Sirius Minerals

Phase 7 Works

NYMNPA 60 and 79 Surface Water Drainage Scheme

40-ARI-WS-7100-CI-RP-01001

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Ove Arup & Partners Ltd
Admiral House Rose Wharf
78 East Street
Leeds LS9 8EE
United Kingdom
www.arup.com

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		Name	V. Stoyanova	N. Ferro	A. Hornung
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		Name	Chris Williams	Nick Ferro	Andrew Hornung
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Contents

1 Introduction

1.1 Overview

This document has been prepared on behalf of Sirius Minerals PLC and details the surface water drainage scheme for the Phase 7 construction activity at Woodsmith Mine (Phase 7 Works). This is required to discharge conditions 60 and 79 of the North York Moors National Park Authority (NYMNPA) planning permission NYM/2014/0676/MEIA, as subsequently varied by NYM/2017/0505/MEIA [1].

This report only details the works required at the Woodsmith Mine site.

The Phase 7 Works comprise:

- **Completion of Service Shaft headgear chamber**.

  These works comprise excavation beyond 168.17m AOD as determined in Phase 5 within the headgear chamber diaphragm wall to full depth, at around 157.67m AOD. Also included is the installation of a 5m sub-cellar in the base of the headgear chamber in order to facilitate the safe construction of the main mine shafts.

  SW Drainage Impact Assessment: The works described above have no impact on the surface water drainage strategy, except for the discharge of small quantities of treated non-domestic waste water into the surface water drainage system. Refer to Section 1.2.2 for details.

- **Completion of Service Shaft to 83.17m AoD via VSM method**

  The Vertical Shaft-Sinking Machine (VSM) (similar to Phase 4A) will be utilised to construct the shaft from the floor level of headgear chamber (162.17m AOD) to 83.17m AOD, using precast concrete segmental liner. There will be a reinforced concrete guide collar at the top which will be subsequently removed in order to construct sub-basement.

  SW Drainage Impact Assessment: The works described above have no impact on the surface water drainage strategy, except for the discharge of treated water non-domestic waste water on completion of the works into the surface water drainage system. Refer to Section 1.2.2 for details.

- **Excavation of Production Shaft Headgear Chamber**

  These works comprise excavation within the headgear chamber diaphragm wall at the production shaft to a depth of around 158.16m AOD and construction of the 2.5m thick concrete floor anchored down by piles. These works also include the removal of the top portion of the deeper diaphragm walls that form the start of the main shaft. Also included is the installation of a 5m sub-cellar in the base of the headgear chamber in order to facilitate the safe construction of the main mine shaft, the winder basement and the building foundations.

  SW Drainage Impact Assessment: The proposed works above have no impact on the surface water drainage strategy, except for the discharge of treated water non-domestic waste water during the works into the surface water drainage system. Refer to Section 1.2.2 for details

- **Excavation from base of Production Shaft Headgear Chamber to 83.66m AOD**

  These works comprise excavation within the 120m deep diaphragm wall to a level of 83.66m AoD, this will be similar in nature to the method defined for the excavation of the Service Shaft headgear chamber within Phase 5.

  SW Drainage Impact Assessment: The works described above have no impact on the surface water drainage strategy, except for the discharge of treated water non-domestic waste water during the works into the surface water drainage system. Refer to Section 1.2.2 for details

- **Erection of temporary facilities to enable mobilisation of deep shaft sinking contractor**

  These works comprise the construction of the temporary facilities required in order for the main shaft sinking contractor to begin mobilisation to site:

  - Winch houses for Service Shaft, Production Shaft and MTS Shaft
  - MTS temporary headframe
  - MTS galloway delivery and installation
  - Temporary workshops and stores
  - Erection of steel headframes within the Service Shaft and Production Shaft headgear chambers
  - Compressed air house

  SW Drainage Impact Assessment: The works described above have no impact on the surface water drainage strategy.

- **Contingency Grouting of the MTS Shaft**

  As approved under Phase 4a, the VSM operation is planned to take the MTS shaft to a depth of 120m. However, in the event that the VSM operation has to be ceased prior to reaching the target depth (e.g. in the event of a breakdown), it may be necessary to grout through any remaining water bearing strata.

  SW Drainage Impact Assessment: The works described above **have an impact** on the surface water drainage strategy. Impacts are outlined in Section 1.2.

- **Earthworks and Drainage**

  Earthworks associated with the above activities, including installation of drainage associated with earthworks to capture and treat run off water.

  SW Drainage Impact Assessment: The works described above **have an impact** on the surface water drainage strategy. Impacts are outlined in Section 1.2.

- **Surface Water Run-Off Silt Treatment Facility Building**

  Construction of a bespoke building to house the dedicated surface water treatment facility located adjacent to the attenuation ponds – cladding to suit previous schemes for main buildings.

<u>SW Drainage Impact Assessment:</u> The works described above **have an impact** on the surface water drainage strategy. Impacts are outlined in Section 1.2.

1.2 Works Impact on Surface Water Drainage Strategy

1.2.1 Management of Runoff from Earthworks

The Phase 7 earthworks (as described on drawings 40-ARI-WS-7100-CI-18-01005 and 40-ARI-WS-7100-CI-18-01011) will involve the exposure of unfinished ground in preparation for stockpiling of material extracted from the shafts in future phases and the extension and reforming of some of the permanent and temporary storage bunds on site. To accommodate the collection and attenuation of surface water runoff from these new earthworks, the existing drainage network will be extended, as set out in this document.

The silt mitigation strategy for the surface water runoff approved as part of previous phases, will be applied for the new earthworks areas. The main principle is to minimise the sediment entrainment with measures applied at source. Additional silt fences will be installed around newly disturbed earth; check dams will be placed in the new/extended swales and ditches; all runoff will be attenuated and sediment particles will be allowed to settle.

In previous phases the surface water management strategy made a provision for the use of environmentally friendly coagulants where required to aid the settlement of the fine clay particles on site. In addition to this it is proposed to install a temporary surface water treatment facility, where the surface water quality discharged from the attenuation ponds can be monitored in real time and coagulants added to the water at the treatment facility when required. This is proposed to be a temporary facility which will not be required for the long-term operation of the permanent surface water drainage system following the completion of the construction phase.

The plant is to be installed between Pond C and Wetland A in the northern drainage network, and it is to be provided as a package plant provided by Silt Buster. To provide the same quality of treatment for the runoff from the whole site, the previously separate Southern drainage network is to be temporarily connected to the surface water treatment facility through a temporary overland pipe. It is envisaged that the temporary connection will be removed once the permanent ponds for the southern network are built and established.

Refer to Appendix A for a general arrangement of the proposals, and Section 2.3.5 for details of the surface water treatment facility arrangement.

1.2.2 Groundwater Discharge

The continuing works to excavate the Service and Production Shafts to -83.17 and 83.66m AOD respectively will result in dewatering due to the works interacting with groundwater aquifers. The groundwater extracted during the shaft construction is to be treated as outlined in the Non-Domestic Wastewater Management Strategy (document reference: 40-ARI-WS-7100-CI-RP-01002). Treated water will then be discharged into the surface water drainage network.

The overall discharge from site will be managed to ensure that the flood risk from the site is not increased. This management will include ensuring that during periods of wet weather, non-domestic wastewater will be buffered and retained on site within storage tanks to ensure that the permitted drainage outfall rates from the site are not exceeded. A $500m^3$ storage tank is already available on site within the bentonite treatment plant which can be used to provide buffer storage capacity if required.

1.2.3 Contingency Grouting Drilling Wastewater

Wastewater from the drilling process will be passed through settlement tanks, siltbusters and a sand filter and re-used as far as practicable, however when water quality deteriorates beyond that required by the grouting contractor the “used” water will be bled-off and tankered off-site for disposal off site, and the tanks will be refilled with fresh water. No water will be discharged to the surface water drainage system from this activity.

1.2.4 Storage of Extractive Materials

In future phases, extracted material is to be used to construct landscape bunds, with a basal drainage layer being provided at the base of the bunds. It is expected that after the bunds are constructed, the quantities of water percolating through the material will be minimal.

In preparation for the future works, the basal drainage layer for the first permanent storage area will be prepared during Phase 7. The basal drainage will be collected and conveyed to the perimeter swale which outfalls in to Wetland C. (Refer to Appendix A for proposed General Arrangement).

1.3 Compliance with Conditions

The wording of planning condition 60, and where the necessary material has been provided within the report, is set out in the table below:

NYMNPA 60	**Compliance with Condition 60**
Surface water management at the Doves Nest Farm site during construction shall incorporate measures to slow water flow such that sediment settles out prior to surface water draining from the site into the Sneaton Thorpe Beck. Prior to the commencement of preparatory works the design of the surface water management system at Doves Nest Farm shall be submitted to and agreed in writing by the MPA to ensure it incorporates measures that may be required to prevent sediment entering the Sneaton Thorpe Beck causing harm to the brown trout population present there.	Refer to the Surface Water Management Plan in Appendix C.

