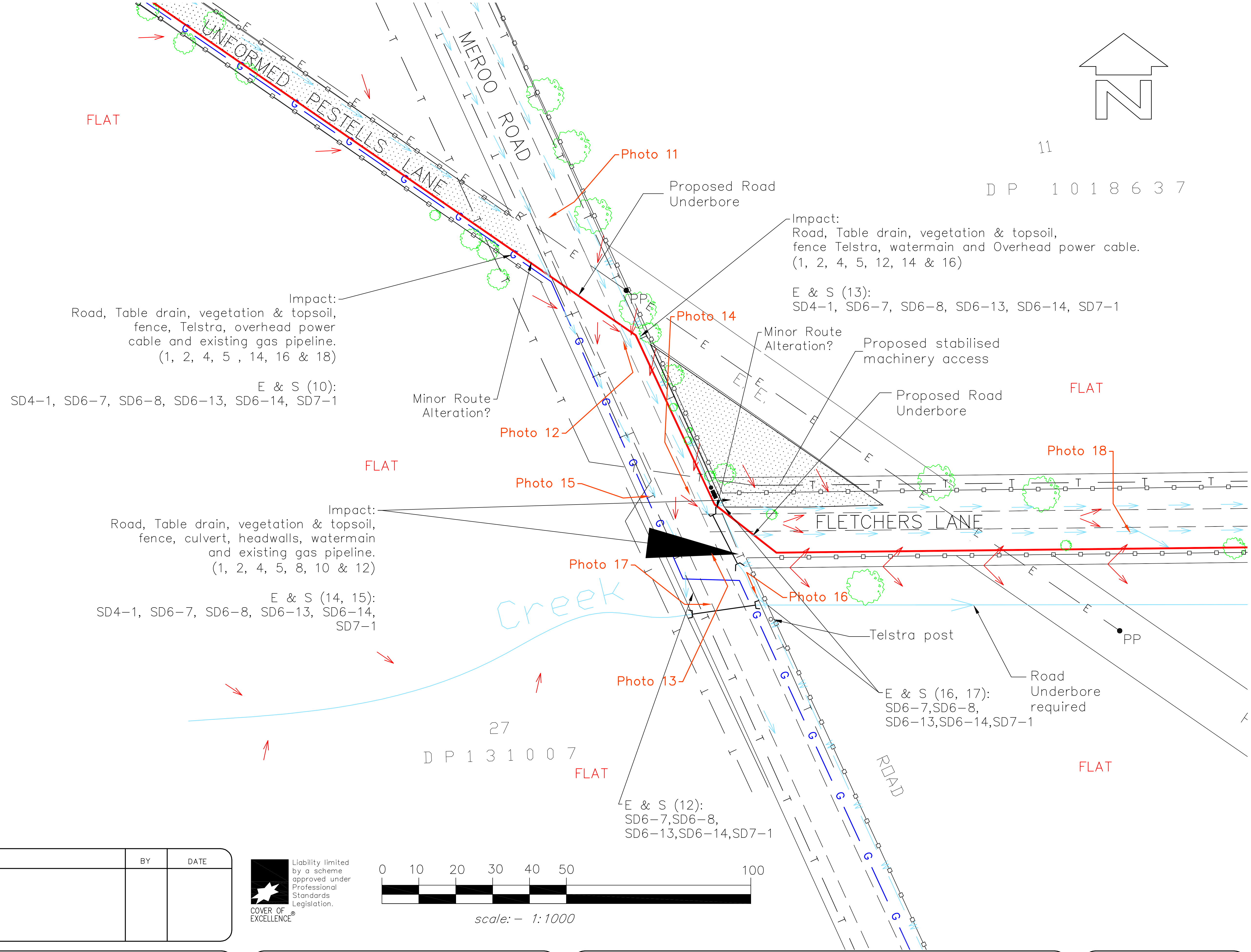

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sheet 5 of 16

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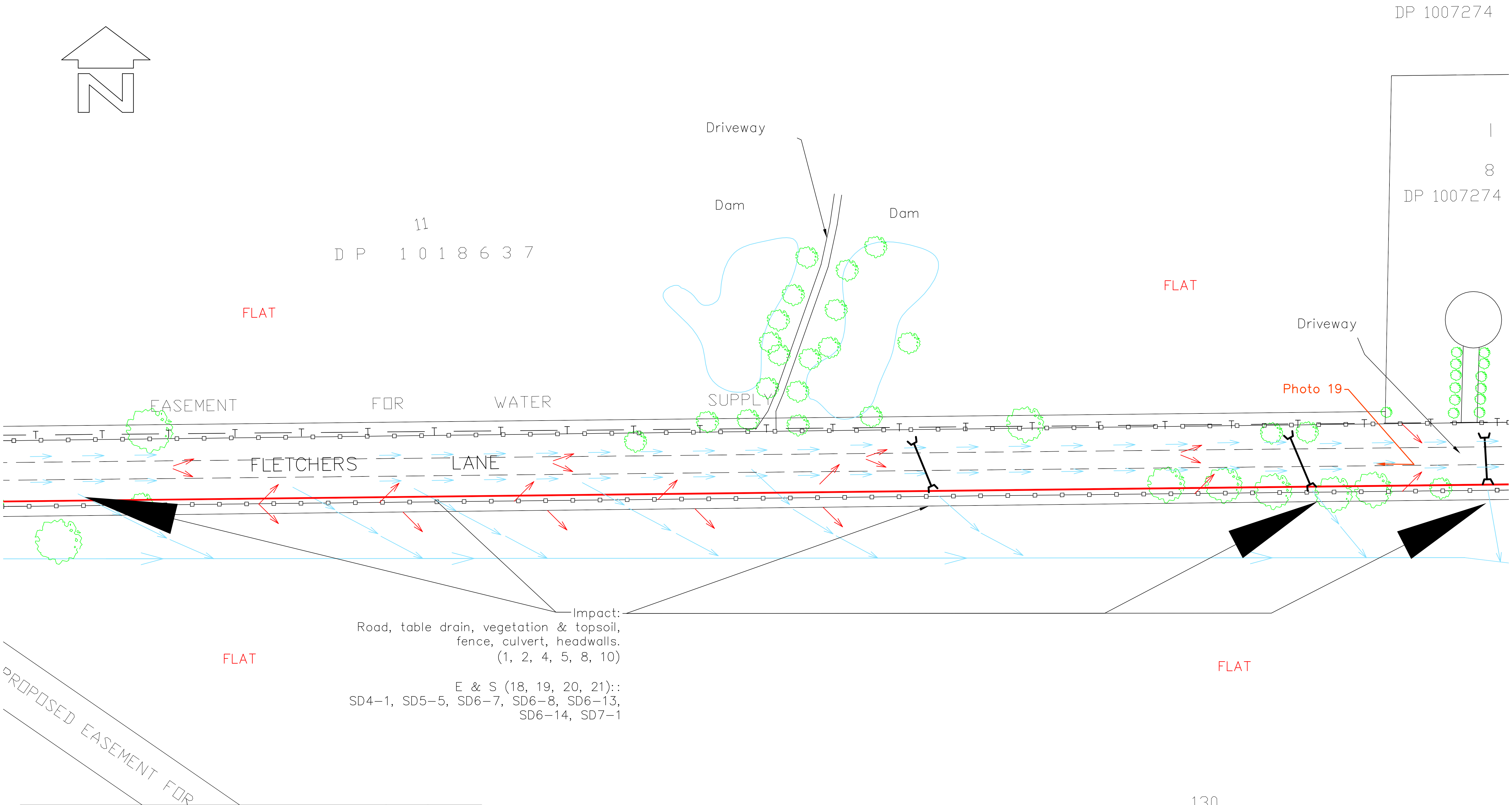

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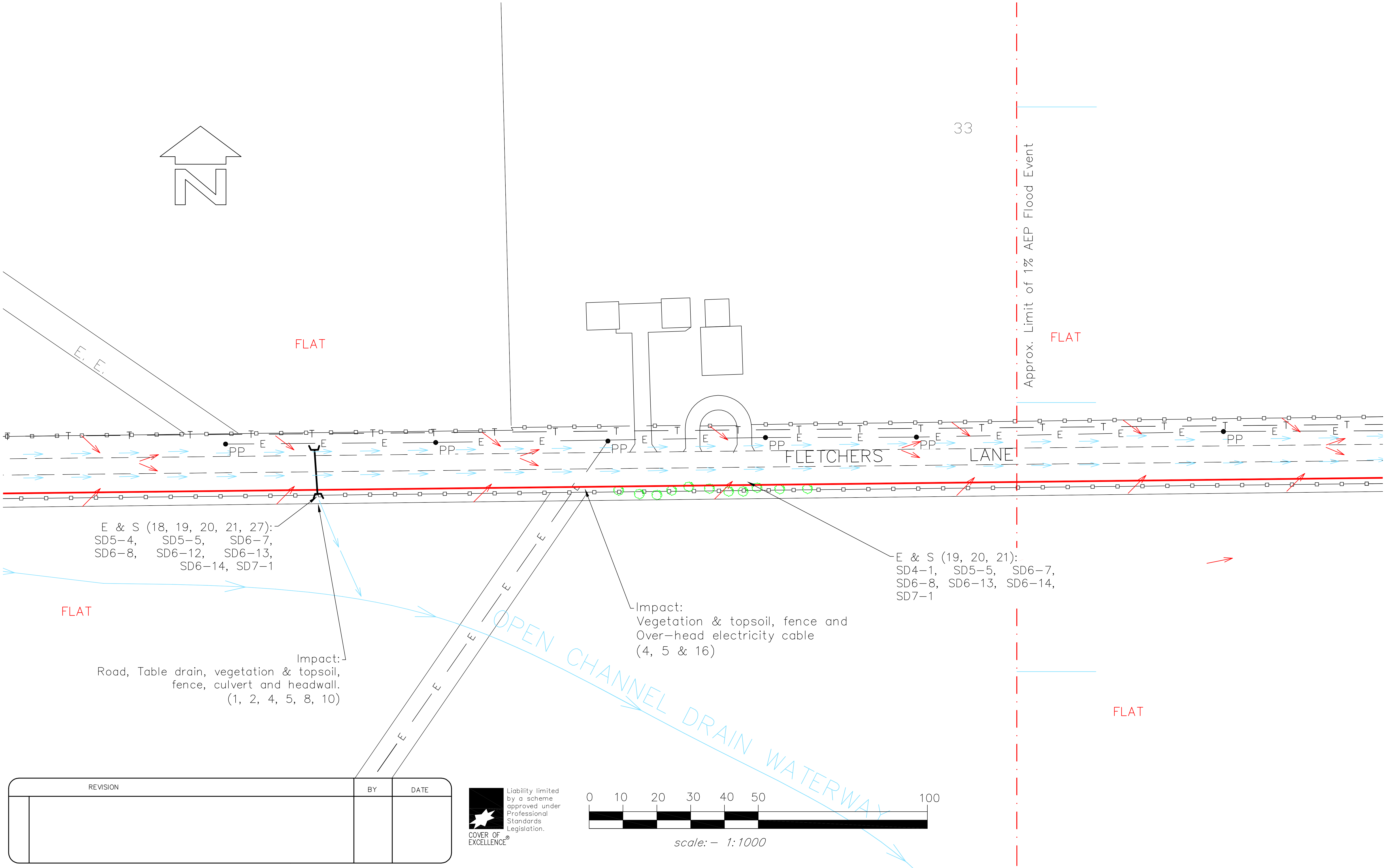

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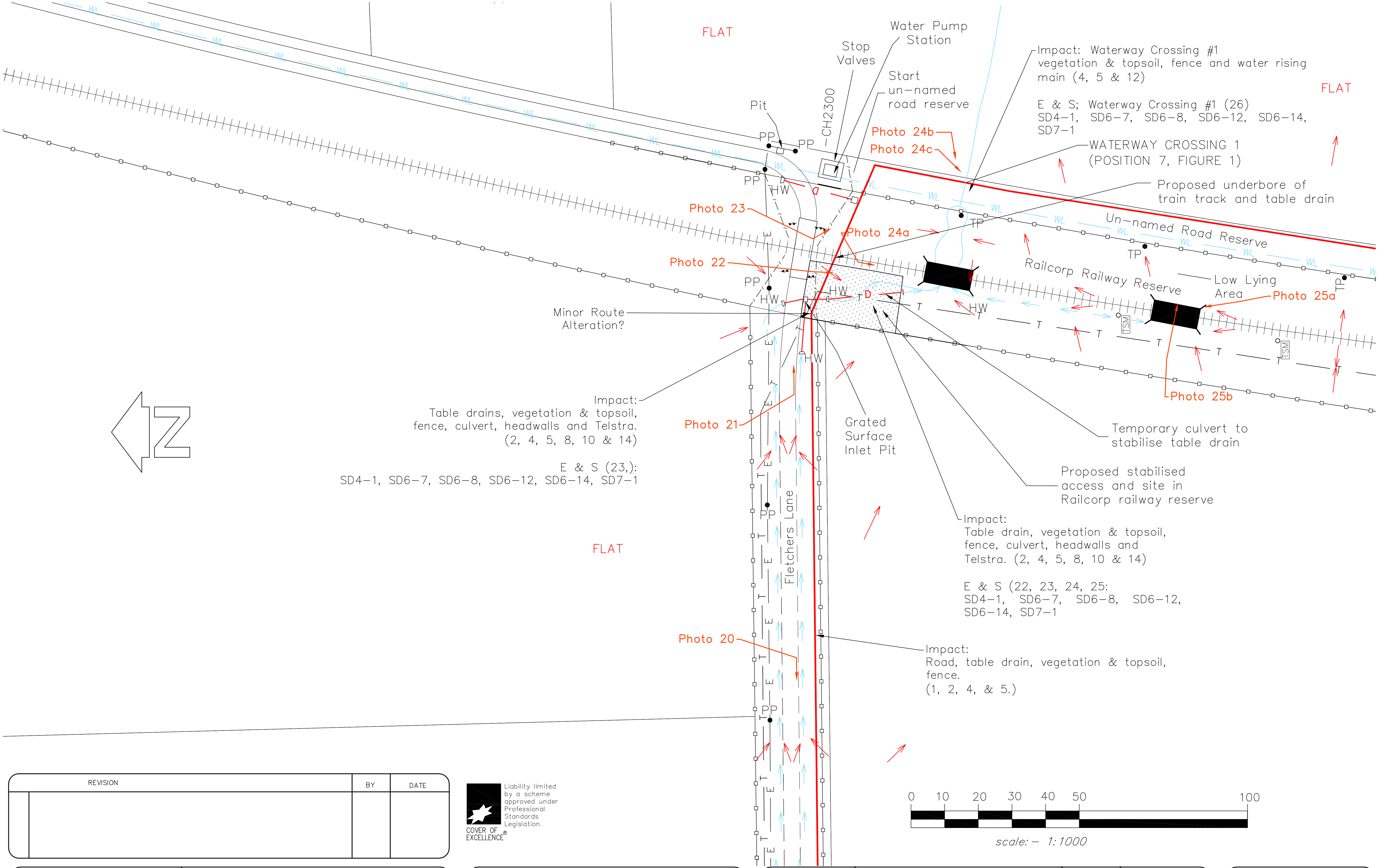

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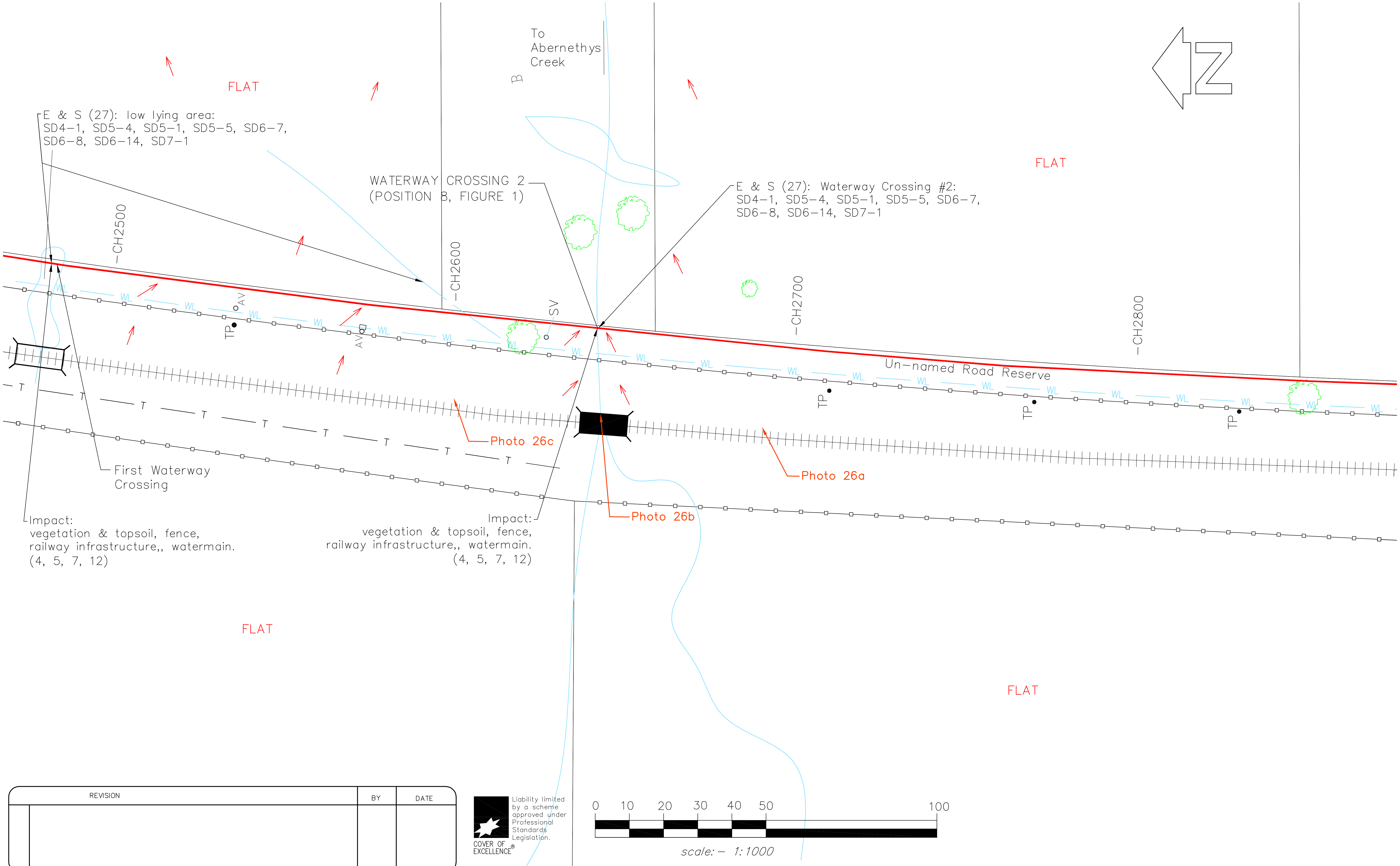

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sheet 9 of 16

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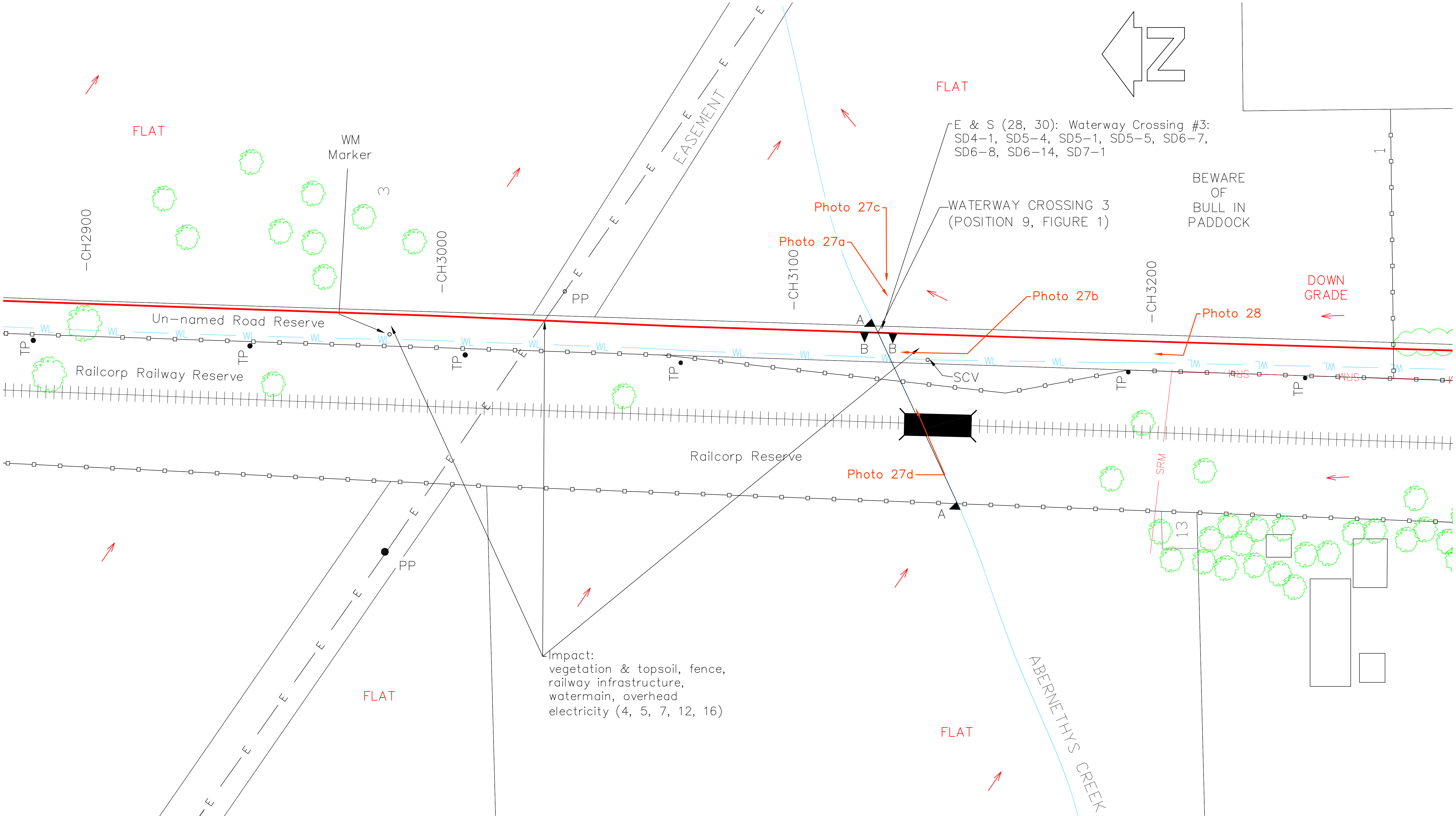

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sheet 10 of 16
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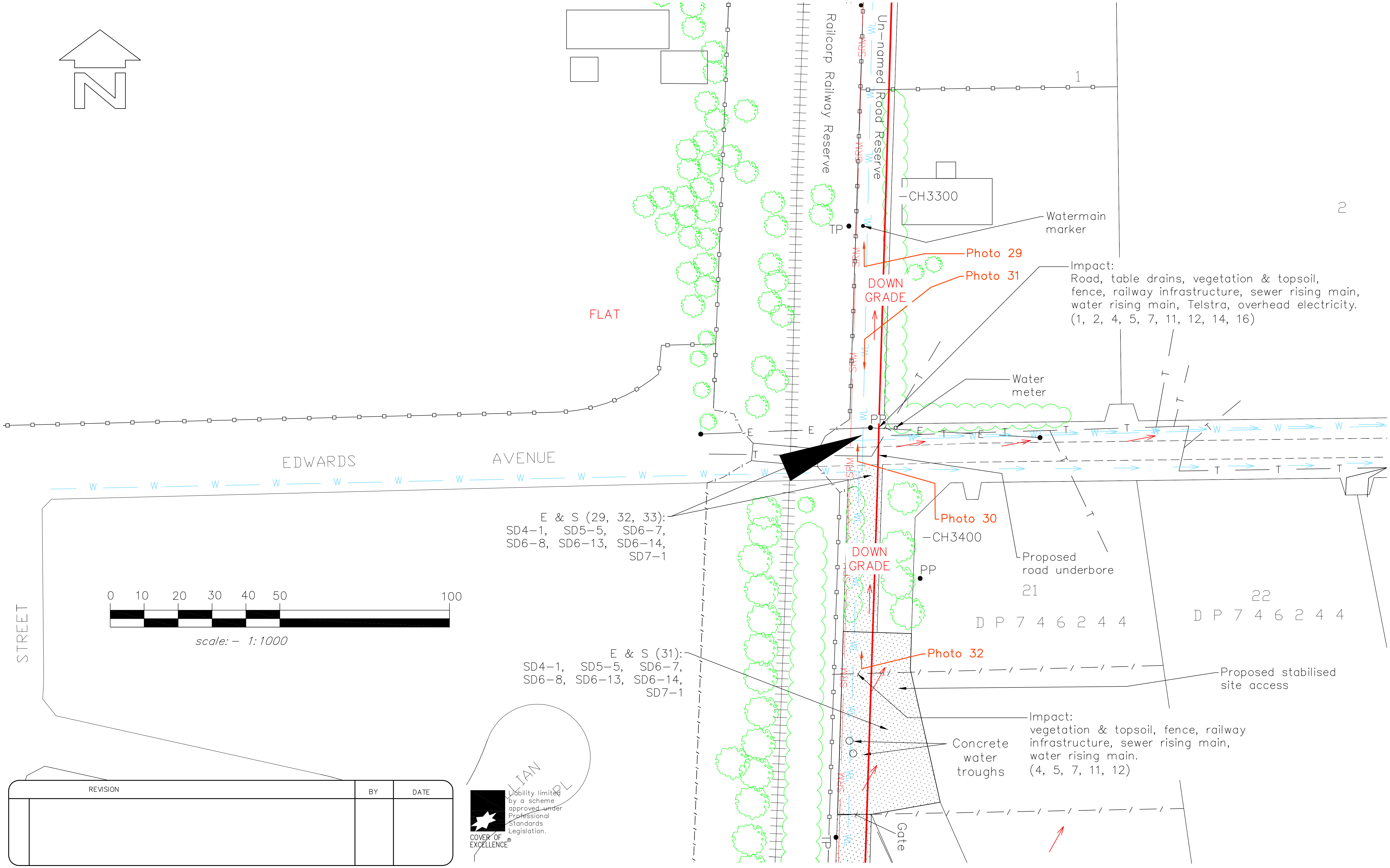

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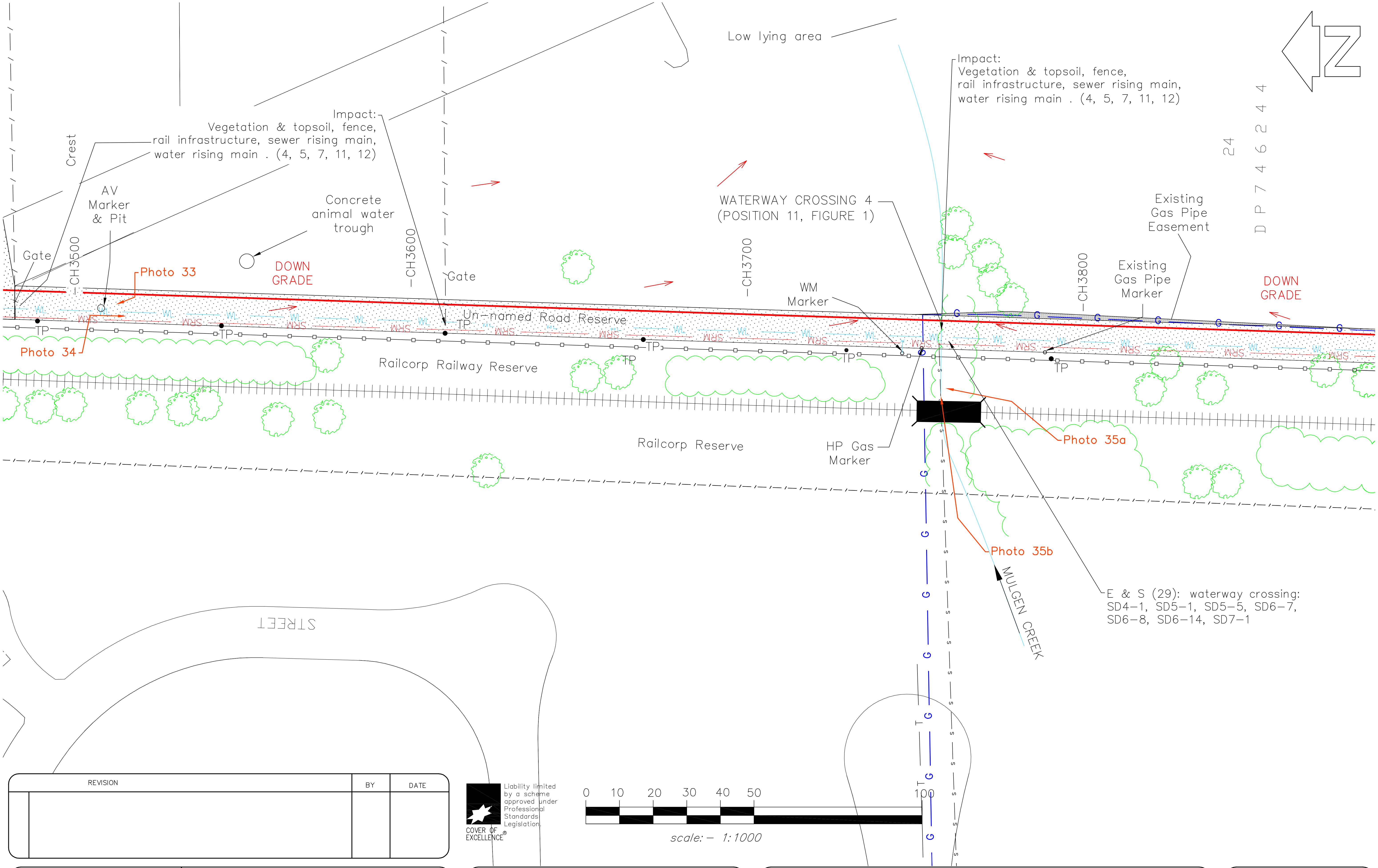

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EROSION & SEDIMENT CONTROL MANAGEMENT PLAN FOR PROPOSED SHOALHAVEN STARCHES GAS PIPELINE, FROM PESTELLS LANE TO THE BOLONG ROAD FACTORY

REF. No. 24710-04

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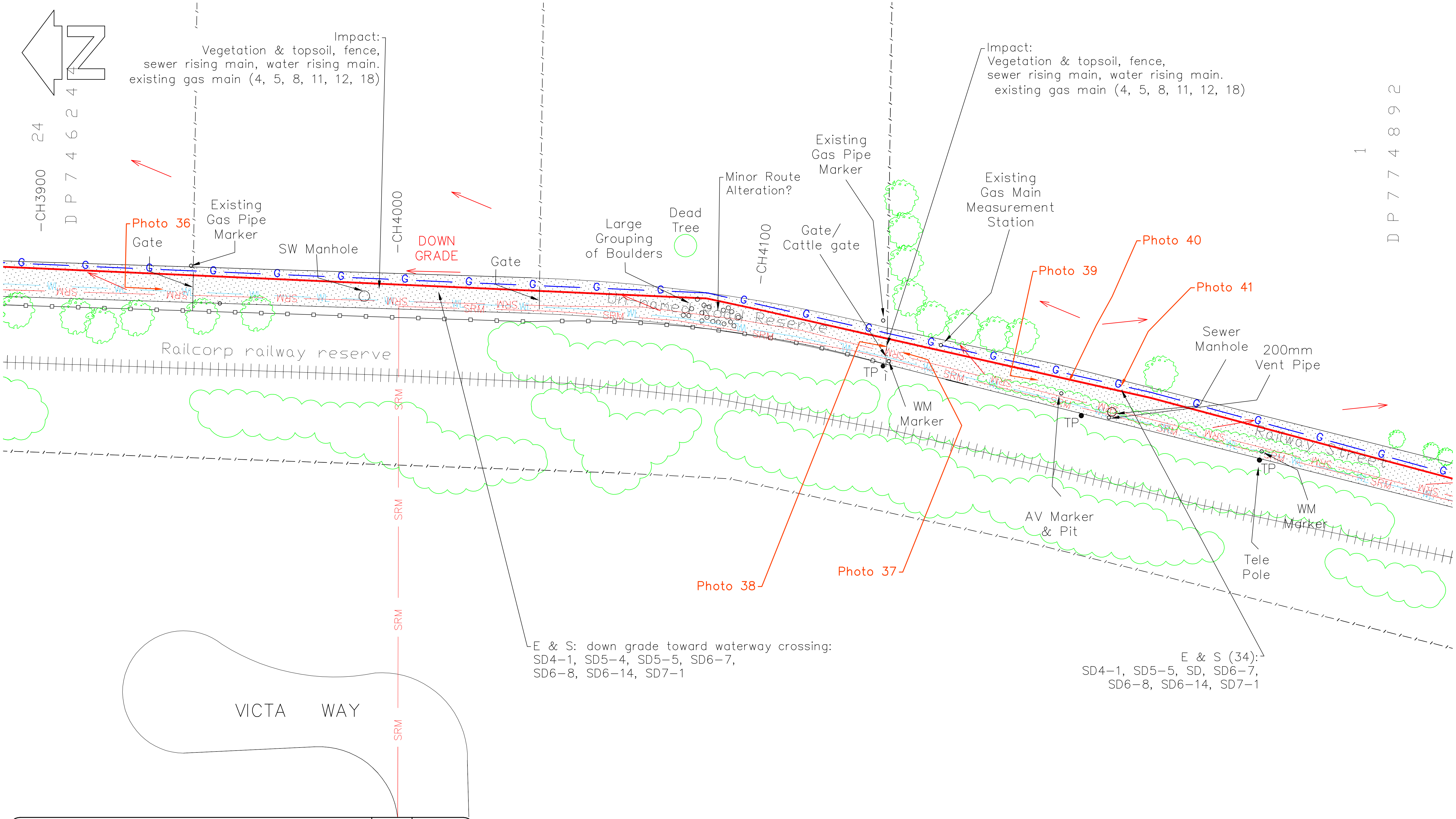

