REPORT

Validation Report for Sediment Dredging and Placement in Containment Sites

Kopeopeo Canal Remediation Project

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Executive Summary

Kopeopeo Canal is located northwest of the township of Whakatane, in the Bay of Plenty Region of New Zealand. The Kopeopeo Canal was constructed to convey drainage and floodwaters from low lying farmlands in the Rangitaiki Plains into the Whakatane Estuary.

Between 1950 and 1989, the canal received discharges of surface run-off and stormwater from the NZ Forests Products Limited sawmill. These discharges contained timber treatment chemicals, including technical grade pentachlorophenol (PCP). PCP imported into New Zealand for use in the timber processing industry during this period had a small percentage of impurities including dioxins and furans.

Historical discharges into the canal from the timber treatment industry have led to contamination of the canal sediments with dioxins. Bay of Plenty Regional Council (BoPRC) has undertaken a programme of remedial works to remove dioxin contaminated sediment along a 5.1 km stretch of the canal, between State Highway 30 (at the intersection with Kope Drain Road) and the confluence with the Orini Stream. The primary driver for the remediation works was to address unacceptable risks to human health, primarily via the consumption of dioxin contaminated eel tissue harvested from the canal, associated with the presence of dioxins within Kopeopeo Canal.

The remedial project comprised the dredging of dioxin contaminated sediments from the canal and containment of dredged sediment in Geotube® bags at two purpose-built containment sites (CS1 and CS3). The containment sites provide for long-term containment and bioremediation of the dredged sediment.

Sediment volumes removed from the canal have been calculated from hydrographic surveys of the canal and geo-processing of images captured from drone flight images undertaken pre- and post-filling of the Geotube® bags and oversize bags. Based on the processed data, a total of 35,707 m^3 of sediment was dredged and placed into the Geotube® bags. This comprises 25,707 m^3 of sediment at CS1 and 10,000 m^3 at CS3. Analysis of the pre- and post-hydrographic survey data yielded a dredged sediment volume of 34,465 $m^{3.}$

In addition to the sediment contained within the Geotube® bags, the dredging also removed an additional 1,608 m^3 of oversize material stored separately to the Geotube® bags. This comprised approximately 1,018 m^3 at CS1 and 590 m^3 at CS3.

Sediment validation samples collected from residual in-situ canal sediments provided the primary measure of assessing compliance with the remedial criteria. Following clarification from the Consent Authority in May 2019, the remedial validation criteria was defined as being where the 95 % Upper Confidence Limit (UCL_{95}) for dioxin concentration was at or below 60 pg/g I- TEQ and and no individual concentration exceeded 120 pg/g I-TEQ.

The overall UCL_{95} for sediment dioxin was calculated based on a total of 213 samples representative of residual sediment quality and suitable for calculating the UCL_{95}. Concentrations in the samples used to calculate the UCL_{95} ranged between 20 pg/g I-TEQ and 160 pg/g I-TEQ with a mean concentration of 37 pg/g I-TEQ. The calculated UCL_{95} for the data set is **39 pg/g I-TEQ**.

Overall, the validation undertaken during the project has documented that the Kopeopeo Canal remedial area has been successfully remediated to a standard that satisfies the remedial criteria. Specifically, sediment dioxin concentrations in the residual canal base sediments post-dredging have a UCL_{95} of 39 pg/g I-TEQ and with the exception of one sample (KC084e2 collected from the upstream side of the wastewater pipeline at Chainage 2800), sediment dioxin concentrations were below 120 pg/g I-TEQ. Based on further assessment of residual sediment conditions in the area of this exceedance, and in consultation with the Independent Monitor, it is considered that the area was remediated to the extent practicable.

In addition to the sediment validation, monitoring was undertaken at CS1 and CS3 in accordance with the Consent to assess potential impacts from the placement and storage of the dioxin contaminated sediment within the containment sites. Monitoring of the containment sites up to the completion of the sediment placement work did not record exceedances of the triggers specified in the Consent. On this basis it is considered that placement of the sediment in the containment cells has not impacted the receiving environment around CS1 and CS3 during and up to completion of the sediment dredging and containment phase of the remedial project.

The sediment removal and containment, and associated validation of residual canal base sediments, represent one element of the overall approach to achieving the human heath objectives for the Project. Further work as part of the Kopeopeo Canal Remediation Project includes:

- Containment of sediment provided for the sediment to be inoculated to facilitate bioremediation within the Geotube® bags as part of the next phase of the project. Given the anticipated timeframe (up to 15 years) for the bioremediation (Anderson and Kelly 2012), ongoing management and monitoring is required.
- A primary driver for the remediation works was to mitigate risks to human health via the consumption of dioxin contaminated eels harvested from Kopeopeo Canal. The Consent requires ongoing monitoring of eels to evaluate exposure and uptake of residual sediment dioxin concentrations within the eel population once it re-establishes within Kopeopeo Canal.

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1.0 INTRODUCTION

1.1 Purpose

Kopeopeo Canal is located northwest of the township of Whakatane, in the Bay of Plenty Region of New Zealand. The Kopeopeo Canal was constructed to convey drainage and floodwaters from low lying farmlands in the Rangitaiki Plains into the Whakatane Estuary.

Between 1950 and 1989, the canal received discharges of surface run-off and stormwater from the NZ Forest Products Limited sawmill. These discharges contained timber treatment chemicals, including technical grade pentachlorophenol (PCP). PCP imported into New Zealand for use in the timber processing industry during this period had a small percentage of impurities including dioxins and furans.

Historical discharges into the canal from the timber treatment industry have led to contamination of the sediments with dioxins (Bay of Plenty Regional Council (BoPRC) 2005a, 2005b; Sinclair Knight Merz (SKM) 2006; Tonkin & Taylor Limited (T&T) 2015). The main findings of these investigations indicated that a 5.1 km stretch of the canal, between State Highway (SH) 30 (at the intersection with Kope Drain Road) and the confluence with the Orini Stream required remediation.

The primary driver for the remediation works was to address unacceptable risks to human health, primarily through the consumption of eel harvested from Kopeopeo Canal, associated with the presence of dioxins within Kopeopeo Canal. In addition to mitigating risks to human health, the remediation works were identified to be required to facilitate maintenance dredging of Kopeopeo Canal in order for it to continue to function as part of the Rangitaiki Drainage Scheme.

In 2014, BoPRC (as the Consent Authority) issued resource consent (Consent Number: 67173; the Consent) to BoPRC (as the Principal) granting approval to remove contaminated sediment from the Kopeopeo Canal, and transport the sediment to up to three separate sites to be stored within containment cells and remediated using bioremediation techniques.

Golder Associates (NZ) Limited (Golder) has prepared this Validation Report (SVR) to satisfy conditions 25.3 and 47.5 of the Consent. Specifically, this report has been prepared to document:

- The sediment removal works undertaken, the sediment validation sampling and associated results of the sediment validation samples, and to confirm that the remediation target has been met.
- The environmental monitoring of soil, sediment and groundwater quality at the two containment sites prior to and post-placement of sediment.

This report has been prepared in accordance with the requirements of a Site Validation Report, where relevant and applicable, as outlined in the Ministry for the Environment's (MfE 2011a) Contaminated Land Management Guideline No. 1: Reporting on Contaminated Sites in New Zealand.

Golder has prepared this report on behalf of Enviro (NZ) Limited (Enviro NZ) who was engaged by the Principal as the Remedial Contractor.

1.2 Report Structure

This report has been organised into the following sections:

- Section 2.0 provides an overview of the Kopeopeo Canal Remediation Project including an outline of the Consent conditions relevant to the remedial works and this report, and the remedial criteria.
- Section 3.0 provides an overview of the sediment remediation methodology.

- Section 4.0 summarises the sediment dredging and containment.
- Section 5.0 documents the sediment validation methodology including the results of the sediment validation sampling.
- Section 6.0 outlines the quality assurance and quality control implemented during the sediment validation.
- Section 7.0 summarises the monitoring of soil, sediment and groundwater pre- and post-sediment placement at Containment Site 1.
- Section 8.0 summarises the monitoring of soil, sediment and groundwater pre- and post-sediment placement at Containment Site 3.
- Section 9.0 presents a revised Conceptual Site Model (CSM) for Kopeopeo Canal following completion of the sediment dredging and containment phase of the Kopeopeo Canal Remediation Project.
- Section 10.0 provides a summary of the sediment dredging and containment works and the key outcomes of this work with respect to achieving the remedial objectives.