The wording of planning condition 79, and where the necessary material has been provided within the report, is set out in the table below:

NYMNPA 79	**Compliance with Condition 79**
No development shall take place at Doves Nest Farm until a Surface Water Drainage Scheme for the site, based on sustainable drainage principles and an assessment of the hydrological and hydro-geological context of the development, has been submitted to and approved in writing by the MPA.	Refer to this report and appendices for the surface water drainage scheme. Refer to Sections 2.2, 2.3, 2.4, 2.5 and 2.6.
The drainage strategy must demonstrate that surface water run-off generated up to and including the 1 in 100 critical storm will not exceed the run-off from the undeveloped site following the corresponding rainfall event.	This element of condition 79 does not need to be discharged for the Phase 7 Works because the 1 in 100 critical storm is only applicable to the post construction, operational phase. Refer to Section 2.2.
The scheme shall include: *Confirmation that the surface water drainage system is to be built first so that it is available to provide the drainage for the construction phase as well as the completed mine head, and is to be in accordance with information provided in the Supplementary Environmental Information report (specifically Section 15 and Appendix C). Details of the surface water drainage system will include a plan for silt management and reduction during the construction phase;*	Refer to the Surface Water Management Plan in Appendix C. Refer to Sections 1.4, 2.2, 2.3 and 2.6.
The scheme shall include: *In order to construct the settlement facility/facilities some site preparation works have to be undertaken before the settlement facility/facilities are operational -*	Refer to the Surface Water Management Plan in Appendix C. For Typical Drainage Details Refer to 40-ARI-WS-71-PA-RP-1050 - Phase

details of temporary silt reduction and management measures shall be included;	3 Works, NYMNPA 60 and 79 Surface Water Drainage Scheme - Appendix F.
The scheme shall include: *Surface water discharge rates from the impermeable areas of the site are to be limited to greenfield Qbar flows as calculated in Appendix C of the Supplementary Environmental Information report (an overall maximum surface water discharge of 6.5 litres per second per hectare);*	Refer to Section 2.6 and Appendix D.
The scheme shall include: *Sufficient attenuation storage for up to and including the 1 in 100 year storm event plus a 30% allowance for climate change, and surcharging the drainage system can be stored on the site without risk to people or property and without overflowing into a watercourse;*	This element of condition 79 does not need to be discharged for the Phase 7 Works because the 1 in 100 critical storm is applicable only to the operational phase. Refer to Section 2.2.
The scheme shall include: *Details of the design of the attenuation storage basins;*	Refer to Section 2.6 for summary of storage volume and utilisation. For Typical Drainage Details Refer to 40-ARI-WS-71-PA-RP-1050 - Phase 3 Works, NYMNPA 60 and 79 Surface Water Drainage Scheme - Appendix F.
The scheme shall include: *Details of the outfalls to watercourse(s), including the provision of a penstock, erosion protection measures and measures to ensure velocities are limited to no more than 0.3m per second unless otherwise agreed by the MPA in consultation with the Environment Agency;*	Refer to Section 2.6 and Appendix E
The scheme shall include: *Details of how the whole surface water drainage system will be designed so as to maximise its biodiversity benefits;*	This element of condition 79 does not need to be discharged for the Phase 7 Works because the final restoration of the site will occur during later phases of the project.
The scheme shall include: *Drainage from the landscaped areas is to drain into the proposed swales, upstream of a check dam where required to reduce velocities;*	Refer to Section 2.3.1 and Appendix B, D and 40-ARI-WS-71-PA-RP-1050 - Phase 3 Works, NYMNPA 60 and 79 Surface Water Drainage Scheme - Appendix F.
The scheme shall include: *Details of the proposed rainwater harvesting system;*	This element of condition 79 does not need to be discharged for the Phase 7 Works because no permanent buildings are to be constructed in this phase.
The scheme shall include: *The provision of permeable surfacing on areas where it can be demonstrated that the risk of pollution is low;*	This element of condition 79 does not need to be discharged for the Phase 7 Works because no permanent permeable surfacing is proposed during this phase.
The scheme shall include: *Details of how clean roof water shall be discharged to ground;*	This element of condition 79 does not need to be discharged for the Phase 7 Works because no permanent buildings are to be constructed in this phase.

The scheme shall include: *Details of how the entire surface water drainage system will be maintained and managed throughout the lifetime of the development, including the construction phase. This must include details of maintenance to deal with any siltation of the attenuation storage basins and any resultant loss of capacity; and*	Refer to the Surface Water Management Plan in Appendix C.
The scheme shall include: *A timetable for the implementation of the Surface Water Drainage Scheme, including during the construction phase. This is to include details regarding the phasing of the construction works demonstrating that the storage available during construction is maximised (i.e. that the period of time that only the minimum 1 in 20 standard of protection is kept to the shortest possible).*	Refer to the Surface Water Management Plan in Appendix C. Refer to Section 2.6.
Development shall thereafter proceed only in strict accordance with the approved Surface Water Drainage Scheme and the timetable included within it. Once implemented, the Surface Water Drainage Scheme shall be retained and maintained throughout the lifetime of the development such that it continues to function in the manner intended and so as to ensure identified limits are not breached.	Refer to the Surface Water Management Plan in Appendix C.

1.4 Site and Location

The Woodsmith Mine site is located approximately 5 km south of Whitby bounded by the B1416 to the West/South. The site is located in the River Esk catchment and at the very upper reaches of the Sneaton Thorpe Beck.

1.5 Other Documents Key to this Report

BWB undertook the Baseline Surface Hydrology report, Ref: LDT/2021/BSH [2]. This has been used to inform the surface water drainage (SWD) design. The SWD design follows the principles set out in the Surface Water Drainage Design Parameters report, Ref: LDT/2021/SWDS [3] and the Surface Water Drainage - Design Basis Report for Dove's Nest Site, Ref: REP-P2-CD-001 [4]. The design has been developed in parallel with the masterplan for the site which is shown in Appendix A, *"Woodsmith Mine Construction Phase 7 Masterplan 40-ARI-WS-7100-CI-18-01005"*.

1.6 Design Guidance

The design standards and guidance used in the SWD design for the site include:

- Sewers for Adoption (7th Edition, 2012).
- BS EN 752 Drains and sewer systems outside buildings.
- DEFRA, Rainfall runoff management for developments – Report SC030219.
- Technical Guidance to National Planning Policy Framework (NPPF).
- Design Analysis of urban storm drainage – The Wallingford Procedure.

- CIRIA Report C697, The SuDS Manual, 2007.
- CIRIA Report C753, The SuDS Manual, 2015.
- CIRIA Report C609, Sustainable Drainage Systems – Hydraulic, Structural and water quality advice, 2004.
- CIRIA Book 14, The Design of Flood Storage Reservoirs, 1993.
- CIRIA Report 156, Infiltration Drainage – Manual of Good practice, 1996.
- Environment Agency and Department for Environment, Food & Rural Affairs, Pollution prevention for businesses, 12 July 2016.
- BRE Digest 365, Soakaway Design 2012.
- Environment Agency Guidance on Outfalls: Flood Defence Information Sheet No. 3.
- Fluvial Forms and Processes, A New Perspective, David Knighton, 1998.
- Open-channel hydraulics: New York, McGraw-Hill, Chow, V.T., 1959.

2 Phase 7 Works Surface Water Drainage Design

2.1 General Arrangement

The masterplan for the Phase 7 Works, drawing 40-ARI-WS-7100-CI-18-01005 is included in Appendix A.

2.2 Design Principles

The Phase 7 works provides a continuation of the drainage principles incorporated and approved as part of the previous planning phases. The addition and expansion of the drainage network resulting from the proposed Phase 7 works follows the principles outlined in Report 40-ARI-WS-71-PA-RP-1050, Phase 3 Works, NYMNPA 60 and 79 Surface Water Drainage Scheme. The Phase 3 document provided details on the overarching principles agreed in the previous construction phases of the scheme.

This report provides an update on how the drainage network constructed in the previous planning phases is adapted to meet the drainage requirements for the Phase 7 works. The additions and changes to the design principles are stated below and in the relevant sections for the different drainage features.

In addition to the previous design principles:

1. Preparation of the initial area for the permanent placement of extracted materials arising during future phases.
2. Where required, the swales and ditches constructed in the previous construction phases will be extended to accommodate the additional runoff from newly exposed ground areas and temporary bunds. Silt fences will be constructed at the base of all bunds to limit the entrainment of sediment in the surface water runoff. Additional check dams will be constructed in the ditches where it is expected that due to the increased design flows there will be an increase in the flow velocities.
3. A new surface water treatment facility will be constructed to control the discharge from Pond C, significantly reducing the risk of surface water with high concentration of suspended solids leaving the site. The function of the treatment facility is to aid the sediment removal, in addition to the measures already present on site.

2.3 Drainage Features

A plan for the Woodsmith Mine site has been developed, refer to Appendix B. The drainage plan shows the principal drainage infrastructure for the drained areas during Phase 7, including silt fences, swales, ditches, carrier pipes, oil separators, a silt removal facility, attenuation ponds, surface water treatment facility, wetlands and outfalls.

2.3.1 Swales/Ditches

Additional swales and ditches to those constructed in the previous construction phases will be provided to collect surface water runoff from the toe of the landscaping bunds and around the perimeter of the hard-standing platforms.

There will be no change in the design principles for the already constructed swales and ditches in the previous phases. Refer to the general arrangement drawing in Appendix B.

2.3.2 Silt Removal Facility

The temporary connection of the southern network will discharge in the upstream end of the silt removal facility, thus providing additional settlement and retention time for the runoff from the southern drainage network. As the southern network is attenuated in the preceding temporary pond and wetland, the addition of the southern network has little impact on the performance of the silt removal facility. The additional flow towards the silt removal facility during a critical duration 1-in-20-year storm is approximately 3% of the flow through the silt removal facility. The coarser suspended solids in the southern catchment runoff such as sands and silts are settling out in the Southern Pond and Wetland B. (Refer to Table 2.3).

2.3.3 Attenuation Ponds

There is no change in the design principles for the attenuation ponds in this phase, except for Pond C. For the changes in the design principles for Pond C refer to Sections 2.3.4 and 2.3.5 and the general arrangement drawing in Appendix B.

2.3.4 Flow controls

The discharge from the attenuation ponds, with the exception of Pond C in the Northern Network, will be controlled by flow control devices such as orifice plates, which will be installed as soon as the ponds are constructed.

The orifice plates for this phase will be modified to provide maximum attenuation in the ponds preceding Pond C, to limit the risk of overwhelming the surface water treatment facility. The attenuation provided by the upstream ponds will ensure that the maximum allowable rate of discharge, equating to 6.5 litres per second per hectare, is not exceeded.

There is a very low risk that the surface water treatment facility capacity might be exceeded. In a 1-in-20-year storm there are only a few specific durations of storm events that would cause Pond C to be completely full. A very small amount of excess water (only 1.7% of the volume of these specific storm duration events) would be discharged through the Pond C emergency spillway into the final Wetland A for treatment within the wetland. The operation of the drainage network in this case was modelled using Windes Microdrainage, and the results demonstrated that the combined discharge from the treatment facility and the overflow does not exceed the permitted discharge rate. Refer to Appendix D for modelling results.