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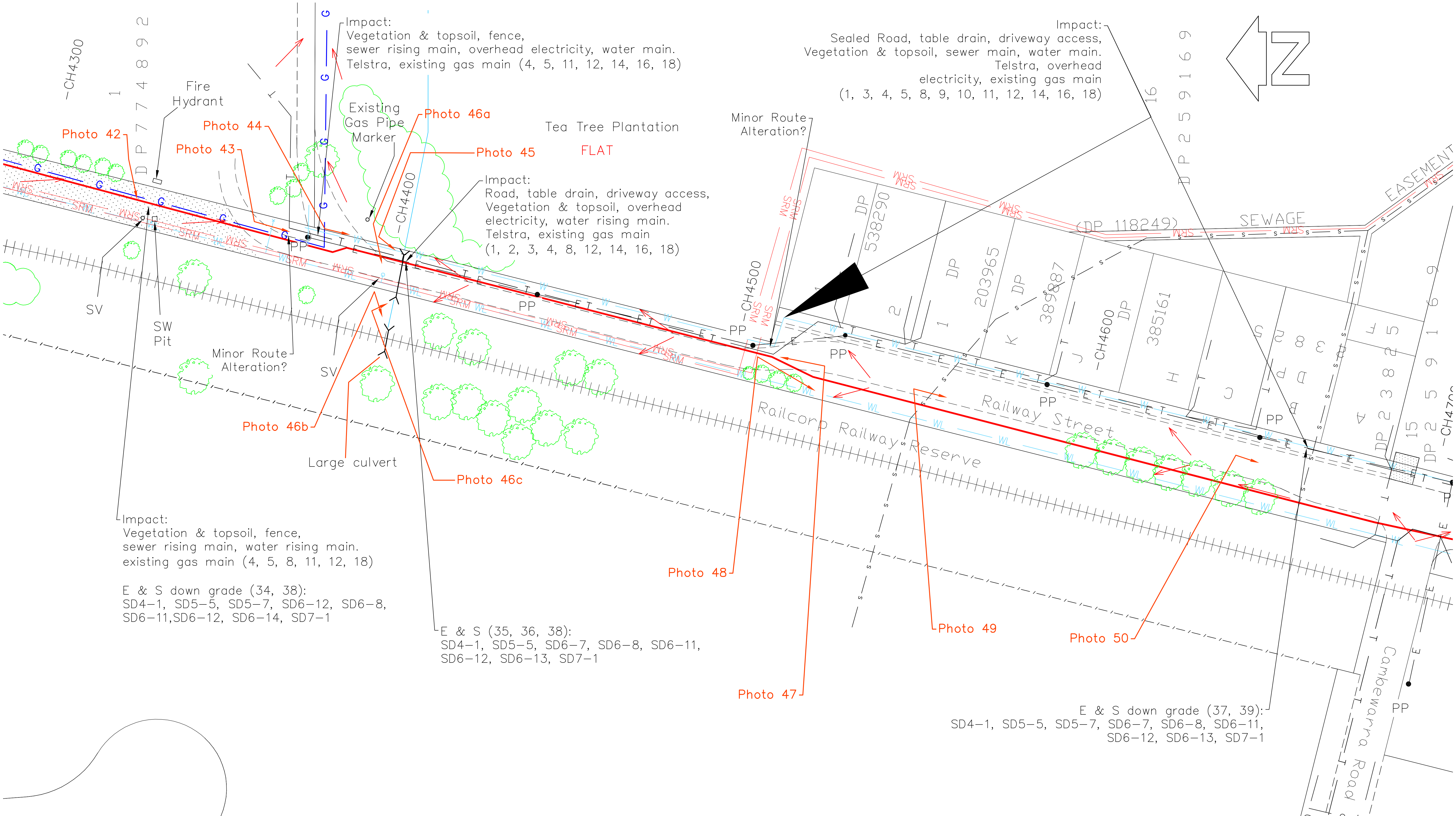

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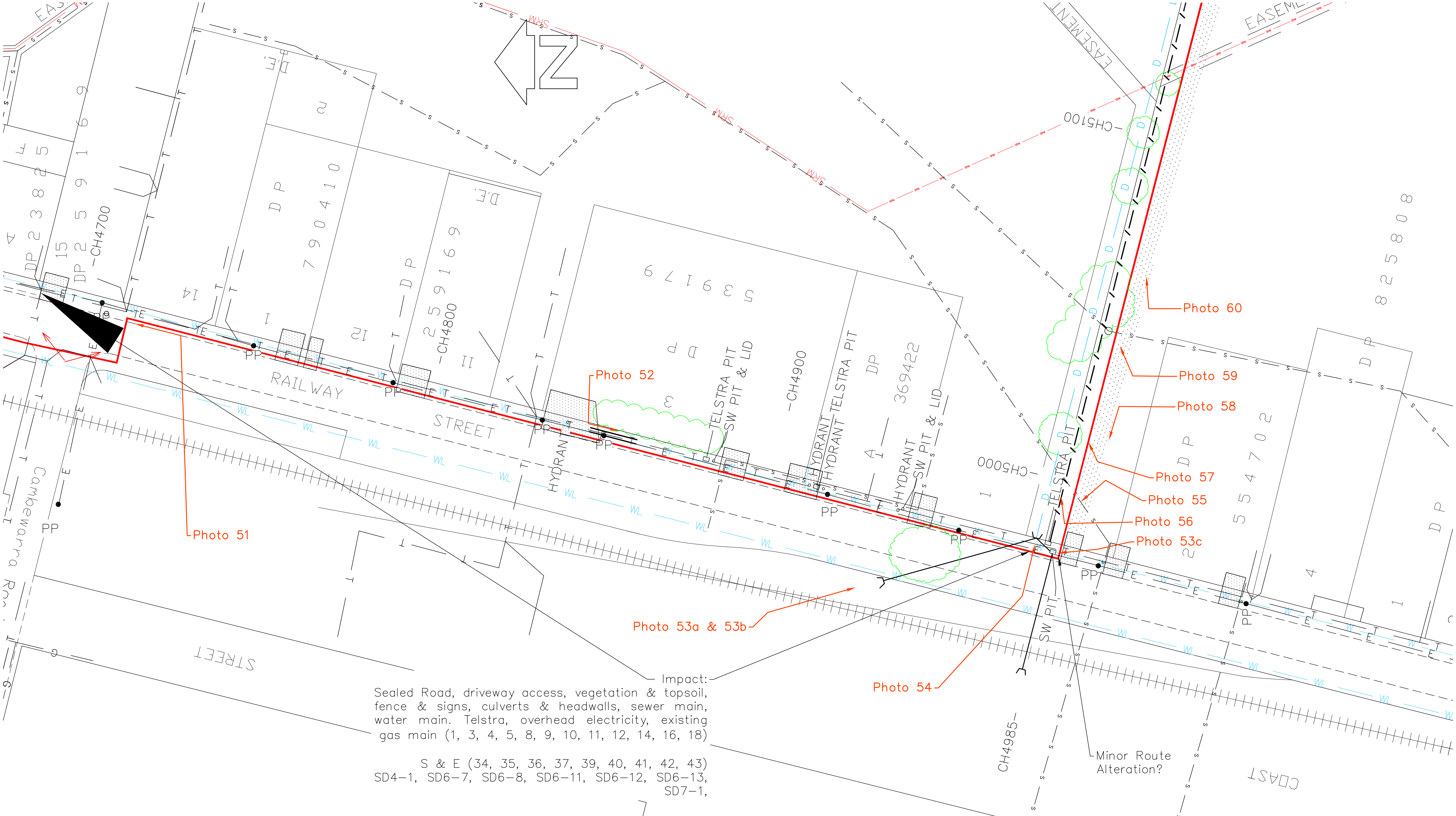

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sheet 15 of 16

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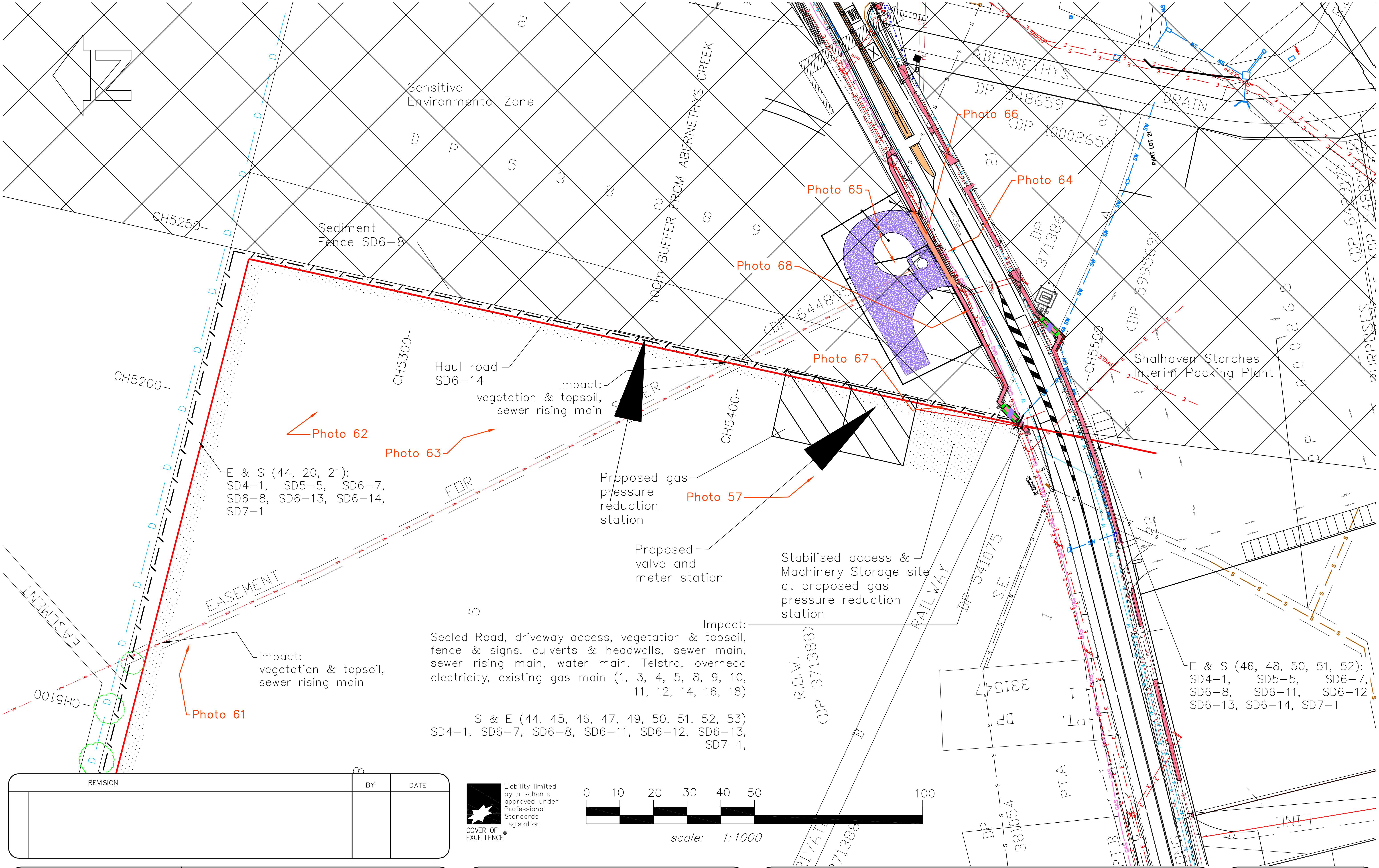

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sheet 16 of 16
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Appendix D – Erosion and Sediment Control Figures

Appendix D:

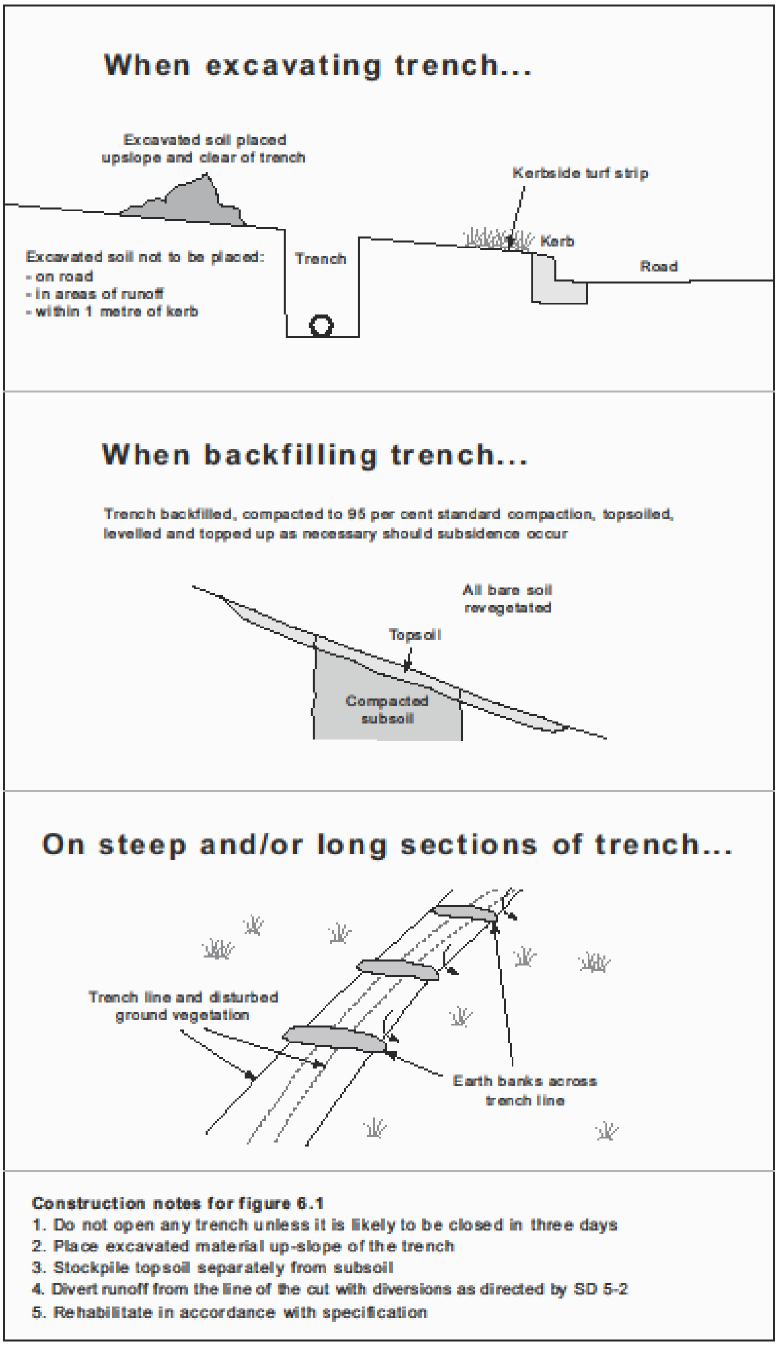


Figure 2: Erosion and sediment control details for trench construction on steep sites

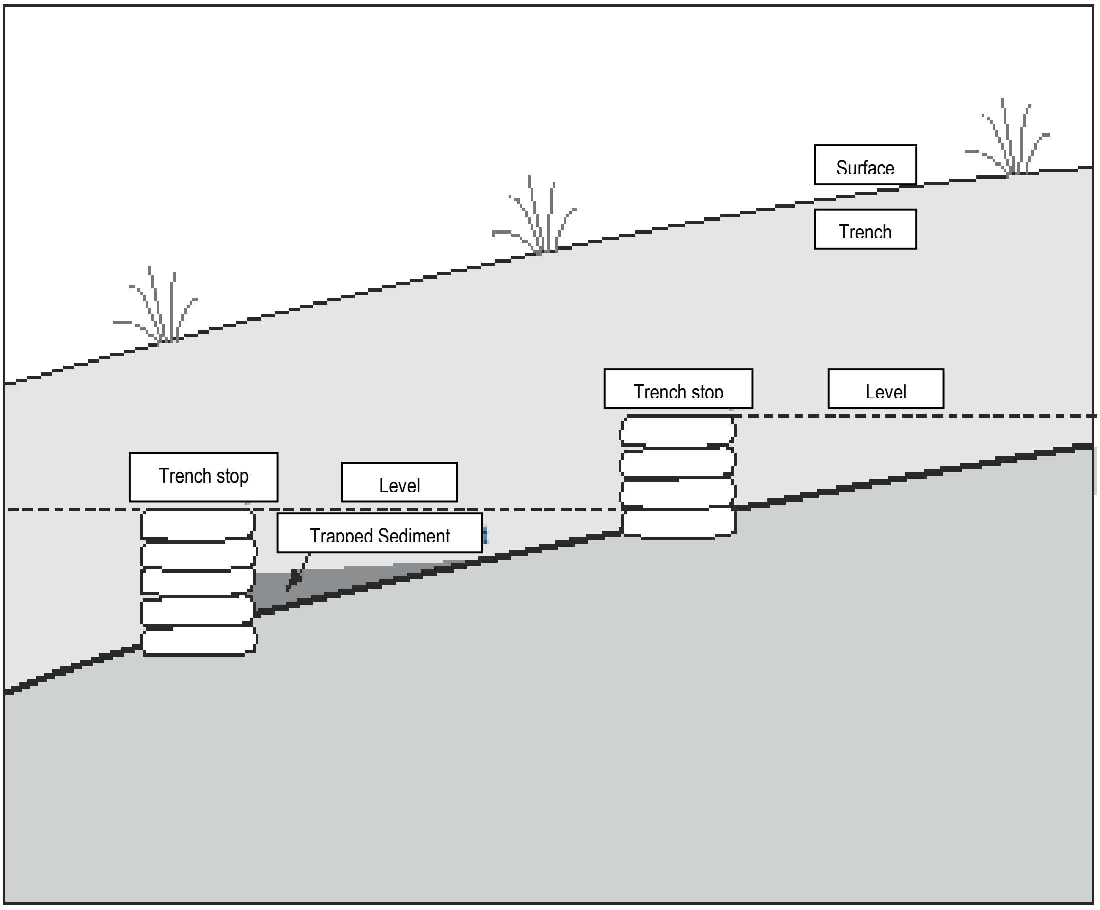
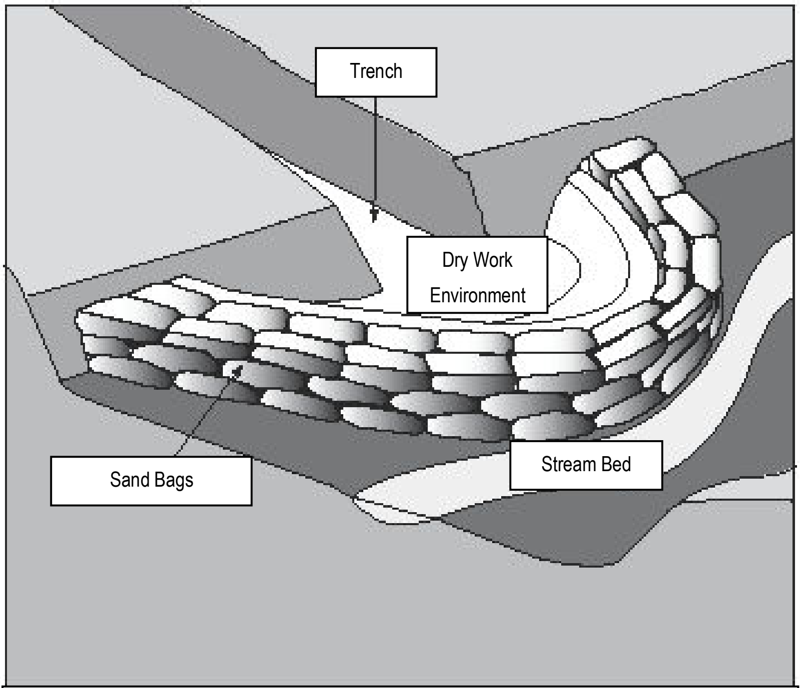
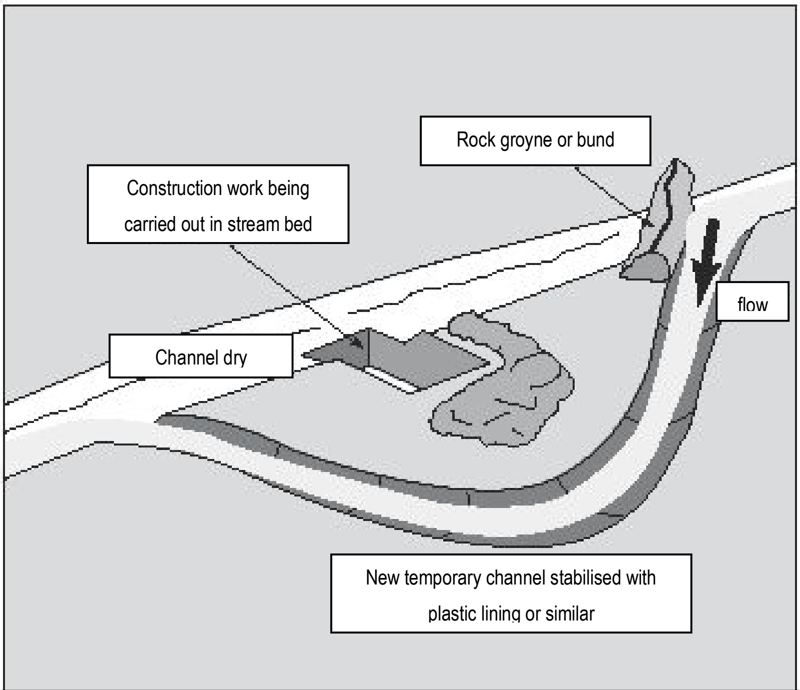


Figure 3: Typical trench stop detail for steep grades

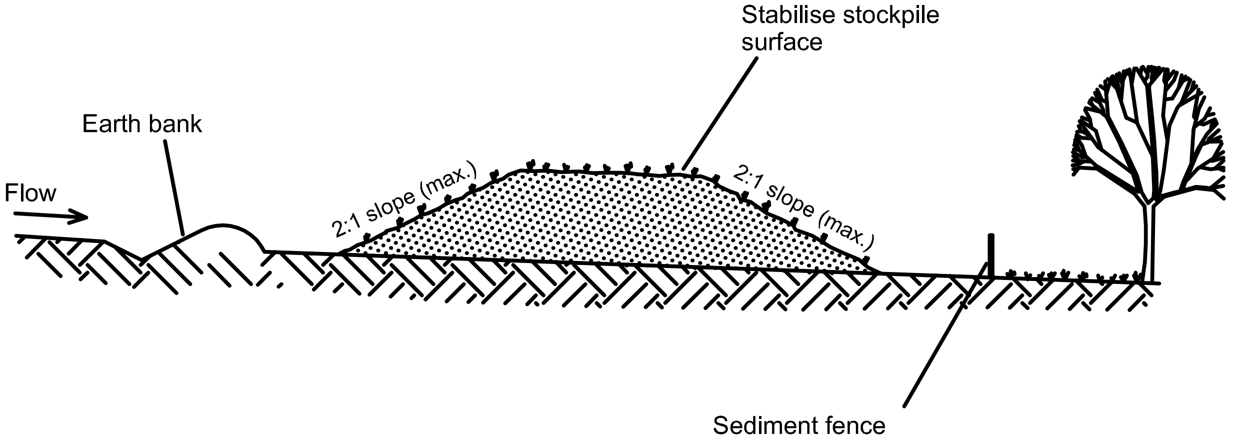


Option 1 – Stream diversion located within stream bed



Option 2 – Stream diversion via a new excavated channel

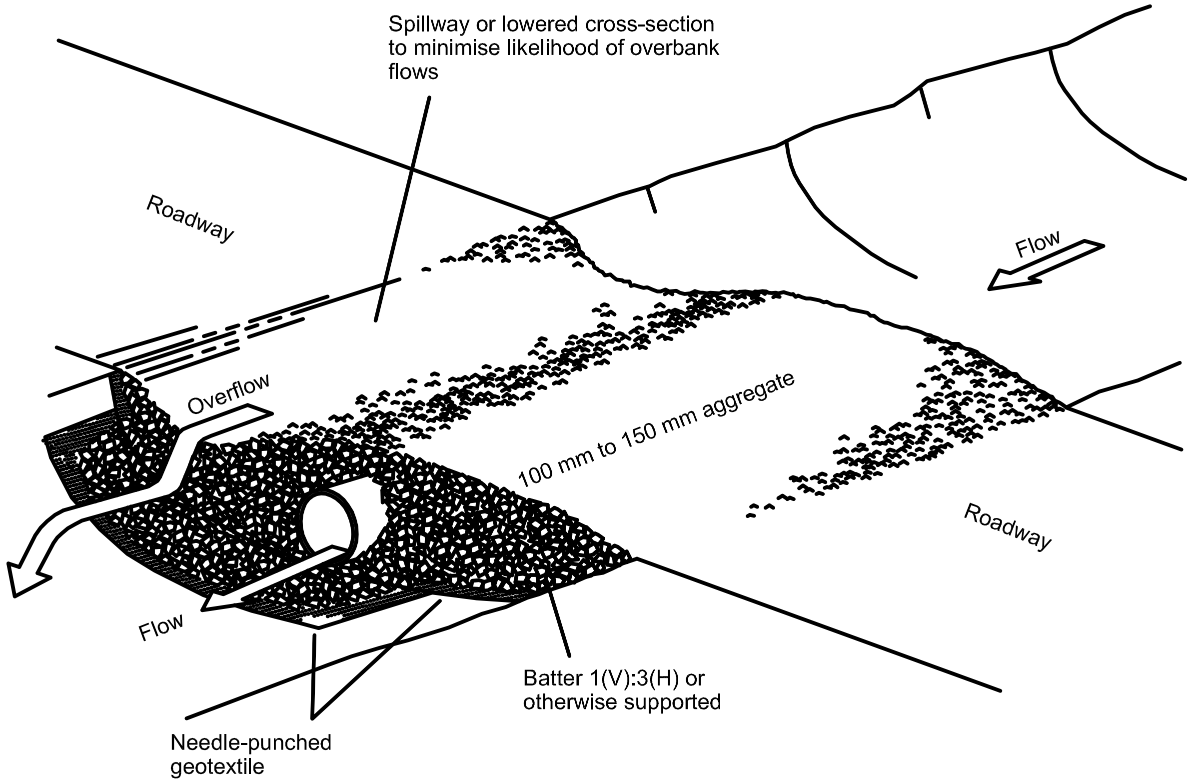
Figure 4: Typical options for waterway crossings



Construction Notes

1. Place stockpiles more than 2 (preferably 5) metres from existing vegetation, concentrated water flow, roads and hazard areas.
2. Construct on the contour as low, flat, elongated mounds.
3. Where there is sufficient area, topsoil stockpiles shall be less than 2 metres in height.
4. Where they are to be in place for more than 10 days, stabilise following the approved ESCP or SWMP to reduce the C-factor to less than 0.10.
5. Construct earth banks (Standard Drawing 5-5) on the upslope side to divert water around stockpiles and sediment fences (Standard Drawing 6-8) 1 to 2 metres downslope.

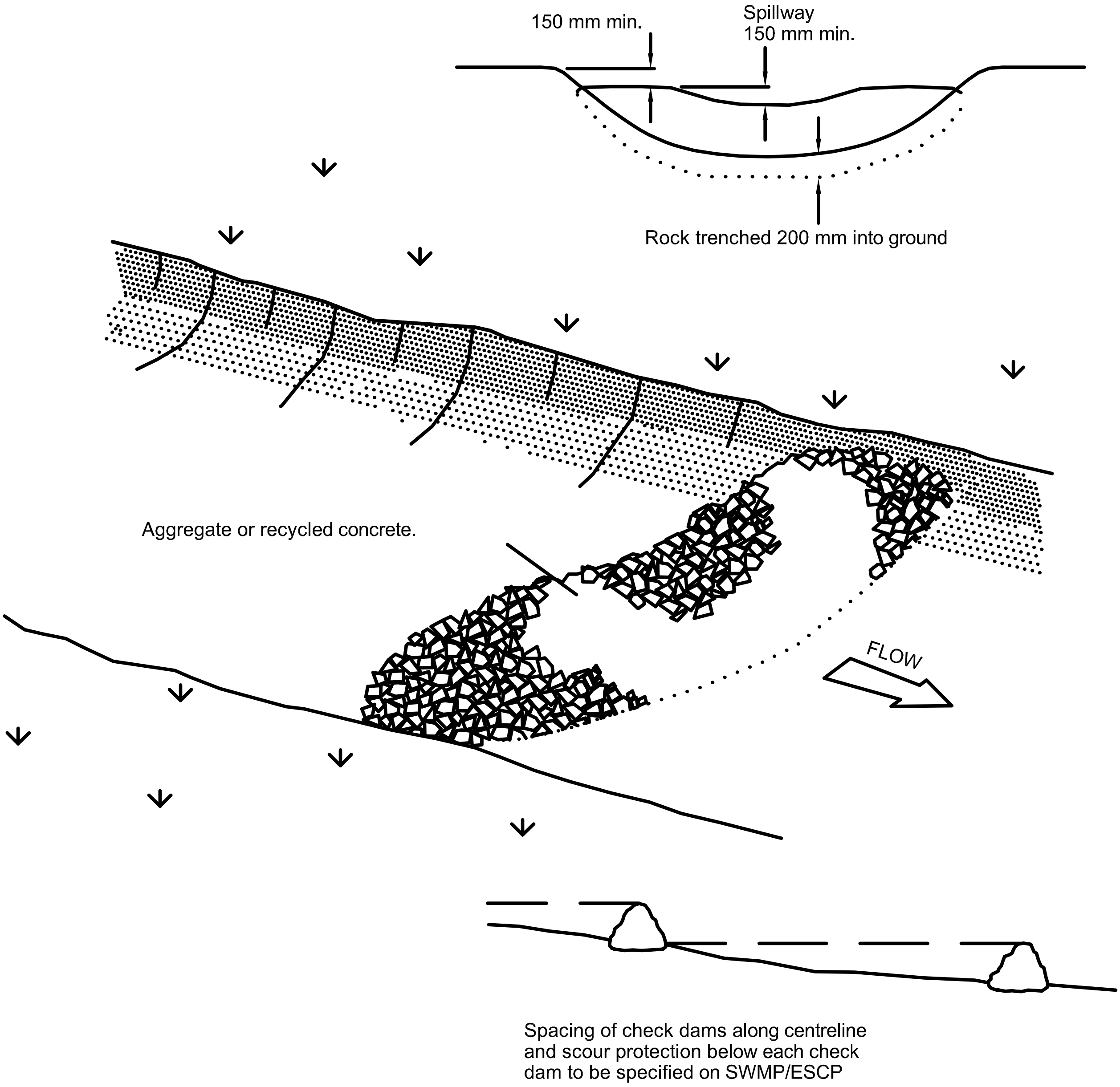
STOCKPILES SD 4-1



Construction Notes

1. Prohibit all traffic until the access way is constructed.
2. Strip any topsoil and place a needle-punched textile over the base of the crossing.
3. Place clean, rigid, non polluting aggregate or gravel in the 100 mm to 150 mm size class over the fabric to a minimum depth of 200 mm.
4. Provide a 3-metre wide carriageway with sufficient length of culvert pipe to allow less than a 3(H): 1 (V) slope on side batters.
5. Install a lower section to act as an emergency spillway in greater than design storm events.
6. Ensure that culvert outlets extend beyond the toe of fill embankments.

TEMPORARY WATERWAY CROSSING SD 5-1

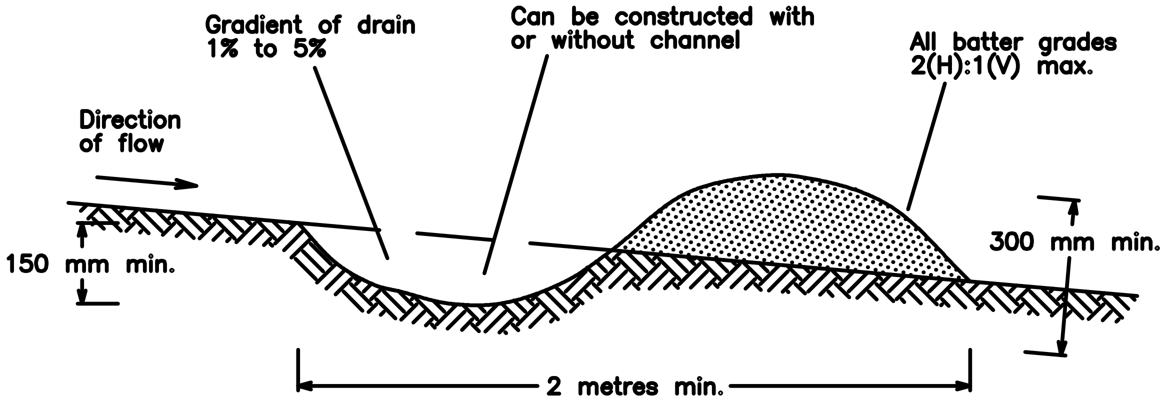


Construction Notes

1. Check dams can be built with various materials, including rocks, logs, sandbags and straw bales. The maintenance program should ensure their integrity is retained, especially where constructed with straw bales. In the case of bales, this might require their replacement each two to four months.
2. Trench the check dam 200 mm into the ground across its whole width. Where rock is used, fill the trenches to at least 100 mm above the ground surface to reduce the risk of undercutting.
3. Normally, their maximum height should not exceed 600 mm above the gully floor. The centre should act as a spillway, being at least 150 mm lower than the outer edges.
4. Space the dams so the toe of the upstream dam is level with the spillway of the next downstream dam.

ROCK CHECK DAM

SD 5-4



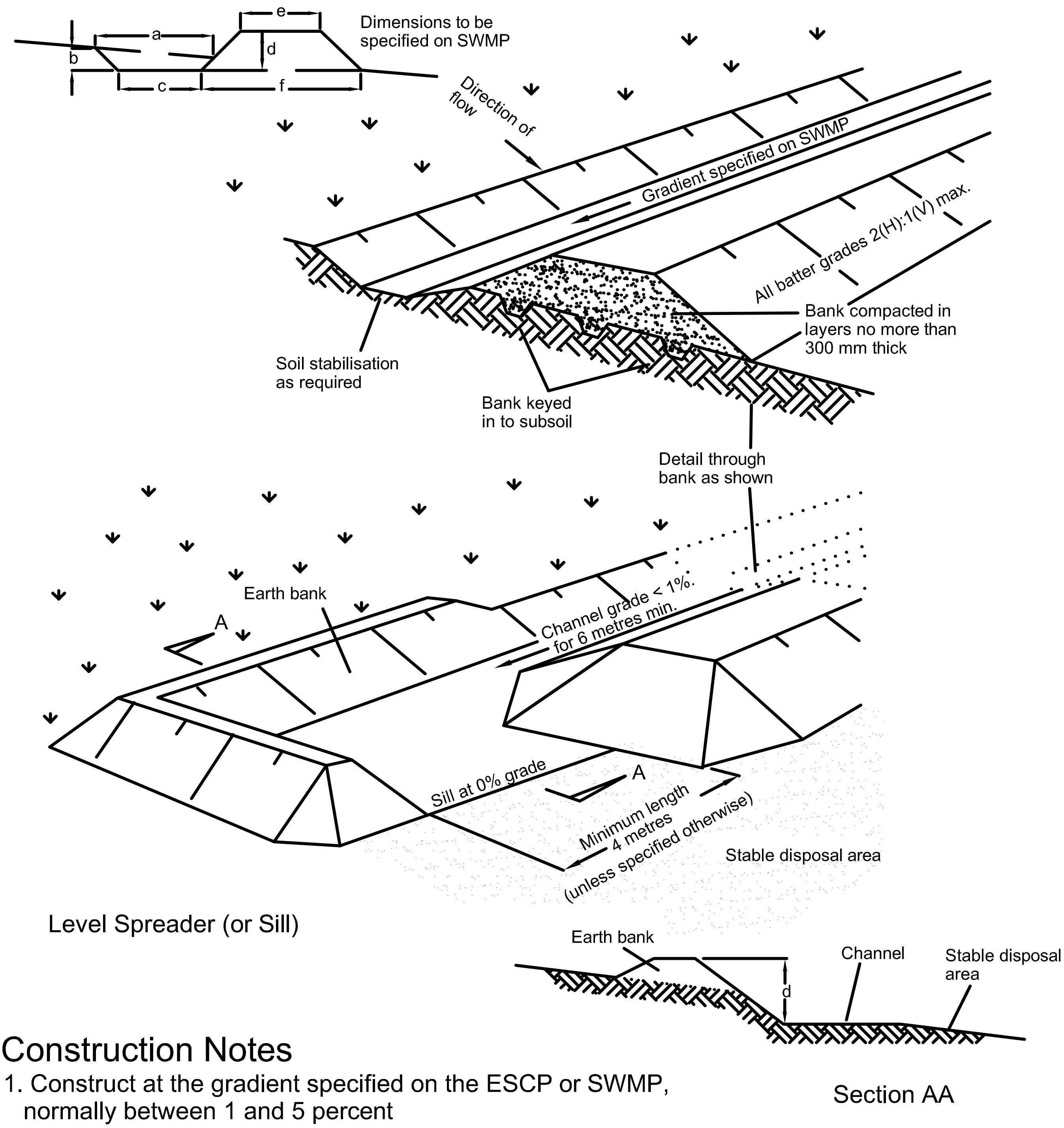
NOTE: Only to be used as temporary bank where maximum upslope length is 80 metres.

