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Review of Forest Practice Guide

Dissertation Project

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Abstract

Sediment is well known to be one of the main pollutants that damages our waterways and forestry operation often results in excessive sediment flowing into waterways. Increase in sediment flowing into waterways can disturb aquatic habitat, water quality and hydrology of waterways. Therefore, if a human activity is expected to increase in sediment, it should be managed. However, increase in sedimentation is inevitable for forestry operation as it involves large volume of earthworks, which exposes significant portion of the land in bare soils which essentially increases erosion hence sedimentation. To limit forestry operations from resulting in a detrimental environmental outcome, Resource Management Act (RMA) and regional/district plans had been enforced to achieve certain environmental outcome. However, there was a variation between regional/district plans which resulted in inconsistent environmental outcomes between regions. This encouraged National Environmental Standard for Plantation Forestry (NES-PF) to be set, which is a single set of regulations under RMA to be applied throughout New Zealand to achieve consistent environmental outcome. The problem is that NES-PF's regulation regards to sediment is difficult to implement as it provides only desirable outcomes, but it doesn't instruct how to achieve them. To provide foresters a guidance in complying with NES-PF, Forest Owners Association is in progress to develop Forest Practice Guide. It is important to review these documents and ensure that they provide the best knowledge that is available and ensure that they are providing the best practices that are appropriate and effective for forestry environment. In this study, two erosion and sediment control measures were reviewed from Forest Practice Guide, which are cut-out, sediment trap and soak hole. This attempt essentially reveals that overall the Forest Practice Guide is providing appropriate and the best information regards to these measures. Also, its initial purpose was well-served by successfully implementing NES-PF into practices. However, there is a few aspects that can be improved especially design specification. Many guidelines that are explored in this study reveal that they all provide more detailed design specification compared to Forest Practice Guide. As an example, Forest Practice Guide often utilises "sufficient" to construct and utilise cut-outs, sediment traps and soak holes. In contrast to many guidelines, Forest Practice Guide doesn't provide any diagram to visualise design specifications and construction methods. In addition, there is a disagreement in cut-out spacing given in the Forest Practice Guide, as it is revealed that spacing of cut-out must be shorter than spacing of other storm water control measures. Yet Forest Practice Guide asserts that spacing of culvert can be used for spacing of cut-out. These collectively reveal that further studies are required to complete Forest Practice Guide. Testing and evaluating appropriate design specification for cut-out, sediment trap and soak holes will be required to determine which is more appropriate for New Zealand. Also, only two measures are reviewed in this study, hence reviews on other documents in Forest Practice Guide are required to ensure that they are also providing the best practices for those measures.

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Contents

Introduction

Waterway is an important resource that we must protect and utilise it in a sustainable manner, yet forest operation is one of land disturbing activities which often results in damaging these waterways by increasing the level of sedimentation. This results in importance of guidelines that provide appropriate practices for managing sedimentation and Forest Practice Guide is a new guideline that has been published to provide best management practices for forest operations. Therefore, it is important to review this document and evaluate whether its providing sufficient and appropriate practices to manage sediment in forest operation. Cross-referencing will be utilised as a measure to verify the information and practices given in Forest practice Guide. The expected results from the review is that practices from Forest Practice Guide are effective practices supported by many other guidelines and well implementation of national environmental standard for plantation forestry is also expected, which is a new regulation that has been enforced for forestry operations.

The objectives of this study are to:

- Explore many different guidelines, not limited to New Zealand guidelines, but also other countries' and international guidelines.
- Review the information given in Forest Practice Guide using other guidelines and relevant literatures.
- Evaluate whether the Forest Practice Guide can be the Best Management Practice for forestry industries to comply with NES-PF.
- Suggest any potential improvement for Forest Practice Guide

Background Knowledge

What is sediment

Collin English Dictionary (2018) defines sediment is the matter that settles to the bottom of a liquid; or mineral or organic matter deposited by water, air or ice. Sediment can naturally occur in a waterway and the amount is influenced by the geology of the surrounding area. Processes that naturally deliver sediments to the streams are riverbed being washed off by the water flow and the surrounding catchment depositing eroded sediments from natural slips and any exposed soil. Human activities such as building a dam, road construction and land-use change from native forest to grassland can greatly increase the amount of sediment that enters the waterway (Sediment, n.d.). There are two types of sediment: fine sediment (clay and silt) and coarse sediment (sand, gravel and boulders). Wentworth (1922, cited in Clapcott et al (2011)) developed a sediment classification system, which defines that clay and silt is particle smaller than 0.0625mm and sand is particle between 0.0625mm and 2mm. These sediments can be transported by either suspension or bedload transport: fine sediment is likely to move as suspended sediment, whereas coarse sediment is likely to move as bedload. The energy required to transport them is different, as fine sediment requires less energy (Wallis and McMahon, 1994). However, their movements are determined by shape and flow of the channel.

Sediment's effect on environment

A range of studies has been conducted to discover a sediment's potential impact on the environment. Yet, some of the primary sources were not readily available and required payment to view. Therefore, the review on the sediment's effect on environment had to rely on secondary sources.

From the global perspective, increase in the fine sediment load due to human activities that disturbs soil are among the most significant cause of damage on waterways as it results in more severe damage compared to coarse sediment (Davies-Colley et al, 2015). Large input of fine sediments can affect living organisms in stream like macro-invertebrates and salmonid. Newcombe and MacDonald, and Bozek and Young (1991; 1994, cited in Lewis (1998)) discovered that a stream with high sediment concentration can damage the respiratory system of salmonids and micro-invertebrates. Gregory and Northcote (1993, cited in Lewis (1998)) revealed that the poor water clarity due to fine sediments can limit fish from locating food and can reduce the depth at which photosynthesis can take place. Clapcott et al (2011, cited in Davies-Colley et al, 2015) found that the increase input of fine sediments can degrade habitat for organisms living in a riverbed by reducing oxygen exchange and in extreme cases, burial and suffocation of fish eggs can occur. Furthermore, poor water clarity due to fine sediments can also devaluate aesthetic and recreational value of water bodies and beaches. Although with less severe environmental impact than fine sediment, large inputs of coarse sediment can also cause destabilisation of stream beds and channels, by blocking pipelines and reducing reservoir capacity in long term (Hutton et al, 2008). Sediment can also have social impact as Lloyd et al (1987, cited in Ryan (1991) stated that, generally water with high turbidity level is less accpetable than clear water for consumption, recreation area and aestheitic enjoyment. They further noted that when Chatanika River became turbid by fine sediment from mining activity, fishing activity on Chatanika River decreased by 55%. In addition, increase in sediment accumulation in river can raise the level of the riverbed and increase water level which collectively decrease the capacity of the river. This essentially contributes to more frequent flooding which can result in property damage, contamination of water supplies, loss of crops, social dislocation and temporary homelessness and even loss of life (International sediment initiative, 2011).

New Zealand regional councils have conducted a survey in 2009 to discover perceptions on what in-stream values are affected by excess sediment. This survey collectively revealed that invertebrate community composition and abundance, native fish spawning/habitat and habitat for trout and other salmonids were the top 3 values that the people's most concerns around the damages that sediment does to our waterways. (Clapcott et al, 2011)

Relationship between sediment and forestry

Despite the sediment causing a lot of damage to our environment, depositing sediment from forest operation is inevitable, as it involves earthworks and site disturbance which increases the rate of erosion. Megahan and Kidd (1972, cited in Anderson, 1972) discovered that logging operations increase the amount of sediment flowing into waterway. Keppeler et al and Ziemer (1994; 1968, cited in Lewis (1998)) suggested that removing trees reduce evapotranspiration and rainfall interception resulting in wetter soils. Further study conducted by O'Loughlin and Ziemer (1982), and Ziemer (1981) discovered that the loss of root strength and wetter soils could decrease slope stability, resulting in more erosion hence more sediment. In addition, forestry operations cause more sediment as they involve a lot of heavy equipment, which compact soils and essentially decrease infiltration and increase surface water (Lewis, 1998).

Almost every stage of forestry operation contributes to increasing sediment deposition, with site preparation, drainage, road/bridge construction and harvesting being the most significant (Hutton et al, 2008). In New Zealand, 23 recent commercial forestry operation sites, which associated a stream channel were surveyed, and it revealed that there were 3.4 sediment intrusion to stream (breakthrough) per kilometre of stream or one breakthrough for every 6.5 hectares of harvest area and concentrated runoff from roads, skid trails, or machine traffic disturbance on the hillslope being the most significant cause of breakthroughs (Brown and Visser 2017).

To minimise the sediment being deposited to waterway, forestry industry has been under legal obligations through Resource Management Act (RMA) and Regional council requirements, but now forestry industry also has National Environmental Standard for Plantation Forest (NES-PF) to comply with. Also, NZFOA Environmental Code of practices (ECOP) are available to guide industries to protect waterway. ECOP's overall purpose is to provide harvesting practices that will reduce environmental impacts and help to ensure that forests are sustained for future generations. (Dkystra and Heinrich, 1996). Although ECOP for erosion and sediment control should cover erosion and sediment control measures associated with forestry activity that result in high soil disturbance, it is not doing so yet (Pendly et al, 2013). Limited but some information regarding sediment control design can be found in the Forest Road Engineering manual. In case of regional council requirement, which are commonly referred to as regional plan, their requirements vary depending on the region. Some regional plans in New Zealand tend to have limited information on sediment control design. For example, Oceania Gold is a mining company which operates in Otago. They were encouraged to use Auckland regional Council's guideline for the design of sediment control, due to limited information in the Otago regional plan. (Alderton, 2015).