For a limited period, the southern catchment drainage will be routed into the northern catchment silt removal facility via a pipe from the southern wetland. This arrangement is only expected to be in place for two years while the southern ponds are being constructed. There is enough spare capacity in the northern catchment attenuation ponds that the additional inflow will not cause an exceedance of the permitted discharge rate. The combined flow through the Siltbuster and the overflow from Pond C is a total of 101 l/s (Refer to Table 2.1), which remains below the permitted discharge rate of 166 l/s.

2.3.5 Surface Water Treatment Facility

To keep the concentration of suspended solids in site runoff below permitted levels during construction, an active treatment process has been incorporated into the site surface water management system. This comes in the form of package treatment plant provided by Siltbuster, which uses a coagulant (when required) and settlement to remove suspended solids from the site runoff. In addition to suspended solids, the site runoff has an elevated pH due to the use of lime for improving the condition of earthworks materials. The pH is managed within permitted limits by dosing the treatment stream with carbon dioxide.

The Siltbuster plant has a total throughflow capacity of 67 l/s. Of the three attenuation ponds in the northern catchment, ponds A and B provide enough passive storm runoff attenuation to ensure the peak flow rate, having a 1-in-20-year critical duration storm, remains below the permitted discharge rate of 166 l/s (Refer to Table 2.1).

Pond C then provides further attenuation to limit this peak flow rate to the available Siltbuster capacity of 67 l/s. This is achieved by automatically starting the pumps supplying the Siltbuster when the water depth in pond C reaches 300mm, and only stopping them when the water level reaches a specified minimum level. If the pond and plant capacity is exceeded, the runoff will bypass the Siltbuster and discharge via the Pond C spillway to the downstream Wetland A. This will be diluted in the wetland by the treated water stream before discharging to the watercourse.

2.3.6 Wetlands

There are three wetlands as part of the drainage network forming the final stage of SuDS treatment before discharge to the tributaries of Sneaton Thorpe Beck. There is no change in the design principles for the wetlands in this Phase 7. Refer to the general arrangement drawing in Appendix B.

In Phase 7 the outfall from the southern network wetland will be temporarily diverted through an overland pipe connecting to the Silt Removal Facility, to receive final treatment through the Surface Water Treatment facility. (See Sections 2.3.4 and 2.3.5).

2.3.7 Additional Sediment Control

There is no change in the design principles for the additional sediment control methods in Phase 7. Refer to Report 40-ARI-WS-71-PA-RP-1050, Phase 3 Works, NYMNPA 60 and 79 Surface Water Drainage Scheme, for the full text of the principles used in the previous construction phases of the scheme.

2.3.8 Oil Separators

There is no change in the design principles for the oil separators in Phase 7. Refer to Report 40-ARI-WS-71-PA-RP-1050, Phase 3 and 6 Works, NYMNPA 60 and 79 Surface Water Drainage Scheme, for the full text of the principles used in the previous construction phases of the scheme.

2.3.9 Outfalls

Two additional temporary outfalls were included in Phase 6, for the drainage of the additional platform in Haxby Plantation. No additional outfalls are to be constructed as a result of the Phase 7 works.

2.4 Groundwater

There is no change in the design principles for the additional ground water interaction with the drainage network in Phase 7. Refer to Report 40-ARI-WS-71-PA-RP-1050, Phase 3 Works, NYMNPA 60 and 79 Surface Water Drainage Scheme, for the full text of the principles used in the previous construction phases of the scheme.

2.5 Calculation Methodology

The Phase 7 Works layout for the Woodsmith Mine has been assessed and the required attenuation volumes calculated. The results are shown in section 2.6.

The allowable rates of discharge from the ponds have been calculated for the Phase 7 Works based on the Q_{Bar} greenfield runoff rate for the total contributing area.

For the Phase 7 Works, a 1-in-20-year return period design storm with no climate change allowance has been applied to a MicroDrainage model of the proposed network. Simulations have been undertaken using a range of durations from 15 minutes to seven days to determine the critical duration for each part of the network to ensure no flooding occurs and the attenuation is sufficient.

2.6 Calculation Results

The MicroDrainage model outputs in Appendix D demonstrate that the design described in this report meets the requirements set out in the planning conditions [1]. In particular, the discharge rate from the developed areas has been limited to the Q_{Bar} greenfield runoff rate and the volume of attenuation provided is sufficient to attenuate flows up to the 1-in-20-year return period event. This includes the expected overflow from Pond C when the total capacity of the Surface Water Treatment Facility is exceeded.

Runoff Rates

The allowable Q_{Bar} greenfield runoff rate is 6.5 l/s/ha, based on the Baseline Surface Hydrology report [2].

The flow rate is controlled by flow control devices at the outlets of the attenuation ponds. Table 2.1 summarises the modelling outputs in Appendix D.

	Northern Catchment	**Southern Catchment**	**Additional Platform in Haxby Plantation**	**Refer to:**
Gross Area drained	25.4 hectares	6.5 hectares	0.4ha	Appendix B General Arrangement
Greenfield Runoff Rate (Allowable Rate of Discharge)	6.5 x 25.4 = 166 l/s	6.5 x 6.5 = 42.24 l/s	6.5 x 0.4 = 2.6 l/s (min 5l/s)*	
Maximum modelled rate of discharge	76.7 l/s (Combined with the Southern Catchment 101.5 l/s)	18.8 l/s	4.1 l/s	Appendix D, critical results by maximum level for Pipes PH3-N-1.040, PH3-N-21.016 and HPP-2.007

Table 2.1 Summary of modelled Runoff Rates

* Where Catchments are small and limits of discharge are less than 5l/s (risk of throttle blockage), a minimum of 5l/s is allowed, Reference: DEFRA, Rainfall runoff management for developments.

Volume of Attenuation

A summary of the MicroDrainage modelling results are shown in Table 2.2 and the modelling outputs are shown in Appendix D.

	Northern Catchment	**Southern Catchment**	**Refer to:**
Volume used in MicroDrainage model	9900 m^3	981 m^3	Appendix D, Graphs for Pipe 1.039 and Pipe 19.006
Volume Available as Constructed	9900 m^3	1100 m^3	Volumes provided on General Arrangement Drawing in Previous Planning Documents

Table 2.2 Summary of modelled attenuation volume requirements

In both catchments the attenuation ponds provided in the earthworks design have sufficient storage volumes to attenuate surface water runoff to the allowable rate of discharge.

As explained in section 2.3.4, there are a few specific durations of a 1-in-20-year storm event where Pond C is completely full and a small volume is allowed to spill over the emergency spillway (Refer to Appendix D). The combined outflow however would **not** exceed the allowable discharge rate as shown in table 2.1 above.

Silt Removal

As stated in the Surface Water Drainage Design Parameters report, Ref: LDT/2021/SWDS [3], a minimum of three stages of treatment have been provided to minimise the risk of sediments entering the tributaries of Sneaton Thorpe Beck. The design in Phase 7 incorporates; swales and ditches with check dams, infiltration to ground, oil separators with silt traps, a silt removal facility; a series of attenuation ponds; a surface water treatment facility and wetlands for final treatment.

Calculations have been carried out to estimate the percentage removal of sediments in the attenuation features preceding the surface water treatment facility, during the critical duration 1-in-20-year storm event. CIRIA Book 14, Chapter 6.5, "Estimating Pollutant Removal Efficiency" was used for this calculation. A summary of the results is shown in the table below. The calculations are provided in Appendix E.

Particle Size	Typical Settling velocities (mm/s)	% Removal Southern Pond	% Removal Southern Wetland	% Removal Silt removal facility	% Removal Wetland C	% Removal Pond A	% Removal Pond B	% Removal Pond C	% Removal Wetland A	Total % Efficiency
Coarse Sand	200	100%		100%	100%					100%
Fine Sand	22	100%		100%	100%					100%
Coarse Silt	6.7	100%		100%	100%					100%
Fine Silt	0.18	100%	100%	36%	62%	100%				100%
Coarse Clay	0.016	67%	85%	3%	5%	26%	41%	43%	19%	77%
Fine Clay	0.011	46%	58%	2%	4%	18%	28%	29%	13%	61%

Particle Size	Overall Removal
Sand	100%
Silt	100%
Clay	69%

Table 2.3 Summary of Silt Removal Calculations for the combined Northern and Southern Catchment.

The results above take into consideration the relative proportion of the flow treated in the different facilities. However, the potential of different suspended solids concentration in the flows from the southern and the northern network is not taken into consideration. For example, runoff from the hard-surfaced platforms is expected to have lower concentration of silt compared to exposed soft storage bunds. The additional settlement that would occur in the swales, the oil separator, behind the silt fences and in the check dams, the final wetland, as well as the benefit provided by the silt removal capacity of the surface water treatment facility is also not taken in consideration in the silt removal calculation.

The supplier of the surface water treatment facility – Silt Buster has been provided with the plant performance requirements. The requirements are as follows:

1. Total Suspended Solids (TSS) <24mg/l, and
2. Turbidity: 26FTU, and
3. pH value: pH6 to pH9

Outfall Velocities

Appendix E contains an assessment of the existing tributaries of Sneaton Thorpe Beck downstream of the site. The assessment demonstrates that a maximum allowable velocity of 1.2m/s would be appropriate for these tributaries.

There are two outfalls to be constructed during the Phase 6 Works near the addition construction platform in Haxby Plantation, as shown on the general arrangement drawing in Appendix B.

The first outfall drains the additional construction platform in Haxby Plantation. The calculations show that using an outfall with an up-stand or "stilling basin" the maximum velocity discharging in the critical storm event is 0.21 m/s (refer to Appendix E). This is less than the allowable discharge velocity of 1.2m/s and therefore can be considered acceptable.

The second outfall is for diverting an existing drainage ditch upstream of the additional construction platform in Haxby Plantation. The gradient of the diversion ditch ensures peak flow velocities remain below 1.2m/s.