Construction Notes

1. Build with gradients between 1 percent and 5 percent.
2. Avoid removing trees and shrubs if possible - work around them.

3. Ensure the structures are free of projections or other irregularities that could impede water flow.
4. Build the drains with circular, parabolic or trapezoidal cross sections, not V shaped.
5. Ensure the banks are properly compacted to prevent failure.
6. Complete permanent or temporary stabilisation within 10 days of construction.

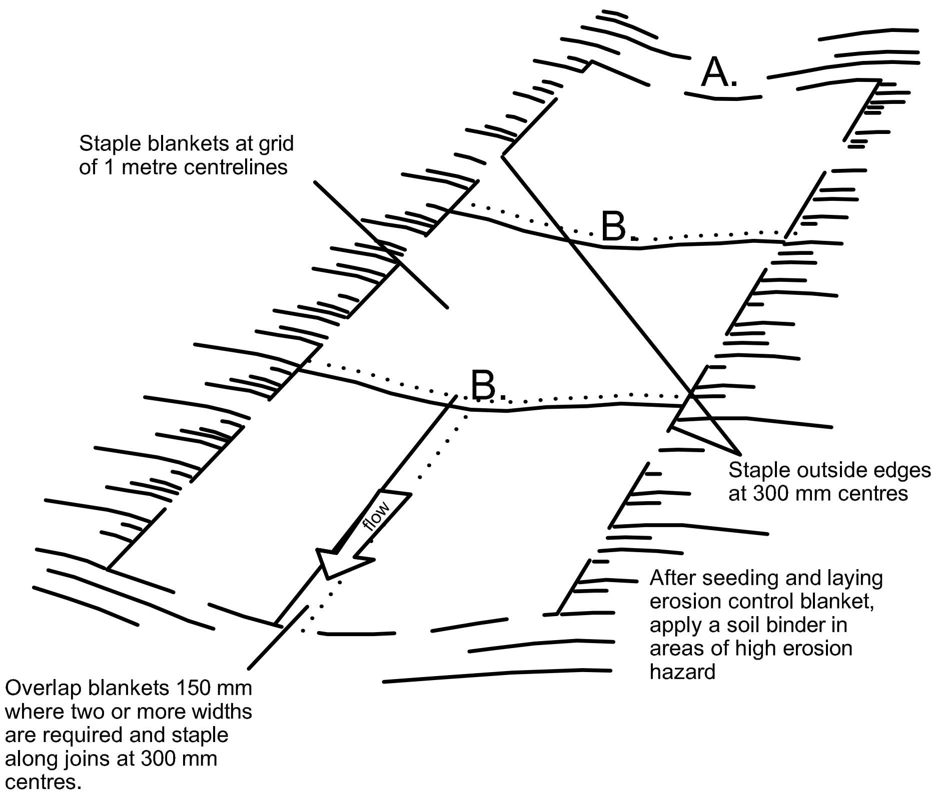
EARTH BANK (LOW FLOW) — SD 5-5

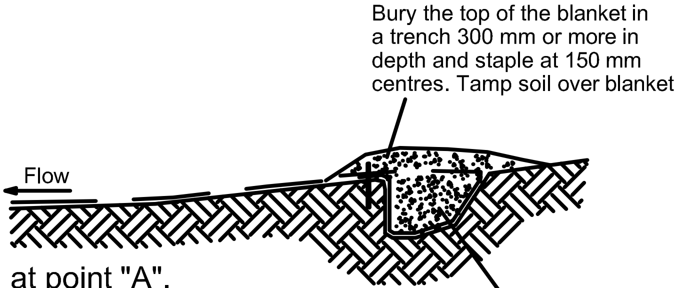


Construction Notes

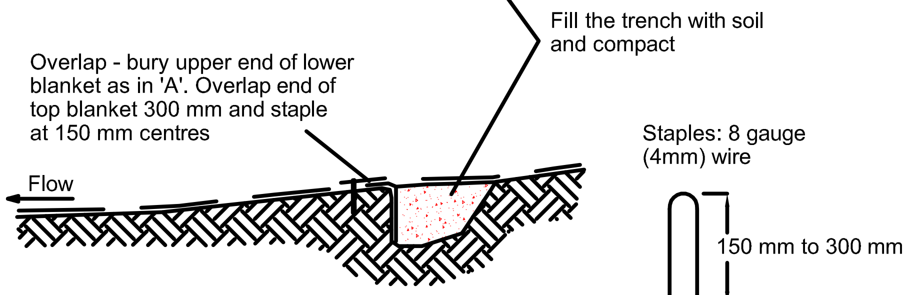
1. Construct at the gradient specified on the ESCP or SWMP, normally between 1 and 5 percent
2. Avoid removing trees and shrubs if possible - work around them.
3. Ensure the structures are free of projections or other irregularities that could impede water flow.
4. Build the drains with circular, parabolic or trapezoidal cross sections, not V-shaped, at the dimensions shown on the SWMP.
5. Ensure the banks are properly compacted to prevent failure.
6. Complete permanent or temporary stabilisation within 10 days of construction following Table 5.2 in Landcom (2004).
7. Where discharging to erodible lands, ensure they outlet through a properly constructed level spreader.
8. Construct the level spreader at the gradient specified on the ESCP or SWMP, normally less than 1 percent or level.
9. Where possible, ensure they discharge waters onto either stabilised or undisturbed disposal sites within the same subcatchment area from which the water originated. Approval might be required to discharge into other subcatchments.

EARTH BANK (HIGH FLOWS) SD 5-6





Centreline section at point "A".

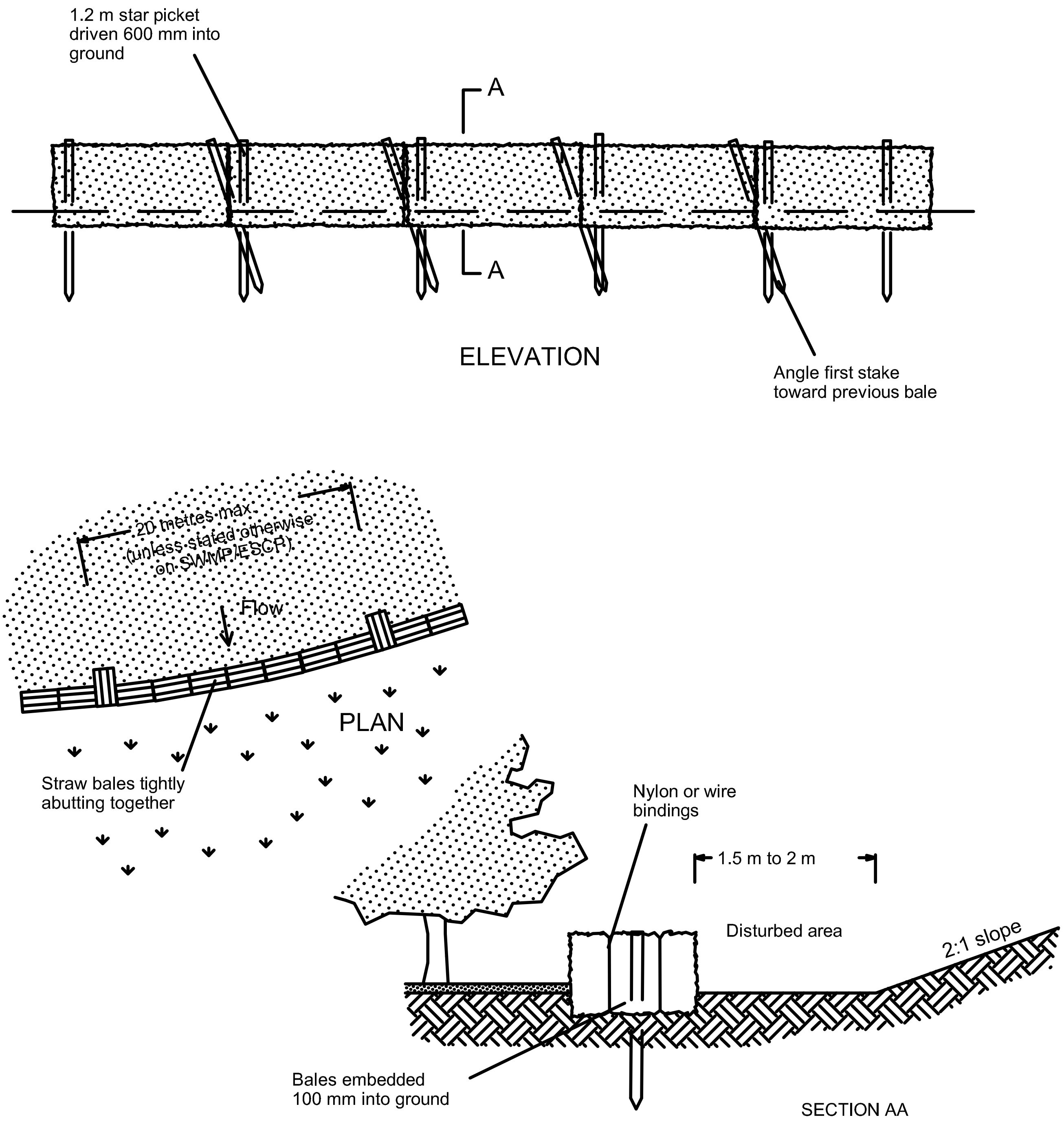


Centreline section at points "B".

Construction Notes

1. Remove any rocks, clods, sticks or grass from the surface before laying matting
2. Ensure that topsoil is at least 75 mm deep.
3. Complete fertilising and seeding before laying the matting.
4. Ensure fabric will be continuously in contact with the soil by grading the surface carefully first.
5. Lay the fabric in "shingle-fashion", with the end of each upstream roll overlapping those downstream. Ensure each roll is anchored properly at its upslope end (Standard Drawing 5-7b).
6. Ensure that the full width of flow in the channel is covered by the matting up to the design storm event, usually in the 10-year ARI time of concentration storm event.
7. Divert water from the structure until vegetation is stabilised properly.

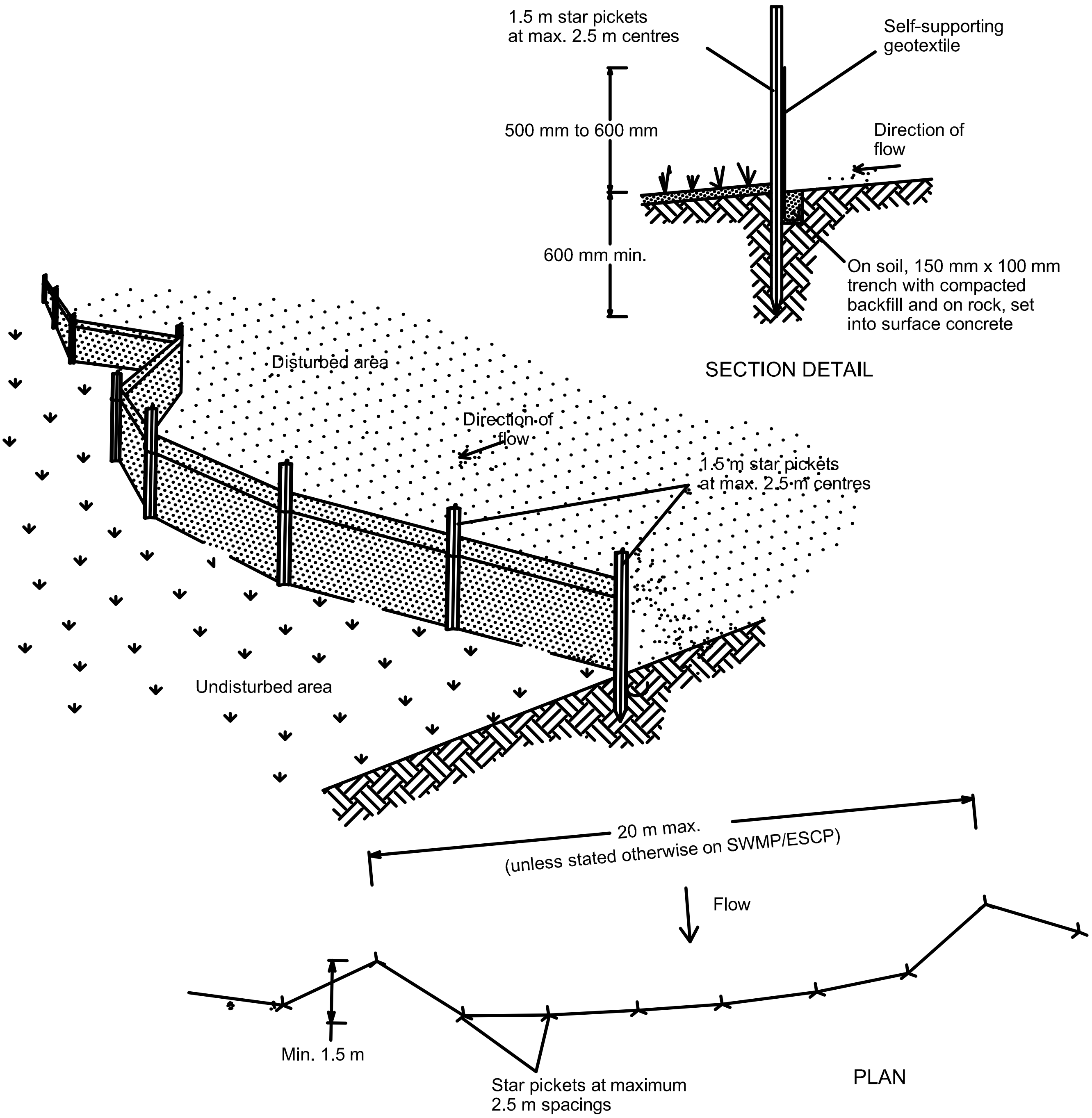
RECP : CONCENTRATED FLOW SD 5-7



Construction Notes

1. Construct the straw bale filter as close as possible to being parallel to the contours of the site.
2. Place bales lengthwise in a row with ends tightly abutting. Use straw to fill any gaps between bales. Straws are to be placed parallel to ground.
3. Ensure that the maximum height of the filter is one bale.
4. Embed each bale in the ground 75 mm to 100 mm and anchor with two 1.2 metre star pickets or stakes. Angle the first star picket or stake in each bale towards the previously laid bale. Drive them 600 mm into the ground and, if possible, flush with the top of the bales. Where star pickets are used and they protrude above the bales, ensure they are fitted with safety caps.
5. Where a straw bale filter is constructed downslope from a disturbed batter, ensure the bales are placed 1 to 2 metres downslope from the toe.
6. Establish a maintenance program that ensures the integrity of the bales is retained - they could require replacement each two to four months.

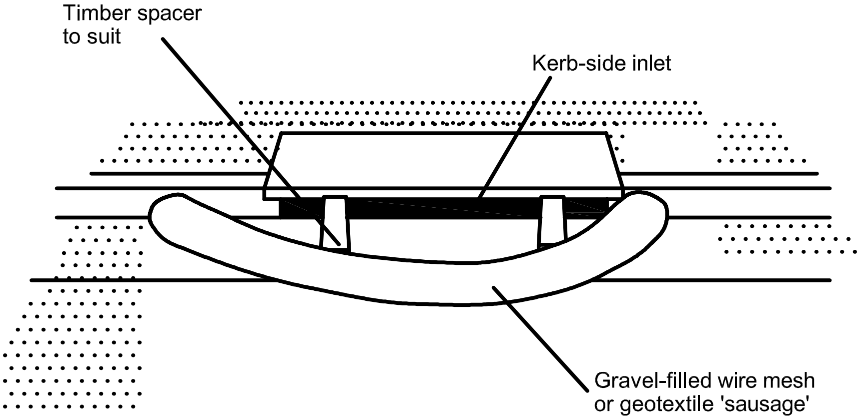
STRAW BALE FILTER SD 6-7

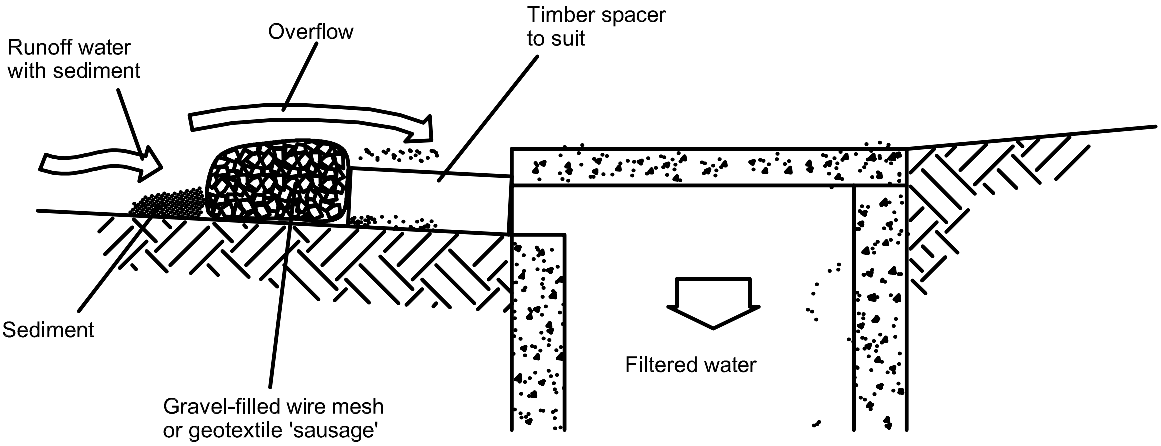


Construction Notes

1. Construct sediment fences as close as possible to being parallel to the contours of the site, but with small returns as shown in the drawing to limit the catchment area of any one section. The catchment area should be small enough to limit water flow if concentrated at one point to 50 litres per second in the design storm event, usually the 10-year event.
2. Cut a 150-mm deep trench along the upslope line of the fence for the bottom of the fabric to be entrenched.
3. Drive 1.5 metre long star pickets into ground at 2.5 metre intervals (max) at the downslope edge of the trench. Ensure any star pickets are fitted with safety caps.
4. Fix self-supporting geotextile to the upslope side of the posts ensuring it goes to the base of the trench. Fix the geotextile with wire ties or as recommended by the manufacturer. Only use geotextile specifically produced for sediment fencing. The use of shade cloth for this purpose is not satisfactory.
5. Join sections of fabric at a support post with a 150-mm overlap.
6. Backfill the trench over the base of the fabric and compact it thoroughly over the geotextile.

SEDIMENT FENCE SD 6-8



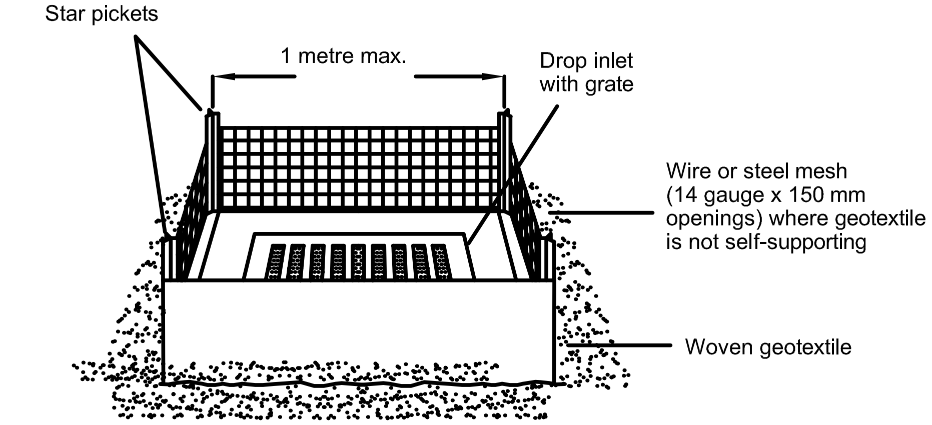


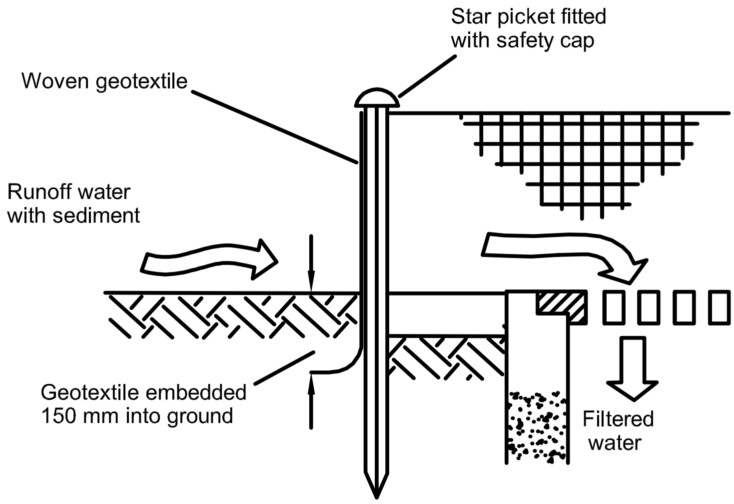
NOTE: This practice only to be used where specified in an approved SWMP/ESCP.

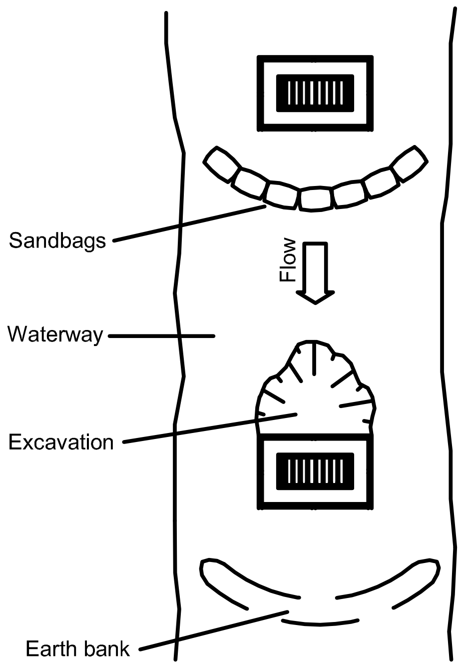
Construction Notes

1. Install filters to kerb inlets only at sag points.
2. Fabricate a sleeve made from geotextile or wire mesh longer than the length of the inlet pit and fill it with 25 mm to 50 mm gravel.
3. Form an elliptical cross-section about 150 mm high x 400 mm wide.
4. Place the filter at the opening leaving at least a 100-mm space between it and the kerb inlet. Maintain the opening with spacer blocks.
5. Form a seal with the kerb to prevent sediment bypassing the filter.
6. Sandbags filled with gravel can substitute for the mesh or geotextile providing they are placed so that they firmly abut each other and sediment-laden waters cannot pass between.

MESH AND GRAVEL INLET FILTER SD 6-11







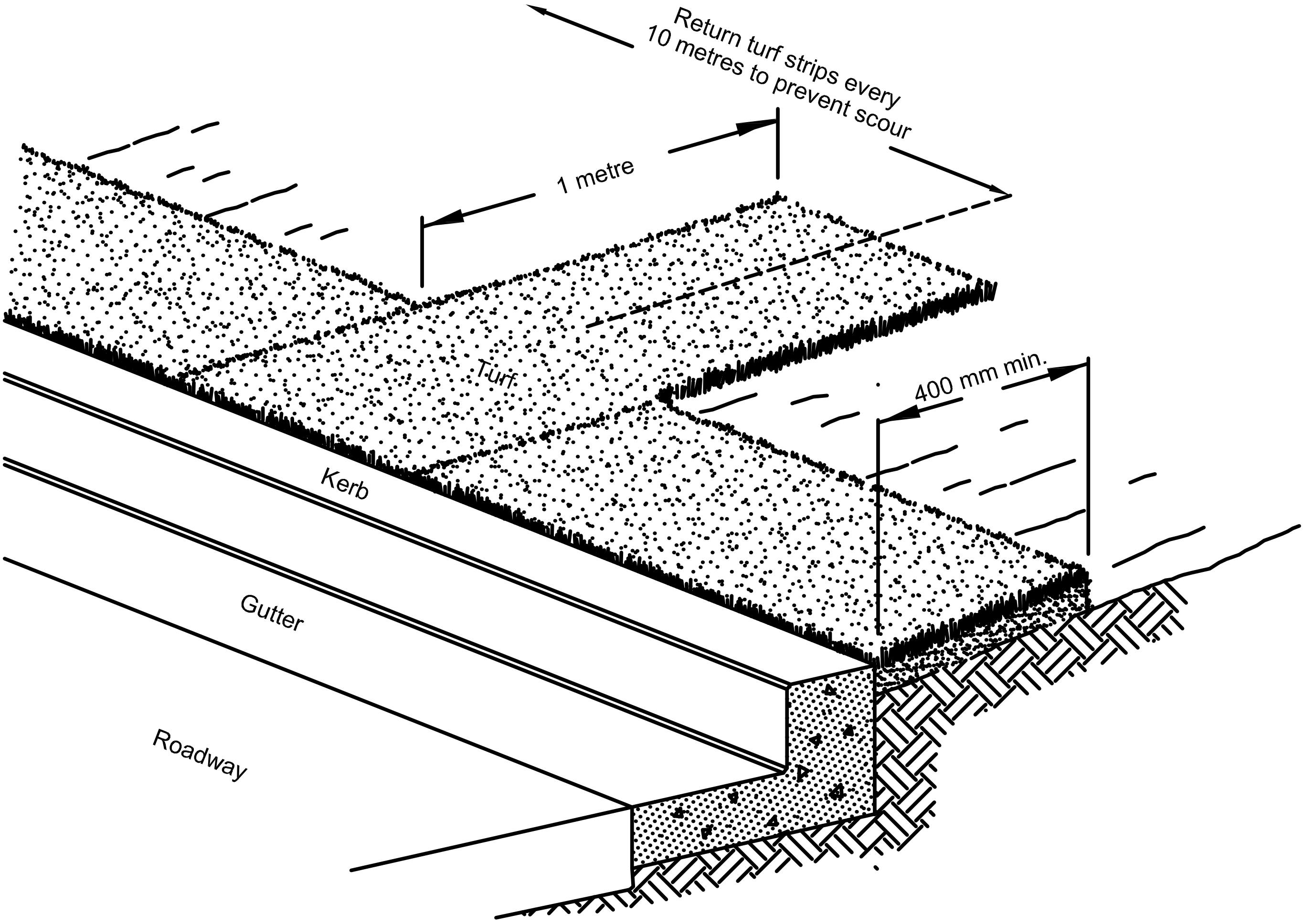
For drop inlets at non-sag points, sandbags, earth bank or excavation used to create artificial sag point

Construction Notes

1. Fabricate a sediment barrier made from geotextile or straw bales.
2. Follow Standard Drawing 6-7 and Standard Drawing 6-8 for installation procedures for the straw bales or geofabric. Reduce the picket spacing to 1 metre centres.
3. In waterways, artificial sag points can be created with sandbags or earth banks as shown in the drawing.
4. Do not cover the inlet with geotextile unless the design is adequate to allow for all waters to bypass it.

GEOTEXTILE INLET FILTER

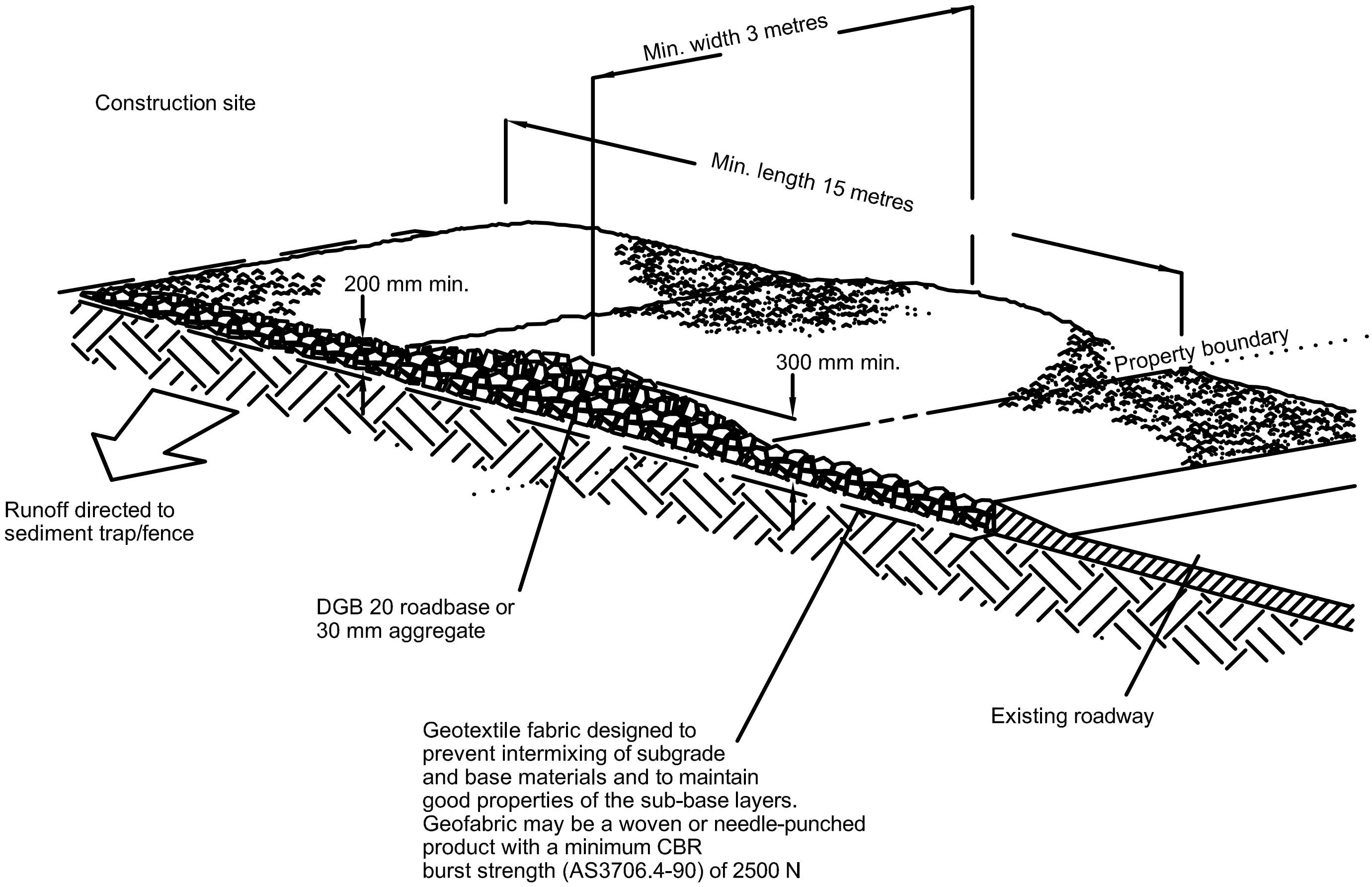
SD 6-12



Construction Notes

1. Install a 400 mm minimum wide roll of turf on the footpath next to the kerb and at the same level as the top of the kerb.
2. Lay 1.4 metre long turf strips normal to the kerb every 10 metres.
3. Rehabilitate disturbed soil behind the turf strip following the ESCP/SWMP.

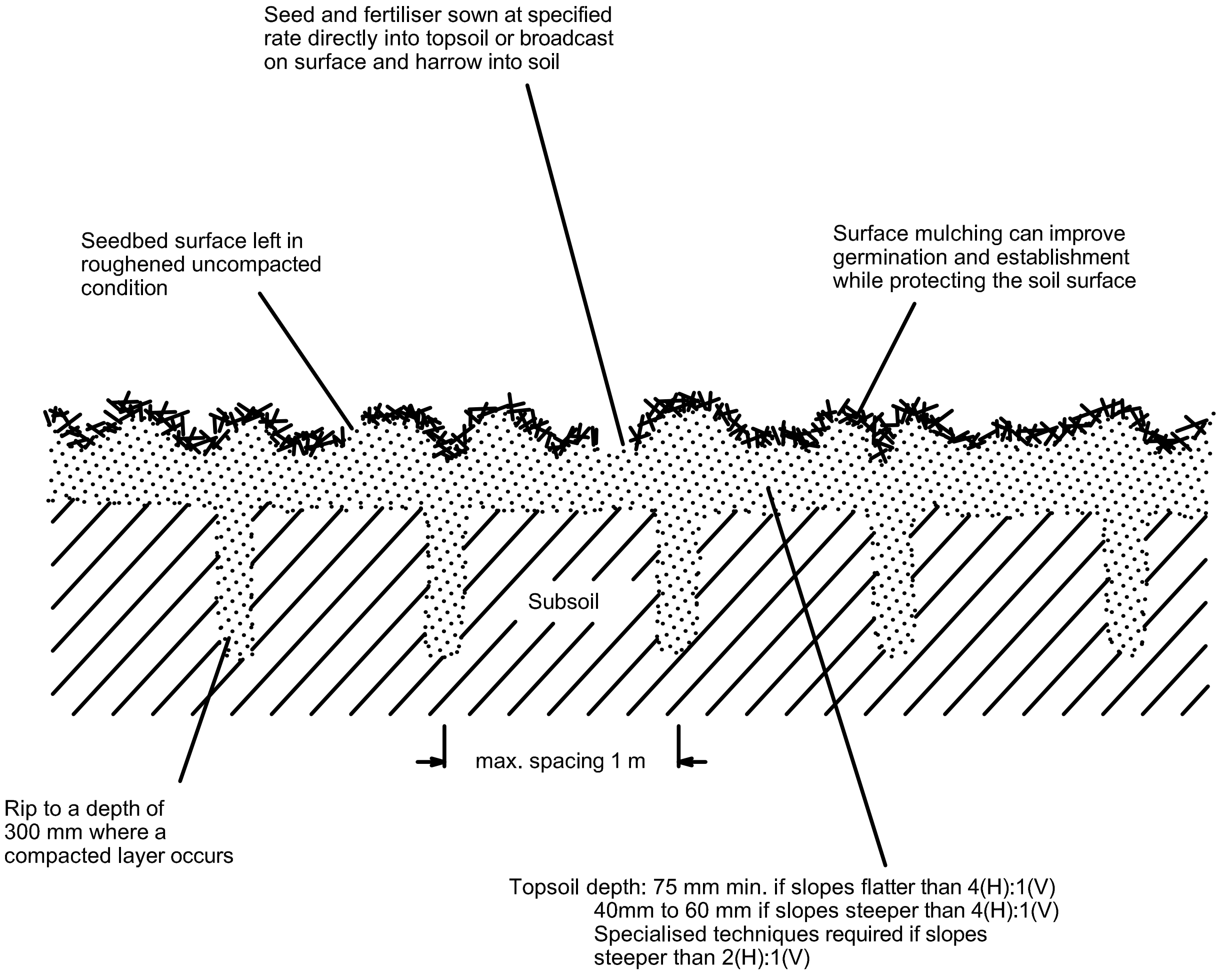
KERBSIDE TURF STRIP SD 6-13



Construction Notes

1. Strip the topsoil, level the site and compact the subgrade.
2. Cover the area with needle-punched geotextile.
3. Construct a 200 mm thick pad over the geotextile using road base or 30 mm aggregate.
4. Ensure the structure is at least 15 metres long or to building alignment and at least 3 metres wide.
5. Where a sediment fence joins onto the stabilised access, construct a hump in the stabilised access to divert water to the sediment fence

STABILISED SITE ACCESS SD 6-14



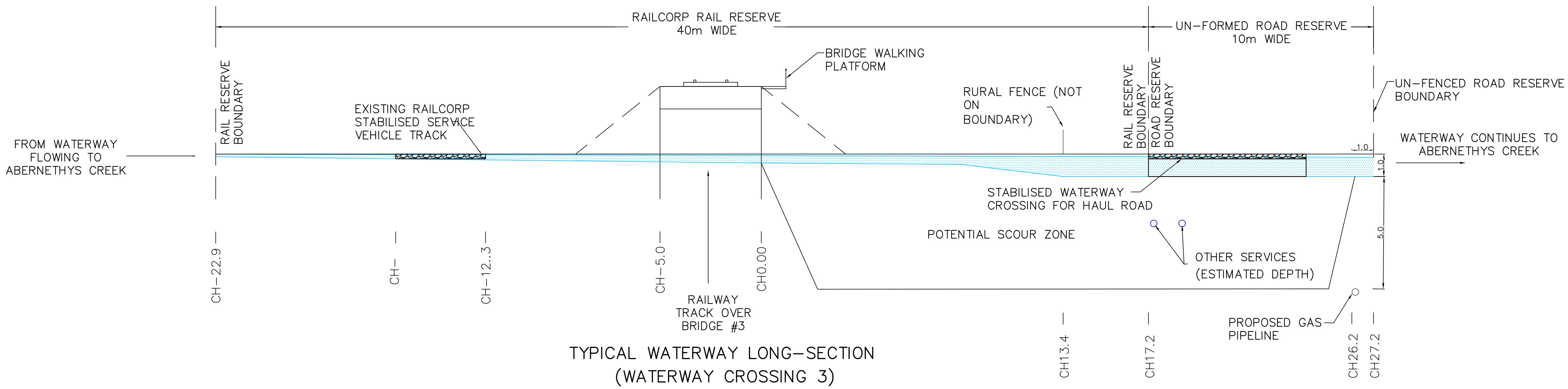
Construction Notes

1. Loosen compacted soil before sowing any seed. If necessary, rip the soil to a depth of 300 mm. Avoid rotary hoe cultivation.
2. Work the ground only as much as necessary to achieve the desired tilth and prepare a good seedbed.
3. Avoid cultivation in very wet or very dry conditions.
4. Cultivate on or close to the contour where possible, not up and down the slope.