Resource Management Act (RMA), National Environmental standard for Plantation Forestry (NES-PF) and Forest Practice Guide

Resource Management Act (RMA) is a "principal statute for management of air, land and water resources". RMA (1991) states that the purpose is to promote sustainable management of natural and physical resources, which is "managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural wellbeing and for their health and safety while –

a) Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and

b) Safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and

c) Avoiding, remedying, or mitigating any adverse effects of activities on the environment."

This act is administered by the Ministry for the Environment, regional and district councils. The further objectives, policies and rules around activities that can potentially damage the environment are set by regional and district councils in a form known as regional plan and district plan. RMA is essentially a framework for different regions and districts to produce plans in a consistent manner, yet there is inconsistency between regional and district plans. This results in forestry industry to have following problems:

a) Re-litigation of the same issues across the country

b) Inconsistent treatment of forestry operations
c) Operational inefficiency
d) Inconsistent level of environmental management
e) Investment uncertainty

Therefore, National Environmental Standard for Plantation Forestry (NES-PF) has been approved to secure a consistent approach and decision-making process throughout New Zealand. (Visser, 2018a)

NES-PF is a single set of regulations which was published on 3rd August 2017 and came into force on 1st May 2018, which is aimed to maintain or improve the environmental outcomes associated with plantation forestry activities and to increase the efficiency and certainty of managing plantation forestry activities. NES-PF is implemented under RMA throughout New Zealand and this provides national regulations for 8 core plantation forestry activities that can potentially inflict environmental damage, which are:

- Afforestation,
- Pruning and thinning to waste,
- Earthworks,
- River crossings,
- Forestry quarrying,
- Harvesting,
- Mechanical land preparation
- Replanting

NES-PF considers these activities to be a "permitted activity" and allow them to be carried out under the condition that the environmental impacts are managed. In addition, Resource consent will be required if the effects of these activities cannot be managed (Te Uru Rākau (Forestry New Zealand)). This means that NES-PF is in addition to regional and district plans not replacing them (Brown and Visser, 2018).

However, NES-PF is difficult to implement in terms of erosion and sediment control measures as it only illustrates what should be done and what shouldn't happen, but it doesn't provide how to achieve those. To guide foresters to comply with these NES-PF, Forest Owners Association recently published Forest Practice Guide. This does not constitute a statutory obligation under RMA and NES-PF, but this document can be referenced as the best management practices (BMP). The purpose of BMPs are to protect water quality and maintain site productivity (Visser, 2018c).

In United States BMPs are well implemented, as an example State forestry agencies took survey and discovered that forestry BMPs are commonly used with implementation level of more than 90% across the country. (Warrington et al, 2017). Furthermore, Cristan et al (2016) discovered that in south east part of United States, BMP implementation levels were approximately 92% and their BMPs were continually refined using research findings despite that it has been proven to be effective in protecting water quality. As an example, study conducted by Williams et al (2000, cited in Ice (2004)) compared sediment yield pre and post implementation of BMP which revealed that increased sediment yield due to harvesting activity was reduced by 10 times. However, in New Zealand some commented that they do not use regional council erosion and sediment control guidelines and question council's design philosophy (Basher et al, 2016).

Therefore, it is important to review Forest Practice Guide to evaluate whether it will be able to provide the best available knowledge and appropriate practices for plantation forestry that can be applied throughout New Zealand.

Method

Two groups of erosion and sediment control measures from Forest Practice Guide are reviewed in this study, which are Cut-outs and sediment trap and soak holes. These two groups of measures are chosen to be reviewed as they are more likely to be utilised for forest operations given their simplicity and cost effectiveness.

To review the information given in the Forest Practice Guide, other erosion and sediment control guidelines that are available in New Zealand are cross-referenced first then international document: *Best Practice Erosion and Sediment Control document* (Witheridge, 2010) is utilised to further validate the technical information. This is because there is a chance that other guidelines being used in New Zealand and Forest Practice Guide may be using the same technical information derived from the same source hence containing the same inaccuracy in information and design specification. Literatures are utilised to validate the information where it is required and cross-referencing is conducted mainly utilising following guidelines;

- *Forestry Operations in the Auckland Region: A Guideline for Erosion and Sediment control* (Bryant et al, 2007), this document was chosen as this is known as the most detailed forestry specific erosion and sediment control guideline in New Zealand. Also, this is derived from TP90 which was also known as comprehensive erosion and sediment control guideline.
- *Erosion and sediment control Guidelines for Land Disturbing Activities in the Auckland Region* (Leersnyder et al, 2016), this document was chosen as this is updated version of TP90.
- *Erosion & Sediment Control Guidelines for Vegetable Production* (Barber, 2014), this document was chosen to explore if there is difference between horticultural erosion and sediment control practices to forestry.
- *New Zealand Forest Road Engineering Manual* (Forest Owners Association, 2012), this document was chosen, because in-depth knowledge and detail in practices were expected as roading and earthwork is the major cause of sediment in forest operation.
- *Erosion and Sediment control Guidelines for Forestry Operation* (Bay of Plenty regional council, 2013), this document was chosen as cross-referencing only Auckland regional guidelines has potential to be misleading. As there is a probability that those documents are derived from same source hence same information and practices.

The selection of guidelines is focused on Auckland region as the guidelines from this region tend to be more credible. However, this does not imply that other regional guidelines are not useful, as Bay of Plenty regional forestry guidelines are utilised where appropriate.

Furthermore, a field inspection is conducted to 2 forestry sites in Blenheim to witness cut-outs and sediment traps in action to discover any aspects and practices that must be emphasised in Forest Practice Guide. Findings from all these tasks will be used to evaluate the document and to make recommendation on potential improvements.

The review of two Erosion and Sediment control measures from Forest Practice Guide will be delivered in result section. Each guideline is divided into 9 sections and each section will be reviewed. The sections are:

a) Introduction
b) Where and When to use
c) Where not to use
d) Design
e) Construction
f) Maintenance
g) Other methods
h) Technical specification guidelines

However, cut-outs don't have information on where not to use. It simply states, "Not applicable for this Forest Practice Guide". Therefore, it is omitted in the report.

In addition, those guidelines that are being cross-referenced have relatively long names, hence abbreviations will be used for readability. Those abbreviations are from their names or the Code name that document provided to itself.

- Best Practice Erosion and Sediment Control document = BPESC
- Erosion and sediment control Guidelines for Land Disturbing Activities in the Auckland Region = GD05
- Erosion & Sediment control Guidelines for Vegetable Production = ESGVP
- New Zealand Forest Road Engineering Manual = NZFREM
- Forestry Operations in the Auckland Region: A Guideline for Erosion and Sediment control = TP223
- Erosion and Sediment Control Guidelines for Forestry Operation (Bay of Plenty regional council) = ESGFO
- Forest Practice Guide = FPG

Results

Cut-outs

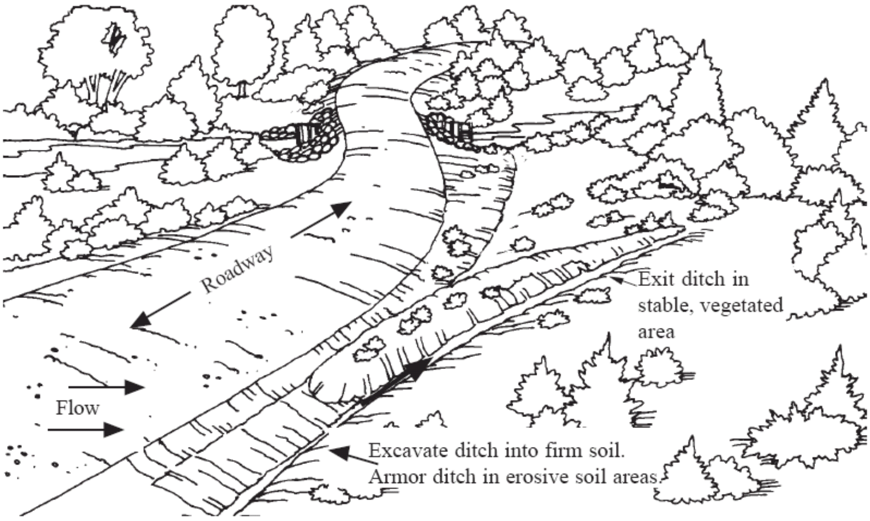

Figure 1. Image of cut-out as an excavated ditch to divert runoff to stable area (Visser, 2018b)

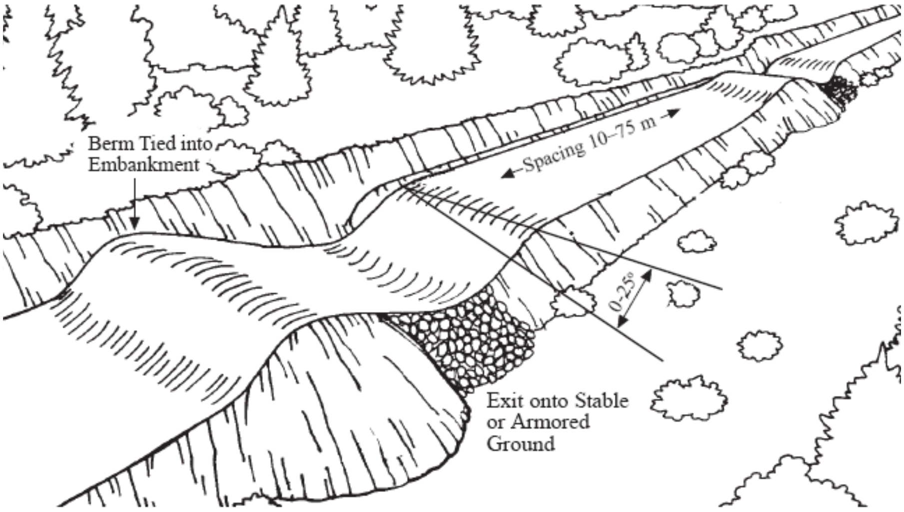

Figure 2. Cut-out (water-bar) installed on track to control stormwater runoff (Visser, 2018b)

Introduction

FPG refers to these structures as cut-outs and only NZFREM also utilises this term and there is name variation between guidelines.