For the Northern network the modelled peak velocity at the outfall for the critical storm event is approximately 0.18m/s (refer to Appendix E). This is less than the allowable discharge velocity of 1.2m/s and therefore can be considered acceptable.

3 Conclusions

This report and design demonstrates how the surface water drainage will be managed on site during the Phase 7 Works. The proposed arrangements will ensure that the site is not at risk of flooding and does not impact on flood risk elsewhere.

The MicroDrainage model outputs demonstrate that the design described in this report meets the requirements set out in the planning conditions. The discharge rates from the developed areas have been limited to the Q_{Bar} greenfield runoff rates and the volume of attenuation provided is sufficient to attenuate flows up to the 1-in-20-year return period event.

The design complies with the sustainable drainage strategy. An appropriate treatment train is proposed and the calculations demonstrate that the provision for sediment removal is sufficient prior to discharging to the watercourse and that the outfall velocity is appropriate to minimise the impact on the receiving water body.

This report demonstrates that the SWD design and management during the Phase 7 Works meets the requirements of conditions 60 and 79 of the North York Moors National Park Authority (NYMNPA) planning permission NYM/2014/0676/MEIA, as subsequently varied by NYM/2017/0505/MEIA.

The necessary land drainage consents will be applied for from North Yorkshire County Council ahead of the works.

References

[1] North York Moors National Park Authority planning permission NYM/2014/0676/MEIA.

[2] Baseline Surface Hydrology, Ref LDT/2021/BSH, Revision F, BWB, 11/09/2014.

[3] Surface Water Drainage Design Parameters, Ref LDT/2021/SWDS, Revision D, BWB, 12/09/2014.

[4] Surface Water Drainage - Design Basis Report for Dove's Nest Site, REP-P2-CD-001, Rev 3, Arup, July 2014.

[5] Highway Improvement 2: Dove's Nest Farm Welfare Access B1416. Technical Note, TN-P10-DNF-CH-001, Rev A, Arup, November 2016.

[6] NYMNPA 60 and 79 Surface Water Drainage Scheme, 40-ARI-WS-71-PA-RP-1050, Rev 0, Arup, April 2017.

[7] Wastewater Management Strategy, 40-ARI-WS-7100-CI-RP-01002, Rev 0, Arup, August 2018.

Appendix A

Phase 7 Masterplan

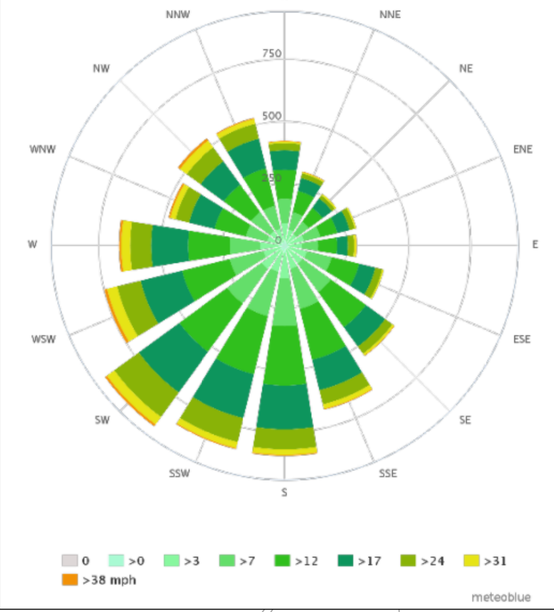
Key:

- Land ownership boundary
- Construction Phase Security Fence
- Topographical survey
- Proposed layout
- 3m high Environmental / acoustic barrier
- Safety Bund
- Proposed drainage ditch
- Surface water drainage attenuation pond
- Surface water drainage wetland
- Telecommunication mast

Key to utilities:

- HV — Existing Northern Powergrid electrical apparatus
- D-wall

Wind Rose:



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0	22/08/18	KK	CW	CW
	Issue			
D	17/08/18	JT	CW	CW
	For Comment			
C	07/08/18	JT	JB	CW
	For Comment			
B	30/07/18	JT	JB	CW
	For Comment			

ARUP

Client
Sirius Minerals Plc

Job Title
Woodsmith Mine
Proposed Minehead

Woodsmith Mine
Construction Phase 7
Masterplan

Scale at A1: 1:2000

Discipline: Highways

Job No: 253285

Drawing Status: Planning

Drawing No: 40-ARI-WS-7100-CI-18-01005

Issue: 1

Do not scale

Appendix B

Phase 7 Drainage Layout

Notes:

1. This drawing shows the proposed surface water drainage network for Site Preparation Phase 7.

Key:

- Land Ownership Boundary
- Proposed General Arrangement layout
- Surface water drainage attenuation pond
- Wetland
- Existing watercourses / ditch
- Manhole and carrier pipe
- Swale
- Check dam
- Silt fence
- Ditch
- Ditch with impermeable liner
- Inlet / outlet headwall
- Filter drain
- Dewatering pipeline and wells
- Basal drainage
- Groundwater drainage

Issue	Date	By	Chkd	Appd
1	29/08/18	JT	CW	CW
	Issue			
0	22/08/18	KK	CW	CW
	Issue			
D	17/08/18	JT	CW	CW
	For Comment			
C	07/08/18	EC	JB	CW
	Planning			
B	30/07/18	JT	VS	CW
	For comment			

ARUP

Client
Sirius Minerals Plc

Job Title
Woodsmith Mine
Proposed Minehead

Woodsmith Mine Site
Construction Phase 7
Drainage General Arrangement

Scale at A1: 1:2000

Discipline: Drainage

Job No: **253285**

Drawing Status: **Planning**

Drawing No: **40-ARI-WS-7100-CI-18-01007**

Issue: **1**

Appendix C

Surface Water Management Plan

Sirius Minerals

Phase 7 Works

NYMNPA 60 and 79: Surface Water Management Plan

40-ARI-WS-71-PA-RP-1051

Draft A | 8 August 2018

Job number 253285

Ove Arup & Partners Ltd
Admiral House Rose Wharf
78 East Street
Leeds LS9 8EE
United Kingdom
www.arup.com

ARUP

Document Verification

ARUP

Job title	Phase 7 Works	**Job number** 253285	
Document title	NYMNPA 60 and 79: Surface Water Management Plan	**File reference** 1-6-05	
Document ref	40-ARI-WS-71-PA-RP-1051		

Revision	**Date**	**Filename**	40-ARI-WS-71-PA-RP-1051_0_IFU_20170313 SWMP_Phase 7.docx		
Draft A	8 Aug 2018	**Description**	First Draft		
			Prepared by	Checked by	Approved by
		Name	V. Stoyanova	N. Ferro	A. Hornung
		Signature			
		Filename			
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		Signature			
		Filename			
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		Name			
		Signature			

Issue Document Verification with Document ✓

Contents

1 Surface Water Management Plan (Phase 7)

Phase 7 provides a continuation to the surface water management strategy agreed as part of previous phases. This strategy has been extended to cover the works in Phase 7. For ease of reading, the differences in the strategy are highlighted in bold in the text below.

There are a range of methodologies for managing sediment contaminated surface water runoff from construction sites have been applied in the management plan for Phase 7. The surface water drainage masterplan for the Phase 7 Works is shown on drawing 40-ARI-WS-7100-CI-18-01007. This drawing shows the location of the main drainage network and the features to manage sediment. **As the majority of the drainage network on the site has been constructed in previous phases, typical details of the drainage features are shown on drawings issued with the Phase 3 NYMNPA 60 and 79 Surface Water Drainage Scheme Report 40-ARI-WS-71-PA-RP-1050_0_IFU_20170403 SWD DoC 60_79.**

As far as practicable, surface water runoff from areas of hard standing will be kept separate from those areas where sediment contaminated surface water runoff is anticipated. While runoff from areas of hard standing is not anticipated to generate large quantities of sediment, this surface water will be collected in hard standing perimeter ditches with check dams and passed through oil separators, a silt removal facility, attenuation storage ponds and a wetland before being discharged to the tributaries of Sneaton Thorpe Beck.

Surface water runoff from temporary spoil bunds and permanent landscaped bunds will be controlled by the aid of swales with check dams and cleansed with hay/heather bales and silt fencing before being passed through the treatment train of attenuation ponds and wetlands. There will be multiple secondary silt fences positioned in fields downstream of some swales to intercept, slow and treat any water that seeps over the edge of the swales to mimic a more ‘natural’ response and avoid surface water ‘sheeting’ off the slopes.

The drainage of the main access road connecting the Welfare entrance and the platform will combine with the drainage from the platform and drain through the treatment train. There is a short section of the access road near the welfare entrance that cannot gravitate to the main attenuation pond. For this section of the access road, local measures will be applied similar to the treatment methodology described in the Technical Note TN-P10-DNF-CH-001 Rev B submitted as part of the Phase 1 planning submission for the highways work at the welfare entrance.

The discharge from the final attenuation pond in the system will be discharge through a newly installed Surface Water Treatment Facility. The facility will have improved capacity to remove suspended solids from the surface water drainage system. Further to that, the facility provides real time monitoring and automated dosing for pH correction of the surface water, prior to discharge in the wetland for final settlement and treatment.

The discharge from the wetlands will be monitored for suspended solids, using a combination of visual monitoring and turbidity meter monitoring in accordance with the Groundwater and Surface Water Monitoring Scheme, condition NYMNPA 46. If the trigger levels are exceeded the appropriate plan of action will be implemented in accordance with the remedial action plan condition NYMNPA 46. Depending on the results a number of options are available:

- The penstock on the attenuation pond can be temporarily closed or partially closed to temporarily reduce the flow to the watercourse and increase the retention time to allow the sediments to settle out. This will be particularly effective for short intense storms. These temporary measures can be put in place without compromising the overall drainage strategy for Phase 7. This would be actively managed so that the pond is empty before the next storm event occurs.
- Additional treatment such as hay/heather bales and silt fences could be put in place in the tributaries of Sneaton Thorpe Beck downstream of the outfall locations but still within the site boundary. An experienced drainage engineer or geomorphologist will supervise the placement of these features to maximise sediment removal. These additional treatments will be readily available and stored local to the beck, should the need arise.
- An environmentally friendly coagulant can be used in specific check dams upstream of the silt removal facility to promote flocculation of the finer particles within the storage areas and speed up the settling rate.
- In addition to inspections of the discharges, regular monitoring of the tributaries of Sneaton Thorpe Beck will be undertaken, as detailed in the Groundwater and Surface Water Monitoring Scheme, to ensure that the discharge is not causing discoloration, erosion of the bank or disturbance of the bed of the watercourse. Records of all monitoring will be kept along with actions that were taken in the event of issues arising.