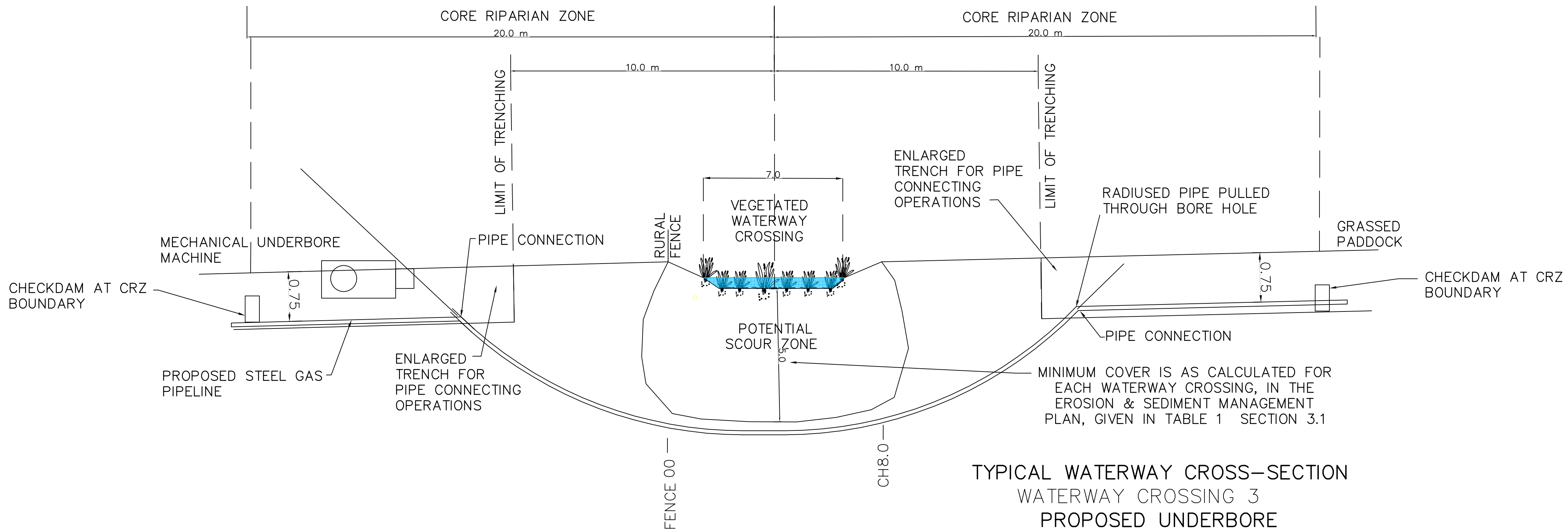
SEEDBED PREPARATION

SD 7-1

Appendix E – Figure 2: Cross Section of Waterway Crossing 3



TYPICAL WATERWAY LONG-SECTION
(WATERWAY CROSSING 3)



TYPICAL WATERWAY CROSS-SECTION
WATERWAY CROSSING 3
PROPOSED UNDERBORE

REVISION	BY	DATE

Liability limited by a scheme approved under Professional Standards Legislation.
COVER OF EXCELLENCE®

0 10 20 30 40 50 100
scale:– 1:1000

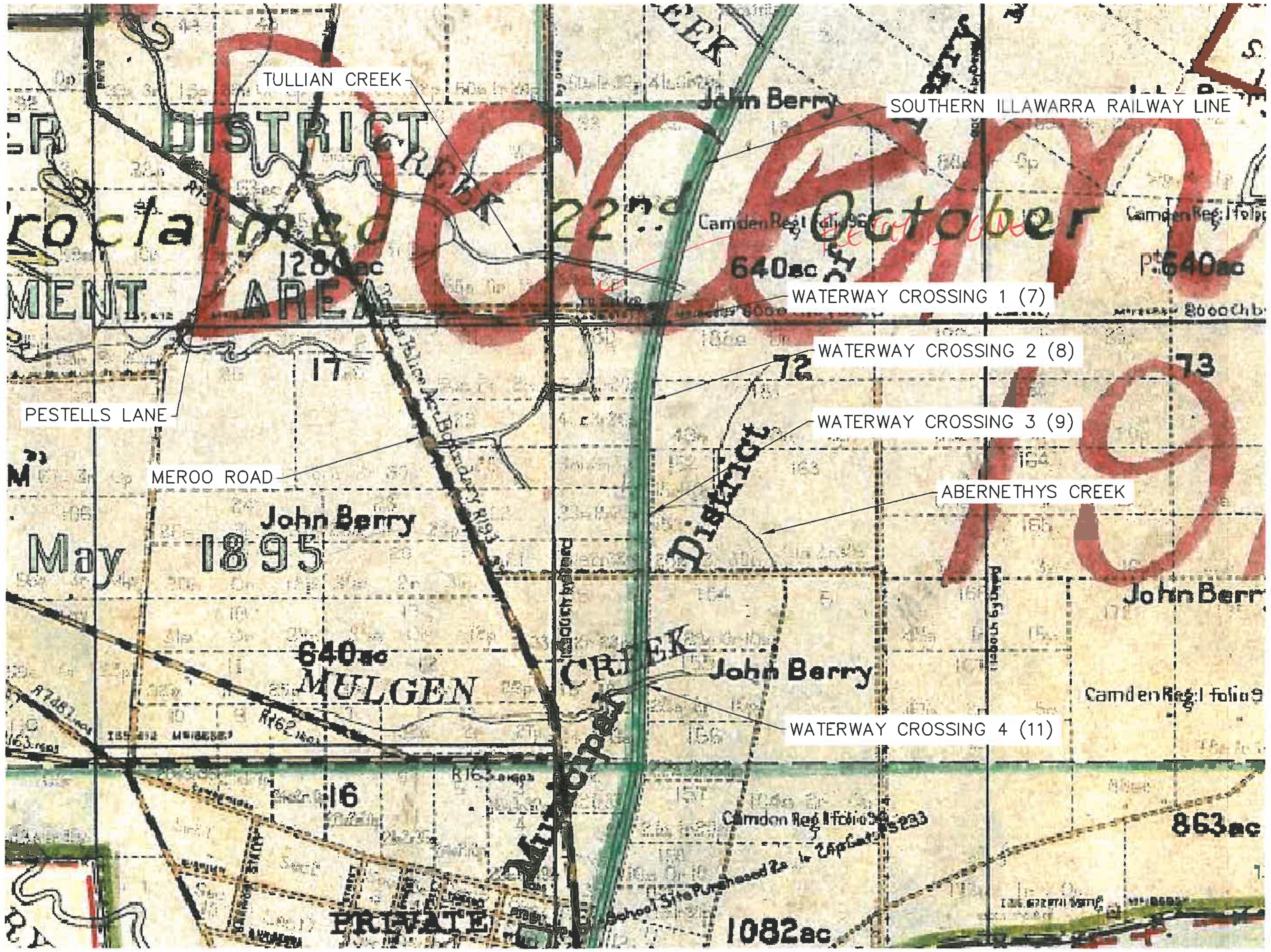
RATIO: 1:1000 @ A3
DATUM:
ORIGIN:
DATE OF PLAN: October 2011

allen, price & associates
land and development consultants
75 plunkett street, nowra, nsw. 2541
phone:(02) 4421 6544 fax:(02) 4422 1821
consultants@allenprice.com.au www.allenprice.com.au

APPENDIX E: YPICAL SECTIONS – WATERWAY CROSSING 3 SHOWING UNDERBORE & SCOUR ZONES FOR PROPOSED GAS PIPELINE AT MEROO MEADOW AND BOMADERRY FOR SHOALHAVEN STARCHES

REF. No. 24710
sheet 1 of 1
REVISION 00

Appendix F: May 1895 Topographic Map Detail



REVISION		BY	DATE

Liability limited by a scheme approved under Professional Standards Legislation.

COVER OF EXCELLENCE®

RATIO: 1:500 @ A3

DATUM:

ORIGIN:

DATE OF PLAN: FEB 2012

allen, price & associates
land and development consultants
75 plunkett street, nowra, nsw. 2541
phone:(02) 4421 6544 fax (02) 4422 1821
consultants@allenprice.com.au www.allenprice.com.au

APPENDIX F – may 1895 1:4000 topographic map for proposed gas pipeline project at Meroo Meadow and Bomaderry, NSW for Shoalhaven Starches

REF. No. 24710
sheet 1 of 1
REVISION 00

Appendix G: Coffey Environments Engineering Log – Excavation (Bore Holes CTP10, CTP12, CTP16 & CTP17)

coffey environments

Engineering Log - Excavation

Excavation No. *CTP10*

Sheet 1 of 1

Office Job No.: *ENAUWOLL04006AA*

Client:	*MANILDRA GROUP*	Date started:	*21.6.2011*
Principal:		Date completed:	*21.6.2011*
Project:	*CONTAMIN, ASS, GEOTECH + GWATER ASSESSMENT*	Logged by:	*CA*
Test pit location:	*PROPOSED GAS PIPELINE, BOMADERRY, NSW, 2541*	Checked by:	*SM*

equipment type and model:	5T EXCAVATOR	Pit Orientation:	N-S	Easting:	282018 m	R.L. Surface:	NOT MEASURED
excavation dimensions:	2m long 0.45m wide			Northing:	6142018 m	datum:	WGS84 (Approx)

excavation information / **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/density index	pocket penetro-meter kPa (100 200 300 400)	structure and additional observations
E		N				0.0–0.5			TOPSOIL; Sandy CLAY: Low to medium plasticity, pale yellow/brown, fine to medium grained sand, with some roots.	M	MD		TOPSOIL
						0.5–1.5		CL	Sandy CLAY: Medium plasticity, red/orange, with some silt, and a trace of roots and fine to coarse grained angular sandstone gravel.	<Wp	St		RESIDUAL
			Seepage (at ~2.3 m)			1.5–2.5		CL	Sandy Gravelly CLAY: Medium plasticity, orange/brown with some pale yellow/pale brown pockets and fine to medium grained highly weathered sandstone gravel.		H		EXTREMELY WEATHERED MATERIAL End on slow progress
						2.5			Test pit CTP10 terminated at 2.5m				

Sketch

method
- N natural exposure
- X existing excavation
- BH backhoe bucket
- B bulldozer blade
- R ripper
- E excavator

support
S shoring N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
- water level on date shown
- water inflow
- water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- V vane shear (kPa)
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description
based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index
- VS very soft
- S soft
- F firm
- St stiff
- VSt very stiff
- H hard
- Fb friable
- VL very loose
- L loose
- MD medium dense
- D dense
- VD very dense

coffey environments

Engineering Log - Excavation

		Excavation No.	CTP12
		Sheet	1 of 1
		Office Job No.:	ENAUWOLL04006AA
Client:	MANILDRA GROUP	Date started:	21.6.2011
Principal:		Date completed:	21.6.2011
Project:	CONTAMIN, ASS, GEOTECH + GWATER ASSESSMENT	Logged by:	CA
Test pit location:	PROPOSED GAS PIPELINE, BOMADERRY, NSW, 2541	Checked by:	SM

equipment type and model: 5T EXCAVATOR — Pit Orientation: N-S — Easting: 282092 m — R.L. Surface: NOT MEASURED

excavation dimensions: 2m long 0.45m wide — Northing: 6142461 m — datum: WGS84 (Approx)

excavation information / **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/density index	pocket penetrometer kPa (100 200 300 400)	structure and additional observations
E		N				0.0			TOPSOIL; CLAY: High plasticity, brown, with some silt and roots.	>Wp	S		TOPSOIL
			▶ (at ~0.5)	ASS		0.5		CH	Sandy CLAY: High plasticity, brown, with some silt, and a trace of roots.			x	ALLUVIAL/ESTUARINE SOIL
				ASS		1.0							
				ASS		1.5		CH	Sandy CLAY: High plasticity, grey, fine grained sand, and some silt.		St	x x x	
				ASS		2.0							
						2.5			Test pit CTP12 terminated at 2.5m				End on steady progress
						3.0							

Sketch

method
- N natural exposure
- X existing excavation
- BH backhoe bucket
- B bulldozer blade
- R ripper
- E excavator

support
- S shoring N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
- water level on date shown
- water inflow
- water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- V vane shear (kPa)
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index
- VS very soft
- S soft
- F firm
- St stiff
- VSt very stiff
- H hard
- Fb friable
- VL very loose
- L loose
- MD medium dense
- D dense
- VD very dense

TESTPIT ENAUWOLL04006AA - LOGS.GPJ COF .GDT 29.7.11

Form GEO 5.2 Issue 3 Rev.2

coffey environments

Engineering Log - Excavation

Excavation No.	CTP16
Sheet	1 of 1
Office Job No.:	ENAUWOLL04006AA

Client:	MANILDRA GROUP	Date started:	22.6.2011
Principal:		Date completed:	22.6.2011
Project:	CONTAMIN, ASS, GEOTECH + GWATER ASSESSMENT	Logged by:	CA
Test pit location:	PROPOSED GAS PIPELINE, BOMADERRY, NSW, 2541	Checked by:	SM

equipment type and model: 5T EXCAVATOR	Pit Orientation: N-S	Easting:	282191 m	R.L. Surface:	NOT MEASURED
excavation dimensions: 2m long 0.45m wide		Northing:	6142933 m	datum:	WGS84 (Approx)

excavation information							material substance						
method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
E		N							TOPSOIL; CLAY: High plasticity, brown, with some roots.	<Wp	F		TOPSOIL
				ASS		0.5		CH	CLAY: High plasticity, grey with some iron stained orange/brown pockets, with a trace of roots and fine to coarse grained sub-angular gravel.	Wp	VSt	x	ALLUVIAL SOIL
				ASS		1.0							
				ASS		1.5							
				ASS		2.0		CH	Sandy CLAY: High plasticity, grey with orange/brown pockets, with a trace of roots and fine to coarse grained sub-angular gravel.	>Wp (Saturated)	St	x	
			▶			2.5							End on steady progress
						3.0			Test pit CTP16 terminated at 2.5m				

Sketch

method	support	notes, samples, tests	classification symbols and soil description	consistency/density index
N natural exposure	S shoring N nil	U_{50} undisturbed sample 50mm diameter	based on unified classification system	VS very soft
X existing excavation	penetration 1 2 3 4	U_{63} undisturbed sample 63mm diameter	moisture	S soft
BH backhoe bucket	no resistance ranging to refusal	D disturbed sample	D dry	F firm
B bulldozer blade	water	V vane shear (kPa)	M moist	St stiff
R ripper	water level on date shown	Bs bulk sample	W wet	VSt very stiff
E excavator	water inflow	E environmental sample	Wp plastic limit	H hard
	water outflow	R refusal	W_L liquid limit	Fb friable
				VL very loose
				L loose
				MD medium dense
				D dense
				VD very dense

coffey environments

Engineering Log - Excavation

Excavation No. CTP17
Sheet 1 of 1
Office Job No.: ENAUWOLL04006AA

Client:	MANILDRA GROUP	Date started:	22.6.2011
Principal:		Date completed:	22.6.2011
Project:	CONTAMIN, ASS, GEOTECH + GWATER ASSESSMENT	Logged by:	CA
Test pit location:	PROPOSED GAS PIPELINE, BOMADERRY, NSW, 2541	Checked by:	SM

equipment type and model: 5T EXCAVATOR	Pit Orientation:	Easting:	282284 m	R.L. Surface:	NOT MEASURED
excavation dimensions: 2m long 0.45m wide		Northing	6143258 m	datum:	WGS84 (Approx)

excavation information / **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/density index	pocket penetrometer kPa	structure and additional observations
E		N	NONE OBSERVED						TOPSOIL; CLAY: Medium plasticity, brown, with some fine grained roots.	Wp	F		TOPSOIL
								CH	CLAY: High plasticity, brown with some orange pockets, with a trace of fine grained sand, roots and fine to coarse grained gravel.	<Wp	VSt		ALLUVIAL SOIL
						0.5						x	
				ASS									
				ASS		1.0						x	
				ASS		1.5							
						2.0						x	
						2.5							End on steady progress
									Test pit CTP17 terminated at 2.5m				
						3.0							

Sketch

method
N natural exposure
X existing excavation
BH backhoe bucket
B bulldozer blade
R ripper
E excavator

support
S shoring N nil

penetration
1 2 3 4
no resistance ranging to refusal

water
water level on date shown
water inflow
water outflow

notes, samples, tests
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
V vane shear (kPa)
Bs bulk sample
E environmental sample
R refusal

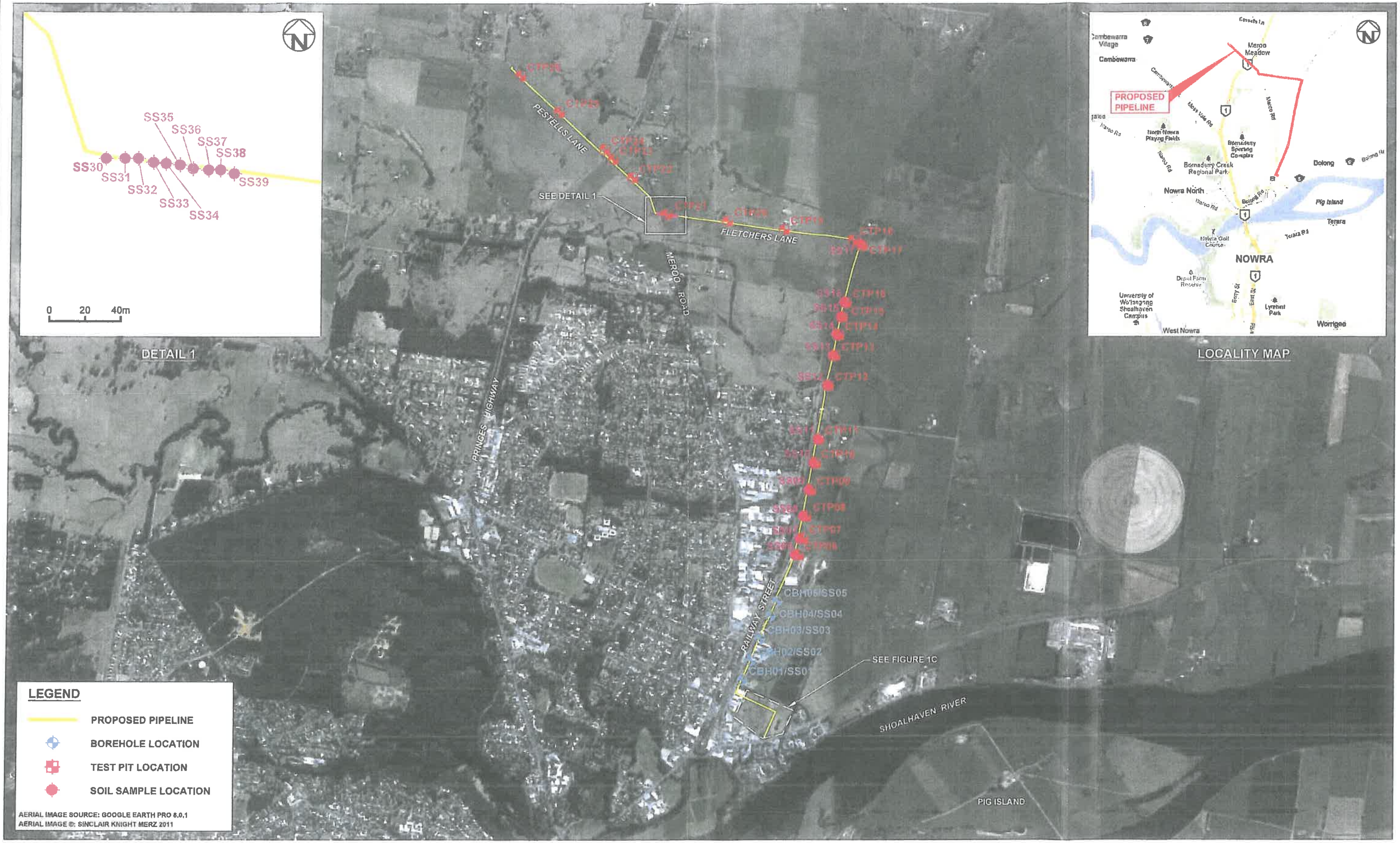
classification symbols and soil description
based on unified classification system

moisture
D dry
M moist
W wet
Wp plastic limit
W_L liquid limit

consistency/density index
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

Form GEO 5.2 Issue 3 Rev.2

TESTPIT ENAUWOLL04006AA - LOGS.GPJ COF DT 29.7.11



revision	description	drawn	approved	date

200 0 200 600 1000

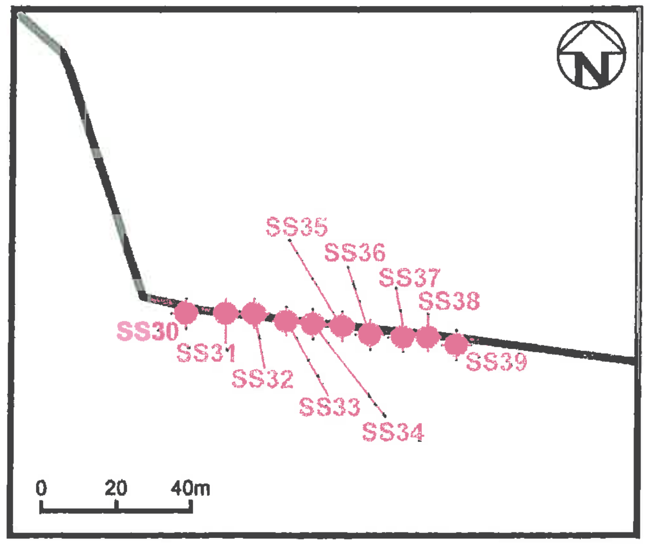
Horizontal Scale (metres) 1:20 000

drawn	CA/AW
approved	CA
date	28.07.11
scale	AS SHOWN
original size	A3

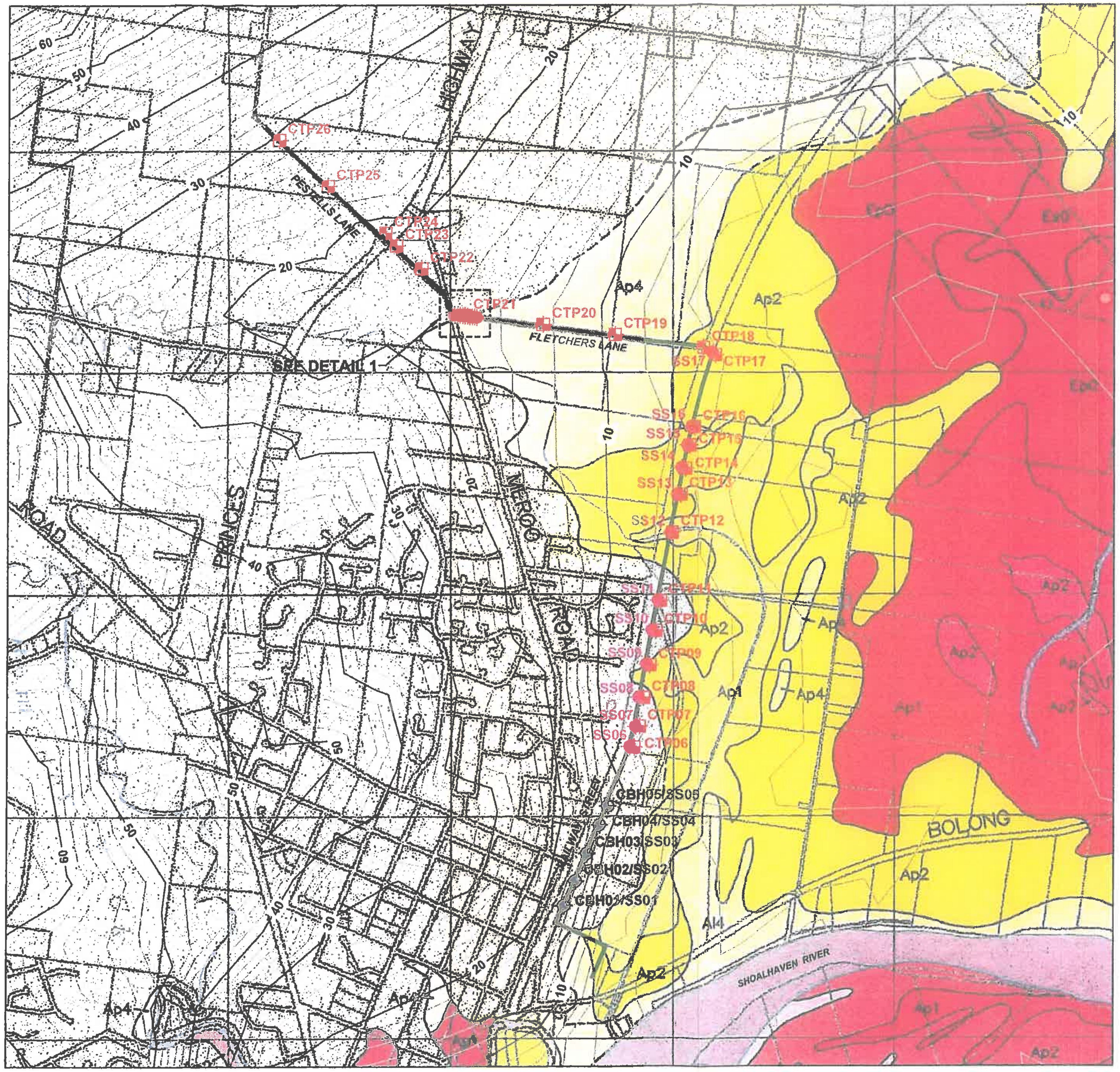
coffey environments
SPECIALISTS IN ENVIRONMENTAL, SOCIAL AND SAFETY PERFORMANCE

client:	MANILDRA GROUP PTY LTD
project:	ACID SULFATE SOIL, CONTAMINATION AND GEOTECHNICAL INVESTIGATION PROPOSED GAS PIPLINE, BOMADERRY, NSW
title:	PROPOSED PIPELINE ROUTE WITH COFFEY TEST LOCATIONS
project no:	ENAUWOLL04006AA-R01
figure no:	FIGURE 1

Map Class Description	Depth to Acid Sulfate Soil Materials	
HIGH PROBABILITY	Below water level	Bottom sediments.
High probability of occurrence of acid sulfate soil materials within the soil profile. The environment of deposition has been suitable for the formation of acid sulfate soil materials. Acid sulfate soil materials are widespread or sporadic and may be buried by alluvium or windblown sediments.		At or near the ground surface.
		Within 1 metre of the ground surface.
		Between 1 and 3 metres below the ground surface.
		Greater than 3 metres below the ground surface.*
LOW PROBABILITY	Below water level	Bottom sediments.
Low probability of occurrence of acid sulfate soil materials within the soil profile. The environment of deposition has generally not been suitable for the formation of acid sulfate soil materials. Soil materials are often Pleistocene in age. Acid sulfate soil materials, if present, are sporadic and may be buried by alluvium or windblown sediments.		At or near the ground surface.
		Within 1 metre of the ground surface.
		Between 1 and 3 metres below the ground surface.
		Greater than 3 metres below the ground surface.*
NO KNOWN OCCURRENCE		No known occurrences of acid sulfate soil materials.
Acid sulfate soils are not known or expected to occur in these environments.		



DETAIL 1



LEGEND

- PROPOSED PIPELINE
- BOREHOLE LOCATION
- TEST PIT LOCATION
- SOIL SAMPLE LOCATION

REFERNCE: BURRIER/BERRY 1:25 000 ACID SOIL RISK MAP (1997) EDITION 2, PREPARED BY THE NSW DEPARTMENT OF LAND AND WATER CONSERVATION (DLWC)

revision	description	drawn	approved	date

200 0 200 600 1000

Horizontal Scale (metres) 1:20 000

drawn	CA/AW
approved	CA
date	28/07/11
scale	AS SHOWN
original size	A3

coffey environments
SPECIALISTS IN ENVIRONMENTAL, SOCIAL AND SAFETY PERFORMANCE

client:	MANILDRA GROUP PTY LTD
project:	ACID SULFATE SOIL, CONTAMINATION AND GEOTECHNICAL INVESTIGATION PROPOSED GAS PIPLINE, BOMADERRY, NSW
title:	PROPOSED PIPELINE ROUTE WITH 1:25000 BURRIER/BERRY ASS RISK MAP
project no:	ENAUWOLL04006AA-R01
figure no:	FIGURE 2

Appendix H: Catchment Stormwater Runoff Calculations

CATCHMENT 1 RUNOFF CALCULATIONS

Shoalhaven City Council

Discharges for 1:5 ARI

Nowra

Rational Method Q = FCIA

Total Area (A)	11.74 ha
Time of Concentration (mins)	20.20 mins
Rainfall Intensity (I)	102 mm/hr
Runoff Coefficient (C)	0.70
Factor (F)	0.00278
DISCHARGE (Q)	**2.33 m3/sec**

CATCHMENT 1 RUNOFF CALCULATIONS

Shoalhaven City Council

Discharges for 1:100ARI

Nowra

Rational Method Q = FCIA

Total Area (A)	11.74 ha
Time of Concentration (mins)	20.20 mins
Rainfall Intensity (I)	174 mm/hr
Runoff Coefficient (C)	0.70
Factor (F)	0.00278
DISCHARGE (Q)	**3.97 m3/sec**

CATCHMENT RUNOFF CALCULATIONS

Shoalhaven City Council

Discharges for 1:5 ARI

Nowra

Rational Method Q = FCIA

Total Area (A)	545.40 ha
Time of Concentration (mins)	86.88 mins
Rainfall Intensity (I)	47 mm/hr
Runoff Coefficient (C)	0.60
Factor (F)	0.00278
DISCHARGE (Q)	**42.72 m3/sec**

CATCHMENT RUNOFF CALCULATIONS

Shoalhaven City Council

Discharges for 1:100ARI

Nowra

Rational Method Q = FCIA

Total Area (A)	545.40 ha
Time of Concentration (mins)	86.88 mins
Rainfall Intensity (I)	85 mm/hr
Runoff Coefficient (C)	0.60
Factor (F)	0.00278
DISCHARGE (Q)	**77.27 m3/sec**

CATCHMENT 3 RUNOFF CALCULATIONS

Shoalhaven City Council

Discharges for 1:5 ARI

Nowra

Rational Method Q = FCIA

Total Area (A)	896.50 ha
Time of Concentration (mins)	104.94 mins
Rainfall Intensity (I)	41 mm/hr
Runoff Coefficient (C)	0.70
Factor (F)	0.00278
DISCHARGE (Q)	**71.47 m3/sec**

CATCHMENT 3 RUNOFF CALCULATIONS

Shoalhaven City Council

Discharges for 1:100ARI

Nowra

Rational Method Q = FCIA

Total Area (A)	896.50 ha
Time of Concentration (mins)	104.94 mins
Rainfall Intensity (I)	76 mm/hr
Runoff Coefficient (C)	0.70
Factor (F)	0.00278
DISCHARGE (Q)	**132.48 m3/sec**

CATCHMENT 4 RUNOFF CALCULATIONS

Shoalhaven City Council

Discharges for 1:5 ARI

Nowra

Rational Method Q = FCIA

Total Area (A)	115.40 ha
Time of Concentration (mins)	48.15 mins
Rainfall Intensity (I)	66 mm/hr
Runoff Coefficient (C)	0.80
Factor (F)	0.00278
DISCHARGE (Q)	**16.93 m3/sec**

CATCHMENT 4 RUNOFF CALCULATIONS

Shoalhaven City Council

Discharges for 1:100ARI

Nowra

Rational Method Q = FCIA

Total Area (A)	115.40 ha
Time of Concentration (mins)	48.15 mins
Rainfall Intensity (I)	117 mm/hr
Runoff Coefficient (C)	0.80
Factor (F)	0.00278
DISCHARGE (Q)	**30.00 m3/sec**

Appendix I: HY-8 Culvert Analysis Reports for Waterway Crossings 1, 2, 3 and 4, with Scour Depth Calculation Results

HY-8 Culvert Analysis Report

Table 1 - Summary of Culvert Flows at Crossing: CROSSING 1

Headwater Elevation (m)	Total Discharge (cms)	Culvert 1A Discharge (cms)	Culvert 1B Discharge (cms)	Culvert 1C Discharge (cms)	Culvert 1D Discharge (cms)	Culvert 1E Discharge (cms)	Culvert 1F Discharge (cms)	Roadway Discharge (cms)	Iterations
0.43	2.33	0.39	0.39	0.39	0.39	0.39	0.39	0.00	16
0.44	2.49	0.42	0.42	0.42	0.42	0.42	0.42	0.00	3
0.46	2.66	0.44	0.44	0.44	0.44	0.44	0.44	0.00	3
0.48	2.82	0.47	0.47	0.47	0.47	0.47	0.47	0.00	3
0.50	2.99	0.50	0.50	0.50	0.50	0.50	0.50	0.00	3
0.52	3.15	0.52	0.52	0.52	0.52	0.52	0.52	0.00	3
0.53	3.31	0.55	0.55	0.55	0.55	0.55	0.55	0.00	3
0.55	3.48	0.58	0.58	0.58	0.58	0.58	0.58	0.00	3
0.57	3.64	0.61	0.61	0.61	0.61	0.61	0.61	0.00	2
0.58	3.81	0.63	0.63	0.63	0.63	0.63	0.63	0.00	2
0.60	3.96	0.66	0.66	0.66	0.66	0.66	0.66	0.00	2
2.00	13.88	2.31	2.31	2.31	2.31	2.31	2.31	0.00	Overtopping