2.0 KOPEOPEO CANAL REMEDIATION PROJECT

2.1 Site Description

The Kopeopeo Canal is approximately 12.5 km long and is part of the Rangitaiki Plains drainage system (Figure 1). The canal runs across the northern portion of the plains between a tributary of the Rangitaiki River in the west to the confluence of the Orini Stream and the Whakatane River in the east. The canal is predominantly surrounded by agricultural land, with an area of commercial/industrial land (Gateway Industrial Estate) on the southern side of the canal. Residential properties are scattered along the edge of the canal with an increase in density at the eastern end of the canal nearer Whakatane. Whakatane Growers has a large glass house operation growing vegetables and melons on Paroa Road adjacent to the canal.

The section of the canal subject to remedial works is a 5.1 km section of the canal between SH30 (at the intersection with Kope Drain Road) the confluence with the Orini Stream (Figure 1). The section of Kopeopeo Canal subject to the remedial works comprises a formed channel approximately 20 m wide.

In addition to the Kopeopeo Canal remediation area, the remediation project also comprised two containment sites identified as CS1 and CS3.

Containment Site 1 (CS1) is located at the western end of the remediation area at the intersection of Kope Drain Road and SH30. The property is identified as 1 Kope Drain Road and is legally described as Section 1 SO 487058.

Containment Site 3 (CS3) is located on a narrow peninsula of land lying between Kopeopeo Canal and the Whakatane River at the eastern end of the remediation area (Figure 1). CS3 is located on land identified as 44 Keepa Road, Whakatane which is legally described as Allot 216 Rangitaiki Parish. CS3 is a long rectangular shape bounded by the Whakatane River stop bank to the east and the Kopeopeo Canal to the west. The containment site is bisected by a small canal connecting the Kopeopeo Canal to the Whakatane River via a pump station. The majority (~90 %) of CS3 is located to the northeast of the pump station canal with a small area of CS3 (~10 %) located to the southwest.

2.2 Background

Work to investigate the presence and extent of contamination in the Kopeopeo Canal and its surroundings was undertaken between 2004 and 2015 (BoPRC 2005a, 2005b; SKM 2006a; T&T 2015). The source of the contamination has been linked to historical stormwater discharges (via an outfall at Chainage 2975 (Figure 1)) from the local timber treatment plant which formerly used dioxin contaminated PCP for timber treatment.

The main findings of the previous investigations are summarised below:

- Sediment sampling in November 2005 documented dioxin concentrations ranging between 12 pg/g WHO-TEQ and 2,300 pg/g WHO-TEQ with the most elevated concentrations found close by to the stormwater outfall (BoPRC 2005b). Samples of eel flesh were also taken at four sites with concentrations ranging between 0.11 pg/g WHO-TEQ and 3.56 pg/g WHO-TEQ. These concentrations also reduced with distance from the outfall.
- Concentrations of dioxins within sediments in the remediation area ranged between 0.17 pg/g I-TEQ and 1,950 pg/g I-TEQ (SKM 2006a). Eel tissue concentrations ranged between 0.016 pg/g I-TEQ and 0.344 pg/g I-TEQ with higher concentrations generally detected in the eastern reaches of the canal.

LEGEND

- Containment sites
- Kopeopeo Canal remediation area
- Stormwater outfall from mill to Kopeopeo Canal

NOTES

1. Aerial: LINZ and Eagle Technology, CC-BY-3.0-NZ.
2. Map image: Sourced from the LINZ Data Service and licensed for re-use under the Creative Commons Attribution 4.0 New Zealand licence
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3. Schematic only, not to be interpreted as an engineering design or construction drawing.

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METRES

REFERENCE SCALE: 1:13,000 (at A3)

PROJECTION: NZGD 2000 New Zealand Transverse Mercator

CLIENT	ENVIRO (NZ) LIMITED		
PROJECT	KOPEOPEO CANAL REMDIATION		
TITLE	**SITE LOCATION**		
CONSULTANT	GOLDER	YYYY-MM-DD	2019-12-05
		PREPARED	AE
		REVIEW	AH
		APPROVED	AH
PROJECT NO. 1894562	REPORT 005	REV. 0	FIGURE **01**

- Risk assessments completed based on the investigation work identified that a sediment dioxin concentration of 60 pg/g I-TEQ would be protective of human health with respect to the dermal contact and eel ingestion pathways (SKM 2006b; ESR 2006).
- Based on the findings of the risk assessment work, a 5.1 km stretch of the Kopeopeo Canal was identified as contaminated with concentrations of dioxin exceeding 60 pg I-TEQ/g.
- Various estimates of the volume of contaminated sediment have been made during the project based on the information available at the time of the estimates. Accounting for the differing methods used to calculate the sediment volumes and the associated assumptions, estimates of dioxin contaminated sediments ranged between 30,236 m^3 (T&T 2016), 33,000 m^3 (based on topographical surveys for BoPRC in October 2010 (Golder 2011) and 41,250 m^3 (Discovery Marine Limited (DML) 2016).

2.3 Consent Conditions

The Consent includes a suite of conditions in relation to the various work elements required to be undertaken as part of the remediation programme. The key conditions in relation to the sediment remediation and validation are summarised in Table 1.

Table 1: Summary of consent conditions relevant to sediment remediation and validation.

Condition	Description
19.1	The extraction of sediment from the Kopeopeo Canal shall be undertaken in general accordance with the methods in the variation application and the Dredging Management Plan referred to in conditions 3.1 and 4.6 of this consent.
20.1	The sediment extracted from the Kopeopeo Canal shall be transported and deposited at the containment sites in general accordance with the variation application and the Dredging Management Plan required by conditions 3.1 and 4.6 of this consent.
25.1	Immediately upon the completion of the extraction of sediments from the remediation zone within the Kopeopeo Canal, sampling shall be undertaken to confirm that the remediation target for the canal has been achieved. The sampling shall be undertaken in accordance with the parameters and methods detailed in the Environmental Monitoring and Validation Plan referred to in condition 4.5 of this consent.
25.2	The analysis of 1 in 20 sediment samples taken in accordance with condition 25.1 shall be split and analysed at two different laboratories for the purposes of quality assurance.
25.3	The Consent Holder shall provide a report to the Chief Executive of the BoPRC within 30 days of the sampling referred to in condition 25.1 of this consent, which shall provide details on the results of the sampling undertaken, and a description of the extraction and deposition of sediment carried out.
25.4	The remediation zone within the Kopeopeo Canal shall be deemed as being remediated when the 95 % Upper Confidence Limit ('UCL') for dioxin concentration is determined to be at or below 60 pg I- TEQ-g using the validation methodology set out in the Environmental Monitoring and Validation Plan required by condition 4.5.

Condition	Description
25.5	The control structures shall remain in the Kopeopeo Canal until the Consent Holder provides documentation to the Chief Executive of the BoPRC demonstrating that the remediation target has been achieved within the remediation zone in the canal.
25.10	The Consent Holder shall confirm the volumes of sediment removed from the canal by preparing and submitting to the Chief Executives of the BoPRC and WDC within 6 months of completing works within the Kopeopeo Canal, cross-section drawings based on surveys undertaken prior to and following the excavation of sediments.
47.2	All soil and sediment sampling shall be carried out in accordance with 'Contaminated Land Management Guidelines No.5 – Site Investigation and Analysis of Soils' Ministry for the Environment, February 2004, Revised 2011, or its successor, including the use of split samples to be analysed by a secondary laboratory at a rate of 1 in 20 samples.
47.5	Within 60 working days of the completion of the extraction of sediment from the canal, the Consent Holder shall submit a final Validation Report confirming that the remediation target has been met within the Kopeopeo Canal (i.e., a dioxin concentration no greater than 60 pg I-TEQ-g). The Validation Report shall be prepared in accordance with the MfE Contaminated Land Management Guidelines No. 1: Reporting on Contaminated sites in New Zealand 2011 guideline referred to in condition 47.1 of this consent.

2.4 Remedial Criteria

The sediment validation methodology comprised a multiple lines of evidence approach to evaluate that the sediment remediation objectives were achieved. The validation methodology comprised the following to assess the volume of sediment dredged from the canal and document the quality of residual sediment within the canal:

- Hydrographic surveys of the canal. Surveys were undertaken pre- and post-completion of the remedial dredging works to estimate the volume of sediment removed and the final bed profile.
- Visual inspections of the composition of the residual in-situ sediment following completion of the dredging.
- Sediment validation sampling to document in-situ dioxin sediment concentrations following completion of the dredging.

Condition 25.4 of the Consent specifies a sediment dioxin remedial criterion for the Kopeopeo Canal Remediation Project. As per condition 25.4, the remediation zone within the Kopeopeo Canal shall be deemed as being remediated when the 95 % Upper Confidence Limit (UCL_{95}) for dioxin concentration is determined to be at or below 60 pg/g I- TEQ (as Total PCDD/F Upperbound) using the validation methodology set out in the Environmental Monitoring and Validation Plan (EMVP) (Golder 2017a).