During Phase 7 all newly formed permanent landscaped bunds and temporary spoil bunds will be grass seeded as soon as practicable to ensure that sediment laden surface water runoff is minimised. Erecting silt fences at source around these spoil bunds, in combination with swales and check dams is the main method to prevent siltation getting into the drainage system. Silt fences will be installed to manufacturer’s recommendations (such as http://www.geofabrics.co.nz/media/2910/silt-fence-installation.pdf).

The silt fences and check dams will be monitored through regular surveys. If silt builds up and 30% of the available storage is used up, then scraping, dredging or emptying and re-profiling will be undertaken to ensure the full storage volume is maintained.

The silt removal facility and attenuation storage will be monitored through regular surveys. If silt builds up to a depth of 200mm then scraping, dredging or emptying and re-profiling will be undertaken to ensure the full storage volume is maintained.

Throughout the Phase 7 Works, the surface water drainage system will be inspected daily to ensure that it is in good working order and when necessary all pipework, swales and other drainage elements, such as the oil separators and flow control devices, shall be cleaned out to guarantee unobstructed flow and prevent build-up of sediment. Any extracted sediment will be redistributed thinly over the works area to dry out and become integrated into the landscaping.

Due to the nature of the works, and their phasing, the drainage arrangements will alter during construction and as a result, the Surface Water Management Plan will be a live and flexible document. While the attenuation pond will be sized to take account of storm events, the flexibility of the Plan will also allow rapid response to weather conditions and unexpected events.

2 Surface Water Drainage – Sequence of Works and Construction Methods

The drainage network supporting the construction activities has been largely constructed prior to the Phase 7 works. Sequencing of the drainage related work in this phase is outlined below.

- **Extension to and provision of additional Some swale extensions are required to support the earthworks in Phase 7. The work on the drainage network will be completed in advanced preparation before the earthworks in the relevant area commences.**
- **The surface water treatment facility will be completed offline to the existing attenuation and treatment features on site. It will be brought into operation after completion.**

Appendix D

Micro Drainage Model Outputs

Ove Arup & Partners International Ltd		Page 1
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XP Solutions	Network 2016.1.1	

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2880 minute 20 year Winter I+0%
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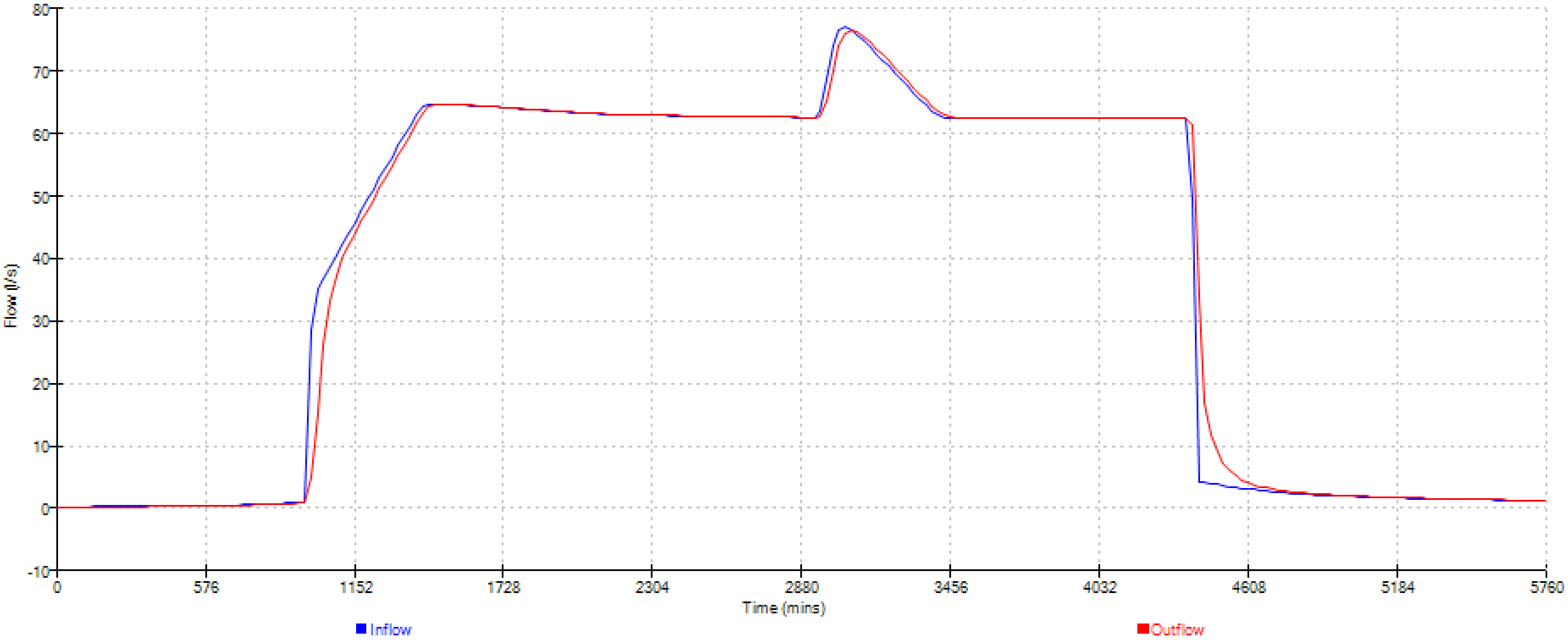

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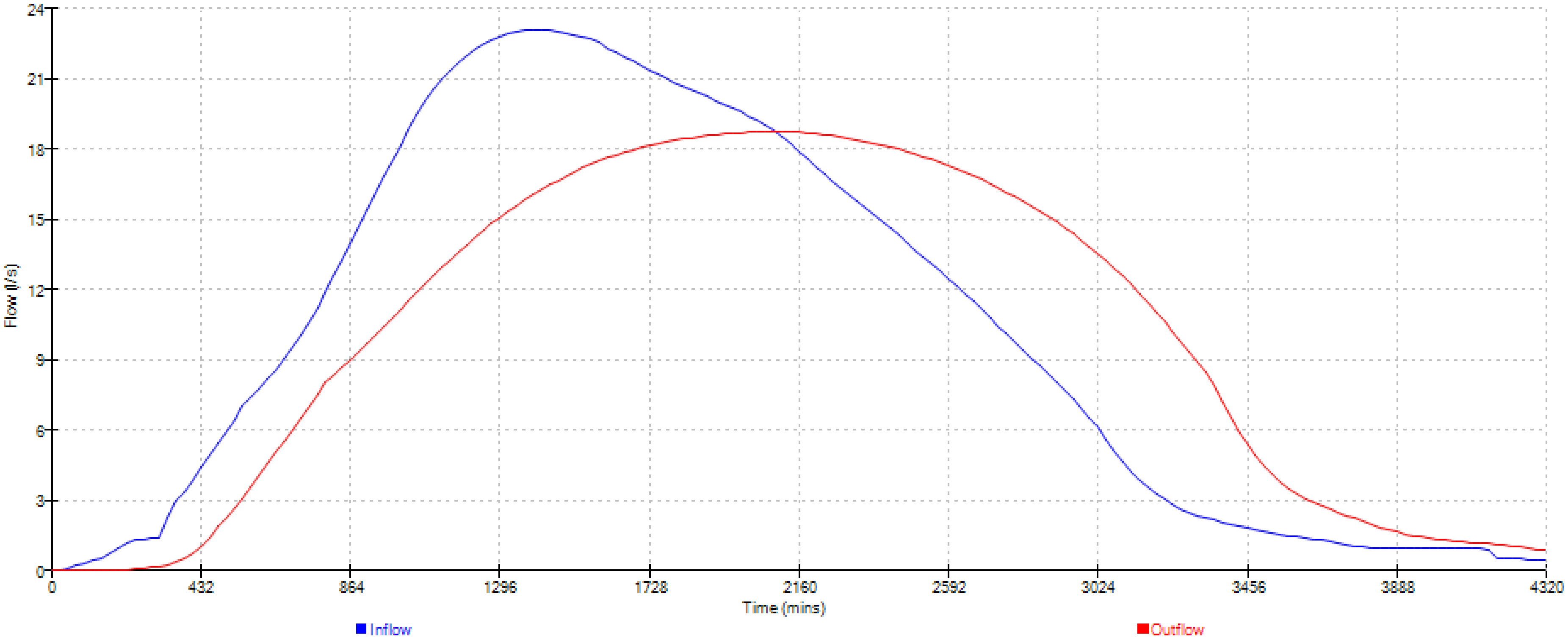

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XP Solutions	Network 2016.1.1	