Table 2 - Culvert Summary Table: Culvert 1A

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
2.33	0.39	0.43	0.425	0.382	6-FFt	0.700	0.250	0.700	0.357	0.557	1.143
2.49	0.42	0.44	0.443	0.400	6-FFt	0.700	0.261	0.700	0.371	0.594	1.170
2.66	0.44	0.46	0.462	0.418	6-FFt	0.700	0.272	0.700	0.385	0.633	1.196
2.82	0.47	0.48	0.480	0.436	6-FFt	0.700	0.283	0.700	0.399	0.672	1.220
2.99	0.50	0.50	0.498	0.454	6-FFt	0.700	0.294	0.700	0.412	0.711	1.244
3.15	0.52	0.52	0.515	0.471	6-FFt	0.700	0.305	0.700	0.425	0.750	1.266
3.31	0.55	0.53	0.533	0.489	6-FFt	0.700	0.315	0.700	0.438	0.789	1.288
3.48	0.58	0.55	0.550	0.507	6-FFt	0.700	0.325	0.700	0.450	0.828	1.309
3.64	0.61	0.57	0.567	0.524	6-FFt	0.700	0.335	0.700	0.462	0.867	1.329
3.81	0.63	0.58	0.583	0.542	6-FFt	0.700	0.345	0.700	0.474	0.906	1.349
3.96	0.66	0.60	0.599	0.558	6-FFt	0.700	0.355	0.700	0.485	0.942	1.367

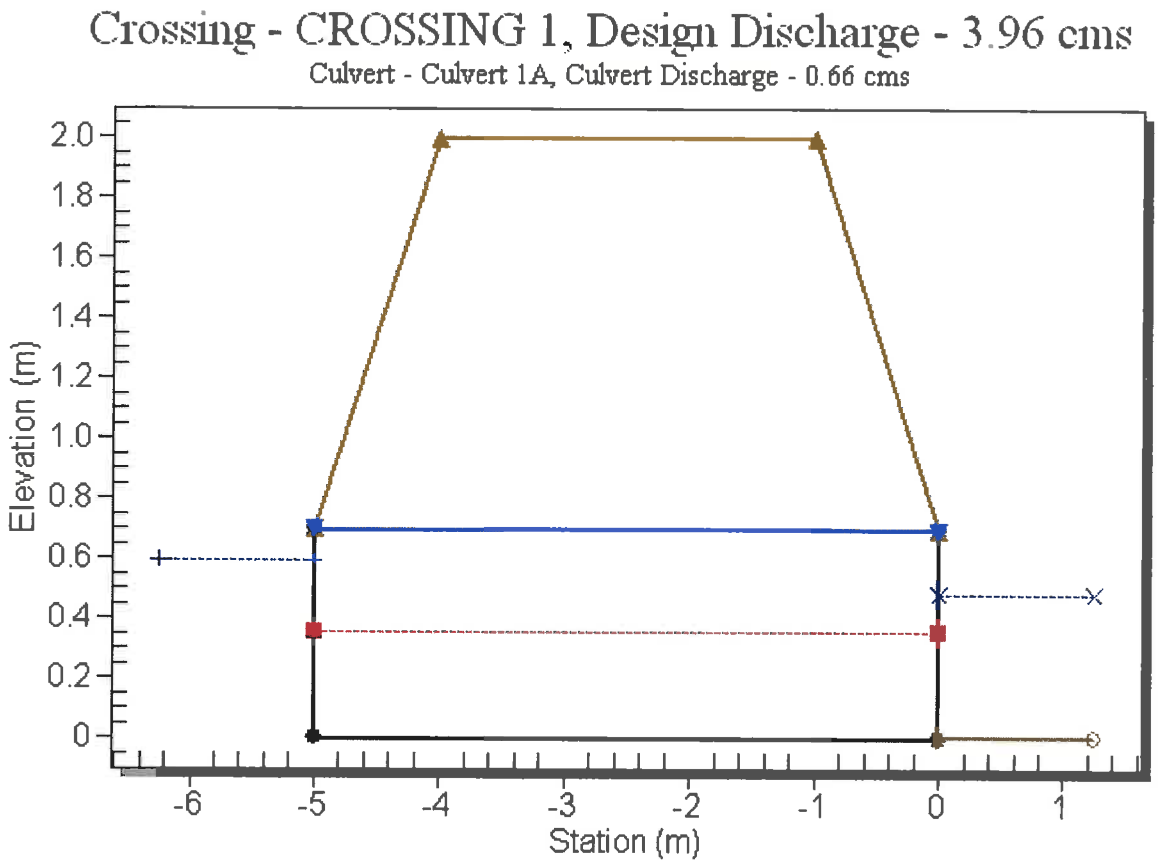
****

Inlet Elevation (invert): 0.00 m, Outlet Elevation (invert): -0.00 m

Culvert Length: 5.00 m, Culvert Slope: 0.0001

****

Water Surface Profile Plot for Culvert: Culvert 1A



Site Data - Culvert 1A

Site Data Option: Culvert Invert Data

Inlet Station: -5.00 m

Inlet Elevation: 0.00 m

Outlet Station: 0.00 m

Outlet Elevation: -0.00 m

Number of Barrels: 1

Culvert Data Summary - Culvert 1A

Barrel Shape: Concrete Box

Barrel Span: 1000.00 mm

Barrel Rise: 700.00 mm

Barrel Material: Concrete

Embedment: 0.00 mm

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: NONE

Table 3 - Culvert Summary Table: Culvert 1B

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
2.33	0.39	0.43	0.425	0.382	6-FFt	0.700	0.250	0.700	0.357	0.557	1.143
2.49	0.42	0.44	0.443	0.400	6-FFt	0.700	0.261	0.700	0.371	0.594	1.170
2.66	0.44	0.46	0.462	0.418	6-FFt	0.700	0.272	0.700	0.385	0.633	1.196
2.82	0.47	0.48	0.480	0.436	6-FFt	0.700	0.283	0.700	0.399	0.672	1.220
2.99	0.50	0.50	0.498	0.454	6-FFt	0.700	0.294	0.700	0.412	0.711	1.244
3.15	0.52	0.52	0.515	0.471	6-FFt	0.700	0.305	0.700	0.425	0.750	1.266
3.31	0.55	0.53	0.533	0.489	6-FFt	0.700	0.315	0.700	0.438	0.789	1.288
3.48	0.58	0.55	0.550	0.507	6-FFt	0.700	0.325	0.700	0.450	0.828	1.309
3.64	0.61	0.57	0.567	0.524	6-FFt	0.700	0.335	0.700	0.462	0.867	1.329
3.81	0.63	0.58	0.583	0.542	6-FFt	0.700	0.345	0.700	0.474	0.906	1.349
3.96	0.66	0.60	0.599	0.558	6-FFt	0.700	0.355	0.700	0.485	0.942	1.367

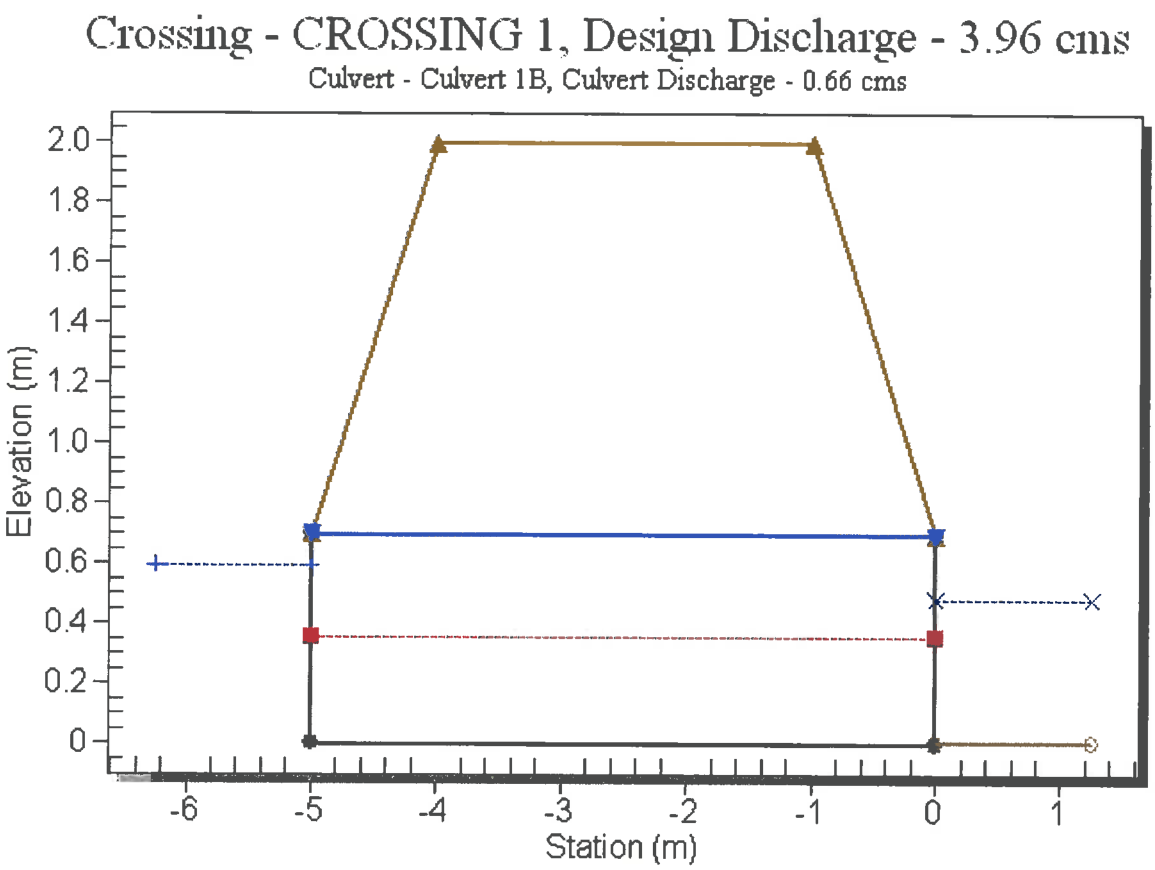
****

Inlet Elevation (invert): 0.00 m, Outlet Elevation (invert): -0.00 m

Culvert Length: 5.00 m, Culvert Slope: 0.0001

****

Water Surface Profile Plot for Culvert: Culvert 1B



Site Data - Culvert 1B

Site Data Option: Culvert Invert Data

Inlet Station: -5.00 m

Inlet Elevation: 0.00 m

Outlet Station: 0.00 m

Outlet Elevation: -0.00 m

Number of Barrels: 1

Culvert Data Summary - Culvert 1B

Barrel Shape: Concrete Box

Barrel Span: 1000.00 mm

Barrel Rise: 700.00 mm

Barrel Material: Concrete

Embedment: 0.00 mm

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: NONE

Table 4 - Culvert Summary Table: Culvert 1C

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
2.33	0.39	0.43	0.425	0.382	6-FFt	0.700	0.250	0.700	0.357	0.557	1.143
2.49	0.42	0.44	0.443	0.400	6-FFt	0.700	0.261	0.700	0.371	0.594	1.170
2.66	0.44	0.46	0.462	0.418	6-FFt	0.700	0.272	0.700	0.385	0.633	1.196
2.82	0.47	0.48	0.480	0.436	6-FFt	0.700	0.283	0.700	0.399	0.672	1.220
2.99	0.50	0.50	0.498	0.454	6-FFt	0.700	0.294	0.700	0.412	0.711	1.244
3.15	0.52	0.52	0.515	0.471	6-FFt	0.700	0.305	0.700	0.425	0.750	1.266
3.31	0.55	0.53	0.533	0.489	6-FFt	0.700	0.315	0.700	0.438	0.789	1.288
3.48	0.58	0.55	0.550	0.507	6-FFt	0.700	0.325	0.700	0.450	0.828	1.309
3.64	0.61	0.57	0.567	0.524	6-FFt	0.700	0.335	0.700	0.462	0.867	1.329
3.81	0.63	0.58	0.583	0.542	6-FFt	0.700	0.345	0.700	0.474	0.906	1.349
3.96	0.66	0.60	0.599	0.558	6-FFt	0.700	0.355	0.700	0.485	0.942	1.367

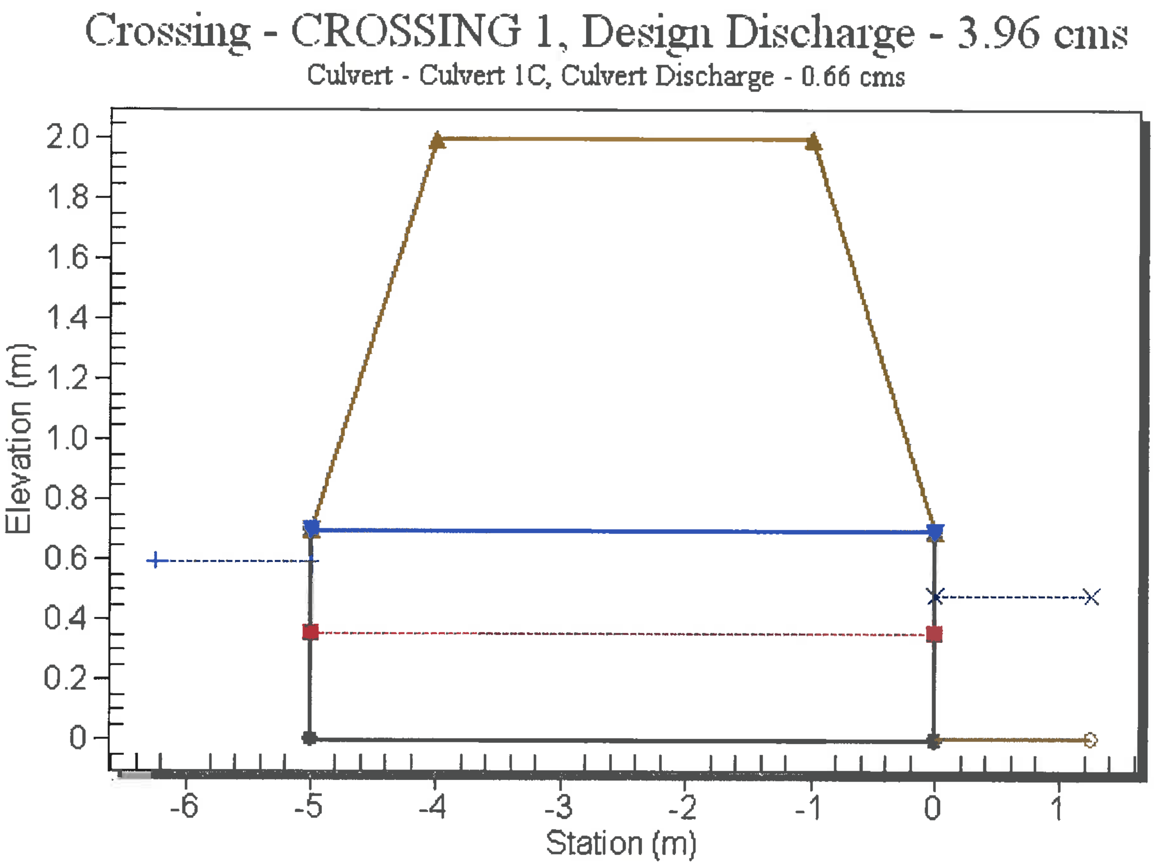
****

Inlet Elevation (invert): 0.00 m, Outlet Elevation (invert): -0.00 m

Culvert Length: 5.00 m, Culvert Slope: 0.0001

****

Water Surface Profile Plot for Culvert: Culvert 1C



Site Data - Culvert 1C

Site Data Option: Culvert Invert Data

Inlet Station: -5.00 m

Inlet Elevation: 0.00 m

Outlet Station: 0.00 m

Outlet Elevation: -0.00 m

Number of Barrels: 1

Culvert Data Summary - Culvert 1C

Barrel Shape: Concrete Box

Barrel Span: 1000.00 mm

Barrel Rise: 700.00 mm

Barrel Material: Concrete

Embedment: 0.00 mm

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: NONE

Table 5 - Culvert Summary Table: Culvert 1D

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
2.33	0.39	0.43	0.425	0.382	6-FFt	0.700	0.250	0.700	0.357	0.557	1.143
2.49	0.42	0.44	0.443	0.400	6-FFt	0.700	0.261	0.700	0.371	0.594	1.170
2.66	0.44	0.46	0.462	0.418	6-FFt	0.700	0.272	0.700	0.385	0.633	1.196
2.82	0.47	0.48	0.480	0.436	6-FFt	0.700	0.283	0.700	0.399	0.672	1.220
2.99	0.50	0.50	0.498	0.454	6-FFt	0.700	0.294	0.700	0.412	0.711	1.244
3.15	0.52	0.52	0.515	0.471	6-FFt	0.700	0.305	0.700	0.425	0.750	1.266
3.31	0.55	0.53	0.533	0.489	6-FFt	0.700	0.315	0.700	0.438	0.789	1.288
3.48	0.58	0.55	0.550	0.507	6-FFt	0.700	0.325	0.700	0.450	0.828	1.309
3.64	0.61	0.57	0.567	0.524	6-FFt	0.700	0.335	0.700	0.462	0.867	1.329
3.81	0.63	0.58	0.583	0.542	6-FFt	0.700	0.345	0.700	0.474	0.906	1.349
3.96	0.66	0.60	0.599	0.558	6-FFt	0.700	0.355	0.700	0.485	0.942	1.367

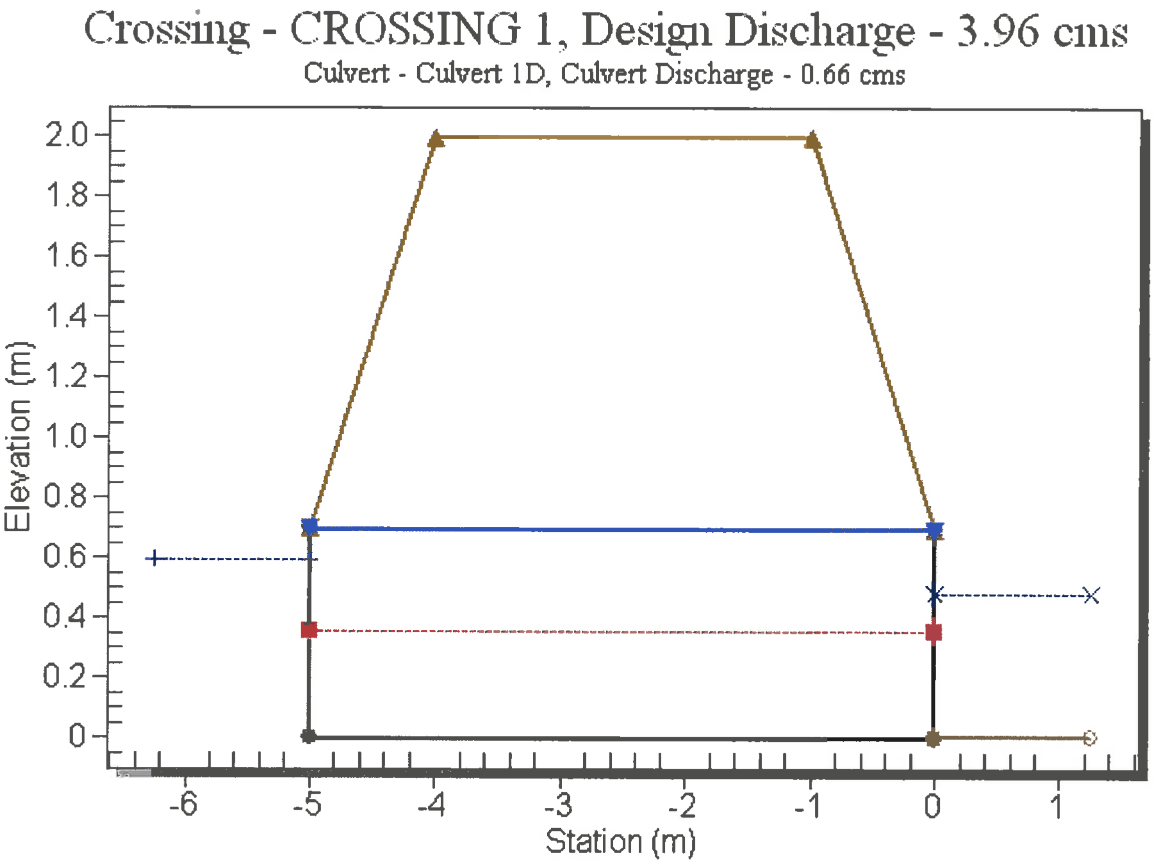
****

Inlet Elevation (invert): 0.00 m, Outlet Elevation (invert): -0.00 m

Culvert Length: 5.00 m, Culvert Slope: 0.0001

****

Water Surface Profile Plot for Culvert: Culvert 1D



Site Data - Culvert 1D

Site Data Option: Culvert Invert Data

Inlet Station: -5.00 m

Inlet Elevation: 0.00 m

Outlet Station: 0.00 m

Outlet Elevation: -0.00 m

Number of Barrels: 1

Culvert Data Summary - Culvert 1D

Barrel Shape: Concrete Box

Barrel Span: 1000.00 mm

Barrel Rise: 700.00 mm

Barrel Material: Concrete

Embedment: 0.00 mm

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: NONE

Table 6 - Culvert Summary Table: Culvert 1E

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
2.33	0.39	0.43	0.425	0.382	6-FFt	0.700	0.250	0.700	0.357	0.557	1.143
2.49	0.42	0.44	0.443	0.400	6-FFt	0.700	0.261	0.700	0.371	0.594	1.170
2.66	0.44	0.46	0.462	0.418	6-FFt	0.700	0.272	0.700	0.385	0.633	1.196
2.82	0.47	0.48	0.480	0.436	6-FFt	0.700	0.283	0.700	0.399	0.672	1.220
2.99	0.50	0.50	0.498	0.454	6-FFt	0.700	0.294	0.700	0.412	0.711	1.244
3.15	0.52	0.52	0.515	0.471	6-FFt	0.700	0.305	0.700	0.425	0.750	1.266
3.31	0.55	0.53	0.533	0.489	6-FFt	0.700	0.315	0.700	0.438	0.789	1.288
3.48	0.58	0.55	0.550	0.507	6-FFt	0.700	0.325	0.700	0.450	0.828	1.309
3.64	0.61	0.57	0.567	0.524	6-FFt	0.700	0.335	0.700	0.462	0.867	1.329
3.81	0.63	0.58	0.583	0.542	6-FFt	0.700	0.345	0.700	0.474	0.906	1.349
3.96	0.66	0.60	0.599	0.558	6-FFt	0.700	0.355	0.700	0.485	0.942	1.367

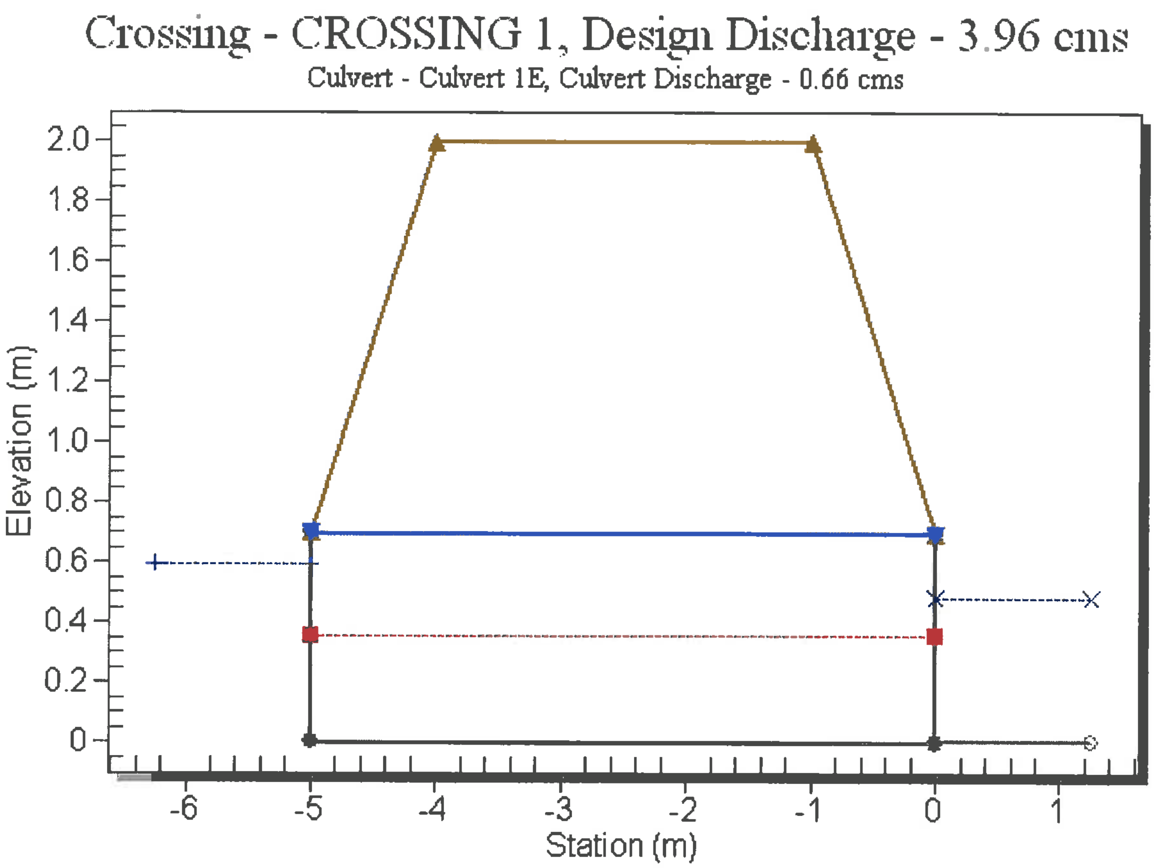
****

Inlet Elevation (invert): 0.00 m, Outlet Elevation (invert): -0.00 m

Culvert Length: 5.00 m, Culvert Slope: 0.0001

****

Water Surface Profile Plot for Culvert: Culvert 1E



Site Data - Culvert 1E

Site Data Option: Culvert Invert Data

Inlet Station: -5.00 m

Inlet Elevation: 0.00 m

Outlet Station: 0.00 m

Outlet Elevation: -0.00 m

Number of Barrels: 1

Culvert Data Summary - Culvert 1E

Barrel Shape: Concrete Box

Barrel Span: 1000.00 mm

Barrel Rise: 700.00 mm

Barrel Material: Concrete

Embedment: 0.00 mm

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: NONE

Table 7 - Culvert Summary Table: Culvert 1F

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
2.33	0.39	0.43	0.425	0.382	6-FFt	0.700	0.250	0.700	0.357	0.557	1.143
2.49	0.42	0.44	0.443	0.400	6-FFt	0.700	0.261	0.700	0.371	0.594	1.170
2.66	0.44	0.46	0.462	0.418	6-FFt	0.700	0.272	0.700	0.385	0.633	1.196
2.82	0.47	0.48	0.480	0.436	6-FFt	0.700	0.283	0.700	0.399	0.672	1.220
2.99	0.50	0.50	0.498	0.454	6-FFt	0.700	0.294	0.700	0.412	0.711	1.244
3.15	0.52	0.52	0.515	0.471	6-FFt	0.700	0.305	0.700	0.425	0.750	1.266
3.31	0.55	0.53	0.533	0.489	6-FFt	0.700	0.315	0.700	0.438	0.789	1.288
3.48	0.58	0.55	0.550	0.507	6-FFt	0.700	0.325	0.700	0.450	0.828	1.309
3.64	0.61	0.57	0.567	0.524	6-FFt	0.700	0.335	0.700	0.462	0.867	1.329
3.81	0.63	0.58	0.583	0.542	6-FFt	0.700	0.345	0.700	0.474	0.906	1.349
3.96	0.66	0.60	0.599	0.558	6-FFt	0.700	0.355	0.700	0.485	0.942	1.367

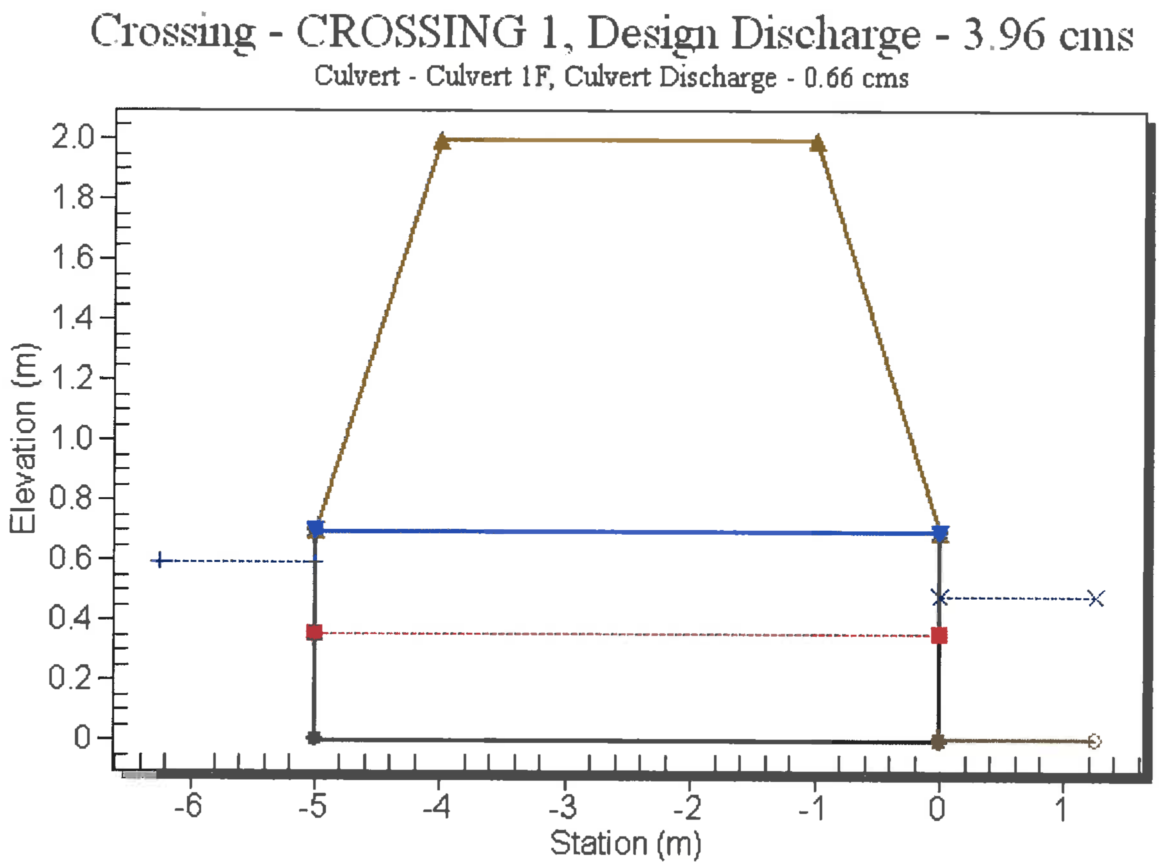
****

Inlet Elevation (invert): 0.00 m, Outlet Elevation (invert): -0.00 m

Culvert Length: 5.00 m, Culvert Slope: 0.0001

****

Water Surface Profile Plot for Culvert: Culvert 1F



Site Data - Culvert 1F

Site Data Option: Culvert Invert Data

Inlet Station: -5.00 m

Inlet Elevation: 0.00 m

Outlet Station: 0.00 m

Outlet Elevation: -0.00 m

Number of Barrels: 1

Culvert Data Summary - Culvert 1F

Barrel Shape: Concrete Box

Barrel Span: 1000.00 mm

Barrel Rise: 700.00 mm

Barrel Material: Concrete

Embedment: 0.00 mm

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: NONE

Table 8 - Downstream Channel Rating Curve (Crossing: CROSSING 1)

Flow (cms)	Water Surface Elev (m)	Depth (m)	Velocity (m/s)	Shear (Pa)	Froude Number
2.33	0.36	0.36	1.14	34.97	0.65
2.49	0.37	0.37	1.17	36.39	0.65
2.66	0.39	0.39	1.20	37.77	0.65
2.82	0.40	0.40	1.22	39.10	0.66
2.99	0.41	0.41	1.24	40.41	0.66
3.15	0.43	0.43	1.27	41.68	0.66
3.31	0.44	0.44	1.29	42.92	0.67
3.48	0.45	0.45	1.31	44.14	0.67
3.64	0.46	0.46	1.33	45.33	0.67
3.81	0.47	0.47	1.35	46.50	0.67
3.96	0.49	0.49	1.37	47.57	0.68

Tailwater Channel Data - CROSSING 1

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 5.00 m

Side Slope (H:V): 2.00 (_:1)

Channel Slope: 0.0100

Channel Manning's n: 0.0400

Channel Invert Elevation: 0.00 m

Roadway Data for Crossing: CROSSING 1

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 300.00 m

Crest Elevation: 2.00 m

Roadway Surface: Paved

Roadway Top Width: 3.00 m

HY-8 Energy Dissipation Report

Scour Hole Geometry

Parameter	Value	Units
Select Culvert and Flow		
Crossing	CROSSING 1	
Culvert	Culvert 1A	
Flow	3.96	cms
Culvert Data		
Culvert Width (including multiple barrels)	1.0	m
Culvert Height	0.7	m
Outlet Depth	0.70	m
Outlet Velocity	0.94	m/s
Froude Number	0.36	
Tailwater Depth	0.49	m
Tailwater Velocity	1.37	m/s
Tailwater Slope (SO)	0.0001	
Scour Data		
Time to Peak		
Note:	if Time to Peak is unknown, enter 30 min	
Time to Peak	30.000	min
Cohesion	Cohesive	
Saturated Shear Strength		
Note:	ASTM D211-66-76	
Saturated Shear Strength	100.000	kPa
Plasticity Index		
Note:	ASTM D423-36	
Note:	Plasticity must be between 5 and 16	
Plasticity Index	15.0	
Tailwater Flow Depth after Culvert Outlet	Normal Depth	
Results		
Assumptions		
Tractive shear stress	0.161	kPa
Modified Shear Number	0.264	
Scour Hole Dimensions		
Length (LS)	3.768	m
Width (WS)	3.777	m
Depth (DS)	0.871	m
Volume (VS)	1.464	m^3
DS at 0.4(LS)	1.507	m
Tailwater Depth (TW)	0.485	m
Velocity with TW and WS	0.286	m/s

HY-8 Culvert Analysis Report

Table 1 - Summary of Culvert Flows at Crossing: CROSSING 2

Headwater Elevation (m)	Total Discharge (cms)	Culvert 2A Discharge (cms)	Culvert 2B Discharge (cms)	Culvert 2C Discharge (cms)	Culvert 2D Discharge (cms)	Roadway Discharge (cms)	Iterations
1.69	42.00	7.86	13.11	13.11	7.86	0.00	32
1.73	45.50	8.05	13.41	13.41	8.05	2.52	9
1.75	49.00	8.13	13.55	13.55	8.13	5.57	6
1.77	52.50	8.20	13.67	13.67	8.20	8.68	5
1.78	56.00	8.27	13.78	13.78	8.27	11.87	5
1.80	59.50	8.33	13.88	13.88	8.33	15.03	4
1.81	63.00	8.35	13.94	13.94	8.35	18.38	4
1.83	66.50	8.20	13.69	13.69	8.20	22.68	4
1.84	70.00	8.04	13.43	13.43	8.04	27.01	4
1.86	73.50	7.88	13.17	13.17	7.88	31.36	4
1.87	76.00	7.77	12.98	12.98	7.77	34.48	4
1.70	42.23	7.92	13.20	13.20	7.92	0.00	Overtopping