In May 2019, the Consent Authority[1] provided clarification regarding interpretation and use of the UCL_{95}. The clarification referred to the application of a UCL_{95} as outlined in MfE (2011b) guidance in that "*the result will be acceptable if the 95% upper confidence limit is at or below the guideline, provided no result is more than twice the guideline value*".

[1] Email from BoPRC (Emma Joss) to BoPRC (Brendon Love) titled Consent 67173 clarifications from Consent Authority dated 1 May 2019.

Based on this clarification, the sediment dioxin validation criterion was interpreted as being where the sediment dioxin concentration UCL_{95} is at or below 60 pg/g I-TEQ and no individual concentration exceeded 120 pg/g I-TEQ.

The Consent also specifies criteria for other elements of the project including ongoing eel monitoring to assess uptake by eels of residual dioxins in sediment following repopulation of Kopeopeo Canal (condition 25.6) and bioremediation of the dioxin contaminated sediments within the containment sites (condition 24.1). These works are to be completed following completion of the sediment dredging and containment phase of the project and hence are not addressed in this report.

3.0 SEDIMENT REMEDIATION METHODOLOGY

BoPRC considered several options for the remediation and/or risk management of sediment contamination in the canal. A successful pilot remediation trial was undertaken in November/December 2015 (EnviroWaste 2015). The selected remedial approach involved the removal of contaminated sediments via dredging, and pumping the resultant slurry to designated containment sites for storage in Geotube© bags. Following dewatering, the sediment may be bioremediated over a period of up to 15 years.

Enviro NZ was engaged as the Remedial Contractor and was responsible for the dredging programme, construction of the containment sites, the transfer of the dredged sediment to the containment sites for storage in the Geotube© bags and closure of the containment sites at the completion of the remedial dredging works. NZ Pump and Generators (NZPGS) was engaged by Enviro NZ as the dredging contractor.

The dredging works were undertaken in line with the methodology presented in the Dredging Management Plan (DMP) (Golder 2017b) as required under condition 19 of the Consent. The following provides a summary of the dredging and containment methodology.

Dredging was primarily undertaken from a floating pontoon using a 12-tonne excavator. The excavator was fitted with a cutter suction head and Dragflow® sludge pump mounted to the dipper arm. The dredge head was fitted with Trimble GCS Flex Dredge Monitoring equipment. Dredging was also undertaken using a smaller Truxor® amphibious dredge and Sandbug dredge where access limited the use of the primary dredge unit.

Dredging was undertaken to an agreed survey level (-0.2 m reduced level (m RL) based on the Moturiki Vertical Datum (MVD)) and by feel controlled by the presence of marine sediments and clays which are more compact compared to the sediment targeted for remediation. Guide rails on the base of the cutter head restricted the dredge to penetrate the canal base material and held the dredge at an optimal distance above the canal base to allow for soft sediment extraction only. Areas where the dredging survey profile was not achieved, or the presence of other material in the canal restricted the dredging, these were noted and agreed with the Principal as exceptions. A copy of the exceptions log is provided in Appendix A.

Sediment removed from the canal was transferred to the containment sites via a high-density polyethylene (HDPE) pipeline. The HDPE pipeline was established on the canal flood-bank or within the canal where practical. The pipeline comprised 200 mm diameter HDPE pipe fusion welded to create longer sections as required.

Prior to first use, the HDPE feedline was hydrotested for leaks. During dredging, the section of feedline in use was subject to twice daily inspections – morning and afternoon. Inspections were undertaken to verify that flanged joints remained securely bolted and leak free, and that fusion welded joins were leak free.

The dredge equipment included a floating/flexible hose from the Dragflow® pump on the barge back to the shore where it connected to the HDPE slurry transfer line. The equipment allowed for the removal of 200 to 300 m^3 per hour (m^3/hr) of slurry at a solids concentration of between 3 and 6 %.

The slurry was pumped through the HDPE pipeline directly to the screening/agitated balance tank located at each containment site.

The containment sites were purpose built for the project and were designed for long-term (15 year) containment of the dredged sediment within the Geotube® bags. Construction of the containment sites comprised bulk earthworks to remove unsuitable material (natural soils at CS1 and fill material at CS3) followed by placement and compaction of 'rotten rock' gravel platform as outlined in the geotechnical design reports (Golder 2017c, 2018). Bidim was placed across the surface of each containment site prior to placement of the HDPE (CS1) and linear low-density polyethylene (LLDPE) (CS3) liners. As-built plans for each containment site are included in Appendix B.

At the containment sites, the slurry was passed over screening equipment which removed debris greater than 4 mm in size. Screening of slurry was undertaken within the water treatment plant at the containment sites. The screening was undertaken to provide the following:

- Monitoring of the slurry for presence of kōiwi and taonga.
- Elimination of the risk of large objects damaging instrumentation in the pipework.
- Allowing for the correct amount of flocculant to be added (large solids will tend to create overdose).
- Minimising the risk of sharp objects damaging the Geotube® bags.

Oversized screened material was placed into 1 m^3 polypropylene bags from a chute under the screens. Full bags of screenings were transferred and stored into a dedicated area of each HDPE lined containment cell.

The screened slurry was then dosed with flocculant (Orica Crystalfloc B400 series), along with the addition of wood pellets and lime and the treated slurry transferred by pump into Geotube® bags. Geotube® technology involves permeable containment of sediment waste using specially engineered textiles. The textiles allow the passage of water while retaining solids.

Water within the containment cells originated from two sources:

- Rainwater which has fallen within the catchment of the containment cell.
- Filtrate, liquids present as a result of the dewatering of the sediment filled Geotube® bags.

Rainwater present within the containment cells prior to the placement of sediment within the Geotube® bags was discharged directly to the canal.

After the first placement of sediment within a containment site, filtrate from within the Geotube® bags was collected at drainage points (sumps) within the containment sites from where it was discharged back into the canal via gravity.

4.0 SEDIMENT DREDGING AND CONTAINMENT

4.1 Methodology

The remedial dredging was undertaken in two primary stages based on which containment site sediment was transferred to. Within each stage, the canal was divided into sections based on the presence of structures (bridges and pipes) crossing the canal.

The 2.8 km length of canal between SH30 and the wastewater treatment pipeline across the canal at Chainage 2800 was divided in five sections (Section 1 to Section 5) (Table 2). Sediment dredged from this section of the canal was transferred to CS1. The remaining 2.3 km length of Kopeopeo Canal between the wastewater pipeline at Chainage 2800 and the end of the canal at the confluence with Orini Canal at Chainage 5100 was divided into two sections (Section 6 and Section 7). Sediment dredged from this section of the canal was transferred to CS3.

Table 2: Remedial dredging sections.

Containment site	Canal section	Chainage (m)
CS1	1	0-268
	2	270-660
	3	660-1,184
	4	1,184-1,872
	5	1,910-2,820
CS3	6	2,820-3,980
	7	3,980-5,100

Prior to commencement of dredging activities, control structures were constructed at the upstream and downstream ends of the remediation area to control water levels and flows, and contain water disturbed by dredging. The control structures comprised small dams with a 900 mm internal diameter steel pipe through the dam to enable flow control. The dams also included an auxiliary spill way to enable the release of high flows during flood events (T&T 2017). The control structures remained in place for the duration of the remediation works and were removed in August 2019.

4.2 Sediment Disposed to CS1 – Sections 1 to 5

Sections 1 to 5 of Kopeopeo Canal comprised the canal between SH30 at the western upstream end of the remediation area and the wastewater pipeline across the canal at Chainage 2800. Kopeopeo Canal within these sections generally comprises a regular landform approximately 20 m wide with the canal banks typically 1 m above the canal water level. The canal drains in an east-southeast direction between the SH30 bridge and Chainage 950 where it turns and flows in a northeasterly direction up to Chainage 1900. The canal then drains in an easterly direction adjacent to SH30 up to the Keepa Road bridge at Chainage 3980.

Dredging within Sections 1 to 5 was undertaken along the dredge corridor which generally comprised a 10 m width either side of the central alignment of the canal. Dredging occurred within the dredge corridor to the agreed survey level (-0.2 m RL in terms of MVD). Dredging works are also undertaken in the area of the western containment structure adjacent to the SH30 at Chainage 0 (validation sample KC001 was collected from the area beneath the western control structure). Dredging within Sections 1 to 5 was constrained by the following:

- The bridge abutments at the Paroa Road bridge at Chainage 1200.
- The bridge abutments of the SH30 bridge at Chainage 1870 to 1880.

Sediment transferred to CS1 was stored in 26 of the 30 Geotube® bags available for storage at CS1. Sediment volumes transferred and stored within CS1 have been estimated based on geo-processing of images captured from drone flights undertaken by Eastern Bay Aerial Imaging on 7 January 2019 (Appendix C). The estimated volume of sediment retained in the Geotube® bags is approximately 25,707 m^3 (Table 3).