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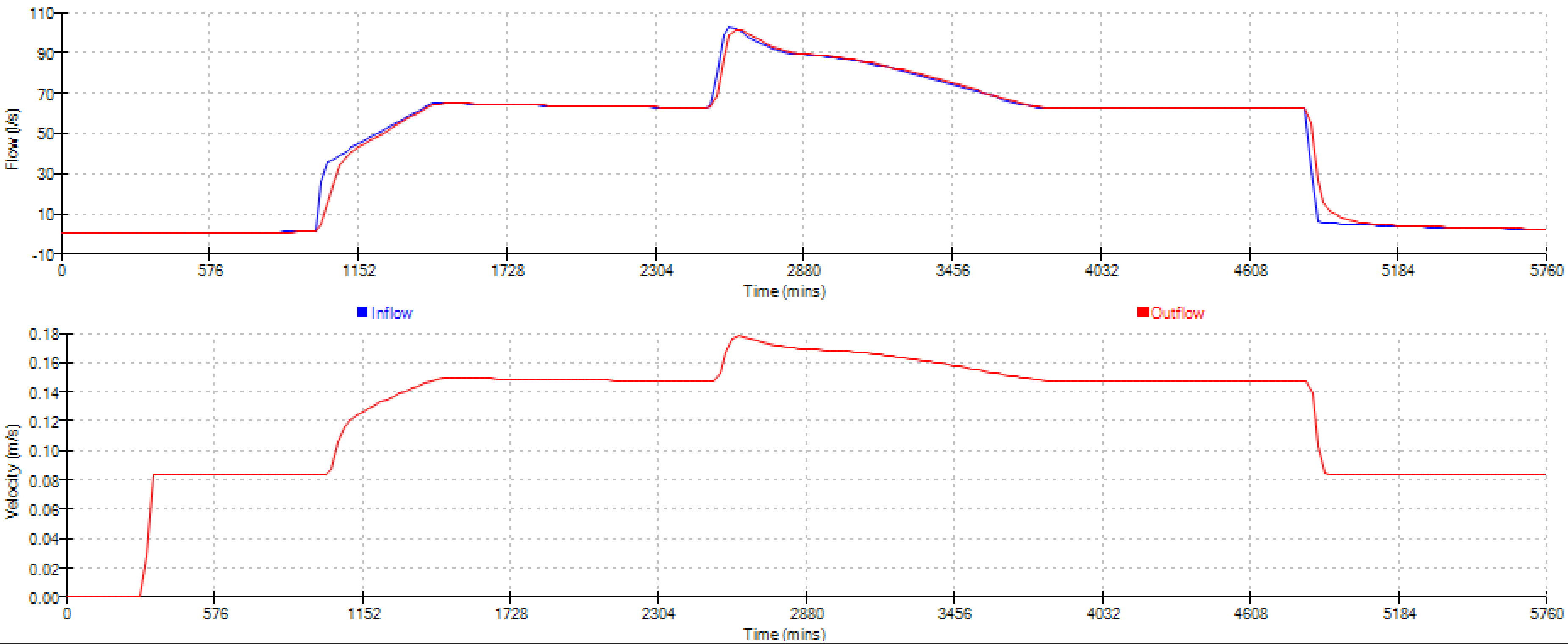

Ove Arup & Partners International Ltd		Page 1
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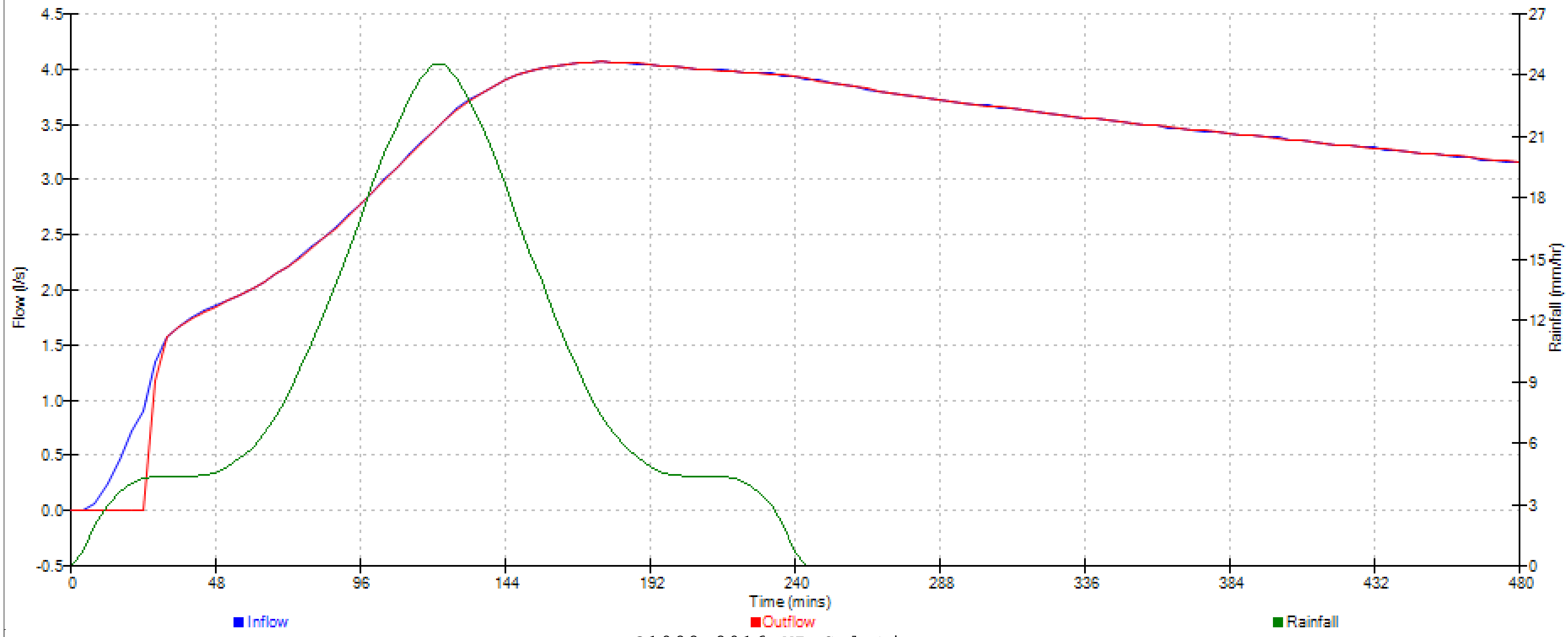

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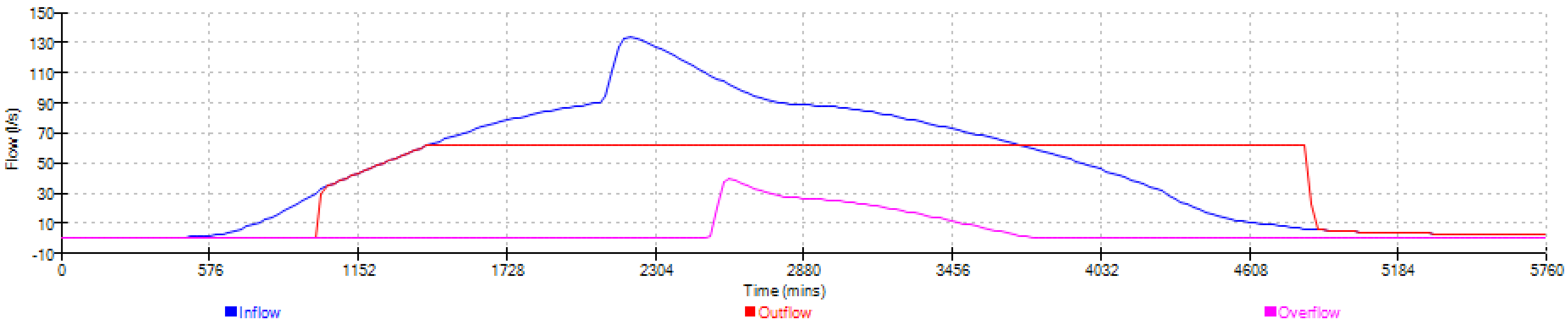