Table 1. Terms used for cut-out in the reference documents

Document	Cut-out	Contour drain	Cut-off	Earth-lined catch drains	Water-bar
FPG	×				
NZFREM	×				×
TP223		×	×		
GD05		×	×		
ESGVP		×	×		
ESGFO			×		×
BPESC				×	

This clearly shows that terminology for cut-outs is an issue in New Zealand as other guidelines are utilising different terms for this structure. Therefore, to prevent confusion only "cut-out" will be used to reference this measure throughout the report.

It appears that terminology for cut-outs is an issue in New Zealand as other guidelines are utilising different terms for this structure. NZFREM utilises both water-bars and cut-outs but doesn't consider them as the same structure and ESGFO uses water bars or cut-offs. This difference in terminology is based on regional differences. Therefore, it is important for Forest Practice Guide to ensure that terminologies are appropriate and correct as this may implement a standardized terminology for this measure throughout New Zealand.

FPG describes the cut-out as a constructed drain to discharge stormwater runoff from road surface or water table to stable ground and cut-outs (water bars) are also drains that are installed on decommissioned road or tracks to control stormwater runoff**.** According to GD05, TP223 and ESGVP, contour drains or cut-offs fit the description of cut-out as they commonly describe them as a runoff control measure to intercept and convey runoff to stable areas or convey sediment-laden runoff from site to sediment control devices. This clearly supports the purpose and function of cut-outs given in FPG. However, NZFREM utilises both terms "cut-outs" and "water bars". It utilises "cut-outs" along with culverts throughout the document in a form of "culverts or cut-outs". This suggests that NZFREM views cut-outs somewhat the same as the culverts which is a common water table drainage structure. In case of water bars, it is introduced as cross-ditches (water bars) and illustrates that their functions are removing water from water table, catching and diverting surface run-off on road or tracks. This clearly supports that function of cut-outs explained in FPG is correct. Information on cut-outs being utilised on decommissioned tracks and roads can be found in ESGFO, as it states that water bars can be installed on decommissioned temporary tracks.

FPG states that cut-outs are simple to construct, effective and easily maintained. This is partially supported by NZFREM stating that cross-ditches are effective and inexpensive method to divert surface runoff on road. However, it also adds that it is difficult to maintain as they often erode and wear quickly, which partially disagrees with FPG. However, A Guide for Management of Landslide-Prone Terrain in the Pacific Northwest (Second Edition) (Chatwin et al, 1994) states that if they are constructed properly at right locations and spaced closely to each other, then very little maintenance is required, which clearly supports the information given in the FPG. NZFREM doesn't specifically state that cross-ditches are difficult to maintain when it is installed correctly and appropriately, hence it is fair to conclude that cut-outs are easily maintained if they are constructed appropriately.

FPG states that "cut-outs" can also be utilised as a tool to divert runoff into sediment control measures like sediment traps. This is logical and appropriate as it previously illustrated that it could collect and convey runoff to stable ground. Also, GD05 supports this by stating that contour drains are utilised to assist in diverting sediment-laden water to sediment control structures**.** However, putting this sentence after the first sentence might have improved the flow of information. Currently, this sentence comes after “They are simple to construct, effective, and easily maintained.”, which doesn’t appear to have any relevance. Therefore, by placing it after the first sentence makes “A cut-out is a constructed drain that takes stormwater from a road surface or water table and allows the water to discharge to an area of stable ground. They may be used to divert stormwater into stormwater or sediment control measures like flumes or sediment traps.” appears more logical in terms of flow of information.

FPG states that cut-outs essentially increase the life of the road or track and water table by reducing erosion and maintenance costs. Also, it adds that they can reduce the chance of sediment being delivered to rivers. This is logical to state as these will be the outcome if the cut-outs are installed properly and successfully carry out their tasks, which is supported by Brinker and Tufts (1995) stating that if surface runoff managing devices like water bars are properly constructed using appropriate intervals, they can reduce road maintenance cost, erosion and sedimentation of streams.

Where and When to use

FPG states that cut-outs should be used to direct stormwater:

a) Off all roads and tracks which have water channelled in water tables or along the road edges and where it is not diverted by road drainage culverts
b) Onto stable ground along with additional stormwater measures like flumes and culverts if necessary
c) To sediment control measures such as through slash bunds, sediment traps and sediment retention ponds, or over stable ground, where necessary.

Many other available guidelines do not explicitly mention when and where cut-outs can be used, instead they convey when and where it can be used within description or purpose section. They all support FPG by commonly addressing that the purpose of cut-out is to intercept runoff from road or tracks and divert it to non-erodible sites or to sediment control structures if runoff contains sediment. Nevertheless, ESGFO explicitly addresses when a water-bar can be utilised, which are to

- shorten runoff distance on surface and to divert it.
- to direct flow to safe disposal areas from road and track surfaces.
- temporary control installed on hauling tracks in critical situation.
- as a stormwater control on temporary tracks when they are decommissioned.

Despite FPG providing the right information, ESGFO appears to provide information on more specific use of cut-outs. In addition, ESGFO specifically references vegetation as the safe disposal area for the water bars to direct to, which is missing in FPG. This may not be required information, given that the audience of this document is foresters who are most likely to be aware of what types of area are stable and safe to divert runoff to. Yet to provide clarity, adding what types of area are stable to divert runoff to in forestry perspective can be an improvement for the FPG.

Design

FPG addresses design process of cut-out, which is considering location of cut-out as a part of sediment or storm water control measures for road or landing and considering additional measures like armouring the water table or utilising berm, if cut-off spacing is restricted by terrain and soils are highly erodible. In this section, the document uses “cut-off” instead of “cut-out”. This can be due to a spelling mistake or auto-correct, but it is important to ensure that terminology is consistent throughout the document, and it is important to revise and replace “cut-off” with “cut-out”. Furthermore, this information is insufficient to design how cut-outs should be compared to other guidelines. In Auckland guidelines some design requirements were**:** In TP223, it states that cut-outs must be 0.5m deep and constructed with a “U” shape. GD05 supports this and adds that 0.5m is the minimum depth, compacted bank must be minimum height of 250mm and parabolic or square shape is preferred to minimise erosion. This collectively reveals that there is a design specification for cut-outs in GD05, but FPG and many other guidelines do not demand any design specification. Therefore, it is important to evaluate whether cut-outs require design specification, or it can be installed in any form that provides drainage function. Despite GD05 providing some level of design specification for cut-out, BPESC provides more comprehensive procedure in designing cut-outs, as it provides step by step method which involves obtaining following properties:

- Manning’s roughness for the preferred surface condition of cut-out.
- Allowable flow velocity.
- Shape of the cut-out.
- Iterative process of choosing cut-out dimension.
- Determining longitudinal gradient.
- Time of concentration
- Intensity-frequency-duration
- Catchment area
- Coefficient of discharge
- Maximum allowable catchment area using catchment area and coefficient of discharge
- Maximum horizontal spacing

These all collectively result in designing dimensions and spacing of cut-outs for a catchment, yet this raises a question whether it is necessary to design every cut-out using the method provided by BPESC. If the design specification given by GD05 can result in an effective mean of erosion, sediment and stormwater control, adapting this design will be a more appropriate and practical designing process.

Construction

FPG states that enough cut-outs should be constructed to reduce the volume and velocity of run-off to reduce the erosive power of the water and locate cut-outs where the outlet would not cause additional erosion. ESGFO and GD05 supports this by stating that the outlet runoff must not cause additional erosion. Also, ESGFO further emphasises that velocity of the runoff must be controlled as it may have enough energy to overtop the cut-outs and continue flowing down the main track, which clearly corresponds to what FPG states. However, the FPG stating “enough cut-outs” is vague as the guideline does not provide what is enough cut-outs to reduce the volume and velocity of run-off. Other guidelines provide a few elements that must be ensured for cut-outs to function properly.