In addition to the sediment stored in the Geotube® bags, additional material removed from the canal, considered as oversize material, was removed from the dredge slurry prior to placement in the Geotube® bags. A total of 1,125 bags (with capacity of 1 m^3) containing oversize material from the shaker screens, were filled at CS1 with an estimated volume of 1,018 m^3.

Table 3: Number of Geotube® bags, oversize bags and estimated sediment volumes at CS1 and CS3.

Containment site	CS1	CS3
Geotube® bags filled	26	16
Estimated volume in geobags (m^3)	25,707	10,000
Number of 1 m^3 bags with oversize material	1,125	592

4.3 Sediment Disposed to CS3 – Sections 6 and 7

Sections 6 and 7 comprised the length of Kopeopeo Canal between the wastewater pipeline across the canal at Chainage 2800 and the end of the canal at the confluence with Orini Canal at Chainage 5100. Section 6 of the canal comprises a regularly formed landform between wastewater pipeline and Keepa Road. Downstream of Keepa Road (Section 7), the canal is less well defined and characterised by lower profile sides and more irregular morphology of the channel.

Dredging within Section 6 and Section 7 was undertaken along the dredge corridor which generally comprised a 10 m width either side of the central alignment of the canal. Dredging was constrained by the following:

- The entrance to the Kope/Orini Pumpstation intake channel. The intake channel passes through CS3 on the southern side of the containment cell at Chainage 4160.
- The bridge abutments of the Keepa Road bridge at Chainage 3980.

In addition to the main Kopeopeo Canal channel, dredging was undertaken within the pump channel located on the true right bank of Kopeopeo Canal at Chainage 4170. The pump channel extends in an easterly direction toward Whakatane River. The pump channel was dredged using the Sandbug dredge in August 2018 in the area between Kopeopeo Canal and the control gate.

The area beneath the eastern control structure, located the end of the canal at the confluence with Orini Canal at Chainage 5100, was dredged prior to construction of the structure.

The remedial dredging did not include the area of the salt marsh located at the lower end of the Kopeopeo Canal remediation between Chainage 4650 and Chainage 5100.

Sediment volumes transferred and stored within CS3 have been estimated based on geo-processing of images captured from drone flights on 8 August 2019 and 28 August 2019 (Appendix C). The estimated volume of sediment retained in the Geotube® bags is approximately 10,000 m^3 (Table 3).

In addition to the sediment stored in the Geotube® bags, additional material removed from the canal, considered as oversize material, was removed from the dredge slurry prior to placement in the Geotube® bags. A total of 592 bags containing oversize material from the shaker screens, were filled at CS3 with an estimated volume of 590 m^3.

5.0 SEDIMENT VALIDATION

5.1 Overview

The objective of the remediation was to remove the contaminated sediment to the extent practicable. Adoption of this approach recognised that it would not be possible to remove all of the impacted sediment due to limitations of the dredging equipment, the physical environment of the canal and the presence of structures within the canal. Sediment immediately adjacent to the canal banks, areas of bank subsidence, vegetation growing inside the dredging corridor, and protrusions around critical structures (i.e., bridges, pipeline supports, private jetties, private property inlet drain points and culverts) was not removed due to concerns about structural integrity of the canal banks and structures, and/or damage that could have been caused by the dredging equipment.

The sediment validation methodology comprised a multiple lines of evidence approach to evaluate that the sediment remediation objectives were achieved. The validation methodology comprised the following to assess the volume of sediment dredged from the canal and document the quality of residual sediment within the canal:

- Hydrographic surveys of the canal. Surveys were undertaken pre- and post-completion of the remedial dredging works to estimate the volume of sediment removed and the final bed profile.
- Visual inspections of the composition of the residual in-situ sediment following completion of the dredging.
- Sediment validation sampling to document in-situ dioxin sediment concentrations following completion of the dredging.

5.2 Hydrographic Survey

Hydrographic surveys were undertaken prior to and post-completion of sediment dredging. The hydrographic surveys were carried out by Discovery Marine Limited (DML) on behalf of BoPRC. The pre-dredging survey was undertaken to allow estimation of contaminated sediment volumes and define the dredging profile and dredging corridor. At the completion of dredging, a final post-dredge hydrographic survey was undertaken to confirm the new base elevation of the canal bed and to estimate the volume of sediment removed.

Volumetric estimates of the sediment removal were calculated based on the difference between the pre- and post-dredge survey data. Sediment volumes were calculated by Ausdredge Pty Ltd (Ausdredge) on behalf of BoPRC. The hydrographic survey data is reproduced in Appendix D.

Based on the hydrographic surveys, a total of 34,465 m^3 of sediment was dredged from the canal (Table 4). The sediment volumes calculated from the hydrographic surveys are comparable with the sediment volumes estimated from the geo-processing of the drone images of the Geotube® bags at CS1 and CS3 (refer Section 4.0).

Table 4: Estimated sediment volumes dredged from Kopeopeo Canal remediation area based on pre- and post-dredge hydrographic surveys.

Containment site	Canal section[1]	Volume dredged (m^3)	Volume dredged to each containment site (m^3)
CS1	1	2,062	22,347 m^3 to CS 1
	2	2,673	
	3	2,488	
	4	4,506	
	5	10,618	
CS3	6	5,575	12,118 m^3 to CS 3
	7	6,543	
Total		**34,465**	

Notes: Data provided by BoPRC. [1] The location of the individual subsections is shown on the Ausdredge plans provided in Appendix D.

5.3 Visual Inspections

Previous investigations had documented a physical (grain size, colour etc.) and visual difference between the contaminated sediment requiring dredging and the underlying uncontaminated material considered suitable to remain in place. As part of the validation process, sediment cores recovered during sediment validation sampling were visually inspected to evaluate whether, based on grain size and colour, the dredging process was removing the contaminated sediment to the extent practicable.

Visual inspection of the recovered cores was undertaken by a Golder environmental consultant during the sediment sampling for validation. Visual inspection of the recovered core was also undertaken by the Independent Monitor when present during the sediment validation sampling.

Visual inspection was undertaken of the recovered sediment within the sampling tube prior to decanting and following placement of the recovered core in the tray prior to sampling.

A record of the visual inspections undertaken of the recovered sediment cores is presented in Appendix E. The visual inspection record includes a photograph of the recovered material and description of the composition of the material.

Inspection of the recovered sediment identified variability in the composition and thickness of residual canal base sediment following completion of the dredging works. The recovered material comprised a mixture of sediment, sand, silt and clay. In general, limited evidence of contaminated sediment (as defined by the descriptions from pre-remedial investigation work) was observed in the recovered sediment cores.

However, comparison between the observations and the sediment validation data did not indicate a clear correlation between the composition of the residual post-dredge material and dioxin concentrations. In a number of cases, elevated dioxin concentrations were reported in samples with a different composition to the material considered to be contaminated.

Given this, visual inspections alone were not considered to be a robust indicator of the success of the remedial dredging with the results from lab analysis of the sediment validation samples being the primary measure of the remedial objectives being achieved.

5.4 Sediment Validation Sampling

5.4.1 Validation methodology

Sediment sampling was undertaken progressively during the dredging programme as sections of the canal were dredged to the survey profile. A three-stage validation methodology was adopted during the project. The first stage of validation (Phase 1) occurred following completion of the initial dredging with the second (Phase 2) and third (Phase 3) stages occurring where Phase 1 samples exceeded the remedial criteria and re-dredging was required to be undertaken.

The following sections outline the sampling and validation methodology.

5.4.2 Sampling methodology

Sediment validation samples were collected from the canal base progressively during the dredging works. The sampling process focused on collecting a representative sample of the top 100 mm of material which remained on top of the canal base after dredging had been completed.