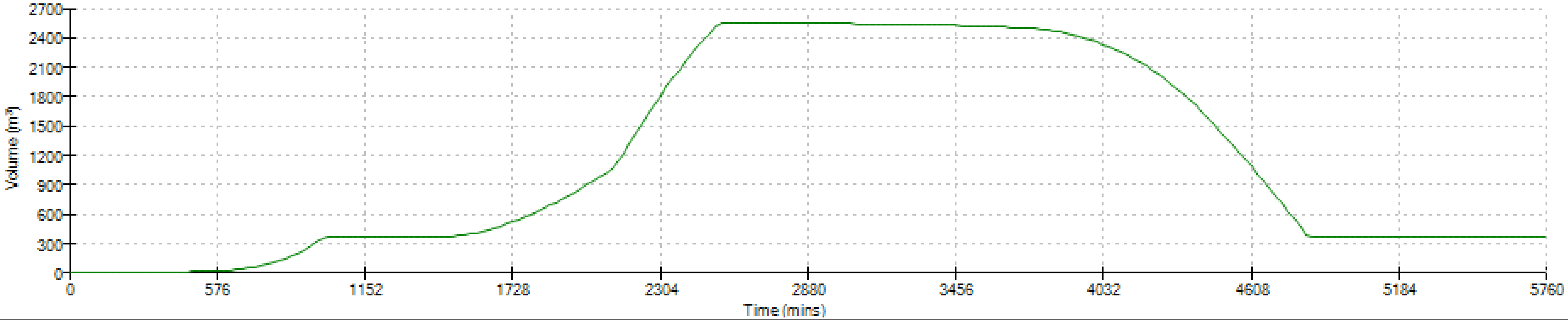

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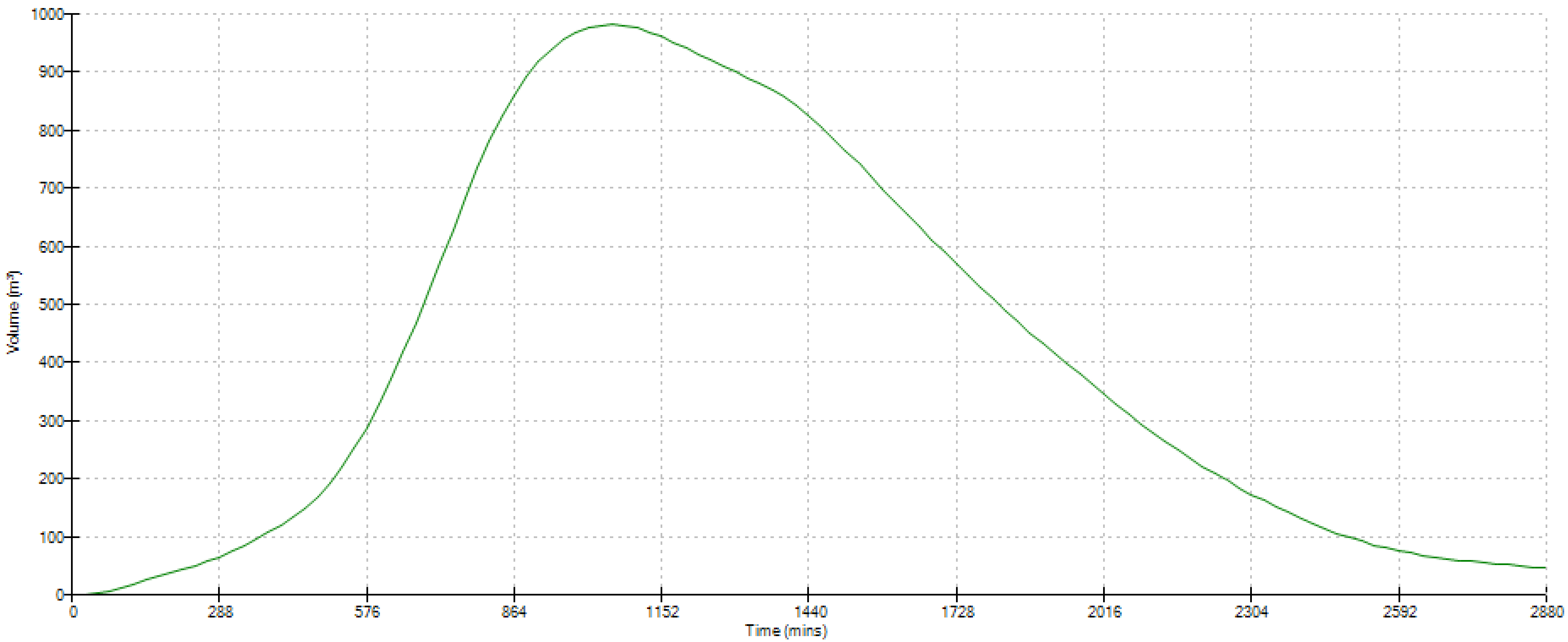
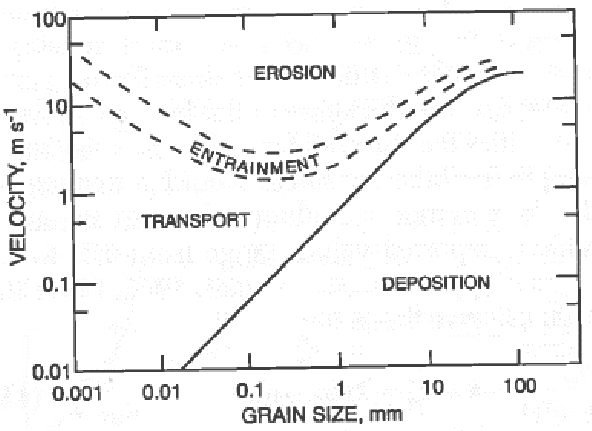


Appendix E

Outfall Velocity and Silt Removal Calculations

Determination of a maximum velocity to discharge surface water into Sneaton Thorpe Beck tributaries.

The textbook “Fluvial Forms and Processes, A New Perspective” contains a graph that gives some basic limiting velocities for sediment erosion and entrainment based on various grain sizes.



The graph shows that no grain sizes are entrained into the flow until velocities are greater than 1m/s.

Using Ordnance Survey maps, topographic surveys and contours produced from lidar, Sneaton Thorpe Beck tributaries have an average gradient of approximately 1 in 20.

The tributaries of Sneaton Thorpe Beck are small. The photograph below shows the typical size of the tributaries downstream from the site. The width of the tributaries have been estimated at approximately 1m wide.

Flow monitoring has been undertaken at a number of locations on Sneaton Thorpe Beck. The monitoring data gives typical depths of flow at three monitoring points on the beck over a 4 month period. During rainfall events the depths at these monitoring points increases to about 200mm. The depths of the water in the beck will be dependent on the geometry at any specific location, but the data offers a guide to allow us to undertake some calculations. If we consider that the depth data only covers a 4 month period, we would expect increased depths during higher return period rainfall events.

Using the above information a manning's calculation was undertaken to give an indication of typical velocities in the existing beck during rainfall events:

Manning's "n" has been estimated using (Chow, 1959):
3a. Mountain Streams, no vegetation in channel, banks usually steep, with trees and brush on banks submerged. Bottom: gravels cobbles and few boulders: normal n = 0.040

Slope: 1 in 20
Width of base = 1m
Depth of flow = varies

Manning's Equation

$$V = \frac{R^{2/3} S^{1/2}}{n}$$

V is average velocity (m/s)
R = hydraulic radius (m)
S = energy slope (m/m)
n = Manning's roughness coefficient

Depth of flow (mm)	Velocity (m/s)
100	1.07
200	1.53
300	1.83
400	2.05

This table gives indicative average velocities in the tributary of Sneaton Thorpe Beck downstream of the outfall during rainfall events.

The results suggest velocities ranging from about 1 m/s to 2m/s would be expected during rainfall events. Velocities nearer the upper end of this range would be expected for large storm events such as a 1 in 20year return period event.

In an email from the Environment Agency on the 18th February 2016 contained guidance notes with typical outfall structures that contained limits to the exit velocities. These were 1.2m/s for a typical outfall without a stilling basin and 1.8m/s for outfalls with a stilling basin.

Using the information above, a conservative maximum discharge velocity to set for the outfalls from the site is 1.2m/s for return periods up to the 1 in 20 year return period event.

Haxby Plantation Platform - Outfall

IL downstream the oil separator	202.748	mAOD
Outfall	201.14	mAOD
Discharge rate	5	l/s

Weir equation

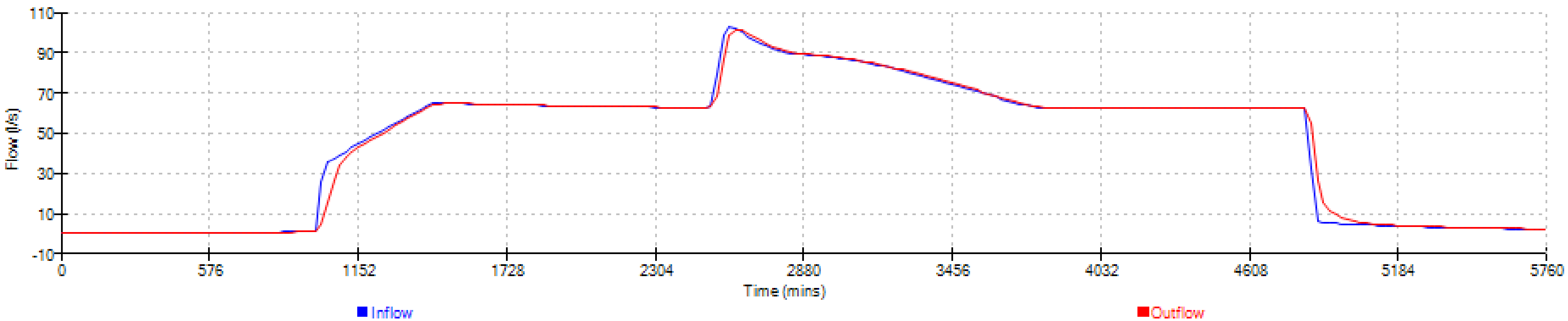
$$Q = C * B * H^{3/2}$$

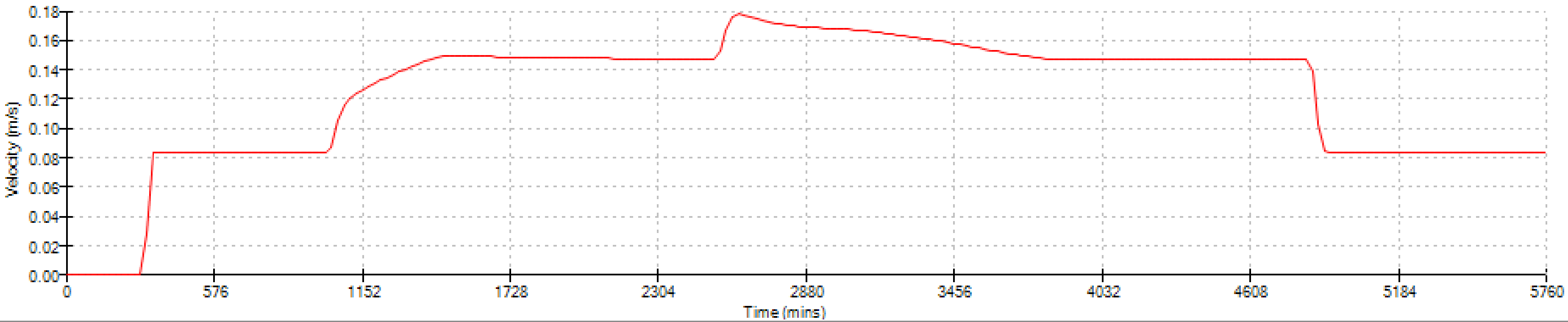
,where

$$C = \frac{2}{3} C_d \sqrt{2 * g} = \quad 1.7$$

Weir Width based on maximum headwall width	1.3	m
Water above the weir crest	0.018	m
Velocity	0.214	m/s

Graphs for Pipe PH3-N-1.040 US/MH PH3-N-1016 (Combined Networks)
2880 minute 20 year Winter I+0%
Status: FLOOD RISK*





The volume and the discharge rates of the silt removal facility, the ponds and the wetlands are based on the results from the WinDES Model:
Northern and Southern Combined.
Maximum utilised flow depth and volume during the critical storm for Pond A -
1 in 20 year Winter 960 minute storm - are used as the most conservative estimate.