Table 2. Design criteria of cut-outs from documents

Document	Design criteria
TP223	• 2% gradient
GD05	• 2% gradient
Best Management Practices for Forest Road Construction and Harvesting operations in Oklahoma (Turton ton et al, 2004)	• 10 to 25° to the road • 3% gradient
Best Management Practice for Erosion Control During Trial Maintenance and Construction (State of New Hampshire, 2004)	• 30 to 45° to the road • 3% gradient
ESGVP	• 1.5 to 2.5% gradient (from trail in Franklin district) • 5 to 7% gradient for clay soil (Test conducted in Tasmania) • 0.5 to 2% for sandy soil (Test conducted in Tasmania)

Table 2 clearly reveals that different best management practices suggest different practices; hence it is important to evaluate which practice is appropriate and suitable to be utilised in New Zealand. However, test conducted in Tasmania clearly reveals that the soil type contributes to the effective slope of the cut-out, which would make it difficult for FPG to propose a certain gradient to be applied throughout New Zealand.

FPG stating "outlet of the structure must be stable ground" has been conveyed twice throughout the guideline for cut-outs. This is an important aspect to be emphasised and perhaps worth repeating. However, providing guidance on how to build cut-outs or notes on elements that must be looked out for could have been more appropriate information for this section.

Maintenance

FPG states that regular maintenance plan including heavy rainfall response measures must be prepared. This is supported by TP223 asserting that regular maintenance and monitoring is required to ensure that cut-outs are functioning well and BPESC recommend weekly inspection as a good regular maintenance plan. The guide adds that cut-outs are required to be repaired regularly, especially on a new construction. This is partially supported by GD05 and ESGFO stating that maintenance work on cut-outs must be carried out immediately once the damage is identified. Yet none of the guidelines suggests the need of regular maintenance and relationship between new construction and regular maintenance are not found. The guide further states that cut-outs must be checked after a heavy rain event to ensure their functionality. In ESGFO and GD05 agrees with FPG to some degree as they state that cut-outs must be checked after every rainfall event, however BPESC states that it must be inspected after runoff inducing storm events. This raises a question which practice is more appropriate. Inspecting the measure after every rainfall is arguably more conservative approach, which will ensure that cut-outs are functioning and allows to identify the needs of maintenance more frequently. Hence it is more appropriate for FPG to state that cut-outs must be inspected after every rainfall.

In other guidelines, they provide more comprehensive maintenance guideline as they address what aspects must be checked and how issues with those aspects can be resolved. ESGVP addresses the potential of cut-outs becoming a depositional area due to low gradient. Depositions can reduce the capacity of cut-out, so it states that check on deposition is important and remove sediment if there is any. This is supported by BPESC advising to ensure that sediment is not blocking the drain and remove sediment to allow free drainage where necessary. A few more in-depth insights into maintaining cut-out can be witnessed from other forestry specific guidelines. TP223 and ESGFO commonly state that stability of outlet area must be checked and repaired if necessary, also add that cut-out must be repaired if its damaged or destroyed by logging operation**.** Overall the level of detail on maintenance instruction given in FPG appears to be good, yet by providing specific aspects to be checked for and ensured will result in FPG more applicable.

Figure 3. Dysfunctional cut-out and consequential runoff

This image is taken from decommissioned site in Blenheim region. The issues with this cut-out was that previous cut-outs were dysfunctional due to settlement of sediment blocking them. This resulted in concentrated runoff to this cut-out, which was enough to cause erosion. This essentially supports the need and the importance of checking up on this measure regularly and after major storm events.

Other Methods

FPG states that water-tables, road drainage culverts, flumes and berms are other methods that can be adapted instead of cut-outs. Other guidelines don't specifically mention that those structures can be used instead of cut-outs. However, in NZFREM water-tables, road drainage culverts, flumes, berms and cut-outs are categorised as water control methods, which supports that those measures are an alternative measure for water control. This is creditable as it informs readers what measures can be used instead of cut-out if installing it is restricted for some reason.

FPG adds that cut-outs are also complement sediment control measure such as sediment traps, soak holes, sediment ponds and slash bunds. This is partially supported by ESGVP stating that cut-outs are often depositional area due to low gradient which allows accumulation of sediment to occur. However, the main objective of the cut-out is to control water flow to reduce its erosive energy, not to capture sediment from controlled water flow. Therefore, cut-out is also a sediment control measure as it reduces erosion and captures small amount of sediment, but it is difficult to claim that it's as effective as those measures listed above as they have sole objective of capturing sediment and more engineered. Therefore, it's more appropriate to state that cut-outs can be utilised in conjunction with other sediment control measures to achieve effective sediment control.

In addition, New Hampshire Best Management Practices for Erosion Control on Timber Harvesting Operations (New Hampshire Division of Forests and Lands and UNH Cooperative Extension, 2016) address open culvert as one of stormwater control measure. The purpose of this structure is to capture runoff from road and divert it off the road, which is arguably the same as cut-out. This structure has more structural integrity as its formed from Wood, concrete or metal, hence less maintenance is required compared to cut-out. This structure can be recommended if the cut-out is required on low traffic road or track.

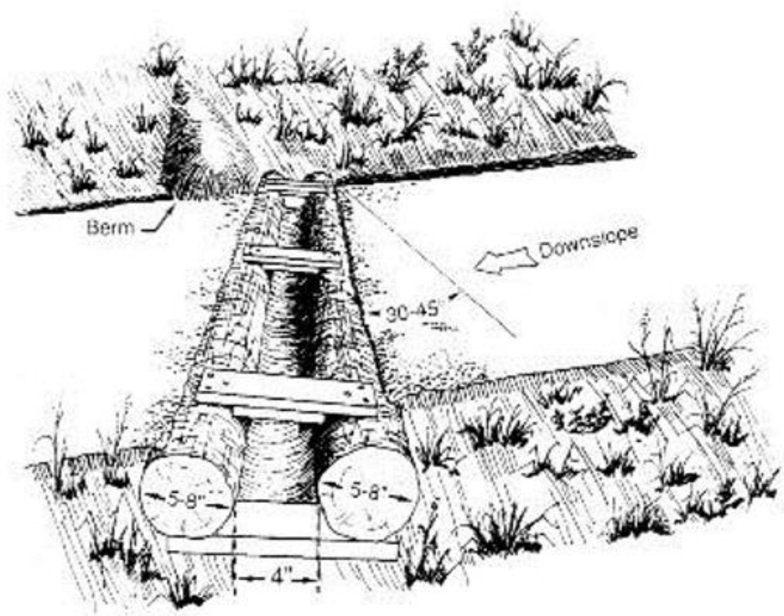

Figure 4. Open-top Culvert (retrieved from New Hampshire Best management practices for Erosion Control on Timber Harvesting Operations)

Technical Specification Guidelines

FPG provides a following table for recommended culvert spacing and states that this can be used for cut-outs spacing.

Table 3. Recommended culvert spacing (FPG)

Grade	Soil or rock erodibility -separation distance in meters			
	High	Moderate	Low	Non-erosive rock
18% (1 in 6)	40	80	120	200
14% (1 in 7)	50	90	140	220
12% (1 in 8)	55	100	160	240
11% (1 in 9)	60	115	180	260
10% (1 in 10)	65	130	210	300
8% (1 in 12)	80	165	250	350

The same table was found in NZFREM for spacing of culverts and it also states that culvert spacing can be utilised to place cut-outs in ideal location. However, in other guidelines different spacings were found. Those tables will be given, but one of the tables is in American unit (feet) hence another column is added to provide metric figures for those.

Table 4. Recommended cut-outs spacing (ESFGO)

	Cut-outs spacing	
Site slope	Cohesive soil	Ash and pumice soil
Up to 12%	40m	30m
From 12% to 30%	30 to 20m	20 to 10m
Over 30% slope	Less than 10m	5m

Table 5. Recommended water bar spacing (Best Management Practices for Forest Road Construction and Harvesting Operations in Oklahoma)

Grade of Road (%)	Water bar Spacing (feet)	Water bar Spacing (meters)
2	250	76
5	135	41
10	80	24
15	60	18
20	45	14
25	40	12
30	35	10
40	30	8

Table 6. Recommended contour drain or cut-out spacing (TP223 and GD05)

Slope of site (%)	Spacing of contour drain (m)
Less than 5	50
5-10	40
10-15	30
15-30	20

These collectively reveal that other guidelines suggest different cut-outs spacing to FPG. Despite that NZFREM supported FPG that culvert spacing can be used for cut-out spacing, it doesn’t provide enough confidence to claim that it’s the right practice as NZFREM and FPG are both written by Forest Owners’ Association.

Table 7. Recommended spacing of stormwater control measure (New Hampshire Best Management Practices for Erosion Control on Timber Harvesting Operations)

Road Grade (%)	Maximum Distance Between water bars (feet)		Maximum Distance between all other drainage structures (feet)	
	High Erosion Risk (sandy or silt soils)	Low Erosion Risk (Rocky or clay soils)	High Erosion Risk (Sandy or silt soils)	Low Erosion Risk (Rocky or clay soils)
0-3	175	250	250	350
4-6	125	200	175	250
7-9	100	175	125	175
10-12	75	150	75	125
13-15	60	100	60	100
16-20	50	75	50	75
21-30	40	65	40	65
30+	30	50	30	50

Table 5 is clearly revealing that cut outs must be spaced closer than culverts. Therefore, it is important for Forest Owners Association to evaluate which one of culvert spacing, cut-out spacing given in Auckland regional guidelines and spacing given in American guidelines is the most appropriate cut-out spacing for New Zealand.