Table 2 - Culvert Summary Table: Culvert 2A

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
42.00	7.86	1.69	1.687	1.488	6-FFt	1.000	0.890	1.000	0.945	2.621	2.235
45.50	8.05	1.73	1.730	1.559	6-FFt	1.000	0.904	1.000	0.990	2.682	2.300
49.00	8.13	1.75	1.750	1.615	4-FFf	1.000	0.910	1.000	1.034	2.711	2.361
52.50	8.20	1.77	1.768	1.668	4-FFf	1.000	0.915	1.000	1.077	2.735	2.418
56.00	8.27	1.78	1.783	1.719	4-FFf	1.000	0.920	1.000	1.119	2.756	2.474
59.50	8.33	1.80	1.797	1.768	4-FFf	1.000	0.924	1.000	1.159	2.775	2.526
63.00	8.35	1.81	1.802	1.811	4-FFf	1.000	0.926	1.000	1.199	2.783	2.577
66.50	8.20	1.83	1.765	1.827	4-FFf	1.000	0.915	1.000	1.237	2.732	2.626
70.00	8.04	1.84	1.728	1.843	4-FFf	1.000	0.903	1.000	1.275	2.680	2.672
73.50	7.88	1.86	1.692	1.857	4-FFf	1.000	0.891	1.000	1.311	2.628	2.718
76.00	7.77	1.87	1.666	1.868	4-FFf	1.000	0.883	1.000	1.337	2.590	2.749

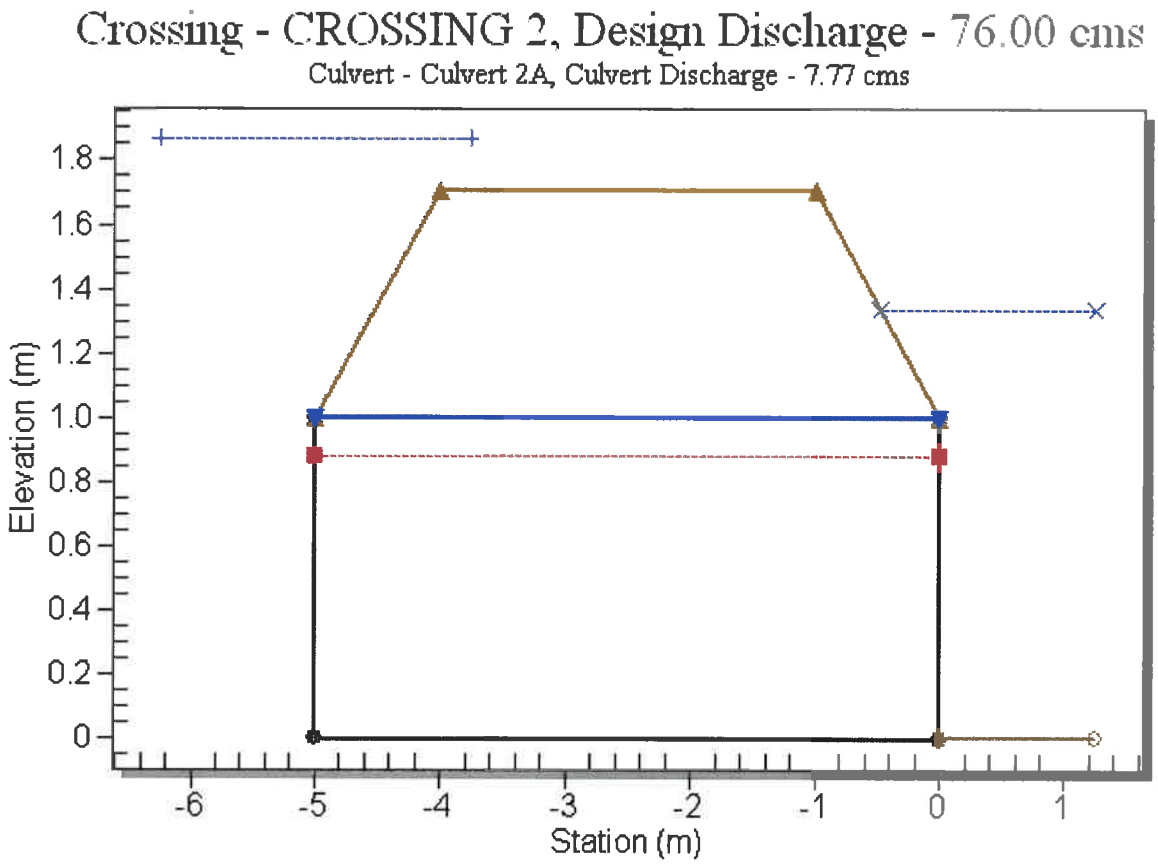
****

Inlet Elevation (invert): 0.00 m, Outlet Elevation (invert): -0.00 m

Culvert Length: 5.00 m, Culvert Slope: 0.0001

****

Water Surface Profile Plot for Culvert: Culvert 2A



Site Data - Culvert 2A

Site Data Option: Culvert Invert Data

Inlet Station: -5.00 m

Inlet Elevation: 0.00 m

Outlet Station: 0.00 m

Outlet Elevation: -0.00 m

Number of Barrels: 1

Culvert Data Summary - Culvert 2A

Barrel Shape: Concrete Box

Barrel Span: 3000.00 mm

Barrel Rise: 1000.00 mm

Barrel Material: Concrete

Embedment: 0.00 mm

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: NONE

Table 3 - Culvert Summary Table: Culvert 2B

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
42.00	13.11	1.69	1.687	1.486	6-FFt	1.000	0.890	1.000	0.945	2.621	2.235
45.50	13.41	1.73	1.730	1.556	6-FFt	1.000	0.904	1.000	0.990	2.682	2.300
49.00	13.55	1.75	1.750	1.613	4-FFf	1.000	0.910	1.000	1.034	2.711	2.361
52.50	13.67	1.77	1.768	1.666	4-FFf	1.000	0.915	1.000	1.077	2.735	2.418
56.00	13.78	1.78	1.783	1.717	4-FFf	1.000	0.920	1.000	1.119	2.756	2.474
59.50	13.88	1.80	1.797	1.765	4-FFf	1.000	0.924	1.000	1.159	2.775	2.526
63.00	13.94	1.81	1.807	1.811	4-FFf	1.000	0.927	1.000	1.199	2.789	2.577
66.50	13.69	1.83	1.770	1.827	4-FFf	1.000	0.916	1.000	1.237	2.738	2.626
70.00	13.43	1.84	1.733	1.843	4-FFf	1.000	0.904	1.000	1.275	2.686	2.672
73.50	13.17	1.86	1.696	1.857	4-FFf	1.000	0.893	1.000	1.311	2.634	2.718
76.00	12.98	1.87	1.670	1.868	4-FFf	1.000	0.884	1.000	1.337	2.596	2.749

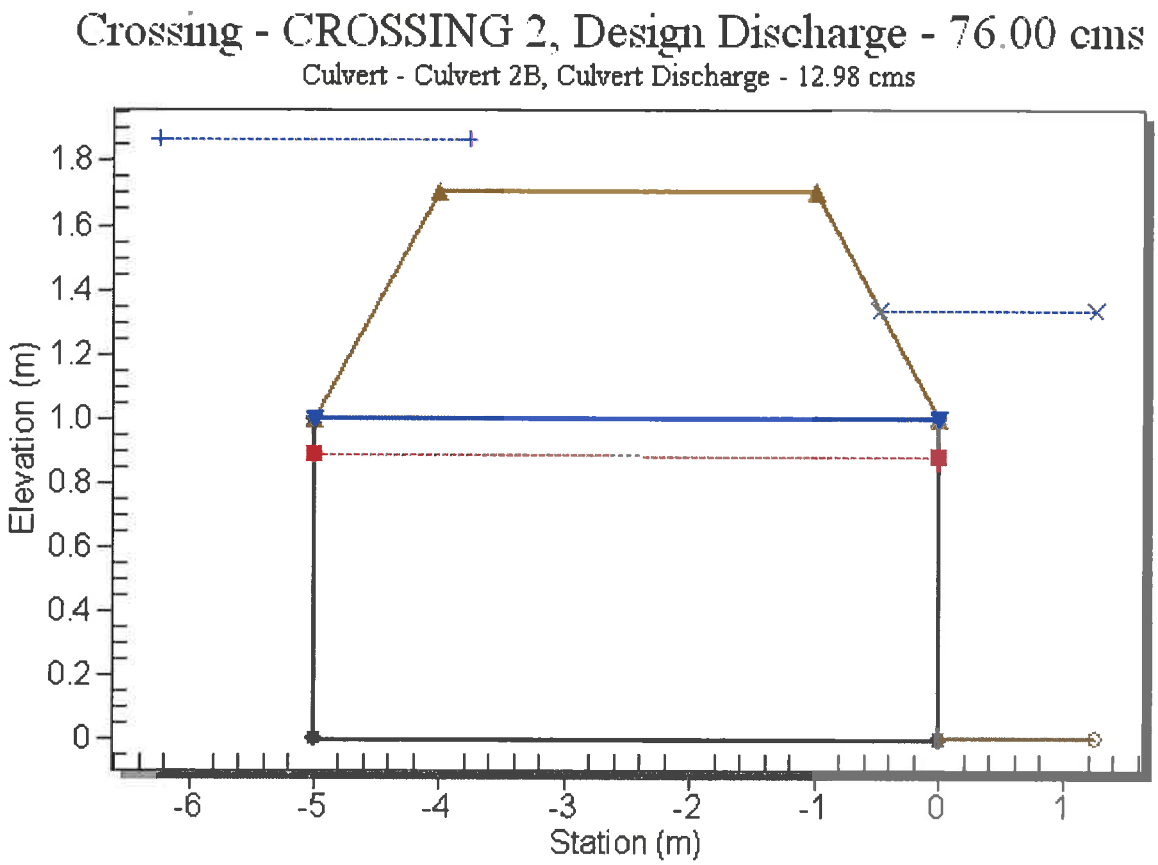
****

Inlet Elevation (invert): 0.00 m, Outlet Elevation (invert): -0.00 m

Culvert Length: 5.00 m, Culvert Slope: 0.0001

****

Water Surface Profile Plot for Culvert: Culvert 2B



Site Data - Culvert 2B

Site Data Option: Culvert Invert Data

Inlet Station: -5.00 m

Inlet Elevation: 0.00 m

Outlet Station: 0.00 m

Outlet Elevation: -0.00 m

Number of Barrels: 1

Culvert Data Summary - Culvert 2B

Barrel Shape: Concrete Box

Barrel Span: 5000.00 mm

Barrel Rise: 1000.00 mm

Barrel Material: Concrete

Embedment: 0.00 mm

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: NONE

Table 4 - Culvert Summary Table: Culvert 2C

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
42.00	13.11	1.69	1.687	1.486	6-FFt	1.000	0.890	1.000	0.945	2.621	2.235
45.50	13.41	1.73	1.730	1.556	6-FFt	1.000	0.904	1.000	0.990	2.682	2.300
49.00	13.55	1.75	1.750	1.613	4-FFf	1.000	0.910	1.000	1.034	2.711	2.361
52.50	13.67	1.77	1.768	1.666	4-FFf	1.000	0.915	1.000	1.077	2.735	2.418
56.00	13.78	1.78	1.783	1.717	4-FFf	1.000	0.920	1.000	1.119	2.756	2.474
59.50	13.88	1.80	1.797	1.765	4-FFf	1.000	0.924	1.000	1.159	2.775	2.526
63.00	13.94	1.81	1.807	1.811	4-FFf	1.000	0.927	1.000	1.199	2.789	2.577
66.50	13.69	1.83	1.770	1.827	4-FFf	1.000	0.916	1.000	1.237	2.738	2.626
70.00	13.43	1.84	1.733	1.843	4-FFf	1.000	0.904	1.000	1.275	2.686	2.672
73.50	13.17	1.86	1.696	1.857	4-FFf	1.000	0.893	1.000	1.311	2.634	2.718
76.00	12.98	1.87	1.670	1.868	4-FFf	1.000	0.884	1.000	1.337	2.596	2.749

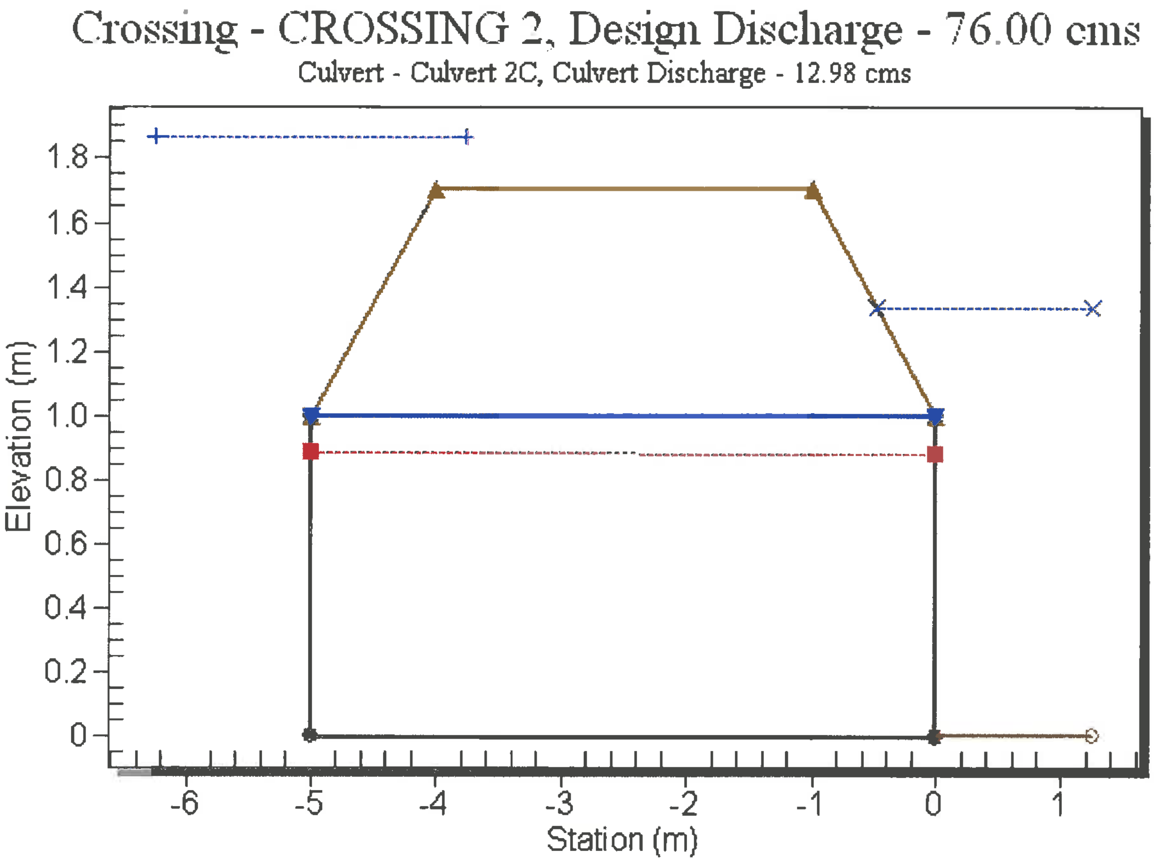
****

Inlet Elevation (invert): 0.00 m, Outlet Elevation (invert): -0.00 m

Culvert Length: 5.00 m, Culvert Slope: 0.0001

****

Water Surface Profile Plot for Culvert: Culvert 2C



Site Data - Culvert 2C

Site Data Option: Culvert Invert Data

Inlet Station: -5.00 m

Inlet Elevation: 0.00 m

Outlet Station: 0.00 m

Outlet Elevation: -0.00 m

Number of Barrels: 1

Culvert Data Summary - Culvert 2C

Barrel Shape: Concrete Box

Barrel Span: 5000.00 mm

Barrel Rise: 1000.00 mm

Barrel Material: Concrete

Embedment: 0.00 mm

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: NONE

Table 5 - Culvert Summary Table: Culvert 2D

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
42.00	7.86	1.69	1.687	1.488	6-FFt	1.000	0.890	1.000	0.945	2.621	2.235
45.50	8.05	1.73	1.730	1.559	6-FFt	1.000	0.904	1.000	0.990	2.682	2.300
49.00	8.13	1.75	1.750	1.615	4-FFf	1.000	0.910	1.000	1.034	2.711	2.361
52.50	8.20	1.77	1.768	1.668	4-FFf	1.000	0.915	1.000	1.077	2.735	2.418
56.00	8.27	1.78	1.783	1.719	4-FFf	1.000	0.920	1.000	1.119	2.756	2.474
59.50	8.33	1.80	1.797	1.768	4-FFf	1.000	0.924	1.000	1.159	2.775	2.526
63.00	8.35	1.81	1.802	1.811	4-FFf	1.000	0.926	1.000	1.199	2.783	2.577
66.50	8.20	1.83	1.765	1.827	4-FFf	1.000	0.915	1.000	1.237	2.732	2.626
70.00	8.04	1.84	1.728	1.843	4-FFf	1.000	0.903	1.000	1.275	2.680	2.672
73.50	7.88	1.86	1.692	1.857	4-FFf	1.000	0.891	1.000	1.311	2.628	2.718
76.00	7.77	1.87	1.666	1.868	4-FFf	1.000	0.883	1.000	1.337	2.590	2.749

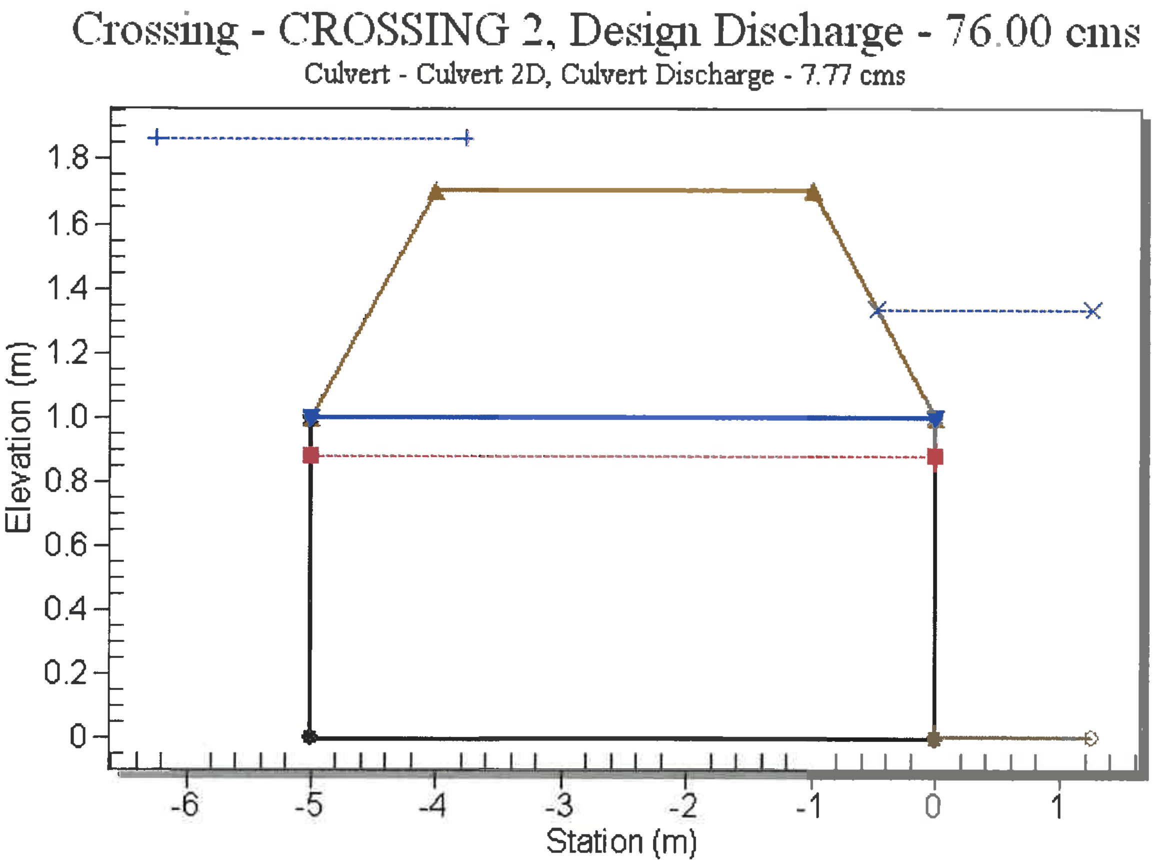
****

Inlet Elevation (invert): 0.00 m,   Outlet Elevation (invert): -0.00 m

Culvert Length: 5.00 m,   Culvert Slope: 0.0001

****

Water Surface Profile Plot for Culvert: Culvert 2D



Site Data - Culvert 2D

Site Data Option: Culvert Invert Data

Inlet Station: -5.00 m

Inlet Elevation: 0.00 m

Outlet Station: 0.00 m

Outlet Elevation: -0.00 m

Number of Barrels: 1

Culvert Data Summary - Culvert 2D

Barrel Shape: Concrete Box

Barrel Span: 3000.00 mm

Barrel Rise: 1000.00 mm

Barrel Material: Concrete

Embedment: 0.00 mm

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: NONE

Table 6 - Downstream Channel Rating Curve (Crossing: CROSSING 2)

Flow (cms)	Water Surface Elev (m)	Depth (m)	Velocity (m/s)	Shear (Pa)	Froude Number
42.00	0.94	0.94	2.24	92.60	0.77
45.50	0.99	0.99	2.30	97.06	0.77
49.00	1.03	1.03	2.36	101.39	0.78
52.50	1.08	1.08	2.42	105.58	0.78
56.00	1.12	1.12	2.47	109.65	0.79
59.50	1.16	1.16	2.53	113.62	0.79
63.00	1.20	1.20	2.58	117.48	0.79
66.50	1.24	1.24	2.63	121.26	0.80
70.00	1.27	1.27	2.67	124.94	0.80
73.50	1.31	1.31	2.72	128.55	0.80
76.00	1.34	1.34	2.75	131.08	0.81

Tailwater Channel Data - CROSSING 2

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 18.00 m

Side Slope (H:V): 2.00 (_:1)

Channel Slope: 0.0100

Channel Manning's n: 0.0400

Channel Invert Elevation: 0.00 m

Roadway Data for Crossing: CROSSING 2

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 300.00 m

Crest Elevation: 1.70 m

Roadway Surface: Paved

Roadway Top Width: 3.00 m

HY-8 Energy Dissipation Report

Scour Hole Geometry

Parameter	Value	Units
Select Culvert and Flow		
Crossing	CROSSING 2	
Culvert	Culvert 2A	
Flow	76.00	cms
Culvert Data		
Culvert Width (including multiple barrels)	3.0	m
Culvert Height	1.0	m
Outlet Depth	1.00	m
Outlet Velocity	2.59	m/s
Froude Number	0.83	
Tailwater Depth	1.34	m
Tailwater Velocity	2.75	m/s
Tailwater Slope (SO)	0.0001	
Scour Data		
Time to Peak		
Note:	if Time to Peak is unknown, enter 30 min	
Time to Peak	30.000	min
Cohesion	Cohesive	
Saturated Shear Strength		
Note:	ASTM D211-66-76	
Saturated Shear Strength	200.000	kPa
Plasticity Index		
Note:	ASTM D423-36	
Note:	Plasticity must be between 5 and 16	
Plasticity Index	15.0	
Tailwater Flow Depth after Culvert Outlet	Normal Depth	
Results		
Assumptions		
Tractive shear stress	0.309	kPa
Modified Shear Number	1.040	
Scour Hole Dimensions		
Length (LS)	12.258	m
Width (WS)	9.868	m
Depth (DS)	2.307	m
Volume (VS)	46.408	m^3
DS at 0.4(LS)	4.903	m
Tailwater Depth (TW)	1.337	m
Velocity with TW and WS	0.463	m/s

HY-8 Culvert Analysis Report

Table 1 - Summary of Culvert Flows at Crossing: CROSSING 3

Headwater Elevation (m)	Total Discharge (cms)	Culvert 3A Discharge (cms)	Culvert 3B Discharge (cms)	Culvert 3C Discharge (cms)	Roadway Discharge (cms)	Iterations
2.14	71.47	23.83	23.83	23.83	0.00	4
2.30	77.57	25.87	25.87	25.87	0.00	4
2.45	83.67	27.90	27.90	27.90	0.00	4
2.61	89.77	29.93	29.93	29.93	0.00	4
2.76	95.87	31.96	31.96	31.96	0.00	4
2.92	101.98	33.98	33.98	33.98	0.00	10
3.03	108.08	34.73	34.73	34.73	3.82	11
3.06	114.18	33.69	33.69	33.69	12.97	6
3.09	120.28	32.49	32.49	32.49	22.66	5
3.12	126.38	31.22	31.22	31.22	32.66	5
3.14	132.00	29.98	29.98	29.98	41.90	4
3.00	109.23	36.41	36.41	36.41	0.00	Overtopping

Table 2 - Culvert Summary Table: Culvert 3A

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
71.47	23.83	2.14	2.036	2.142	6-FFt	2.000	1.201	1.815	2.315	2.263	3.206
77.57	25.87	2.30	2.160	2.296	6-FFt	2.000	1.268	1.911	2.411	2.334	3.276
83.67	27.90	2.45	2.285	2.450	4-FFf	2.000	1.334	2.000	2.502	2.405	3.343
89.77	29.93	2.61	2.414	2.605	4-FFf	2.000	1.398	2.000	2.590	2.580	3.406
95.87	31.96	2.76	2.548	2.762	4-FFf	2.000	1.460	2.000	2.674	2.755	3.465
101.98	33.98	2.92	2.685	2.920	4-FFf	2.000	1.521	2.000	2.755	2.929	3.522
108.08	34.73	3.03	2.737	3.028	4-FFf	2.000	1.543	2.000	2.834	2.994	3.576
114.18	33.69	3.06	2.665	3.063	4-FFf	2.000	1.512	2.000	2.909	2.904	3.627
120.28	32.49	3.09	2.583	3.091	4-FFf	2.000	1.476	2.000	2.983	2.801	3.677
126.38	31.22	3.12	2.498	3.116	4-FFf	2.000	1.438	2.000	3.054	2.691	3.725
132.00	29.98	3.14	2.418	3.136	4-FFf	2.000	1.399	2.000	3.118	2.584	3.767

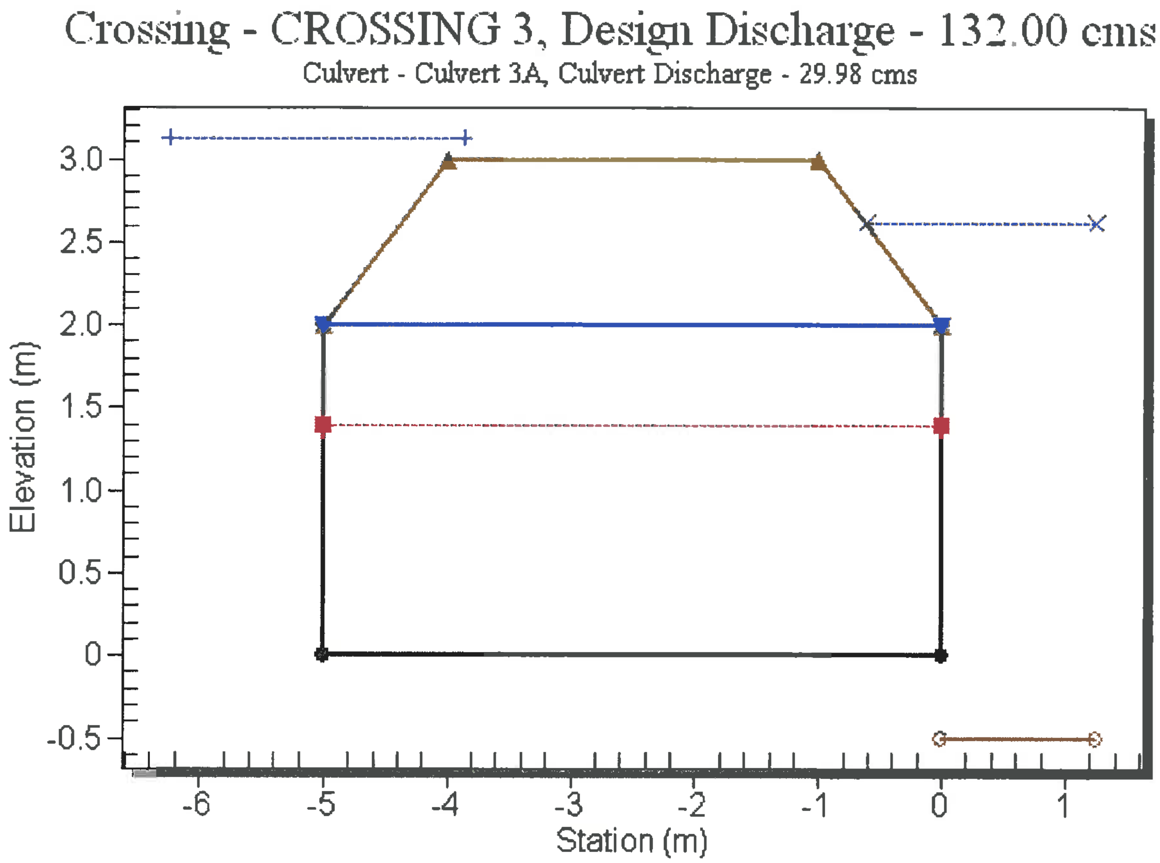
****

Inlet Elevation (invert): 0.00 m, Outlet Elevation (invert): -0.00 m

Culvert Length: 5.00 m, Culvert Slope: 0.0001

****

Water Surface Profile Plot for Culvert: Culvert 3A



Site Data - Culvert 3A

Site Data Option: Culvert Invert Data

Inlet Station: -5.00 m

Inlet Elevation: 0.00 m

Outlet Station: 0.00 m

Outlet Elevation: -0.00 m

Number of Barrels: 1

Culvert Data Summary - Culvert 3A

Barrel Shape: Concrete Box

Barrel Span: 5800.00 mm

Barrel Rise: 2000.00 mm

Barrel Material: Concrete

Embedment: 0.00 mm

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: NONE

Table 3 - Culvert Summary Table: Culvert 3B

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
71.47	23.83	2.14	2.036	2.142	6-FFt	2.000	1.201	1.815	2.315	2.263	3.206
77.57	25.87	2.30	2.160	2.296	6-FFt	2.000	1.268	1.911	2.411	2.334	3.276
83.67	27.90	2.45	2.285	2.450	4-FFf	2.000	1.334	2.000	2.502	2.405	3.343
89.77	29.93	2.61	2.414	2.605	4-FFf	2.000	1.398	2.000	2.590	2.580	3.406
95.87	31.96	2.76	2.548	2.762	4-FFf	2.000	1.460	2.000	2.674	2.755	3.465
101.98	33.98	2.92	2.685	2.920	4-FFf	2.000	1.521	2.000	2.755	2.929	3.522
108.08	34.73	3.03	2.737	3.028	4-FFf	2.000	1.543	2.000	2.834	2.994	3.576
114.18	33.69	3.06	2.665	3.063	4-FFf	2.000	1.512	2.000	2.909	2.904	3.627
120.28	32.49	3.09	2.583	3.091	4-FFf	2.000	1.476	2.000	2.983	2.801	3.677
126.38	31.22	3.12	2.498	3.116	4-FFf	2.000	1.438	2.000	3.054	2.691	3.725
132.00	29.98	3.14	2.418	3.136	4-FFf	2.000	1.399	2.000	3.118	2.584	3.767

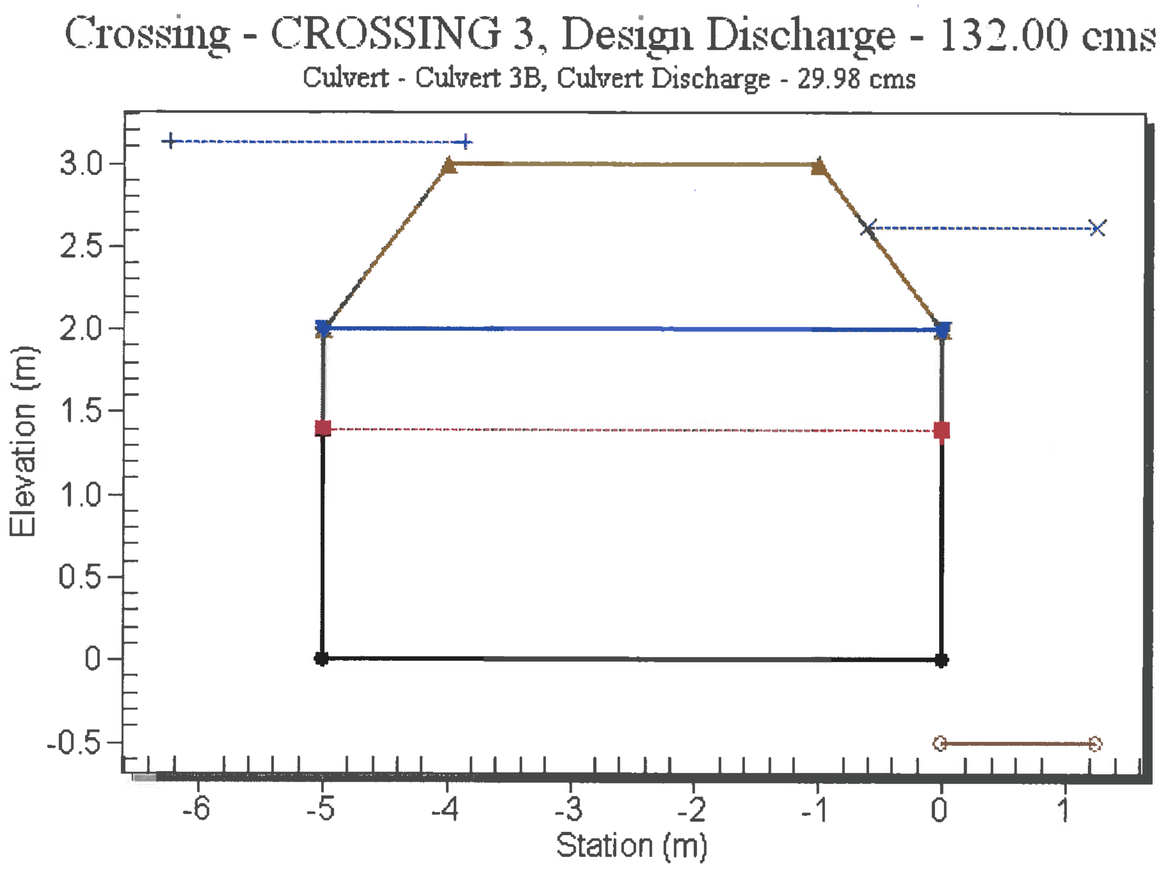
****

Inlet Elevation (invert): 0.00 m,   Outlet Elevation (invert): -0.00 m

Culvert Length: 5.00 m,   Culvert Slope: 0.0001

****

Water Surface Profile Plot for Culvert: Culvert 3B



Site Data - Culvert 3B

Site Data Option: Culvert Invert Data

Inlet Station: -5.00 m

Inlet Elevation: 0.00 m

Outlet Station: 0.00 m

Outlet Elevation: -0.00 m

Number of Barrels: 1

Culvert Data Summary - Culvert 3B

Barrel Shape: Concrete Box

Barrel Span: 5800.00 mm

Barrel Rise: 2000.00 mm

Barrel Material: Concrete

Embedment: 0.00 mm

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: NONE

Table 4 - Culvert Summary Table: Culvert 3C

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
71.47	23.83	2.14	2.036	2.142	6-FFt	2.000	1.201	1.815	2.315	2.263	3.206
77.57	25.87	2.30	2.160	2.296	6-FFt	2.000	1.268	1.911	2.411	2.334	3.276
83.67	27.90	2.45	2.285	2.450	4-FFf	2.000	1.334	2.000	2.502	2.405	3.343
89.77	29.93	2.61	2.414	2.605	4-FFf	2.000	1.398	2.000	2.590	2.580	3.406
95.87	31.96	2.76	2.548	2.762	4-FFf	2.000	1.460	2.000	2.674	2.755	3.465
101.98	33.98	2.92	2.685	2.920	4-FFf	2.000	1.521	2.000	2.755	2.929	3.522
108.08	34.73	3.03	2.737	3.028	4-FFf	2.000	1.543	2.000	2.834	2.994	3.576
114.18	33.69	3.06	2.665	3.063	4-FFf	2.000	1.512	2.000	2.909	2.904	3.627
120.28	32.49	3.09	2.583	3.091	4-FFf	2.000	1.476	2.000	2.983	2.801	3.677
126.38	31.22	3.12	2.498	3.116	4-FFf	2.000	1.438	2.000	3.054	2.691	3.725
132.00	29.98	3.14	2.418	3.136	4-FFf	2.000	1.399	2.000	3.118	2.584	3.767