The sampling methodology employed during the project can be summarised as follows:

- Sediment samples were collected using a manual push tube method deployed from a barge situated within the canal. Samples were collected from within the dredge corridor which was defined as the area of the canal subject to dredging and having a standing water level of at least 1.5 m (i.e., depth to base of canal from water surface). Once the barge was positioned, the location of each sample location was recorded via GPS.
- Individual cores were collected with an acrylic tube connected to an auger head (Figure 2a). Acrylic tubes were decontaminated/cleaned prior to the collection of each sample using the four bucket and acetone wash process outlined in the EMVP (Golder 2017a).
- The acrylic tube was manually pushed into the canal base sediment to a depth of at least 100 mm. The embedment depth varied depending on the type and thickness of the in-situ substrate. The sampling method was such that the tube contained a combination of underlying sediment and water above, with sufficient sediment volume for laboratory analysis (Figure 2b).
- Following recovery of the sediment core to the surface, a cap was placed on the base of the acrylic tube to restrict material from escaping out of the bottom. The tubes were then disconnected from the auger and the water from the top of the tube slowly decanted to ensure that any sediment material was not lost during the decanting process (Figure 2c).
- Sediment recovered in the tube was then deposited into a tray (Figure 2d) to enable logging of the recovered material and collection of the samples for laboratory analysis. The recovered core was photographed and the composition logged prior to sample collection.
- Two samples (one primary sample and one duplicate sample) were collected from the top 100 mm of each core. The samples were placed within laboratory supplied clean sampling jars for transportation to the laboratory under standard chain of custody (COC) procedures. At the laboratory, each sample was homogenised and a subsample taken for analysis.
- Once sampling was completed, excess material was returned to the canal.

a) Sampling tube connected to auger.

b) Sampling tube following recovering of sediment core and prior to decanting.

c) Recovered sediment core (left) post-decanting of excess water.

d) Recovered sediment core placed into the tray for logging and sampling.

Figure 2: Photographic record of sediment validation sampling method.

Sediment samples were submitted to AsureQuality Limited (AsureQuality) in Wellington and analysed for dioxins. AsureQuality reported concentrations for 13 individual dioxin congeners along with the calculated lower-, middle- and upper bound Total PCDD/F WHO-TEQ and Total PCDD/F I-TEQ concentrations.

5.4.3 Phase 1 validation

For validation sampling purposes, the canal was divided into approximate 100 m lengths although this varied with the presence of structures that cross the canal (i.e., bridges, pipes etc.).

Within each 100 m length, three sediment samples were collected at approximately 33 m intervals. One sample was collected from each side of the dredge corridor (mid-way between the centre and the edge of the dredge corridor), and one sample was collected from the centre of the channel (Figure 3).

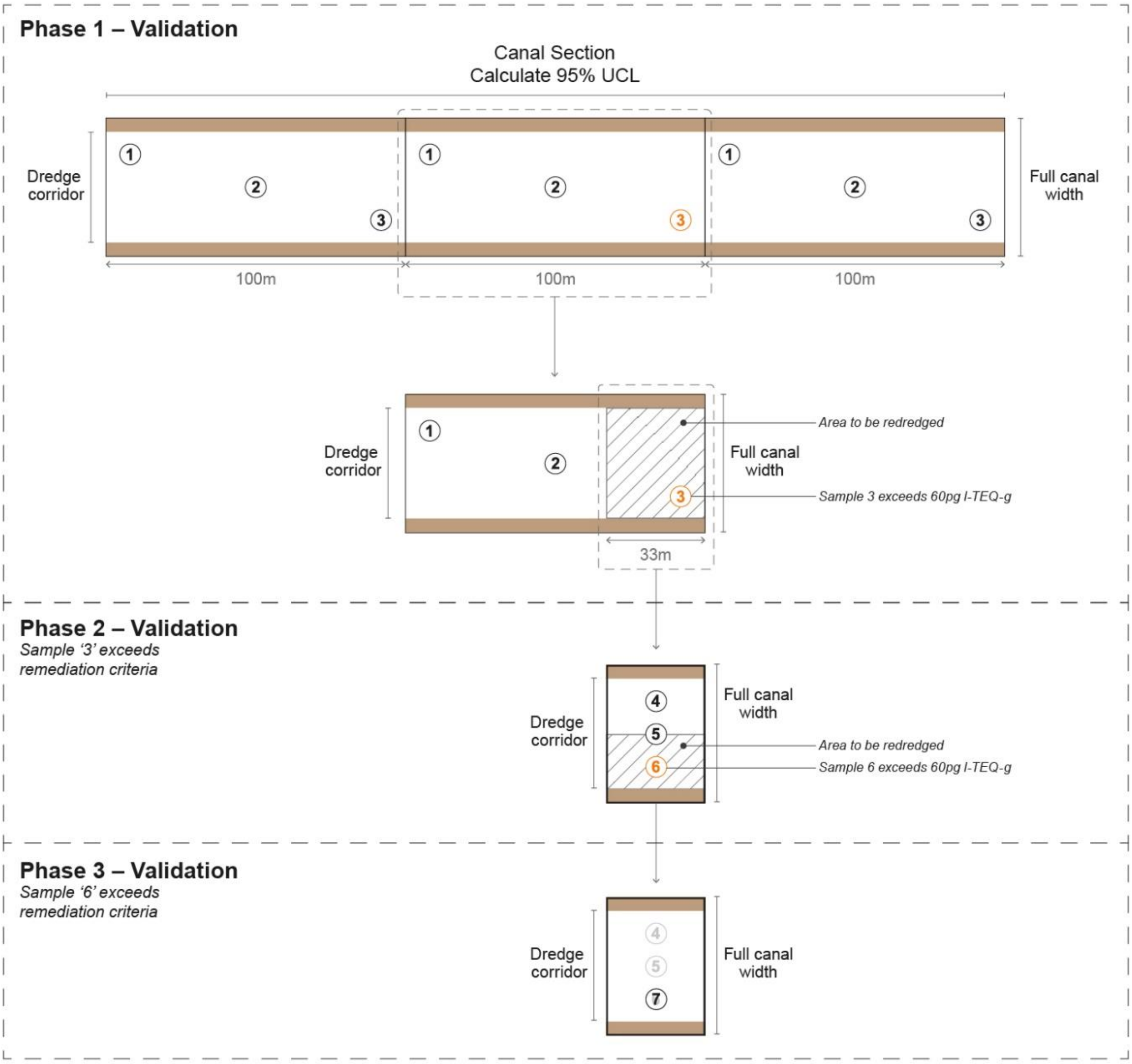


Figure 3: Validation process.

Condition 25.4 of the Consent states that the remediation zone (i.e., dredging corridor) within the Kopeopeo Canal shall be deemed as being remediated when the UCL_{95} for dioxin concentration is at or below 60 pg/g I-TEQ. During the initial stages of the remedial dredging works, Phase 1 validation was considered to be satisfied where each individual sample was below 60 pg/g I-TEQ. Where sediment concentrations exceeded 60 pg/g I-TEQ, the area was re-dredged and subject to further sampling under the Phase 2 validation methodology (see Section 5.4.4).

In May 2019, the Consent Authority[2] provided clarification regarding interpretation and use of the UCL_{95}. The clarification referred to the application of a UCL_{95} as outlined in MfE (2011b) guidance in that "*the result will be acceptable if the 95% upper confidence limit is at or below the guideline, provided no result is more than twice the guideline value*". The implication of this clarification was that validation criteria was interpreted as being where the sediment dioxin concentration UCL_{95} is at or below 60 pg/g I-TEQ and no individual concentration exceeded 120 pg/g I-TEQ.

[2] Email from BoPRC (Emma Joss) to BoPRC (Brendon Love) titled Consent 67173 clarifications from Consent Authority dated 1 May 2019.

Based on this clarification to the validation criteria, Phase 1 validation was considered to be satisfied where the rolling UCL_{95} was at or below 60 pg/g I-TEQ and no individual concentration exceeded 120 pg/g I-TEQ. Additional dredging and validation sampling (Phase 2 and Phase 3 validation) was only undertaken where individual concentrations exceeding 120 pg/g I-TEQ were detected during the Phase 1 validation.

5.4.4 Phase 2 validation

Where an exceedance of the remedial criteria was detected during the Phase 1 validation, further dredging was undertaken within an approximate 33 m subsection corresponding to the location of the exceedance (Figure 3). Post-completion of the additional dredging, further validation sampling (Phase 2) was undertaken.

For each 33 m stretch of the canal subject to re-dredging, three further samples were collected at evenly spaced locations across the width of the canal (Figure 3). The three samples were submitted for laboratory analysis and analysed for dioxins.

The Phase 2 validation data was reviewed with respect to the remedial criteria as per the Phase 1 validation methodology. Where the remedial criteria were not achieved, consideration was given as to whether a portion of the 33 m subsection of the canal required further dredging. Where required, further dredging was undertaken within the area containing the exceedance of the remedial criteria (Figure 3). This comprised the width of the canal between the edge of the dredge corridor and the nearest sample achieving the remedial criteria or the whole width of the dredge corridor within the 33 m subsection.

5.4.5 Phase 3 validation

Phase 3 validation sampling was undertaken following additional dredging of contaminated sediment based on the Phase 2 validation results. Phase 3 validation sampling comprised the collection of one sample from the location(s) where the Phase 2 validation sample dioxin concentration exceeded the remedial criteria (Figure 3).

If, at this point, dioxin in the sample(s) still exceeded the remedial criteria, consideration was given as to whether a portion of the 33 m subsection of the canal needed additional dredging or whether additional dredging was practicable. Where additional dredging was undertaken, further sampling was undertaken based on the Phase 2 and Phase 3 validation methodology.