Sediment Traps and Soak Holes

Figure 5. Photo of sediment trap installed to reduce the amount of coarse sediment in runoff before its discharged via flume (from NZFREM)

Figure 6. Photo of soak hole. There is only inlet, because sediment laden water will be soaked into porous soil (from NZFREM)

Introduction

FPG introduces sediment traps and soak holes, yet many guidelines only introduce sediment trap and refer to them as silt trap. Following table is summary of terms being used in reference documents

Table 8. Terms used for sediment trap and soak hole in the reference documents

document	Sediment trap	Silt trap	Soak hole	Excavated sediment trap
FPG	×		×	
NZFREM	×		×	
TP223		×		
ESGVP		×		
ESGFO	×		×	
BPESC				×
GD05				

This clearly shows that terms for sediment trap and soak hole is different between documents. Also, GD05 has no information on sediment trap and soak holes.

FPG states that these are small excavated structures which allow sediment to settle by capturing sediment-laden water then discharge or drain the water. This is supported by NZFREM stating that sediment traps allow sediment to settle by slowing the runoff down and ESFGO adds that runoff is either left to discharge to designated outlet or soaked into natural ground.

FPG states that sediment traps and soak holes reduce the volume of sediment that can enter sensitive sites such as water bodies. This is supported by NZFREM stating that sediment traps can be utilised as an option to reduce the amount of mobilised sediment off-site. However, ESGVP states that sediment trap alone is not the only mean to control sediment but is part of the overall system. This is important information that is worth adding in FPG to inform readers that installing sediment trap alone is not enough to solve the sedimentation issue and sediment traps must be utilised in collaboration with other control measures. FPG adds that sediment traps and soak holes must be located near roads and landings for maintenance access. None of the documents agreed with FPG, but similar practice was found in NZFREM. It addresses that sediment traps must be located near the source of sediment and it previously addressed that sediment traps can be an option to use where there is a significant potential for stormwater transporting a lot of sediment from landing and roading to off-site. These collectively convey that landing and roading are the significant source of sediment and sediment trap must be located near them, but no relevant information was found regards to whether positioning these measures near road and landing is for maintenance access.

FPG states that sediment traps are temporary storage of sediment-laden water by allowing some of the larger sediment particle sizes to settle before the water is discharged. This is supported by BPESC stating that it's often utilised to capture coarse sediment. Sediment trap's ability to capture fine sediment is very limited. This is because there is insufficient time for fine sediments to settle in sediment trap as coarse sediments are larger than fine sediment and they settle faster than fine sediments (Molloy, 1998, cited in ESFGO). Also, NZFREM stating that sediment trap must be used for short period of time and it's not a permanent mean of structure confirms that sediment traps are temporary storage of sediment-laden water. However, FPG should try to address a time frame for "temporary". TP223 and BPESC assert that once the site is stabilised these structures can be removed or decommissioned, hence its appropriate to state that time frame for temporary that FPG refers to is until the site is stabilised. Furthermore, it is recommended for FPG to replace temporary with not permanent as temporary suggest they don't require maintenance, but they do.

FPG states that soak holes are to let sediment-laden water to soak in to the soil, hence it must be constructed on porous soil such as sand and pumice. ESGFO supports this statement as it states that sediment controls installed on porous soils such as pumice can keep sediment-laden water long enough to discharge into ground. FPG adds that sediment traps and soak holes are part of water control technique which increases the life of the road, reduce maintenance costs and mitigate potential sedimentation issues. However, this is only partially supported as all others documents commonly state that the purpose of sediment control is to reduce the amount of sediment in runoff and contain it within the site, which essentially mitigate potential sedimentation issues. Only ESGFO stated that the purpose of sediment trap and soak hole is to control stormwater runoff from road and tracks. Unfortunately, FPG's statement of these measures increasing the life of the road and reducing maintenance costs were not found in any guidelines or literatures.

Where and When to use

FPG states that sediment traps and soak holes are to be used to help capture mobile sediment, which is strongly supported by ESGFO, ESGVP and BPESC defining that this structure's purpose is to capture coarse sediment by reducing the water velocity, allowing large coarse sediment to settle. FPG adds that sediment traps and soak holes are to minimise the risk of sediment entering sensitive sites such as water bodies. None of the documents clearly mentioned this aspect of sediment trap and soak holes, but this is arguably the most important practice that all foresters should be aware of. NES-PF clearly states that sediments originated from forestry activity must be managed to ensure that it does not inflict any damage on receiving water. Therefore, FPG must be praised for well-implementing the core aspect of NES-PF in terms of managing sediment into the sediment trap and soak hole practices.

FPG states that a use of a sediment control and soak hole is in conjunction with other water control measures, where necessary. They are inlet or outlet of road drainage culverts, cut-outs or flumes. This is supported by ESGFO stating that a use of a sediment trap and soak hole is in conjunction with water-bars/cut-offs. This is further supported by ESGVP stating that a sediment trap works best when its applied with other practices that reduce the amount of soil reaching the trap. Also, in BPESC it addresses that immediately downstream of low gradient stormwater outlet and immediately upstream of fine sediment capturing measure are the locations where sediment traps can be installed. This is important as a soak hole is designed to capture fine sediment and coarse sediment by allowing sediment-laden runoff to drain into the ground. Yet sediment trap isn't very effective in capturing fine sediments as it usually discharges sediment-laden water before fine sediments settle down. Therefore, it is recommended for FPG to propose a measure which can be utilised along with sediment trap to control the amount of fine sediment in runoff. However, the overall level of details and clarity on where the sediment trap and soak holes can be used is good compared to other guidelines as TP223 and GD05 which do not mention how to utilise sediment traps and soak holes.

Where not to use

FPG states that sediment traps and soak holes must not be used at places like fill batter where risk of bank collapsing is high. This is supported by ESGFO explicitly stating that sediment trap and soak hole must not be installed in an area where there is a risk of slope above them collapsing into them and they must not be installed on the disturbed soils. TP223 further supports this by explaining that if the sediment trap and soak holes are installed on unstable ground, land slumping can occur due to seepage of water. Fill batter is essentially a disturbed soil, which assures that FPG is providing the right information.

FPG states that sediment traps and soak holes must not be located within land area occupied by flood flows of rivers. Similar information was found in NZFREM, which states that they must not be in a natural water channel, or a water table drain. Given that only the guideline also written by Forest Owners Association provides similar statement, it's difficult to conclude that this is correct. However, it appears to be an appropriate practice to apply, as if sediment trap and soak holes are in the flood flows of river, inflow of water is too great settlement of sediment won't occur and potentially this flow will continually scour out the sediment trap and soak holes. Also, it has potential to blow them out if the intensity of the flood flow of river is strong, which will result in captured sediment to discharge with flood flow of river. In addition, FPG adds a note which states that adequately sized cut-outs are difficult to construct near culvert mouths on steep terrain as they may encroach into the roadway. This appears to be an important practice which hasn't been mentioned in other guidelines as well, yet this information is more appropriate for cut-outs guidelines rather than sediment traps and soak holes guidelines.

Design

FPG states that sediment traps and soak holes must be located to suit the terrain. This is supported by ESGFO stating that soak holes are located to suit the terrain, but it adds that getting the right spacing of the soak holes is important and FPG also provides spacing guide, but it is in Technical Specification Guidelines section not in design section. However, other guidelines add more design specifications. Following table is summary of design specifications found in reference documents.

Table 9. Design criteria of sediment trap and soak hole from documents

Document	Design specification
FPG	• Spacing guideline
ESGFO	• Depth = 1 to 1.5m • Width = excavator bucket width • Reasonably flat inlet to avoid erosion
BPESC	• Area must be different depending on the type of sediment and temperature of runoff • Distance between sediment trap and soak hole from source of sediment should be considered. • Minimum depth 0.6m • Maximum depth 1m
TP223	• Treating capacity = 0.5 hectare of catchment area
New Hampshire Best Management Practices for Erosion Control on Timber Harvesting Operations (2016)	• Used for catchment of 5 acre (approx. 2 hectares) • Size is dependent, but approximately 10ft.(approx. 3m) long by 5ft.(approx. 2m) wide and 3ft. (approx. 1m) deep.

This clearly shows that other guidelines provide some aspects that should be designed for sediment trap and soak holes which must be added in the FPG after validating whether design specification can be applied throughout New Zealand.

Construction

A detail guidance on construction of sediment trap can be found in TP223, yet the design provided in the document is different to design given in FPG, NZFREM and ESFGO. Therefore, TP223 was utilised for validating the information rather than validating the design.

FPG states that construction of sediment traps must be done near culvert inlets and outlets and immediately after the water is cut-off a road, track or landing, as necessary. This is supported by BPESC stating that -slope drainage control measures are to be established to ensure that sediment-laden runoff is appropriately directed into the sediment trap. This is essentially instructing that sediment traps must be installed with water control measure such as cut-outs, water table and culverts. FPG adds that the trap must be excavated well below the culvert inlet level, to provide maximum capacity to contain sediment-laden water. This is only partially supported by NZFREM stating that sediment traps need to be large enough for sediment to effectively settle. Therefore, it is difficult to conclude that it's an appropriate and good practice, as only one guideline which is also written by Forest Owners Association supports this practice. However, this is a practice that would add conservative approach in ensuring that sediment traps can function properly. FPG can potentially improve as a referencing document if it could provide what is the appropriate depth of the sediment trap.