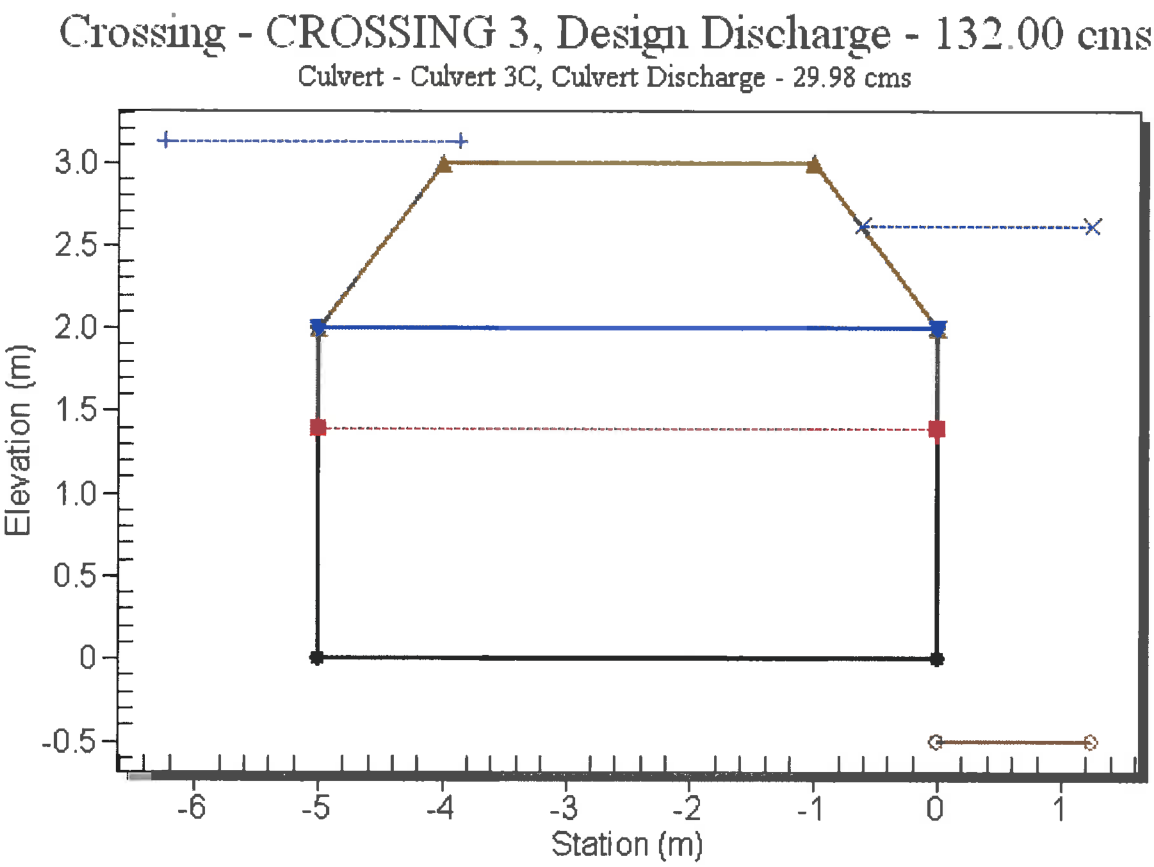
****

Inlet Elevation (invert): 0.00 m, Outlet Elevation (invert): -0.00 m

Culvert Length: 5.00 m, Culvert Slope: 0.0001

****

Water Surface Profile Plot for Culvert: Culvert 3C



Site Data - Culvert 3C

Site Data Option: Culvert Invert Data

Inlet Station: -5.00 m

Inlet Elevation: 0.00 m

Outlet Station: 0.00 m

Outlet Elevation: -0.00 m

Number of Barrels: 1

Culvert Data Summary - Culvert 3C

Barrel Shape: Concrete Box

Barrel Span: 5800.00 mm

Barrel Rise: 2000.00 mm

Barrel Material: Concrete

Embedment: 0.00 mm

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: NONE

Table 5 - Downstream Channel Rating Curve (Crossing: CROSSING 3)

Flow (cms)	Water Surface Elev (m)	Depth (m)	Velocity (m/s)	Shear (Pa)	Froude Number
71.47	1.81	2.31	3.21	226.92	0.82
77.57	1.91	2.41	3.28	236.29	0.82
83.67	2.00	2.50	3.34	245.25	0.83
89.77	2.09	2.59	3.41	253.84	0.83
95.87	2.17	2.67	3.47	262.10	0.83
101.98	2.26	2.76	3.52	270.06	0.84
108.08	2.33	2.83	3.58	277.75	0.84
114.18	2.41	2.91	3.63	285.19	0.84
120.28	2.48	2.98	3.68	292.40	0.84
126.38	2.55	3.05	3.72	299.40	0.85
132.00	2.62	3.12	3.77	305.67	0.85

Tailwater Channel Data - CROSSING 3

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 5.00 m

Side Slope (H:V): 2.00 (_:1)

Channel Slope: 0.0100

Channel Manning's n: 0.0400

Channel Invert Elevation: -0.50 m

Roadway Data for Crossing: CROSSING 3

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 500.00 m

Crest Elevation: 3.00 m

Roadway Surface: Paved

Roadway Top Width: 3.00 m

HY-8 Energy Dissipation Report

Scour Hole Geometry

Parameter	Value	Units
Select Culvert and Flow		
Crossing	CROSSING 3	
Culvert	Culvert 3A	
Flow	132.00	cms
Culvert Data		
Culvert Width (including multiple barrels)	5.8	m
Culvert Height	2.0	m
Outlet Depth	2.00	m
Outlet Velocity	2.58	m/s
Froude Number	0.58	
Tailwater Depth	3.12	m
Tailwater Velocity	3.77	m/s
Tailwater Slope (SO)	0.0001	
Scour Data		
Time to Peak		
Note:	if Time to Peak is unknown, enter 30 min	
Time to Peak	30.000	min
Cohesion	Cohesive	
Saturated Shear Strength		
Note:	ASTM D211-66-76	
Saturated Shear Strength	100.000	kPa
Plasticity Index		
Note:	ASTM D423-36	
Note:	Plasticity must be between 5 and 16	
Plasticity Index	15.0	
Tailwater Flow Depth after Culvert Outlet	Normal Depth	
Results		
Assumptions		
Tractive shear stress	0.161	kPa
Modified Shear Number	1.988	
Scour Hole Dimensions		
Length (LS)	29.855	m
Width (WS)	21.665	m
Depth (DS)	5.099	m
Volume (VS)	644.857	m^3
DS at 0.4(LS)	11.942	m
Tailwater Depth (TW)	3.118	m
Velocity with TW and WS	0.345	m/s

HY-8 Culvert Analysis Report

Table 1 - Summary of Culvert Flows at Crossing: CROSSING 4

Headwater Elevation (m)	Total Discharge (cms)	Culvert 4A Discharge (cms)	Culvert 4B Discharge (cms)	Roadway Discharge (cms)	Iterations
1.02	16.93	8.54	8.54	0.00	11
1.06	18.24	9.20	9.20	0.00	10
1.11	19.54	9.81	9.81	0.00	9
1.15	20.85	10.43	10.43	0.00	8
1.19	22.16	11.12	11.12	0.00	7
1.23	23.47	11.75	11.75	0.00	7
1.27	24.77	12.43	12.43	0.00	6
1.31	26.08	13.06	13.06	0.00	6
1.32	27.39	8.26	8.26	0.00	11
1.32	28.69	18.24	18.24	0.00	6
1.32	29.00	18.24	18.24	0.00	4
3.00	61.39	30.70	30.70	0.00	Overtopping

Table 2 - Culvert Summary Table: Culvert 4A

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
16.93	8.54	1.02	0.807	1.017	6-FFt	1.458	0.470	0.998	0.997	1.007	1.887
18.24	9.20	1.06	0.848	1.062	6-FFt	1.532	0.493	1.040	1.040	1.040	1.932
19.54	9.81	1.11	0.885	1.107	6-FFt	1.601	0.515	1.081	1.081	1.067	1.974
20.85	10.43	1.15	0.922	1.150	6-FFt	1.668	0.537	1.121	1.121	1.095	2.013
22.16	11.12	1.19	0.962	1.192	6-FFt	1.742	0.560	1.160	1.159	1.128	2.051
23.47	11.75	1.23	0.997	1.234	6-FFt	2.000	0.581	1.197	1.197	1.155	2.087
24.77	12.43	1.27	1.033	1.275	6-FFt	2.000	0.603	1.234	1.233	1.186	2.122
26.08	13.06	1.31	1.066	1.315	6-FFt	2.000	0.623	1.269	1.269	1.210	2.155
27.39	8.26	1.32	0.789	1.322	6-FFt	1.426	0.459	1.304	1.304	0.745	2.187
28.69	18.24	1.32	1.322	1.426	6-FFt	2.000	0.779	1.338	1.337	1.604	2.218
29.00	18.24	1.32	1.322	1.434	6-FFt	2.000	0.779	1.346	1.345	1.595	2.225

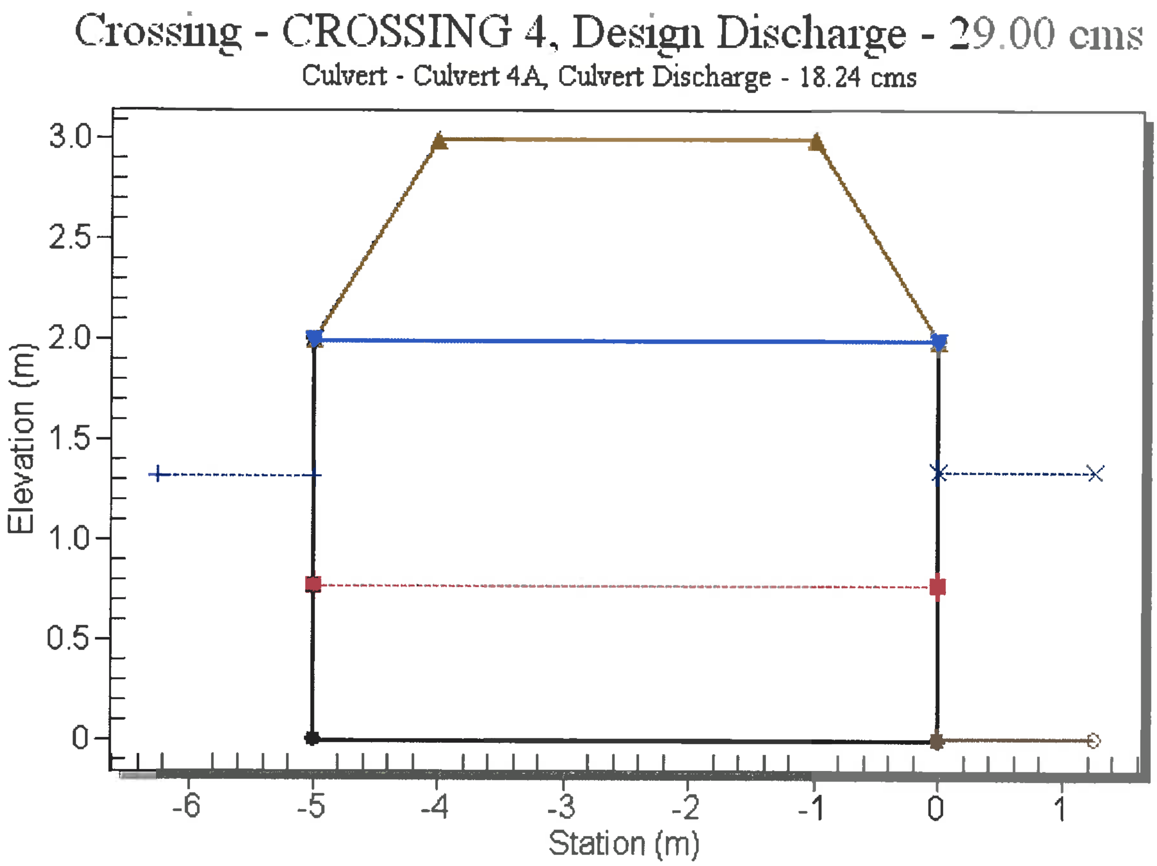
****

Inlet Elevation (invert): 0.00 m, Outlet Elevation (invert): -0.00 m

Culvert Length: 5.00 m, Culvert Slope: 0.0001

****

Water Surface Profile Plot for Culvert: Culvert 4A



Site Data - Culvert 4A

Site Data Option: Culvert Invert Data

Inlet Station: -5.00 m

Inlet Elevation: 0.00 m

Outlet Station: 0.00 m

Outlet Elevation: -0.00 m

Number of Barrels: 1

Culvert Data Summary - Culvert 4A

Barrel Shape: Concrete Box

Barrel Span: 8500.00 mm

Barrel Rise: 2000.00 mm

Barrel Material: Concrete

Embedment: 0.00 mm

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: NONE

Table 3 - Culvert Summary Table: Culvert 4B

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
16.93	8.54	1.02	0.807	1.017	6-FFt	1.458	0.470	0.998	0.997	1.007	1.887
18.24	9.20	1.06	0.848	1.062	6-FFt	1.532	0.493	1.040	1.040	1.040	1.932
19.54	9.81	1.11	0.885	1.107	6-FFt	1.601	0.515	1.081	1.081	1.067	1.974
20.85	10.43	1.15	0.922	1.150	6-FFt	1.668	0.537	1.121	1.121	1.095	2.013
22.16	11.12	1.19	0.962	1.192	6-FFt	1.742	0.560	1.160	1.159	1.128	2.051
23.47	11.75	1.23	0.997	1.234	6-FFt	2.000	0.581	1.197	1.197	1.155	2.087
24.77	12.43	1.27	1.033	1.275	6-FFt	2.000	0.603	1.234	1.233	1.186	2.122
26.08	13.06	1.31	1.066	1.315	6-FFt	2.000	0.623	1.269	1.269	1.210	2.155
27.39	8.26	1.32	0.789	1.322	6-FFt	1.426	0.459	1.304	1.304	0.745	2.187
28.69	18.24	1.32	1.322	1.426	6-FFt	2.000	0.779	1.338	1.337	1.604	2.218
29.00	18.24	1.32	1.322	1.434	6-FFt	2.000	0.779	1.346	1.345	1.595	2.225

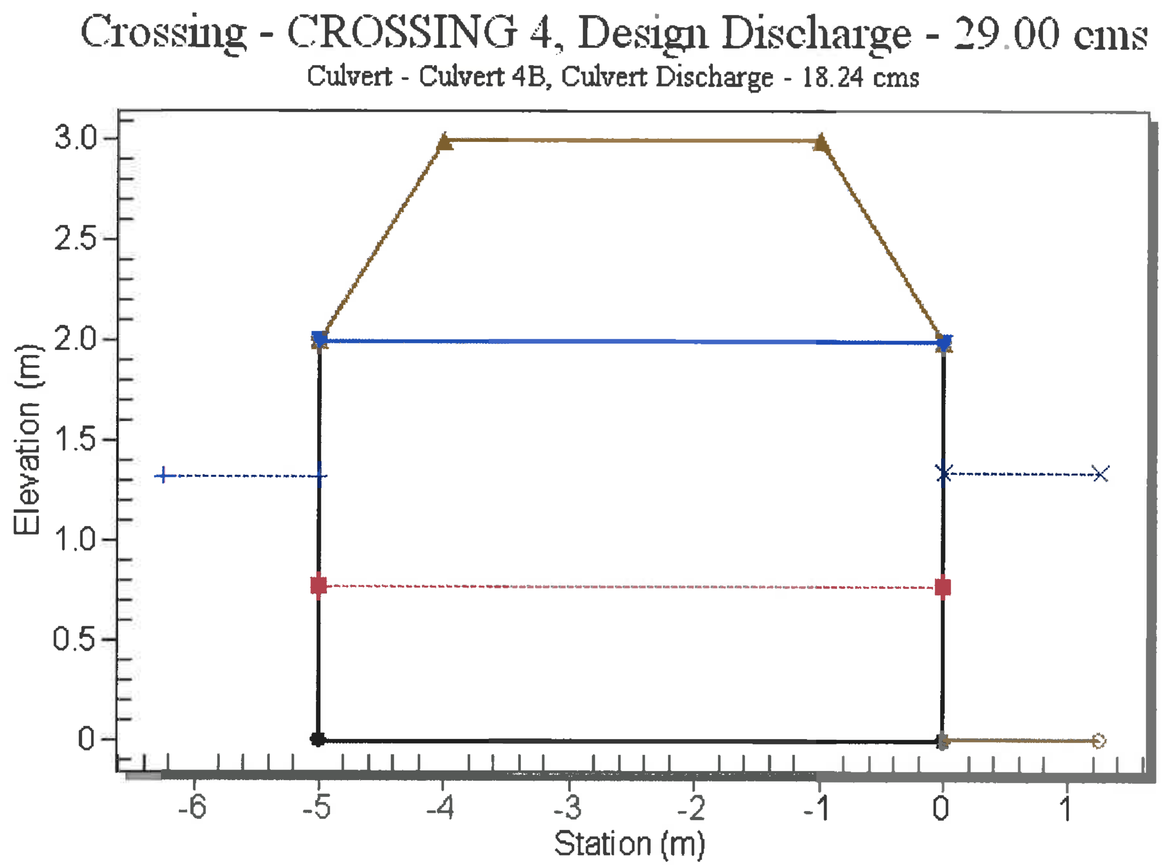
****

Inlet Elevation (invert): 0.00 m,   Outlet Elevation (invert): -0.00 m

Culvert Length: 5.00 m,   Culvert Slope: 0.0001

****

Water Surface Profile Plot for Culvert: Culvert 4B



Site Data - Culvert 4B

Site Data Option: Culvert Invert Data

Inlet Station: -5.00 m

Inlet Elevation: 0.00 m

Outlet Station: 0.00 m

Outlet Elevation: -0.00 m

Number of Barrels: 1

Culvert Data Summary - Culvert 4B

Barrel Shape: Concrete Box

Barrel Span: 8500.00 mm

Barrel Rise: 2000.00 mm

Barrel Material: Concrete

Embedment: 0.00 mm

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: NONE

Table 4 - Downstream Channel Rating Curve (Crossing: CROSSING 4)

Flow (cms)	Water Surface Elev (m)	Depth (m)	Velocity (m/s)	Shear (Pa)	Froude Number
16.93	1.00	1.00	1.89	97.75	0.67
18.24	1.04	1.04	1.93	101.93	0.67
19.54	1.08	1.08	1.97	105.95	0.67
20.85	1.12	1.12	2.01	109.86	0.68
22.16	1.16	1.16	2.05	113.64	0.68
23.47	1.20	1.20	2.09	117.32	0.68
24.77	1.23	1.23	2.12	120.89	0.68
26.08	1.27	1.27	2.15	124.38	0.69
27.39	1.30	1.30	2.19	127.78	0.69
28.69	1.34	1.34	2.22	131.09	0.69
29.00	1.35	1.35	2.22	131.86	0.69

Tailwater Channel Data - CROSSING 4

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 7.00 m

Side Slope (H:V): 2.00 (_:1)

Channel Slope: 0.0100

Channel Manning's n: 0.0450

Channel Invert Elevation: 0.00 m

Roadway Data for Crossing: CROSSING 4

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 330.00 m

Crest Elevation: 3.00 m

Roadway Surface: Paved

Roadway Top Width: 3.00 m

HY-8 Energy Dissipation Report

Scour Hole Geometry

Parameter	Value	Units
Select Culvert and Flow		
Crossing	CROSSING 4	
Culvert	Culvert 4A	
Flow	29.00	cms
Culvert Data		
Culvert Width (including multiple barrels)	8.5	m
Culvert Height	2.0	m
Outlet Depth	1.35	m
Outlet Velocity	1.59	m/s
Froude Number	0.44	
Tailwater Depth	1.35	m
Tailwater Velocity	2.22	m/s
Tailwater Slope (SO)	0.0001	
Scour Data		
Time to Peak		
Note:	if Time to Peak is unknown, enter 30 min	
Time to Peak	30.000	min
Cohesion	Cohesive	
Saturated Shear Strength		
Note:	ASTM D211-66-76	
Saturated Shear Strength	400.000	kPa
Plasticity Index		
Note:	ASTM D423-36	
Note:	Plasticity must be between 5 and 16	
Plasticity Index	15.0	
Tailwater Flow Depth after Culvert Outlet	Normal Depth	
Results		
Assumptions		
Tractive shear stress	0.605	kPa
Modified Shear Number	0.201	
Scour Hole Dimensions		
Length (LS)	13.920	m
Width (WS)	14.573	m
Depth (DS)	3.352	m
Volume (VS)	74.992	m^3
DS at 0.4(LS)	5.568	m
Tailwater Depth (TW)	1.345	m
Velocity with TW and WS	0.785	m/s

ANNEXURE 14

Preliminary Hazard Analysis

prepared by

URS Australia Pty Ltd

ANNEXURE 14

4 March 2011
Project No. 43167736.00001

Manildra Group
PO Box 123
Nowra NSW 2541

Attention: Brian Hanley
Manager Energy and Sustainability

Dear Brian,

Subject:

Shoalhaven Starches Pipeline Project (MP10-0108) Environmental Assessment - Preliminary Hazard Assessment

Shoalhaven Starches engaged URS to provide inputs for a Preliminary Hazard Analysis as part of the Environmental Assessment for the proposed Bomaderry Gas Lateral to satisfy the requirements of the NSW Planning Director General's Requirements – Shoalhaven Starches Pipeline Project (MP10_0108) letter dated 8 November 2010.

URS carried out a multi-discipline review based on the following Policies, Guidelines and Plans:

- State Environment Planning Policy No 33 - Hazardous and Offensive Development
- Applying SEPP 33 - Hazardous and Offensive Development Application Guidelines (DUAP)
- Hazardous Industry Planning Advisory Paper No 3 – Environmental Risk Impact Risk Assessment Guidelines
- Hazardous Industry Planning Advisory Paper No 6 – Guidelines for Hazard Analysis
- AS/NZS 4360:2004 Risk Management (Australian Standards)
- HB 203:2006 Environmental Risk Management – Principles & Processes (Australian Standards)
- Multi-Level Risk Assessment (DUAP).

METHOD

The above Policies, Guidelines and Plans were reviewed as to their application to the proposed development and actioned as applicable.

A multi-discipline hazard identification workshop was used to perform hazard identification (HAZID) facilitated by Plannager Risk Management Consultants Pty Ltd to identify and assess the hazards on the selected route in conjunction with a multi-discipline team.

URS Australia Pty Ltd (ABN 46 000 691 690)
Level 4, 407 Pacific Highway
Artarmon NSW 2064
Australia
T: 61 2 8925 5500
F: 61 2 8925 5555

The multi-discipline team used to assess the risks included professionals with the following skills: design, construction, quality assurance, project management, traffic management, stakeholder interest assessment, planning, environmental (construction and operation), safety, local, state and federal government, community, gas pipeline risk assessment and pipeline operation.

Gaps in data for activities and operations along the proposed pipeline construction route were then answered in consultation with Jemena, the current gas off-take operator, and other searches for affected industries and community activities such as fuel storages and/or potential high risk areas including schools, pre-schools, aged care facilities, hospitals and medical practices.

After further consultation and data collection, the proposed design was modified to reduce the key risks identified. The HAZID was then updated by URS after relevant data gaps were investigated and updated information assessed.

Following the initial HAZID process, the pipeline design and route details were modified to include additional protection in areas assessed as higher risks and mitigation actions identified to reduce the risks. (Refer Attachment 1 – Preliminary Hazard Analysis).

Pinnacle Risk Management Pty Ltd was engaged to perform a quantitative risk Hazard Analysis (HAZAN) on those areas of key risk identified along the pipeline route based on information from current stakeholders and industrial operations as provided by Shoalhaven Starches enquiries.

The highest industrial risk zones identified were:

1. Kells Caltex Distribution (2x 60 -100kL fuel tanks disused) - Lot 1B Cambewarra Rd Bomaderry – Current Tanker truck parking area approximately 60m from the proposed gas pipeline .
2. Hitchcock's Haulage – 14 Concord Way Bomaderry -35 and 25kL above ground horizontal diesel storage tanks approximately 100m from the proposed gas pipeline.

The two locations were assessed quantitatively for Jet Fire, Flash Fire and Explosion risks and the results are tabulated in **Table 1 - Bomaderry Pipeline - Quantitative Risk Assessment**.

Table 1 - Bomaderry Pipeline - Quantitative Risk Assessment

Risk Event Category	Jet Fire Likelihood	Flash Fire Likelihood	Explosion Likelihood
Unit	**Times/year**	**Times/year**	**Times/year**
Event Basis	4.5 x 10-6 per km per year x 0.32 kms	1.8 x 10-6 per km per year x 1.6 kms	2.7 x 10-6 per km per year x 0.45 kms
Frequency	1.4 x 10-6	2.9 x 10-6	1.2 x 10-6
Risk Class **- Safety and Health**	Low II	Low II	Low II
Risk Class **- Financial**	Moderate II / III	Low II	Moderate II / III

The Class I area indicates a high level of risk which is intolerable and where risk reduction is required. This requires the reduction of frequency and/or consequence.

The Class II area indicates a moderate level of risk. Whilst the risk is not unacceptable, there should be practical measures taken to lower the risk if economically viable. For risks where further mitigation is not economically viable, judgement needs to be exercised as to whether the level of risk is acceptable or not. This area is the beginning of the ALARP region (i.e. as low as reasonably practicable).

The Class III area indicates a low level of risk and is broadly considered to be acceptable. Further risk mitigation may not be required / appropriate. However, low and accepted risks should be monitored and routinely reviewed to ensure that they remain acceptable. Few risks remain static. This area includes ALARP as well as what are known as trivial or negligible risks. (Refer Attachment 2).

RESULTS AND CONCLUSIONS

Following the adoption of risk mitigation actions, the overall the Preliminary Hazard Analysis did not identify any major risks on the proposed Shoalhaven Starches Pipeline Project. The highest risk levels were identified was low-moderate. These related to bushfire and lightening risk, train derailment and potential incidents at the proposed Pestells Lane metering station. These were addressed using additional control measures to the proposed modified pipeline design.

Yours faithfully
URS Australia Pty Ltd

Alex Horn
Principal Engineer

Attachments:
1. Attachment 1 – Shoalhaven Starches Pipeline – Preliminary Hazard Analysis
2. Attachment 2 – Shoalhaven Starches Pipeline – Hazard Analysis Manildra Bomaderry Pipeline

Shoalhaven Starches Pipeline Project (MP10-0108) - Preliminary Hazard Analysis

URS Australia Pty Ltd
Job No: 43167736

Risk No.	Stage (Operation / Activity)	Risk description, including causes	Location	Consequences and Comments re Consequence Rating	Current Controls and Comments re Likelihood Rating	Risk Category	Consequences	Likelihood	Initial Risk Rating	Additional Controls	By Who	Consequences	Likelihood	Risk Rating
Identify the Risk							Evaluate the			Treat the Risk		Current Risk		
Engineering design and manufacturing														
1	Design	Incorrect design or engineering analysis of the pipeline, including stress analysis, thermal loading, etc	Non location specific	Pipeline, flanges etc. leak, fire, injury etc. Asphyxiation.	Regulatory compliance. Compliance to design standards. Review of design is included in standards requirements (quality control). Adoption of improvements by operators through ensuring competency of staff. Reputable engineering company used with track record.	PEOPLE ENV.	M S	RE RE	I L	Engineering design expert review	Pipeline designer	M S	RE RE	I L
2	Design	Pipeline failure due to poor engineering practices or inadequate specification of material	Non location specific	As above	As above	PEOPLE	M	RE	I	Engineering design expert review	Pipeline designer	M	RE	I
3	Manufacturing	Pipe manufacturing defect or material under strength	Non location specific	As above. Also loss of supply through faulty pipe.	Local pipe manufacturer used. This allows for quality control and quality assurance.	PEOPLE AND ENVIRONMENT. (SUPPLY TO MANILDRA)	M	H	L			M	H	L
4	Manufacturing	Valves and mechanical equipment manufacturing defect or material under-strength	Non location specific	As above. Also loss of supply through faulty pipe.	Reliance on spec to be robust to capture requirements. Selection of valves (fit for purpose). Valve station are located in the middle of a field - no public in the vicinity. Vegetation control. Maintenance requirements, including inspection. Five-yearly risk assessment. PTW for person maintaining / fixing. 1st response to leak by Manildra. SAOP audit (yearly)	PEOPLE, (SUPPLY ISSUE TO MANILDRA)	MI	RE	NE	Set up SAOP audit regime.	TBA	MI	RE	NE
Construction														
5	Construction and Commissioning	Pipeline not properly cleaned or dried after hydrostatic testing	Non location specific	Internal corrosion which could lead to early failure of the pipeline, particularly in low points. Leak through hole (usually bottom of pipe). Fire potential.	Hydrostatic testing procedures. Supervision and sign-offs to use of correct procedures.	PEOPLE AND ENVIRONMENT. (SUPPLY TO MANILDRA)	MI	RE	NE			MI	RE	NE
6	Construction and Commissioning	Failure during hydrostatic testing, possible injury or damage to third parties	Non location specific	Water damage. Erosion of land if not rectified.	As above. Clear zone (approx 20m either side of PL) along pipeline route during pressure test. Pipeline has previously been X-rayed. Manufacturing and design - see above. Buried pipeline.	PEOPLE, ENVIRONMENT	NE	RE	NE			NE	RE	NE
7	Construction and Commissioning	Failure during welding	Non location specific	Leak at weld. Fire risk. Injury.	Procedures for welding. Qualified welders only (tested by 3rd party at start of job for competency certification). All welds are X-rayed (NDT). Hydrostatic test.	PEOPLE ENVIRONMENT	SE	RE	LOW			SE	RE	LOW

Shoalhaven Starches Pipeline Project (MP10-0108) - Preliminary Hazard Analysis

URS Australia Pty Ltd
Job No: 43167736

Identify the Risk							Evaluate the			Treat the Risk		Current Risk		
Risk No.	Stage (Operation / Activity)	Risk description, including causes	Location	Consequences and Comments re Consequence Rating	Current Controls and Comments re Likelihood Rating	Risk Category	Consequences	Likelihood	Initial Risk Rating	Additional Controls	By Who	Consequences	Likelihood	Risk Rating
8	Construction and Commissioning	Damage of pipe or coating during construction	Non location specific	Corrosion and subsequent failure. Leak and possible long term exposure to gas. If ignition then fire.	Testing of pipe coating before installing. Use of selected backfill material to protect pipe. Corrosion protection devices (see below). Detection through smell, vegetation browning off and sonic.	PEOPLE Long term exposure Fire	SE MI	RE RE	LOW NE	a) Index the pipe after sponge pigging to provide a base-line. b) Determine how to pick up small, slow leaks.		SE MI	RE RE	LOW NE
9	Operation			Long-term leak causes green house effect	as above	ENVIRONMENT	MI	UN	LOW					
10	Operation	Loss of pipe strength due to induction bending	Non location specific	Pipeline leak, fire, injury etc. Asphyxiation.	Industry guidelines and standards. Reputable engineering company with track record.	PEOPLE ENV.	M S	RE RE	I L	Use of long radius bend pipe to allow for pigging		S	RE	LOW
11	Operation	External corrosion due to faulty CP system (CP system installed or commissioned incorrectly)	Non location specific	Corrosion and subsequent failure. Leak and possible long term exposure to gas. If ignition then fire.	QA of installation process. Regular validation of correct operation of CP system.	PEOPLE Long term exposure Fire	SE MI	RE RE	LOW NE			SE MI	RE RE	LOW NE
				Long-term leak causes green house effect	as above	ENVIRONMENT	MI	UN	LOW			MI	UN	LOW
External impact														
12	Operation	Buried utility installation or maintenance (open cut)	Non location specific	Damage to coating or pipeline. May lead to major damage to pipeline depending on force of digging equipment and wall strength. If leak then release of flammable gas. If ignited, fire.	Registered with Dial-Before-You-Dig organisation. Operator supervision during digs near pipeline. Signage. Wall thickness to preclude rupture in T1 and T2 locations. Marker tape above the pipe. Concrete slab over pipeline in high risk areas (railway and road crossings) or increased depth. Heavier pipe (design factor 0.6) at road crossings.	PEOPLE: R1 AND R2 T1	MA MA	RE RE	I I	a) Set up inspection regime (1/week). b) Determine design criteria for Rural Class locations where dwelling is encompassed in the consequence heat radiation contour as per AS2885.1.		MA MA	RE RE	I I
13	Operation		Kell's Caltex fuel storage (about 50m from pipeline)	As above. May lead to propagation to fuel storages.	a) Determine what fire water capability is available at the Caltex fuel tanks. b) Determine what fuel is held in tanks, including volumes. c) Emergency response plan to take this scenario into account. d) Determine distance to fuel storage.	PEOPLE: R1 AND R2 T1	MA MA	LOW		Complete quatitative risk assessement based on information from owner		MA MA	NEG	LOW/ MODE RATE
14	Operation		Hitchcock's Transport company's dangerous good storage (50 m away)	As above. May lead to propagation to nearby storages.	a) Determine type of storages and quantities at Hitchcock's transport. b) Determine distance to the dangerous goods storage.	PEOPLE: R1 AND R2 T1	MA MA	LOW		Complete quatitative risk assessement based on information from owner		MA MA	LOW	LOW