5.5 Sediment Analytical Results

Sediment samples collected during the validation works were submitted to AsureQuality in Wellington and analysed for dioxins. AsureQuality holds International Accreditation New Zealand (IANZ) accreditation for the analytical method used. The laboratory analytical reports are reproduced in Appendix F. The sediment quality data is presented in Table G1 (Appendix G).

A total of 287 sediment validation samples were collected at 155 individual sampling transects (KC001 to KC155) along the length of Kopeopeo Canal between SH30 and the confluence with Orini Canal (Table 5). Accounting for re-dredging of areas where the sediment dioxin remedial criterion was exceeded, a total of 238 samples represent the quality of residual in-situ sediment. Phase 1 validation was achieved at 121 individual sampling transects and the three pump channel sample locations (CS3-HA01, CS3-HA02 and CS3-HA01). Phase 2 validation was achieved at 27 individual sampling transects with Phase 3 validation achieved at seven individual sampling transects.

Table 5: Summary of sediment validation samples.

		Phase 1	Phase 2	Phase 3	Total
Total number of samples collected	Primary	158	84	8	250
	Field Duplicate	28	8	1	37
	Total	**186**	**92**	**9**	**287**
Number of samples representative of in-situ sediment quality	Primary	132	74	8	214
	Field Duplicate	20	6	1	27
	Total	**152**	**80**	**9**	**241**
Number of samples used to calculate UCL_{95}	Primary	125	71	8	204
	Field Duplicate	6	3	0	9
	Total	**131**	**74**	**8**	**213**

The remedial criterion was based on calculating the UCL_{95} for the sediment dioxin data set. The data from the sediment validation sampling was processed in order to calculate the UCL_{95}. The data set was processed based on the following criteria:

- Data for samples in areas re-dredged (i.e., failed Phase 1 or Phase 2 validation) was excluded given this data represented sediment that removed from the canal and was no longer considered representative of residual sediment quality.
- Where a primary and field duplicate sample was collected, preference was given to the higher concentration in either the primary or duplicate sample (with the lower concentration excluded from the calculation). This was considered to provide a more conservative approach to calculating the UCL_{95}.

Based on these criteria, a total of 213 samples were used to calculating the UCL_{95} (Table 5). A register of samples used to calculate the UCL_{95} is provided in Table H1 (Appendix H). The register also includes data excluded from the UCL_{95} calculation and provides commentary as to the rationale for excluding the data from the UCL_{95} calculation.

Concentrations in the samples used to calculate the UCL_{95} ranged between 20 pg/g I-TEQ and 160 pg/g I-TEQ with a mean concentration of 37 pg/g I-TEQ (Table 6 and Figure 4). The calculated UCL_{95} for the data set is **39 pg/g I-TEQ**.

Of the samples representative of residual sediment quality, only one sample (KC084e2) reported a concentration (160 pg/g) exceeding the 120 pg/g I-TEQ maximum (Figure 4). Sample KC084e2 was collected from the upstream side of the wastewater pipeline at Chainage 2800. While the reported concentration does not strictly satisfy the remedial criterion of no concentration exceeding 120 pg/g I-TEQ, it is considered that the area was remediated to the extent practicable given the following:

- The area was dredged on three separate occasions with the dredge operator noting that the area had been dredged to a hard base.
- Cores recovered during the validation sampling showed no visible evidence of target material remaining.
- Further assessment was undertaken by the Independent Monitor using multiple push tube cores following the third dredging phase. The Independent Monitor concurred that the area had been remediated to the extent practicable and there was no visible evidence of target material remaining.

Table 6: Summary statistics for sediment quality data used to calculate UCL_{95}.

Attribute	Value
Number of samples	213
Minimum	20
Maximum	160
Mean	37
Median	32
UCL_{95}	39 *
Number of samples >120 pg/g I-TEQ	1

Notes: Concentrations expressed as pg/g Total PCDD/F I-TEQ Upperbound. * 95 % Student's-t UCL calculated using ProUCL Version 5.1.002 – refer Appendix H.

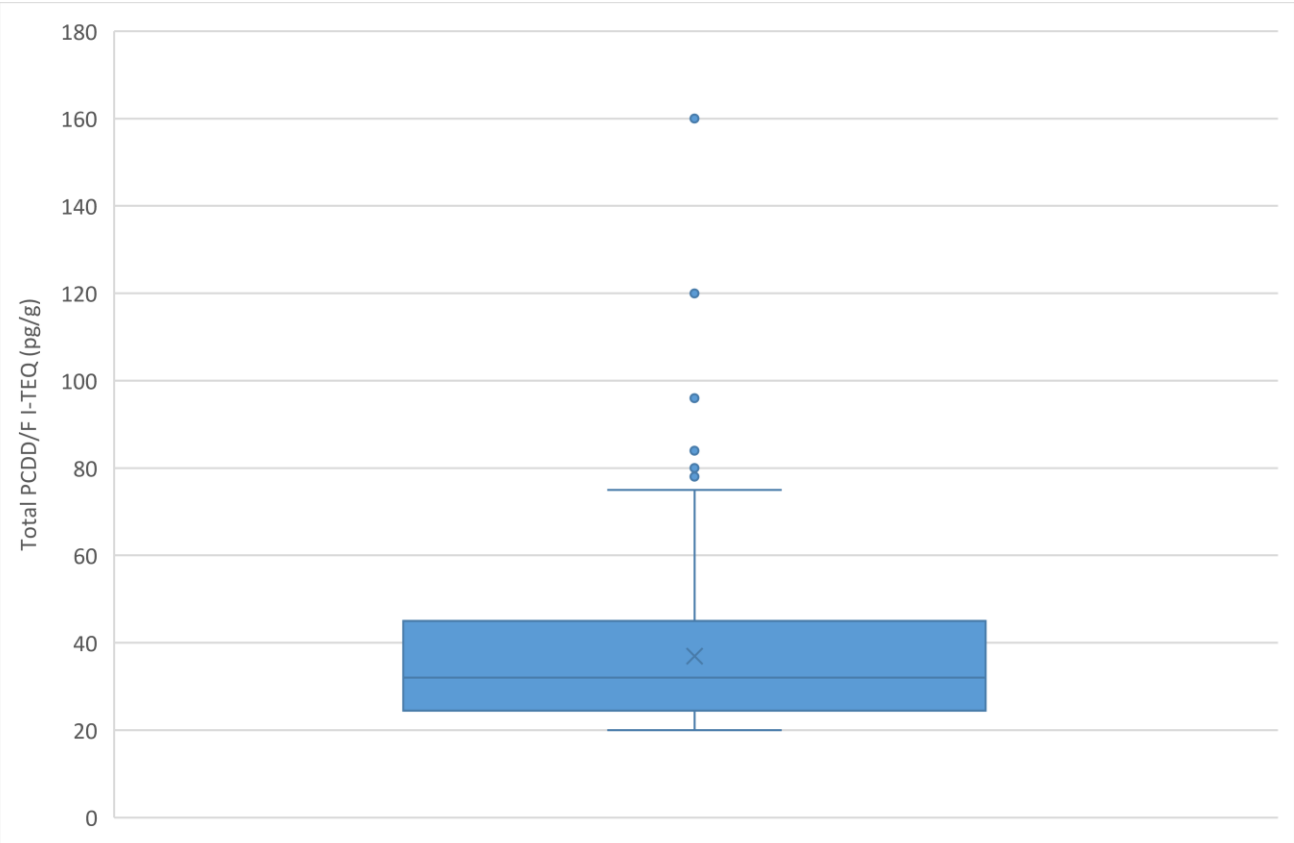
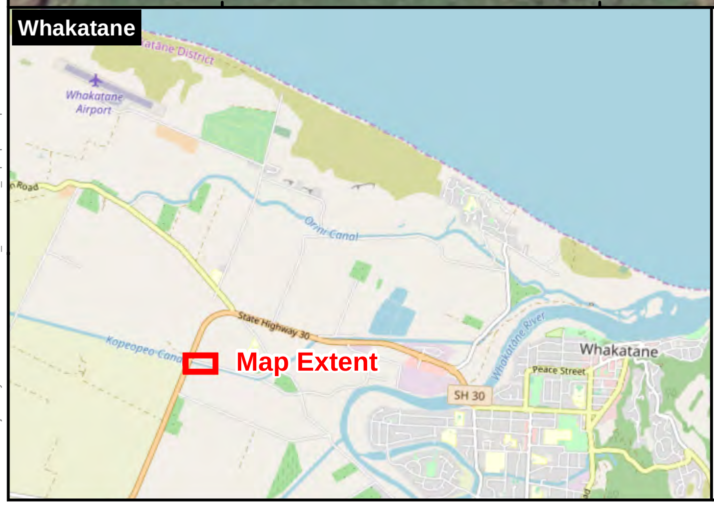


Figure 4: Distribution of Total PCDD/F I-TEQ concentrations used for UCL_{95} calculation.