FPG states that sediment trap must not be installed in fill or disturbed soil. This has been mentioned previously and has been supported by other guidelines. However, it further adds that if it's inevitable for inflow and outflow to pass through fill, then flume must be utilised to let the water into or out of the sediment trap. This is not found in any guidelines, but very practical, appropriate and important practice to conduct, as this provides foresters more comprehensive knowledge in applying this measure.

FPG states that sufficient size of a hole must be excavated to ensure that excavator bucket can remove the retained sediment. This is partially supported by NZFREM stating that sediment traps fill up very fast and regular removal of collected sediment is required to ensure that they function properly. Therefore, surrounding environment of the installed sediment trap and soak holes must allow removal of sediment if its full and to allow that removal process sufficient size of a hole must be excavated. Also, FPG adds that rock bucket is to be utilised for excavation and this information can be found in ESFGO, which states that width of bucket on excavator to be used for the operation. This comes after addressing that sediment traps and soak holes must be 1 to 1.5m deep, which suggests that width of bucket excavator is the width of the sediment traps and soak holes. However, there are many different types of bucket for excavator ranging from digging bucket, rock bucket, v bucket, clean-up bucket and skeleton bucket (Heavy Duty Direct, 2016). They all have different purposes to serve and dimensions are not the same. Also, these buckets come in many different dimensions. Therefore, it is creditable FPG addresses that rock bucket is required but if it adds that excavator with enough capacity and width can be used for efficient construction of sediment trap and soak hole will further improve the quality of FPG.

FPG states that inlet into the soak hole must be reasonably flat to avoid erosion, which is supported by ESGFO providing the same statement. They do not address how flat the inlet should be. However, TP223 states that inlet to the sediment trap should be 33% in slope and usually requires to be stabilised. This is further supported by BPESC stating that the gradient of the inlet into the sediment trap and soak hole must be low, since inflow with high velocity hence high energy level can cause re-suspension of sediments. It further states that any bank that is subject to inflow must be stabilised and suggests that fabric may need to be installed on inflow slope to prevent scour damage. TP223 was the only document that specified the slope of the inlet to these measures. Therefore, it is important to further investigate whether 33% slope of inlet is a good practice to apply throughout New Zealand.

FPG advises to ensure the outflow from sediment trap is on erosion resistant soil, adding that slash or long grass can assist with sediment retention from the outflow. This is supported by TP223, which states that discharged water from sediment trap must be on an erosion resistant outlet like slash. Also, this is an appropriate practice as slash is suggested as one of sediment retention measure in many guidelines. Therefore, discharging outflow to slash will reduce the amount of sediment in runoff, allowing it to go through another sediment control measure. FPG adds that soak holes must be in free draining soils like pumice, sand or non-cohesive ash and immediately after the water is directed off a road or landing. The information regarding soak holes can only be installed on free draining soils has been mentioned previously and supporting statements are found in other guidelines. The information in regards to soak holes have to be installed immediately after the water is directed off a road or landing is partially supported by New Hampshire Best Management Practices for Erosion Control on Timber Harvesting Operations, which states that sediment traps should be installed as close as possible to the unstable area which induces sediment, outlet of stormwater control measures like ditch lines, cross drainage culverts and other areas that has potential to deposit sediment.

FPG clearly provides comprehensive guidance on appropriate practices in constructing sediment trap, yet it does not provide any design specification for minimum requirements for the measure and it still vaguely describe “sufficient” and “reasonably” as a design specification. This will need improvement by either introducing design specifications given in different guidelines or providing own unique design specification that is efficient enough to comply with NES-PF. In addition, BPESC asserted importance of safety issues around sediment traps given that they are potential hazard, yet this information is not given in the FPG. Therefore, it is strongly recommended to add some instructions on safety practices around sediment trap. For example, advising to install a clear indication that can inform the presence of sediment trap or install a physical barrier or not installing them close to road.

Maintenance

FPG states that regular maintenance plan including heavy rainfall response measures are required as a part of maintenance practices. Many guidelines don't agree with this statement as ESGFO and BPESC state that inspection is required after every rainfall event including storm event and structure must be repaired if necessary. Other guidelines have a fair point, as if there is no runoff on site, the probability of sediment trap getting damaged is slim. However, TP223 asserts that sediment trap must be repaired immediately if it's damaged by logging operation, and this suggests that there is a potential that logging operation damaging these measure, hence regular maintenance plan is an essential practice to conduct to maintain sediment trap. FPG then adds that sediment traps must be checked for their functionality after a heavy rain event and requires regular maintenance especially on a new construction. This is already supported by many guidelines stating that sediment traps must be inspected after rainfall event and storm event, yet FPG does not provide what aspects of sediment traps must be ensured to consider it as functional. ESGFO and BPESC clearly states that inlet must be checked for scouring by runoff, BPESC states that blockage of inlet/outlet structure must be checked and ESGFO further adds that it is important to check whether fine material has blocked the bottom of the soak hole. All of these provide comprehensive guidance on what must be ensured to maintain the functionality of sediment trap. However, these guidelines don't provide any potential remedy for those situations. If FPG can provide guidance on appropriate practices to resolve those situations, FPG will be more in depth which can be referenced in a confident manner. Following is an example of a way that FPG can adopt to provide maintenance guidance, Check for any scouring on inlet of sediment trap, if any scouring is witnessed, stabilise it by utilising appropriate practices (armouring water table, applying geotextile and etc). In addition, there was no relevant literature or guideline suggesting the relationship between new construction and regular maintenance of sediment trap, hence this requires a further explanation and validation.

FPG states that spacing of sediment trap and soak holes must be checked whether there is enough number and spacing of sediment traps to manage the stormwater run-off. This is supported by ESGFO, it states that checking whether soak holes spacing is sufficient to manage stormwater runoff especially during heavy rainfall is important. This is a good practice which will ensure a sufficient number of sediment traps are installed for the site and this will reduce the probability of sediment-laden runoff breaching into the protected waterways due to sediment traps' and soak holes' incapability. However, this this appears to be more appropriate information for design or construction section rather than maintenance. Also, it does not provide what must be done if there is insufficient number of sediment trap and soak holes to manage the stormwater runoff. Potential suggestions for insufficient sediment traps are:

- Excavate more sediment traps if possible
- Utilise more stormwater control measures like cut-outs, flumes and berms to divert some portion of sediment-laden water to stabilised area or to other sediment control measures
- Replace sediment trap with other sediment control measure with more capacity.

FPG states that when accumulated sediment in sediment trap and soak holes is removed, it must be placed at where it cannot wash back into the structure or subjected to erosion or enter a sensitive area. This is supported by TP223, BPESC and ESGFO commonly stating that removed sediment must be placed in an area where it cannot enter sensitive areas like natural waterways and back into sediment trap and soak holes. This is a good practice that well implemented NES-PF. However, in contrast to FPG a few guidelines suggest when removal of sediment must occur.

Table 10. When the removal of sediment must occur from documents

Document	When the removal of sediment must occur
TP223	• Accumulated sediment = 20% of capacity.
BPESC	• Accumulated sediment = 30% of capacity.
New Hampshire Best management practices for Erosion Control on Timber Harvesting operations	• Accumulated sediment = 50% of capacity.

FPG states that this structure fills up very quickly and this is clearly supported by many other guidelines. Therefore, it is important to evaluate what percentage of sediment trap capacity must be available to ensure that this measure functions effectively.

Other methods

FPG states that alternative measures for sediment trap and soak hole are sediment pond and slash trap. This is clearly supported by TP223 and ESGFO commonly addressing sediment pond and slash as one of sediment control measures. NZFREM also mentions slash as an alternative measure for sediment control yet it does not address sediment pond. However, TP223 clearly differentiate these measures by the catchment area that it can treat.

Table 11. Maximum operating catchment area of each sediment control practices in TP223

Practice	**Maximum operating catchment area**
Haybale Barrier	1000 m^2
Earth Bund	1000 m^2
Slash Bund	1000 m^2
Decanting Earth Bund	3000 m^2
Silt Fence	5000 m^2
Super Silt Fence (“Debris Dam”)	5000 m^2
Silt trap	5000 m^2
Sediment Retention Pond	5.0 ha

This clearly reveals that each sediment control practices can be a substitute of one another, yet the maximum operating catchment area is different. This must be considered in replacing sediment trap with other sediment control measures as more of those substituting measures may be required. For example, if a site’s catchment area is 5 ha, only one sediment retention pond will be required but if sediment traps are installed, 10 sediment traps will be required to achieve similar outcome to installing one sediment retention pond.

FPG adds that slash can be utilised downslope of sediment trap outlets. This is a good practice to add, as BPESC and TP223 clearly address that there is a potential in runoff to outflank the measure and enter waterways. However, outflanked runoff can be retained and amount of sediment flowing into waterway will be reduced by placing slashes. In addition, Slash is not the only measure that can be utilised in conjunction with sediment trap. ESGFO addresses silt fence and soak holes as one of sediment control measure and that it is utilised to further ensure sediment-laden water does not flow into waterways. Figure 7 is retrieved from NZFREM and ESGFO which illustrates how sediment trap and silt fence can be utilised in conjunction.

Figure 7. Sediment trap and Silt fence together (retrieved from NZFREM and ESGFO)

Therefore, it would be very praiseworthy for FPG to provide silt fence and slash as an additional measure as well as a substitute measure for sediment trap with providing images like figure 7 to demonstrate how additional measure can be utilised along with sediment trap.

Technical Specification Guidelines

FPG provides following table for spacing of soak hole.