Shoalhaven Starches Pipeline Project (MP10-0108) - Preliminary Hazard Analysis

URS Australia Pty Ltd
Job No: 43167736

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15	Operation	Road maintenance or reconstruction, fence construction or replacement, geotechnical investigation (drills or test pits)	Non location specific	As above	As above	PEOPLE: R1 AND R2 T1	MA MA	RE	I	Decide whether the deviation across the Princess Highway (same as existing pipeline) is required).		MA MA	RE	I
16	Operation	Farming equipment / earthmoving equipment damages pipeline	Cross of field before Princess Hwy. Manildra owned cattle grazing field.	As above	As above. Manildra owned land is under their control. Distance of burial set to allow for cropping (1200mm depth).	PEOPLE: R1 AND R2 T1 (industrial land)	MA MA	RE	I			MA MA	RE	I
17	Operation	Pipe damage due to railway track maintenance or reconstruction	Along full length of pipe as it runs along the railway line	As above	RailCorp's internal management practices including knowing what pipelines etc. are in their easement. Depth of boring specified as minimum 1200mm). Thrust boring or under boring at railway crossing provides excessive depth (maybe 2.5m depth). Signage.	PEOPLE: R1 AND R2 T1 (industrial land)	MA	RE	I			MA	RE	I
18	Operation	Train derailment damages buried pipeline	Along full length of pipe as it runs along the railway line	Train hurtling worn the track, derails and damages the pipeline.	Railway internal management, including speed limits. No bend on railway line and no road crossing in the full length of the pipeline - derailment highly unlikely. Depth of burial 1200mm in railway corridors. Thrust boring or directional boring under railway crossings. Wall thickness and robust design.	PEOPLE	CA MA	HY RE	I	Bury pipeline suitable distance from rail line		CA MA	UN	I
19	Operation	Heavy vehicle damages buried pipeline	Princes Hwy crossing of pipeline. Along Maroo Road.	Heavy vehicle plunges onto pipeline causing damage.	Speed limits. Weight restrictions on Maroo Rd. Thrust boring under Highway. Depth of burial min 1,200mm under road. Wall thickness and robust design.	PEOPLE	MA	HY	LOW			MA	UN	LOW
			Through compaction by HVs on pipeline (in front of transport/courier company)	Compactation may lead to stress and leak at pipeline	Weight restrictions on Railway St. Depth of burial min 1,200mm under road. Wall thickness and robust design.	PEOPLE Long term exposure Fire	SE MI	HY	N	Pipeline to go on other side of the transport receiving company (Courier Company).		SE MI	HY	N
20	Operation	Above ground equipment damaged by out of control vehicle	Pestells Lane	Damage to above ground pipe and associated equipment leads to leak, fire, injury.	Straight road. Low traffic on country access laneway Fence. Robust piping design.	PEOPLE	MA	UN	HIGH	Install Armco (or similar) fencing at Pestells Lane site.		MA	RE	LOW
			Meter Station at Bolong Rd	Damage to above ground pipe and associated equipment.	Straight road. Speed restriction (60km/hr zone). Robust piping design. Distance from road to meter station is about 30-40 meters.	PEOPLE	MA	RE	I	a) Install Armco (or similar) fencing at metering station on Bolong Road. b) Install cyclone fence at metering station at Bolong Rd.		MA	HY	L
Natural event														

Shoalhaven Starches Pipeline Project (MP10-0108) - Preliminary Hazard Analysis

URS Australia Pty Ltd
Job No: 43167736

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21	Operation	Damage to pipeline due to Earthquake, Ground movement, due to land instability for a range of causes, mine collapse.	Along full length of pipe as it runs along the railway line	Damage to pipeline. Leak of flammable gas. Possible fire or explosion.	Not known as an earthquake prone location. No mining subsidence known to occur in the area. Pipelines have oncsiderable tensile strength.	PEOPLE	MA	RE	I			MA	RE	LOW
22	Operation	Damage to pipeline due to Floods, leading to erosion or impact damage or Inundation, leading to flotation of the pipeline.	Pipe along the full length.	Erosion damages to earth cover.	Buried pipe is not likely to be affected from flood. Water velocities are low - erosion probability is low. Regular inspections and patrol.	(SUPPLY TO MANILDRA) ENVIRONMENT	MI	UN	L			MI	UN	L
			Pestells Lane above ground facility.	As above	Design of above ground equipment to take impact from debris etc. from floods. Flooding study shown that water velocities are low.	(SUPPLY TO MANILDRA) ENVIRONMENT	MI	UN	L	Flood propensity at Pestells Lane is low.		MI	UN	L
			Bolong Rd meter station.	As above	As above. Also: Water baths and other equipment in the meter station will be located at height (about 2m above ground) as per Flood Study undertaken as part of the ethanol upgrade recently conducted.	(SUPPLY TO MANILDRA) ENVIRONMENT	MI	UN	L			MI	UN	L
23	Operation	Damage to pipeline due to Lightning	Along full length of pipe as it runs along the railway line	Damage to pipeline. Leak of flammable gas. Possible fire or explosion.	Not in a high-likelihood area for lightning. Control of vegetation along the pipeline - no trees close-by. Buried pipeline - some dissipation of lightning energy.	PEOPLE	MA	HY	LOW	Pipeline buried along length and earth protected when above ground.		MA	UN	LOW
24	Operation	Damage to pipeline due to Wind and cyclone or Bush fire	Along full length of pipe as it runs along the railway line	Damage to pipeline if excessive heat radiation.	Not a bush fire prone area (pipeline does not run through wooded areas). Small bush fire will not damage buried pipeline.	PEOPLE	MA	HY	LOW	Ensure vegetation cleared at all times. Gravel surfaced enclosure to reduce fire risk		MA	HY	LOW
Operation & maintenance														
25	Operation	Incident due to inadequate or inaccurate pipeline location information	Non location specific	Excessive risk of external interference, rerouting, issues with construction etc. Time delays. Possible penalties.	Detailed assessment of existing infrastructure to be completed. Infrastructure location, air test, soil sampling, geotec done before final route selection. Early contractor involvement (including at this risk assessment).	PEOPLE, ENVIRONMENT (SUPPLY TO MANILDRA),	MI	UN	LOW			MI	UN	LOW
26	Operation	Damage or defects not detected or not reported	Non location specific	Defects not being picked up could cause damage to pipeline resulting in leak and fire. SCADA system giving false reading leading to excessive alarms and operator not registering alarms.	Reputable companies used, track records checked. NDT tests done on all welds. URS safety management system used for construction, including incident and accident management.	PEOPLE	MA	RE	I	Links to be established between URS safety management system, incident reporting, with Manildra		MA	RE	I

Shoalhaven Starches Pipeline Project (MP10-0108) - Preliminary Hazard Analysis

URS Australia Pty Ltd
Job No: 43167736

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27	Operation	Operated outside design range	Non location specific	EGP may at some stage increase their MAOP to 16,550kPa.	Pipeline designed for current MAOP of supply pipeline	PEOPLE	MA	RE	I	a) Additional wall thickness to be provided at the pipeline in front of the first control valve at Pestells Lane. b) And/or a regulator and relief valve may be installed at the tie-in to the EGP to eliminate the possibility of the MAOP of the Bomaderry-Manildra Lateral being exceeded (Ref FEED study).		MA	RE	I
28	Operation	Maloperation of Openings (Vents, drains, relief discharges, maintenance mistakes, instrument maintenance, sample points, spillage, purging, blockage, accidental isolation, water freezing in vent, failed relief devices)	Above ground equipment (Pestells Lane and Bolong Rd metering Stn).	Leak through a small orifice. Exposure to high pressure gas. If ignition source then possibility of fire.	Detection through smell and SCADA system. Regular inspection and maintenance regime. Training of technicians. PTW system in place including safe work method statements.	PEOPLE	S	UN	I	a) Isolation requirements and ability to depressurise to be verified during detailed design. Suitable by-passing on valves. b) Pipe marking on flows. c) Work permit system to be tailored for the pipeline use. d) Seek industry benchmarking from technicians. e) HAZOP to be conducted on final design. f) Control of any changes to pipeline to be formalised. Appropriate links with Manildra to be established.		S	RE	LOW
Corrosion / Erosion														
29	Operation	External corrosion due to coating damage/ disbonding - tree roots, failure to repair	Non location specific	Corrosion and subsequent failure. Leak and possible long term exposure to gas. If ignition then fire.	Management of the right-of-way to control vegetation along the pipeline route. Regular pipeline inspection and patrol. SCADA system.	PEOPLE Long term exposure Fire	SE MI	RE	LO NE	Decide on how to link into SCADA.		SE MI	RE	LO NE
30	Operation	External corrosion due to faulty CP system (CP system incorrectly monitored or maintained)	Non location specific	Corrosion and subsequent failure. Leak and possible long term exposure to gas. If ignition then fire.	Regular pipeline inspection and patrol. SCADA system. Training of technicians. Supervision and procedures.	PEOPLE Long term exposure Fire	SE MI	RE RE	LOW NE			SE MI	RE RE	LOW NE
31	Operation	External corrosion due to Local earth potential rise due to earthing fault or lightning	Non location specific	May cause damage to coating and pipe. May lead to pipe failure and fire.	Lightning strike is a low frequency event in this location. Vegetation (tree) control. Buried pipeline. Assessment of soil conductivity - for high conductive soils, remediation required (e.g. Coating or non conductive padding). Geotech investigation to be conducted.	PEOPLE Long term exposure Fire	SE MI	RE RE	LOW NE			SE MI	RE RE	LOW NE

Shoalhaven Starches Pipeline Project (MP10-0108) - Preliminary Hazard Analysis

URS Australia Pty Ltd
Job No: 43167736

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32	Operation	Internal corrosion	Non location specific	Internal corrosion is virtually excluded from clean hydrocarbon.	Pipeline assessment by Operator. Independent reviewer contracted to check that the control of corrosion meets with best available practice. Baseline pipeline status to be determined at pipeline installation. Wall thickness and low design factor.	PEOPLE Long term exposure Fire	SE MI	RE RE	LOW NE	Gas testing to be done periodically (regime to be determined) to validate gas composition provided by supplier.		SE MI	RE RE	LOW NE
33	Operation	External corrosion due to coating damage/ disbonding - soil chemistry (contaminated fill, acid sulphate soil)	Non location specific	External corrosion damages pipeline. Leaks and fire. Green house gas emission.	Soil samples to be taken prior to final route selection.	PEOPLE Long term exposure Fire	SE MI	RE RE	LOW NE			SE MI	RE RE	LOW NE
34	Operation	External corrosion due to interference from other CP system	Across the main easement at Princess Hwy. Along Pestells Lane.	External corrosion damages pipeline. Leaks and fire. Green house gas emission.	Setting of CP to over for induced current during installation. Pipeline is installed at opposite side of road along Meroo Rd.	PEOPLE Long term exposure Fire	SE MI	RE RE	LOW NE			SE MI	RE RE	LOW NE
35	Operation	External corrosion due to Induced voltages from parallel power lines (steady state and fault condition) - effects on personnel and equipment	High voltage (11kV): At the pressure reducing station at Bolong Rd (perpendicular to the pipeline). At easement crossing over the Princess Hwy (about 500m). At Pestells Lane. Low voltage (415V): along industrial and residential developments.	External corrosion damages pipeline. Leaks and fire. Green house gas emission.	Installed as per design criteria and guidelines (e.g. API).	PEOPLE Long term exposure Fire	SE MI	RE RE	LOW NE			SE MI	RE RE	LOW NE
36	Operation	External corrosion due to stray currents from the railways	Pipeline along railway	External corrosion damages pipeline. Leaks and fire. Green house gas emission.	Current railway is not electrified.	PEOPLE Long term exposure Fire	SE MI	RE RE	LOW NE	Provide insulation flanges to the pipeline in sections along the railway (in the event of future electrifying of the railway).		SE MI	RE	LOW NE
37	Operation	External corrosion due to Buried HV cables - pipe damage due to cable failure	Possible buried HV cables along Fletchers lane	External corrosion damages pipeline. Leaks and fire. Green house gas emission.	Installed as per design criteria and guidelines (e.g. API).	PEOPLE Long term exposure Fire	SE MI	RE RE	LOW NE	Check whether there are buried cables along Fletchers lane. If thee then re-route to other side of road.		SE MI	H	NE

Long Term Weakening

Shoalhaven Starches Pipeline Project (MP10-0108) - Preliminary Hazard Analysis

URS Australia Pty Ltd
Job No: 43167736

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38		Internal/external corrosion, erosion, stress corrosioncracking, thermal creep, thermal cycling, embrittlement, vibration, metal fatigue	Non location specific	Coastal environment gets changes in atmospheric temperatures. Packed pipe with low off take may cause temperature variation.	Buried pipeline is not sensitive to climatic variation. Long term pressure flictuations leading to potential stress corrosion cracking (30000-40000 cycles). Pipeline is pressurised. Bath heater control. Bath heater design to industrial design practice.	PEOPLE Long term exposure Fire	SE MI	HY	NE	Pipeline shall have provision for intelligent pigging at Pestells Lane and at Bomaderry pressure reduction station. Pig launcher and receiver provisions to be in design.		SE MI	HY	NE
Emergency response														
39	Operation	Malicious damage (vandalism)	Above ground installation at Pestells Lane. Above ground installation at Bolong Road. Buried pipeline.	Damage to equipment. Hazard to person inflicting the damage. Possible removal of protective feature (e.g. CP).	Above ground installations to be fitted with fencing and locked gates. Signs as per Australian Standards for flammable gas. Buried pipelines highly unlikely to be tampered with.	PEOPLE (SUPPLY TO MANILDRA)	S	RE	L	Above ground installations to be fitted with sensor alarm (on gate and possibly on movement) and with CCTV on valves.		S	RE	L
40	Operation	Terrorist attack or civil disobedience	Above ground installation at Pestells Lane. Above ground installation at Bolong Road. Buried pipeline.	Damage to equipment. Hazard to person inflicting the damage.	As above. Also, terrorism attack is unlikely in this location.	PEOPLE (SUPPLY TO MANILDRA)	M	HY	L			M	HY	L
41	Operation	Escalation of incident due to inadequate or ineffective emergency management	Fuel tanks and DG store, refer to 12 Above.	Refer to 12 Above	Refer to 12 Above	Refer to 12 Above								
			Incident at metering station along Bolong Rd.	Consequences (pressure, heat radiation, missiles) to Bolong Rd uses. May cause injury. Closure of road.	Distance to Bolong Rd (about 50 meters) provides some buffer. People tend to move past the metering station by vehicle (some speed). Prevention and protection as discussed above. Isolation of flow at Pestells Lane. Remote closing valve (slam shut) to be installed at the entrance to the metering station.	PEOPLE (SUPPLY TO MANILDRA)	M	RE	I	a) Determine appropriate emergency response in case of an incident at Bolong Rd (with Emergency Services). b) Liaison with Emergency Services regarding new pipeline to be had.		M	RE	I
			Incident at metering station along Pestells Lane.	Consequences (pressure, heat radiation, missiles) may impact on adjacent Jemena metering station.	Prevention of unlawful entry and tampering. Trained technicians only working in compound. Some separation between stations (about 10m). Robust design will cope with some heat radiation. Flowing gas pipelines are less likely to be affected by heat radiation than stagnant. Two networks available for Nowra).	SUPPLY (Jemena)	MA	RE	I	a) Links with Jemena ERP. b) Separation distance to ensure heat radiation barrier impact on future residential development.		NE	RE	LOW/ MODE RATE

Shoalhaven Starches Pipeline Project (MP10-0108) - Preliminary Hazard Analysis

URS Australia Pty Ltd
Job No: 43167736

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42	Operation	Thermal expansion, external fire impacting Manildra above ground equipment (bush fire risk, see above)	Above ground equipment (Pestells Lane and Bolong Rd metering Stn).	Pressure excursion and possible leak through flanges. May lead to jet fire.	Vegetation control. Not high risk bush fire area. Fenced compound with controlled access.	PEOPLE	S	HY	NE	Refer Action 39 b)		MA	LOW	LOW/ MODE RATE

Pinnacle
Risk Management Pty Ltd

HAZARD ANALYSIS,
MANILDRA BOMADERRY PIPELINE,
URS AUSTRALIA,
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Hazard Analysis, Manildra Bomaderry Pipeline

Disclaimer

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Rev	Date	Description	Reviewed By
A	25/2/11	Draft for Comment	URS
B	7/3/11	Final Issue	URS

CONTENTS

LIST OF FIGURES

LIST OF TABLES

REPORT

1 INTRODUCTION

Pinnacle Risk Management has been requested to perform hazard analysis on previously identified potential hazardous events associated with the proposed Manildra to Bomaderry natural gas pipeline. The three potential hazardous events analysed in this report are:

- Jet fire;
- Flash fire; and
- Explosion.

As there are only three events of interest involving pressurised gas releases, the risk is assessed via a risk matrix using appropriate numerical techniques to estimate the consequential impacts and likelihoods. That is, scenario based risk assessment is performed.

For each event assessment, the gas releases are modelled to determine the potential consequential impacts. This allows determination of a consequence rating for use in the risk matrix.

Then the likelihood for each potential event is estimated using published criteria. This allows determination of a likelihood rating for use in the risk matrix.

By combining the consequence rating with the likelihood rating on the risk matrix the overall level of risk for each event can then be determined.

2 JET FIRE

2.1 JET FIRE CONSEQUENCE CALCULATION

The jet fire consequence calculations for this hazard analysis have been performed using the methodologies in TNO's EFFECTS program (Ref 1).

For hazard analysis of jet fires, each scenario defined by the analyst is modelled using an appropriate release rate equation based on the release situation and the initial state of the material. The flame length of the potential jet fires are then calculated based on parameters such as the release rate. The consequential impact value of interest at a particular location (i.e. radiant heat) can be obtained from the results.

To estimate the risk of the worst case outcomes, only full pipe fractures are assessed in this hazard analysis.

Pipe details are summarised as flows:

- Diameter is 150 DN (nominal diameter) (the inside diameter is approximately 156 mm);
- Pipeline length is 5.5 km;
- Operating pressure is 88 to 140 barg (140 barg is used in this assessment as it will representative the largest gas release and hence is worst case);
- Operating temperature is assumed to be ambient (temperature changes have minimal impact on the results).

The analysis of the potential jet fires from the natural gas line failures is shown in Table 1. The estimated maximum (initial) release rate is 286 kg/s. As the pipeline pressure decreases during the event, this flow will also decrease. Note that this flow is also calculated from a one-sided release. The downstream section of the pipeline has little pressure support and hence will rapidly decrease in pressure. For comparison, the results are also shown for half this initial flowrate, i.e. 143 kg/s. Also, a horizontal jet is also modelled to estimate the drop in radiant heat from the tip of the jet (i.e. along the long axis of the jet).

Table 1 – Jet Fires

Scenario	**Release Diameter, mm**	**Length of Jet, m**	**Distance to Specified Radiant Heat Level, m**		
			23 kW/m^2	**12.6 kW/m^2**	**4.7 kW/m^2**
Natural Gas, 140 barg, 20^{o}C, at 286 kg/s – vertical jet	156	122	Note 1	60	135
Natural Gas at half the initial flow, i.e. 142 kg/s – vertical jet	156	83	Note 1	40	95
Natural Gas, 140 barg, 20^{o}C, at 286 kg/s – horizontal jet	156	122	For the horizontal jet case, the radiant heat at a location away from the tip of the jet decreases from 150 kW/m^2 to less than 10 kW/m^2 over 40 m from the jet tip		

Notes:

1. Radiant heat is the heat flux received at ground level assuming a vertical flame from ground level. For a vertical jet, the predicted maximum ground level radiant heat is 20 kW/m^2. This value will be increased if the

jet is at an angle, i.e. closer to the horizontal. See the last line of data in Table 1 for the maximum impact from a horizontal jet.

Typical rules-of-thumb for property and equipment damage escalation are (Ref 2):

- Radiant heat exceeding 37.5 kW/m^2 for 10 minutes;
- Radiant heat above 23 kW/m^2 for longer durations; and
- Jet fire flame impingement on vessels or structural steel that are not protected for 15 minutes.

The modelled event has estimated jet fire lengths that can therefore result in propagation to adjacent property and equipment items. This can be due to radiant heat from a non-vertical jet or direct flame impact if the jet is horizontal (or close to it).

For assessment of the effects of radiant heat on people, it is generally assumed that if a person is subjected to 4.7 kW/m^2 of radiant heat and they can take cover within approximately 20 seconds then no serious injury, and hence fatality, is expected. However, exposure to a radiant heat level of 12.6 kW/m^2 can result in fatality for some people for limited exposure durations. Therefore, fatality from radiant heat exposure is of concern for radiant heat values above 4.7 kW/m^2, in particular, when the exposure duration is long or radiant heat is above 12.6 kW/m^2.

Flame tilt of jet fires is possible due to the wind. However, as the potential jet fire cases (whether the flames are tilted or not) have the potential to result in propagation then modelling of flame tilt is not included in this report. It is assumed that a tilted flame has the potential for propagation as well as a non-tilted flame.

For information, the radiant heat values of interest (DoP, HIPAP No. 4 and ICI HAZAN Course notes) are shown in Table 2 and

Table 3.

Table 2 - Radiant Heat Impact

HEAT FLUX (kW/m^2)	EFFECT
1.2	Received from the sun at noon in summer
2.1	Minimum to cause pain after 1 minute
4.7	Will cause pain in 15-30 seconds and second degree burns after 30 seconds. Glass breaks
12.6	30% chance of fatality for continuous exposure. High chance of injury Wood can be ignited by a naked flame after long exposure

HEAT FLUX (kW/m^2)	EFFECT
23	100% chance of fatality for continuous exposure to people and 10% chance of fatality for instantaneous exposure Spontaneous ignition of wood after long exposure Unprotected steel will reach thermal stress temperatures to cause failure
35	25% chance of fatality if people are exposed instantaneously. Storage tanks fail
60	100% chance of fatality for instantaneous exposure

Table 3 – Estimated Effects of Radiant Heat on People

Radiant Heat (kW/m2)	Impact
37.5	100% lethality in 1 minute
25	1% lethality in 10 seconds
15.8	100% lethality in 1 minute (as above), significant injury in 10 seconds
12.5	1% lethality in 1 minute, first degree burns in 10 seconds
10.4	Pain after 3 seconds of exposure (CIA, Guidance for the Location and Design of Occupied Buildings on Chemical Manufacturing Sites, 1998)
6.3	Emergency actions lasting 1 minute can be performed by personnel without shielding but with appropriate clothing (API RP 510)
4.7	Emergency actions lasting several minutes can be performed by personnel without shielding but with appropriate clothing (API RP 510)
2.1	Minimum to cause pain after 1 minute

Given the results shown in Table 1, both significant property and equipment damage can be expected from a catastrophic pipe failure and corresponding jet fire as well as the potential for multiple injuries or fatalities if people are near to the break. The likelihood of a potential jet fire is analysed in the following section to hence determine the risk.

2.2 JET FIRE LIKELIHOOD ESTIMATION

From the review of historical incidents associated with pipelines, the main cause for losses of containment is third party activities (corrosion and mechanical failures are the other main contributors). Third party activities typically account for 20 to 60% of recorded losses of containment for piping systems outside of site boundaries.

A summary of the likelihood of failure of pipelines is given Table 4 (Refs 3 and 4).

Table 4 – Pipelines Failure Data

Source of Data:	Failure Frequency (per km per year)
US Dept of Transport, Natural Gas Pipelines, 1970 – 74	7.8×10^{-4}
CONCAWE, Oil Industry Pipelines, 1972 – 76	1.05×10^{-3}
CONCAWE, Oil Industry Pipelines, 1987 – 91	0.5×10^{-3}
CONCAWE, Oil Industry Pipelines in Western Europe, 1975 – 80 (6" lines)	1.2×10^{-3}
CONCAWE, Oil Industry Pipelines in Western Europe, 1966 – 76	0.7×10^{-3}
ICI Mond UK, Processing Plant Pipelines, Catastrophic Failure of Lines Greater Than 100 mm diameter	1×10^{-4}
ICI Mond UK, Processing Plant Pipelines, 50 mm Holes in Piping	3×10^{-4}
Canvey Report, Failure of Jetty Pipework	10^{-4} to 10^{-3} (per year)

Note: CONCAWE is an organisation of oil companies.

Work by De La Mare and Andersen (1981) (Ref 3) concluded that the failure rates of pipelines appear similar even where the fluid handled and the environment are different; that the failure rates of oil pipelines depend on the diameter (inversely proportional), that about half of the failures can be attributed to external factors; and that pipelines tend to exhibit wearout failure. The consistency of the data presented above supports these conclusions.

More recent pipeline analysis (Ref 5) shows a downward trend in gas and oil pipeline failure frequencies in the UK. The failure frequency over the last 5 years (2002-2006) is 0.028 incidents per 1000 km per year compared to 0.248 incidents per 1000 km per year during the period 1962-2006. That is, a modern failure rate in the order of 3×10^{-5}/yr.km is expected in countries with advanced controls. This value compares well with the likelihood of major pipeline failures quoted in Ref 6 of 3.3×10^{-5}/yr.km. Given that the pipeline will be built to comply with and in some cases exceed the requirements of AS2885 (Pipelines – Gas and Liquid Petroleum) then use of this pipeline failure rate is justified in this hazard analysis.

Once a leak occurs, the probability of ignition is sourced from Ref 7. For large gas releases, i.e. greater than 50 kg/s, the probability of ignition is taken as 0.3. From this, approximately one third are quoted as leading to an explosion, i.e. the overall probability of ignition and then explosion is 0.09. Given that approximately 50% of the causes are likely to be third party activities and hence ignition sources are likely to be present at the time of initial release then the probability of ignition leading to a jet fire is approximated as 0.15. This results in an approximated probability of ignition resulting in a flash fire of 0.06.

Therefore, the overall likelihood of a jet fire is estimated to be:

Jet Fire Likelihood = 3×10^{-5} per km per year x 0.15 ignition probability

= 4.5×10^{-6} times/year.km

Given that the consequential impact distance of interest in this hazard analysis is up to 160 metres from the point of failure, then the likelihood of a jet fire impacting a particular point of interest from a failure in either direction is:

Jet Fire Likelihood = 4.5×10^{-6} per km per year x 0.32 kms

= 1.4×10^{-6} times/year

It is also understood that in the areas of potentially higher consequential impact, e.g. populated areas, the pipeline is to be encased in concrete to lower the risk of a loss of containment. As approximately half of the pipeline failures are a result of third party activities, e.g. damage by an excavator, then the concrete casing is expected to largely mitigate this cause. Therefore, the estimated likelihood of a jet fire can be halved (i.e.7×10^{-7} times/year) in the areas where the concrete casing exists.

2.3 JET FIRE RISK ANALYSIS

In this hazard analysis, the approach adopted to assess the risk of the identified hazardous events is scenario based risk assessment as only three main types of events are being analysed, i.e. jet fires, flash fires and explosions.

The scenario based risk assessment approach analyses each of the possible hazardous events individually, in this case via a risk matrix (Refs 8 and 9). A mixture of qualitative and quantitative techniques is used as appropriate to assess imposed risk.

A generic risk matrix used for risk assessment by Pinnacle Risk Management is shown in Figure 1. This matrix has been derived from a review of relevant Australian and British standards (e.g. AS 4360).

The risk matrix allows the combination of consequence and likelihood (i.e. risk – the likelihood of any defined adverse outcome) to be shown clearly and quickly on a graphical basis.

The position in the matrix of estimated risk allows an assessment of the magnitude of each risk contributor to the overall level of risk. That is, the higher the combination of likelihood and consequence, the higher the contribution to overall risk. This provides a basis for development of appropriate risk reduction strategies. Through inspection of the major risk contributors and an understanding of the cost associated with particular risk reduction strategies, cost-effective risk reduction strategies can be developed.

Figure 1 – Risk Matrix

Frequent >1/yr	II	I	I	I	I
Probable $>10^{-1}$ to 1/yr	II	II / I	I	I	I
Possible $>10^{-2}$ to 10^{-1}/yr	III	II	II / I	I	I
Unlikely $>10^{-4}$ to 10^{-2}/yr	III	III	II	II / I	I
Very Unlikely $>10^{-6}$ to 10^{-4}/yr	III	III	III	II	II / I
Extremely Unlikely $<10^{-6}$/yr	III	III	III	III	II
Likelihood **Consequence**	Minor	Significant	Severe	Major	Catastrophic

The generic form of the matrix allows its use for various risk categories, e.g.:

- safety and health;
- environment; and
- business impact.

For the risk matrix shown in Figure 1, there are three broad categories of risk.

The Class I area indicates a high level of risk which is intolerable and where risk reduction is required. This requires the reduction of frequency and/or consequence.

The Class II area indicates a moderate level of risk. Whilst the risk is not unacceptable, there should be practical measures taken to lower the risk if economically viable. For risks where further mitigation is not economically viable, judgement needs to be exercised as to whether the level of risk is acceptable or not. This area is the beginning of the ALARP region (i.e. as low as reasonably practicable).

The Class III area indicates a low level of risk and is broadly considered to be acceptable. Further risk mitigation may not be required / appropriate. However, low and accepted risks should be monitored and routinely reviewed to ensure that they remain acceptable. Few risks remain static. This area includes ALARP as well as what are known as trivial or negligible risks.

Consequential impact can take many forms, e.g. impacts on safety and health, environment, public relations, financial, operations, competitive nature, social well being, clients, cultural significance, security and legal issues. Consequence ratings can be determined for the selected area of interest and then applied to a risk matrix. Consequential impacts used in this report for safety and health, and financial impact are given below.

Table 5 – Consequence Rating – Safety and Health

	Definition
Minor	Onsite: Minor injury, first-aid or medical treatment injury (MTI) Offsite: Nuisance / annoyance
Significant	Onsite: Loss time incident (LTI), multiple MTIs Offsite: Minor effect, typically of short duration
Severe	Onsite: Single or a few serious injuries, permanent disability Offsite: Few people requiring medical treatment. Emergency plan and services used
Major	Onsite: Single or a few fatalities (less than 5). Many injuries Offsite: Serious injuries, tens requiring medical treatment
Catastrophic	Onsite: Many fatalities (5 or more). Numerous serious injuries Offsite: One or more fatalities. Tens suffering injuries

Table 6 – Consequence Rating – Financial Impact

	Definition
Minor	Low financial loss, up to $10,000
Significant	Medium financial loss, limit of $100,000
Severe	High financial loss, limit of $1,000,000
Major	Major financial loss, limit of $10,000,000
Catastrophic	Huge financial loss, over $10,000,000

Given the estimated "Safety and Health" impact of "Catastrophic" (i.e. potential for multiple off-site fatalities) with a jet fire likelihood of 1.4×10^{-6} times/year to 0.7×10^{-7}/year then the corresponding level of risk as determined by the risk matrix (Figure 1) is typically II.

Given the estimated "Financial" impact of "Major" (i.e. potential for several millions of dollars damage) with the same jet fire likelihood of 1.4×10^{-6} times/year to 0.7×10^{-6}/year then the corresponding level of risk as determined by the risk matrix (Figure 1) is typically II to III.

Given that the pipeline design is expected to exceed the requirements of AS 2885 then the risk from potential jet fires is considered to be not intolerable and no further safeguards are recommended.

3 FLASH FIRE

3.1 FLASH FIRE CONSEQUENCE CALCULATION

A flash fire is the non-explosive combustion of a vapour cloud resulting from a release of flammable material into the open air. Generally vapour clouds only explode in areas where turbulent transition develops and the flame speed needs to increases significantly to develop overpressures. This usually involves some degree of confinement. The main hazards from flash fires, however, are from thermal radiation and direct flame contact. The duration of flash fires is normally only a few tenths of a second (Ref 10).

The effect distance (i.e. due to radiant heat within the cloud) is typically estimated by performing a dispersion calculation to determine the maximum distance to the LEL (lower explosive limit). For flash fires, any person inside the flash fire cloud is assumed to be fatally injured. As flash fires are of limited duration then those outside the flash fire cloud have a high probability of survival without serious injury. Equipment and property damage is not a significant concern for flash fires as the duration is relatively short.

The analysis of the potential flash fires from catastrophic failure of the pipeline for three typical wind / weather conditions is shown in Table 7. The distances to LEL have been calculated using TNO's EFFECTS program.

Table 7 – Flash Fire Radius

Wind / Weather Conditions	Distance to LEL
F2	800
D4	350
B3	190

Note: The Pasquill atmospheric stability classes are used where F is the most stable (A is the most unstable class). The numbers after the stability classes represent the wind speed in m/s.

Given these potential impact distances then again multiple injuries and/or fatalities could be expected if the flash fire occurred in a location where people where present and did not escape.

3.2 FLASH FIRE LIKELIHOOD ESTIMATION

From Section 2.2, an approximated probability of ignition resulting in a flash fire is 0.06.

Therefore, the overall likelihood of a flash fire is estimated to be:

Flash Fire Likelihood = 3 x 10^{-5} per km per year x 0.06 ignition probability

= 1.8 x 10^{-6} times/year.km

Given that the consequential impact distance of interest in this hazard analysis is up to approximately 800 metres from the point of failure, then the likelihood of a flash fire impacting a particular point of interest from a failure in either direction is as follows. Note that the impact distance of up to 800 m is downwind of the point of release (the wind could be blowing in any direction).

Flash Fire Likelihood = 1.8 x 10^{-6} per km per year x 1.6 kms

= 2.9 x 10^{-6} times/year

This is conservative as the impact distance will be less for other combinations of wind / weather conditions as shown in Table 7 and also the estimated likelihood is not corrected for the probability of a specific wind / weather combination.

Again, the estimated likelihood of a flash fire can be halved (i.e.1.4 x 10^{-6} times/year) in the areas where the concrete casing exists.

3.3 FLASH FIRE RISK ANALYSIS

Given the estimated "Safety and Health" impact of "Catastrophic" (i.e. potential for multiple off-site fatalities) with a flash fire likelihood of 2.9×10^{-6} times/year to 1.4×10^{-6}/year then the corresponding level of risk as determined by the risk matrix (Figure 1) is typically II.

Given that the pipeline design is expected to exceed the requirements of AS 2885 then the risk from potential flash fires is considered to be not intolerable and no further safeguards are recommended.

4 EXPLOSION

4.1 EXPLOSION CONSEQUENCE CALCULATION

Potential vapour cloud explosions can occur from flammable gas releases, i.e. delayed ignition with confinement. This results in overpressures that have the potential to injure people and damage property and the environment.

EFFECTS uses the Multi-Energy method for estimation of explosion effects. The key feature of the Multi-Energy method is that the explosion is not primarily defined by the fuel air mixture but by the environment in which the vapour disperses. Partial confinement is regarded as a major cause of blast in vapour cloud deflagrations. If there is no confinement, a flashfire (i.e. no overpressure effects) would occur rather than explosion.

Within the model, ignition is assumed to occur at the centre of the gas cloud formed.

The degree of confinement must be defined as an input to the model. Essentially, this is the proportion of the total mass in the cloud used in the dispersion and subsequent explosion calculation. For example, if 2,000 kg is entered as a total mass and 50% as confinement then 1,000 kg is the maximum amount that can be included in the explosion calculation. The actual amount used in the Multi-Energy explosion model is calculated by the dispersion module.

For this hazard analysis, the percentage confinement value used is 50% as the area surrounding the pipeline, in places, is built-up and also trees can provide a degree of confinement.

The initial strength of the blast is also variable, depending on the degree of confinement and on the reactivity of the gas. In the Multi-Energy method, the initial strength is represented by a series of curves relating overpressure to distance, where curve 1 means slow deflagration and curve 10 means detonation. An explosion curve number equal to 5 is used in the modelling (i.e. a deflagration as methane is not a strongly reactive gas).

For the release of natural gas, choked flow exists and rapid jet mixing with air occurs. Larger release durations have no significant impact on the size of the vapour cloud as steady state conditions are reached soon after the release occurs (i.e. the distance to the LEL does not change at steady state dispersion conditions).

The effects from explosion overpressures (Ref 11) are summarised in Table 8.

Table 8 – Effects of Explosion Overpressure

OVERPRESSURE, kPa	PHYSICAL EFFECT
3.5	90% glass breakage No fatality, very low probability of injury
7	Damage to internal partitions & Joinery 10% probability of injury, no fatality
14	Houses uninhabitable and badly cracked
21	Reinforced structures distort, storage tanks fail 20% chance of fatality to person in building
35	Houses uninhabitable, rail wagons & plant items overturned. Threshold of eardrum damage, 50% chance of fatality for a person in a building, 15% in the open
70	Complete demolition of houses Threshold of lung damage, 100% chance of fatality for a person in a building or in the open

The analysis of a potential vapour cloud explosion from a catastrophic pipeline failure is shown in Table 9.

Table 9 –Vapour Cloud Explosions

Scenario	Distance (m) to 21 kPa Explosion Overpressure	Distance (m) to 14 kPa Explosion Overpressure	Distance (m) to 7 kPa Explosion Overpressure
Natural Gas, 140 barg, 20°C, at 286 kg/s – vertical jet	70	110	225

Notes: 1. The maximum explosive mass in the vapour is similar for all three typical wind / weather combinations used in the flash fire calculations so only one result is shown (corresponding to the F2 conditions).