The dioxin concentrations in the sediment samples representative of residual canal base sediment are presented in Figure 5 to Figure 18.



LEGEND

- Sediment validation sample - Sediment dioxin concentration
- + Chainage

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4. Sediment dioxin concentrations as Total PCDD/F I-TEQ - Upperbound pg/g.

0 25 50
METRES
REFERENCE SCALE: 1:1,000 (at A3)
PROJECTION: NZGD 2000 New Zealand Transverse Mercator

CLIENT
ENVIRO (NZ) LIMITED

PROJECT
KOPEOPEO CANAL REMEDIATION

TITLE
SEDIMENT VALIDATION RESULTS - CH0 TO CH330

CONSULTANT
GOLDER

YYYY-MM-DD	2019-12-05
PREPARED	AE
REVIEW	AH
APPROVED	AH

PROJECT NO.	REPORT	REV.	FIGURE
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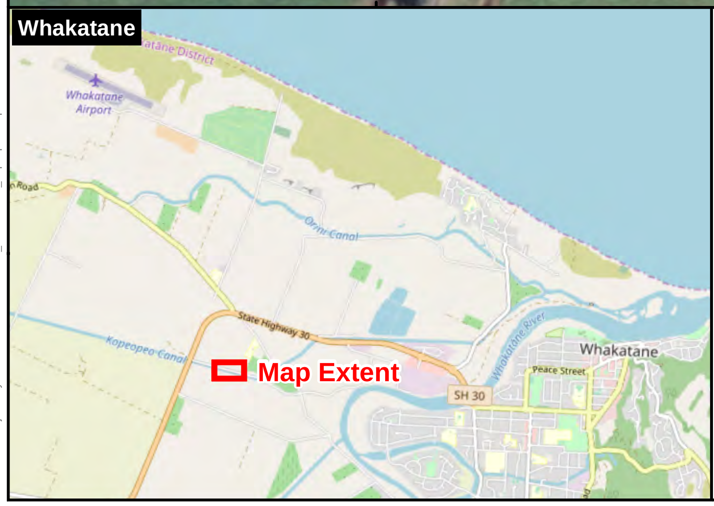

LEGEND

- Sediment validation sample - Sediment dioxin concentration
- Chainage

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4. Sediment dioxin concentrations as Total PCDD/F I-TEQ - Upperbound pg/g.

0 25 50 METRES

REFERENCE SCALE: 1:1,000 (at A3)
PROJECTION: NZGD 2000 New Zealand Transverse Mercator

CLIENT
ENVIRO (NZ) LIMITED

PROJECT
KOPEOPEO CANAL REMEDIATION

TITLE
SEDIMENT VALIDATION RESULTS - CH330 TO CH730

CONSULTANT
GOLDER

YYYY-MM-DD	2019-12-05
PREPARED	AE
REVIEW	AH
APPROVED	AH

PROJECT NO.	REPORT	REV.	FIGURE
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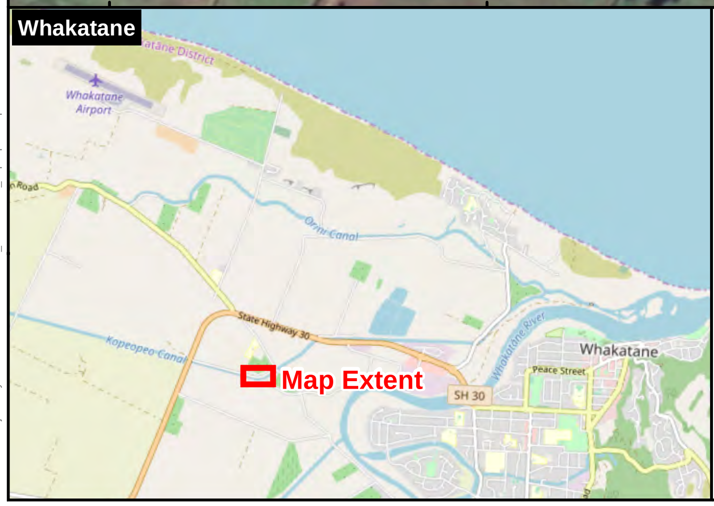

LEGEND

- Sediment validation sample - Sediment dioxin concentration
- Chainage

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4. Sediment dioxin concentrations as Total PCDD/F I-TEQ - Upperbound pg/g.

0 25 50
METRES

REFERENCE SCALE: 1:1,000 (at A3)

PROJECTION: NZGD 2000 New Zealand Transverse Mercator

CLIENT
ENVIRO (NZ) LIMITED

PROJECT
KOPEOPEO CANAL REMEDIATION

TITLE
SEDIMENT VALIDATION RESULTS - CH730 TO CH1170

CONSULTANT
GOLDER

YYYY-MM-DD	2019-12-05
PREPARED	AE
REVIEW	AH
APPROVED	AH

PROJECT NO.	REPORT	REV.	FIGURE
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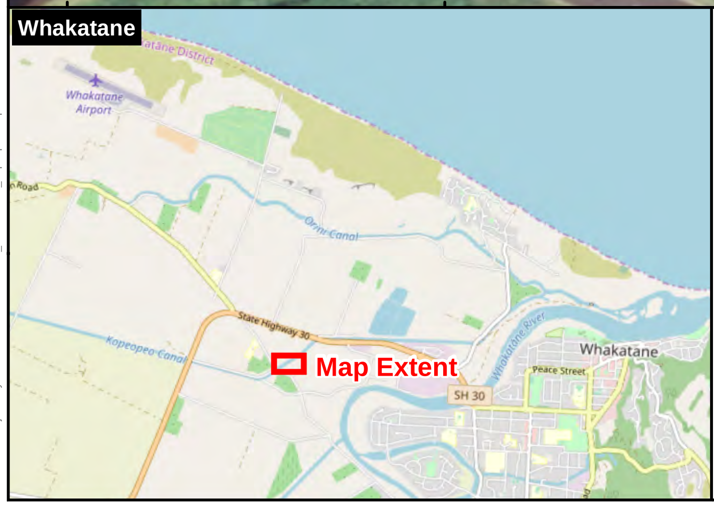

LEGEND

Sediment validation sample - Sediment dioxin concentration

Chainage

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4. Sediment dioxin concentrations as Total PCDD/F I-TEQ - Upperbound pg/g.

0 25 50 METRES

REFERENCE SCALE: 1:1,000 (at A3)

PROJECTION: NZGD 2000 New Zealand Transverse Mercator

CLIENT
ENVIRO (NZ) LIMITED

PROJECT
KOPEOPEO CANAL REMEDIATION

TITLE
SEDIMENT VALIDATION RESULTS - CH1180 TO CH1540

CONSULTANT
GOLDER

YYYY-MM-DD	2019-12-05
PREPARED	AE
REVIEW	AH
APPROVED	AH

PROJECT NO.	REPORT	REV.	FIGURE
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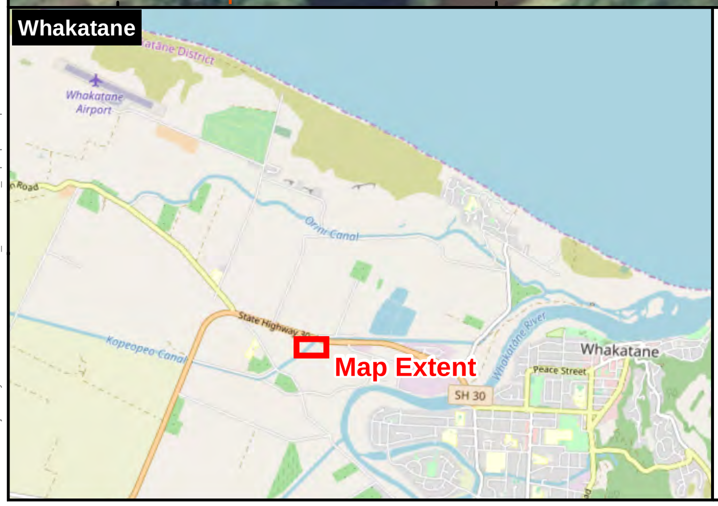

LEGEND

- Sediment validation sample - Sediment dioxin concentration
- Chainage

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4. Sediment dioxin concentrations as Total PCDD/F I-TEQ - Upperbound pg/g.