Table 12. Soak hole spacing from FPG

Site Slope	Soak hole spacing
Less than 12%	40m
More than 12%	30m down to 10m

This is supported by ESGFO, which provides the same spacing guideline as FPG. However, ESGFO is the only guideline that provides spacing of soak holes and spacing information for sediment trap were not found in any other guidelines. This raises a question whether spacing guide provided in ESGFO and FPG are appropriate to be used nationally. In addition, they stated that the given table is spacing for soak hole and this raises a question whether sediment trap and soak hole spacing can be the same. These collectively reveals that there are several issues to be resolved and details to be added to be confident with FPG being a national best practice guide which assists in complying with NES-PF.

Commonalities between cut-out, sediment trap and soak hole guidelines

Auckland regional guidelines explicitly address that sediment-laden water should be diverted to sediment control structures and BPESC clearly states that sediment-laden water should be drain to a suitable sediment trap, yet the FPG doesn't appear to consider delivering sediment-laden water to sediment control as strict as other guidelines. FPG is going to be the nationally referenced document for the best management practices which complies with NES-PF. It is important to identify what is the focal point of NES-PF in terms of sediment and develop appropriate practices for foresters which complies with it. Also, sediment can occur naturally, and it is impossible to control all the sediment-laden runoff ensure that no sediment goes into the waterway.

Both these documents from FPG added which regulations in NES-PF is relevant to sedimentation, they are 26,27,31,33 and 56. This is creditable contents as they have managed to specify which regulations to focus in terms of sedimentation. This will allow foresters to easily refer NES-PF to ensure whether the environmental outcome from their forest operation complies with it.

However, it was disappointing that these guidelines were not providing any guidance on removal/decommissioning process of these measures. In GD05 and BPESC, they both provide some guidance on how to remove these measures once it's not required. Arguably this is not an essential practice to satisfy NES-PF, but it is important to provide guidance on how to remove these measures appropriately. Therefore, authors of FPG should consider adding some guidance on removal process of these measures.

Many guidelines provide diagrams to convey the design specification and construction instruction. This is creditable contents as it essentially improves reader's interpretation of information given in the guideline. FPG provides some photos of cut-outs and sediment trap and soak hole in field, yet it's difficult to interpret what the photo is showing as its not labelled and difficult to see, hence use of diagram is strongly recommended but it doesn't provide any diagram for application of these measures in field. This is an additional guidance that can assist in foresters to correctly apply these measures. Therefore, some diagrams showing how cut-outs, sediment trap and soak hole should be in cross-section and plain view are provided in appendix. Nonetheless, most of diagrams related to use of these group of measures are not found, hence dual-projection of these measures are drawn. For sediment trap and soak hole diagrams, design specifications from New Hampshire Best Management Practices for Erosion Control on Timber Harvesting Operations is used along with some design specifications from other guidelines. For cut-out design specification from TP223 is utilised.

Summary

This part summarises flaws identified while reviewing these two documents from FPG and what this report has contributed regarding them. Flaws are separated into sections where they are found. Major flaws were mostly related to design specification, lack of important practices and lack of diagrams. For those flaws, this study has provided design specification and referenced other BMPs.

Details on major flaws identified in each document and what this study has contributed for those flaws are summarised in following table.

Table 13: identified flaws during the review process and what this project has done for those flaws

Document	Identified major flaws	What this study has done for those flaws
Cut-outs	• Requires more details on how cut-outs can be utilised • Lack of design specification • Lack of maintenance practices and what must be checked during the inspection of this measure. • Wrong cut-out spacing	• Provided information in ESGFO regards to how cut-outs can be utilised • Provided design specification from different guidelines • Illustrated a few maintenance practices and checklist from other guidelines and provided photo of dysfunctional cut-out • Provided cut-out spacing given in other documents
Sediment trap and soak holes	• Clarity is required on definition of “temporary” • Lack of design specification • More clarity on excavator bucket • Clarity is required on “Reasonably flat inlet” • Lack of safety practices around these measures • Lack of information on what must be checked for maintenance • Some contents more appropriate for other section • No information on when the removal of sediment should occur • Not providing any information on catchment capacity difference between different measures	• Provided timeframe for use of sediment trap and soak hole in other documents. • Provided design specifications from other documents • Suggested what can be added for clarity on excavator bucket • Provided what other guidelines consider it as appropriate steepness for inlet. • Suggested potential safety practices for these measures. • Provided what other guidelines provides for maintenance checklist • Suggested which section may be more appropriate for that information. • Listed these measures’ threshold capacity for sediment removal to occur from other documents • Provided table showing catchment capacity of different sediment control measures.
Commonality	• Lack of diagram • No information on removal/decommissioning process	• Provided plan view and cross-sectional view on these two groups of measures. • Provided which documents has information on removal/decommissioning process.

Conclusion

In conclusion, this study is set to review FPG and evaluate whether it is providing the best knowledge and appropriate practices regards to two group of measures “cut-out” and “sediment trap and soak holes”. The study essentially reveals that FPG is a comprehensive guideline which provides appropriate level of details regards to practices for these measures. However, it has several issues which must be resolved to improve the quality of the guideline. There is an inconsistent use of terminology as it uses cut-off instead of cut-out, there is an opportunity to improve the flow of information to improve readability, lack of diagram and frequent use of “sufficient” for design specification. All these collectively allude that the guidelines still require more work to be done before it can be referenced confidently in New Zealand. Also, this study revealed some underlying flaws and suggested potential improvement for them. The major purpose of FPG is to assist foresters to comply with NES-PF and it successfully implements it into these two measures’ practices. Despite the credit the guidelines deserve, they lack a lot of details regarding design specification. This is justifiable as it is difficult to provide design specification that can be used nationally. This study only reviews two groups of measures from FPG. Therefore, further reviews for other measures are strongly suggested and experiments should be carried out to determine which is the most appropriate design specification that can be used nationally or at least address a method to develop adequate design of these measures.

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Appendix

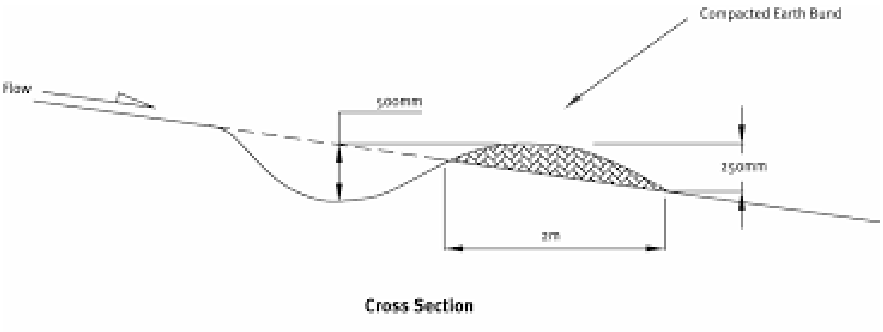

Figure 8. Cross-section of cut-out on track (retrieved from TP223)