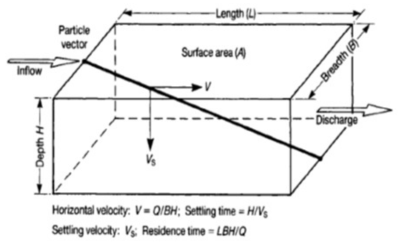


Figure 6.8 *Idealised settlement of discrete particles*

$$\eta = V_s t_R / d_1$$

"*Design of flood storage reservoirs" (CIRIA B14, 1993),*
Chapter 6.5, "estimating Pollutant Removal Efficiency "

Table 6.6 Settling velocities and particle size

Sediment grade	*Particle diameter d (mm)*	*Settling velocity* Sand, density 2650 kg/m³	V_s (mm/s) at 10°C Sewage solids, density 1200 kg/m³
Gravel	10.0	800.0	—
Coarse sand	1.0	200.0	30.0
Medium sand	0.5	70.0	17.0
Fine sand	0.2	22.0	5.0
Very fine sand	0.1	10.0	1.3
Coarse silt	0.06	6.7	0.3
Fine silt	0.01	0.18	0.08
Coarse clay	0.004	0.016	0.002
Fine clay	0.001	0.011	0.001

For soil particles: $V_s = 1/10\,[d/0.0314]^2$

Southern Pond

Volume of Pond	1050 m3		*Based on Geometry of the Pond*
Total Treatment Volume =	982 m3		*Based on 20min Winter 1440min design storm.*
Discharge Rate =	21.3 l/s		
Average Retention Time =	46103 s	12.8 h	
Depth Varies, max:	1.1 m		

Treatment Efficiency Rates

Fine Silt Particles
Settling Velocity Vs= 0.18 mm/s *From Table 6.6*
Removal efficiency is 754%
Therefore it is assumed that all silt and coarser particles will settle out.

Coarse Clay
Settling Velocity Vs= 0.016 mm/s
Removal efficiency is 67.1%
Therefore it is assumed that 67% of coarse clay particles will settle out.

Fine Clay
Settling Velocity Vs= 0.011 mm/s
Removal efficiency is 46.1%
Therefore it is assumed that 46% of the remaining fine clay particles will settle out.

Southern Wetland

Static Volume of Wetland	400 m3		*Based on Geometry of the Wetland*
Storm Stored Volume=	94 m3		*Based on critical design storm*
Total Treatment Volume =	494 m3		
Discharge Rate =	18.7 l/s		*Based on critical design storm*
Average Retention Time =	26417 s	7.3 h	
Depth Varies, approx:	0.5 m		*From the WinDes Model*

Treatment Efficiency Rates

Fine Silt Particles
Settling Velocity Vs= 0.18 mm/s *From Table 6.6*
Removal efficiency is 951%
Therefore it is assumed that all silt and coarser particles will settle out.

Coarse Clay
Settling Velocity Vs= 0.016 mm/s
Removal efficiency is 84.5%
Therefore it is assumed that 84% of the coarse clay particles will settle out.

Fine Clay
Settling Velocity Vs= 0.011 mm/s
Removal efficiency is 58.1%
Therefore it is assumed that 58% of the remaining suspended fine clay particles will settle out

ARUP	Job No. 253285	Sheet No.	Rev.
	Member/Location: Leeds		
Job Title: York Potash	Drg. Ref.		
Calculation: Combined Networks. Silt removal efficiency calculation	Made by: VS	Date: 01/08/2018	Chd.: NF

Silt removal facility

Volume of Silt removal facility=	350 m3	*Based on Geometry*
Total Treatment Volume =	383 m3	*Based on design storm*
Discharge Rate =	303 l/s	*Based on design storm*
Average Retention Time =	1264 s	0.4 h
Depth Varies, approx:	0.625 m	*From the WinDes Model*

Treatment Efficiency Rates

Coarse Silt Particles
Settling Velocity Vs= 6.7 mm/s *From Table 6.6*
Removal efficiency is 1355%
Therefore it is assumed that all the coarser particles will settle out.

Fine Silt Particles
Settling Velocity Vs= 0.18 mm/s *From Table 6.6*
Removal efficiency is 36%
Therefore it is assumed that 36% of fine silt particles will settle out.

Coarse Clay
Settling Velocity Vs= 0.016 mm/s
Removal efficiency is 3.2%
Therefore it is assumed that 3.2% of the coarse clay particles will settle out.

Fine Clay
Settling Velocity Vs= 0.011 mm/s
Removal efficiency is 2.2%
Therefore it is assumed that 2.2% of the fine clay particles will settle out.

Wetland C

Static Volume of Wetland A=	0 m3	*Based on Wetland Geometry*
Storm Stored Volume=	447 m3	*Based on design storm*
Total Treatment Volume =	447 m3	
Discharge Rate =	87 l/s	*Based on design storm*
Average Retention Time =	5138 s	1.4 h
Depth Varies, approx:	1.5 m	*From the WinDes Model*

Treatment Efficiency Rates

Fine Silt Particles
Settling Velocity Vs= 0.18 mm/s *From Table 6.6*
Removal efficiency is 62%
Therefore it is assumed that 62% of the fine silt particles will settle out.

Coarse Clay
Settling Velocity Vs= 0.016 mm/s
Removal efficiency is 5.5%
Therefore it is assumed that 5.5% of the coarse clay particles will settle out.

Fine Clay
Settling Velocity Vs= 0.011 mm/s
Removal efficiency is 3.8%
Therefore it is assumed that 3.8% of the fine clay particles will settle out.

Pond A

Volume of Pond A	3754 m3	*Based on Pond Geometry*
Total Treatment Volume =	3754 m3	*Based on design storm*
Discharge Rate =	153 l/s	*Q From WinDes Model*
Average Retention Time =	24536 s	6.8 h
Depth Varies, approx:	1.51 m	

Treatment Efficiency Rates

Fine Silt Particles
Settling Velocity Vs= 0.18 mm/s *From Table 6.6*
Removal efficiency is 292%
Therefore it is assumed that all silt and coarser particles will settle out.

Coarse Clay
Settling Velocity Vs= 0.016 mm/s
Removal efficiency is 26.0%
Therefore it is assumed that 26% of the suspended coarse clay particles will settle out.

Fine Clay
Settling Velocity Vs= 0.011 mm/s
Removal efficiency is 17.9%
Therefore it is assumed that 18% of the remaining suspended fine clay particles will settle out.

Pond B

Volume of pond	3700 m3	*Based on Pond Geometry*	
Total Treatment Volume =	3700 m3	*Based on design storm*	
Discharge Rate =	90.5 l/s	*Q From WinDes Model*	
Average Retention Time =	40884 s	11.4 h	681.4
Depth Varies, approx:	1.6 m	*Maximum from the WinDes Model*	

Treatment Efficiency Rates

Fine Silt Particles
Settling Velocity Vs= 0.18 mm/s *From Table 6.6*
Removal efficiency is 460%
Therefore it is assumed that all silt and coarser particles will settle out.

Coarse Clay
Settling Velocity Vs= 0.016 mm/s
Removal efficiency is 40.9%
Therefore it is assumed that 41% of the suspended coarse clay particles will settle out.

Fine Clay
Settling Velocity Vs= 0.011 mm/s
Removal efficiency is 28.1%
Therefore it is assumed that 28% of the remaining suspended fine clay particles will settle out.

ARUP

Job No.	Sheet No.	Rev.
253285		
Member/Location	Leeds	
Drg. Ref.		

Job Title	York Potash
Calculation	Combined Networks. Silt removal efficiency calculation

Made by VS | Date 01/08/2018 | Chd. NF

Pond C

Volume of Pond C =	2559 m3		*Based on Pond Geometry*
Total Treatment Volume =	2559 m3		*Based on design storm*
Discharge Rate =	62.5 l/s		*Q From WinDes Model*
Average Retention Time =	40944 s	11.4 h	
Depth Varies, approx:	1.53 m		*From the WinDes Model*

Treatment Efficiency Rates

Fine Silt Particles
Settling Velocity Vs= 0.18 mm/s *From Table 6.6*
Removal efficiency is 482%
Therefore it is assumed that all silt and coarser particles will settle out.

Coarse Clay
Settling Velocity Vs= 0.016 mm/s
Removal efficiency is 42.8%
Therefore it is assumed that 43% of the suspended coarse clay particles will settle out.

Fine Clay
Settling Velocity Vs= 0.011 mm/s
Removal efficiency is 29.4%
Therefore it is assumed that 29% of the remaining suspended fine clay particles will settle out.

Wetland A

Static Volume of Wetland	676 m3		*Based on Wetland Geometry*
Storm Stored Volume=	165 m3		*Based on design storm*
Total Treatment Volume =	841 m3		
Discharge Rate =	101 l/s		*Q From WinDes Model*
Average Retention Time =	8327 s	2.3 h	
Depth Varies, approx:	0.7 m		*From the WinDes Model*

Treatment Efficiency Rates

Fine Silt Particles
Settling Velocity Vs= 0.18 mm/s *From Table 6.6*
Removal efficiency is 214%
Therefore it is assumed that all silt and coarser particles will settle out.

Coarse Clay
Settling Velocity Vs= 0.016 mm/s
Removal efficiency is 19.0%
Therefore it is assumed that 19% of the suspended coarse clay particles will settle out.

Fine Clay
Settling Velocity Vs= 0.011 mm/s
Removal efficiency is 13.1%
Therefore it is assumed that 13% of the remaining suspended fine clay particles will settle out.

Particle Size	Typical Settling velocities (mm/s)	% Removal in Southern Pond	% Removal in Southern Wetland	% Removal in Silt removal facility	% Removal in Wetland C	% Removal in Pond A	% Removal in Pond B	% Removal in Pond C	% Removal in Wetland A	Total % Efficiency
Course Sand	200	100%		100%	100%					100%
Fine Sand	22	100%		100%	100%					100%
Coarse Silt	6.7	100%		100%	100%					100%
Fine Silt	0.18	100%	100%	36%	62%	100%				100%
Coarse Clay	0.016	67%	85%	3%	5%	26%	41%	43%	19%	77%
Fine Clay	0.011	46%	58%	2%	4%	18%	28%	29%	13%	61%

Particle Size	Overall Removal
Sand	100%
Silt	100%
Clay	69%

Excluding any removal benefits from Silt Fences and Check Dams