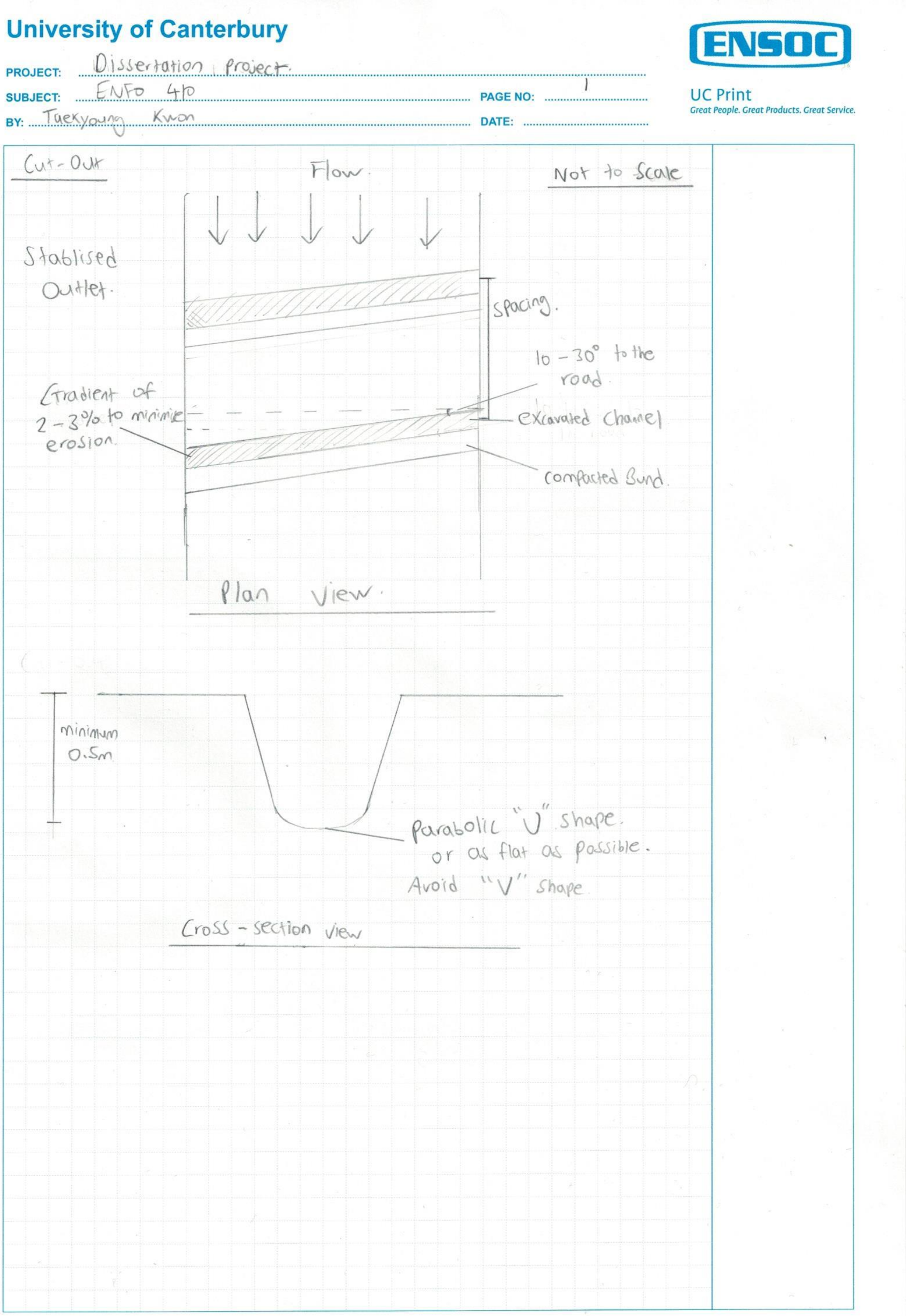

Figure 9. Plan view and cross-section view of cut-out

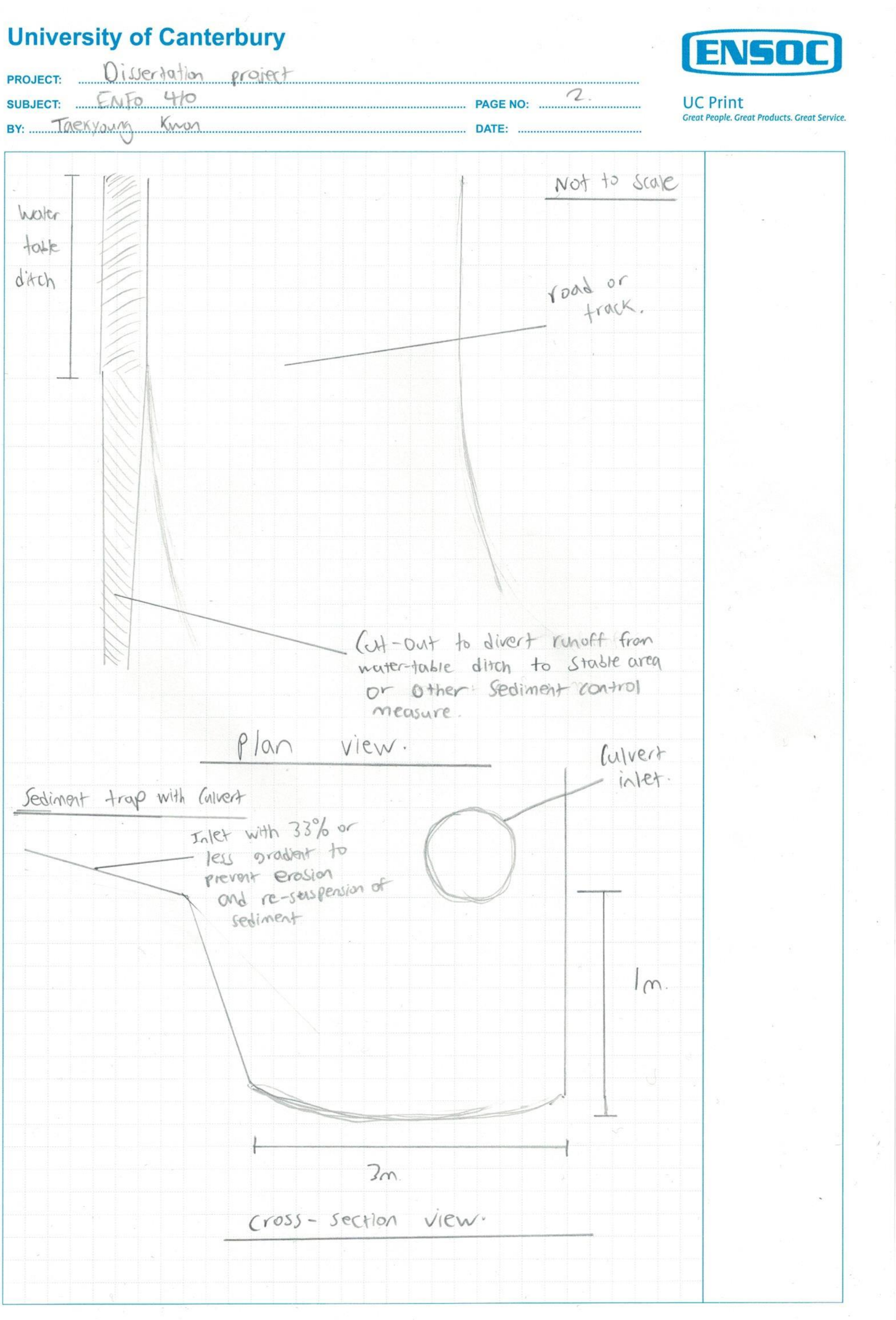

Figure 10. Plan view of cut-out and cross-section view of sediment trap with culvert

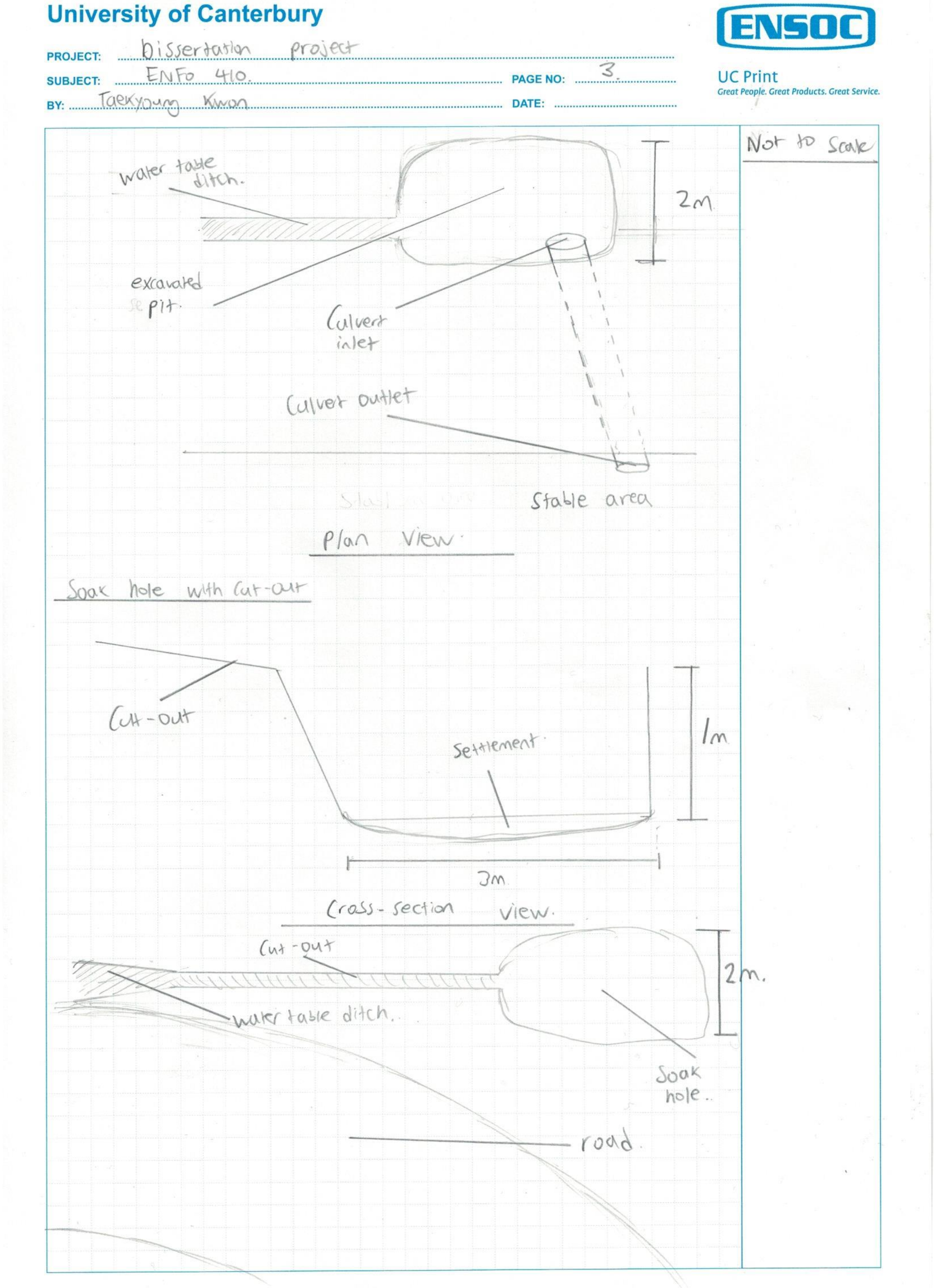

Figure 11. Plan view of sediment trap with culvert and soak hole with cut-out, and cross-section view of soak hole with cut-out.