0 25 50 METRES

REFERENCE SCALE: 1:1,000 (at A3)
PROJECTION: NZGD 2000 New Zealand Transverse Mercator

CLIENT
ENVIRO (NZ) LIMITED

PROJECT
KOPEOPEO CANAL REMEDIATION

TITLE
SEDIMENT VALIDATION RESULTS - CH1540 TO CH1850

CONSULTANT: GOLDER

YYYY-MM-DD	2019-12-05
PREPARED	AE
REVIEW	AH
APPROVED	AH

PROJECT NO.	REPORT	REV.	FIGURE
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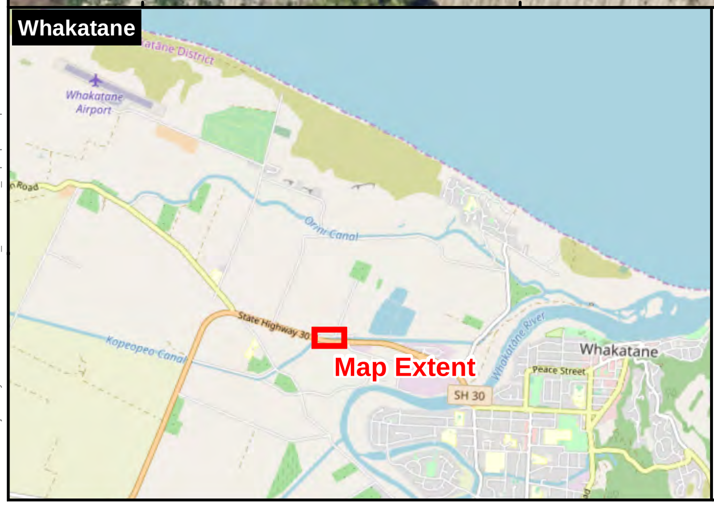

LEGEND

- Sediment validation sample - Sediment dioxin concentration
- Chainage

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4. Sediment dioxin concentrations as Total PCDD/F I-TEQ - Upperbound pg/g.

0 25 50 METRES

REFERENCE SCALE: 1:1,000 (at A3)
PROJECTION: NZGD 2000 New Zealand Transverse Mercator

CLIENT
ENVIRO (NZ) LIMITED

PROJECT
KOPEOPEO CANAL REMEDIATION

TITLE
SEDIMENT VALIDATION RESULTS - CH1860 TO CH2250

CONSULTANT
GOLDER

YYYY-MM-DD	2019-12-05
PREPARED	AE
REVIEW	AH
APPROVED	AH

PROJECT NO.	REPORT	REV.	FIGURE
1894562	005	0	10

25mm

LEGEND

- Sediment validation sample - Sediment dioxin concentration
- Chainage

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4. Sediment dioxin concentrations as Total PCDD/F I-TEQ - Upperbound pg/g.

0 25 50 METRES

REFERENCE SCALE: 1:1,000 (at A3)
PROJECTION: NZGD 2000 New Zealand Transverse Mercator

CLIENT
ENVIRO (NZ) LIMITED

PROJECT
KOPEOPEO CANAL REMEDIATION

TITLE
SEDIMENT VALIDATION RESULTS - CH2250 TO CH2630

CONSULTANT
GOLDER

YYYY-MM-DD	2019-12-05
PREPARED	AE
REVIEW	AH
APPROVED	AH

PROJECT NO.	REPORT	REV.	FIGURE
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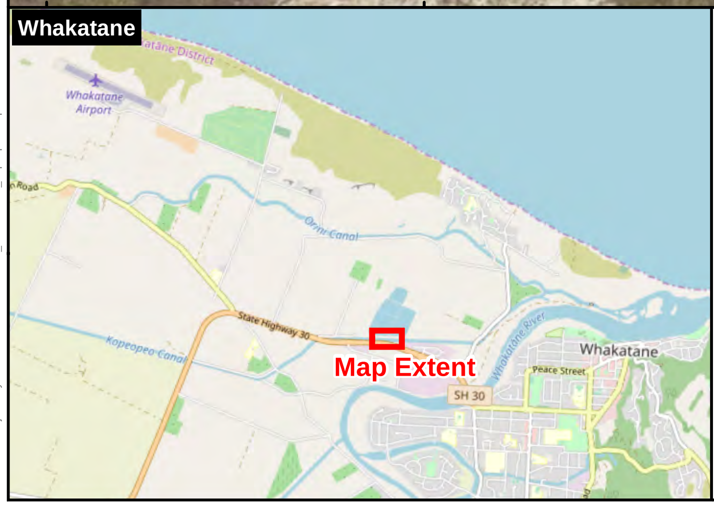

LEGEND

- Sediment validation sample - Sediment dioxin concentration
- + Chainage

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4. Sediment dioxin concentrations as Total PCDD/F I-TEQ - Upperbound pg/g.

0 25 50 METRES

REFERENCE SCALE: 1:1,000 (at A3)

PROJECTION: NZGD 2000 New Zealand Transverse Mercator

CLIENT
ENVIRO (NZ) LIMITED

PROJECT
KOPEOPEO CANAL REMEDIATION

TITLE
SEDIMENT VALIDATION RESULTS - CH2630 TO CH3020

CONSULTANT
GOLDER

YYYY-MM-DD	2019-12-05
PREPARED	AE
REVIEW	AH
APPROVED	AH

PROJECT NO.	REPORT	REV.	FIGURE
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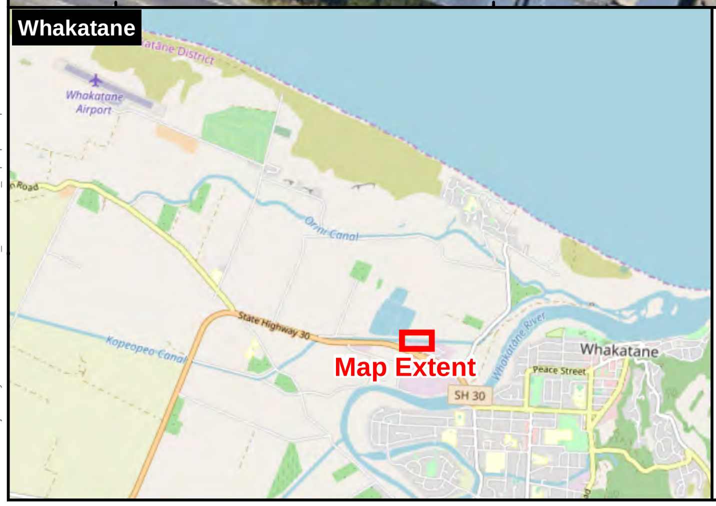

LEGEND

- Sediment validation sample - Sediment dioxin concentration
- + Chainage

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4. Sediment dioxin concentrations as Total PCDD/F I-TEQ - Upperbound pg/g.

0 25 50 METRES

REFERENCE SCALE: 1:1,000 (at A3)
PROJECTION: NZGD 2000 New Zealand Transverse Mercator

CLIENT
ENVIRO (NZ) LIMITED

PROJECT
KOPEOPEO CANAL REMEDIATION

TITLE
SEDIMENT VALIDATION RESULTS - CH3020 TO CH3410

CONSULTANT
GOLDER

YYYY-MM-DD	2019-12-05
PREPARED	AE
REVIEW	AH
APPROVED	AH

PROJECT NO.	REPORT	REV.	FIGURE
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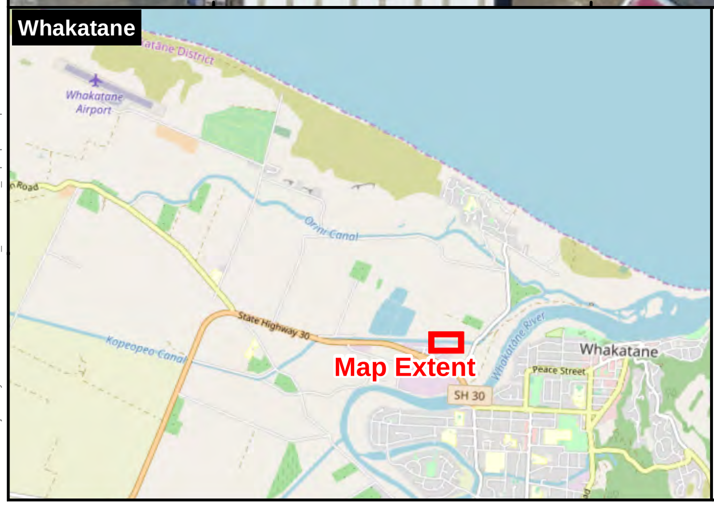

LEGEND

- Sediment validation sample - Sediment dioxin concentration
- + Chainage

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4. Sediment dioxin concentrations as Total PCDD/F I-TEQ - Upperbound pg/g.

0 25 50 METRES
REFERENCE SCALE: 1:1,000 (at A3)
PROJECTION: NZGD 2000 New Zealand Transverse Mercator

CLIENT
ENVIRO (NZ) LIMITED

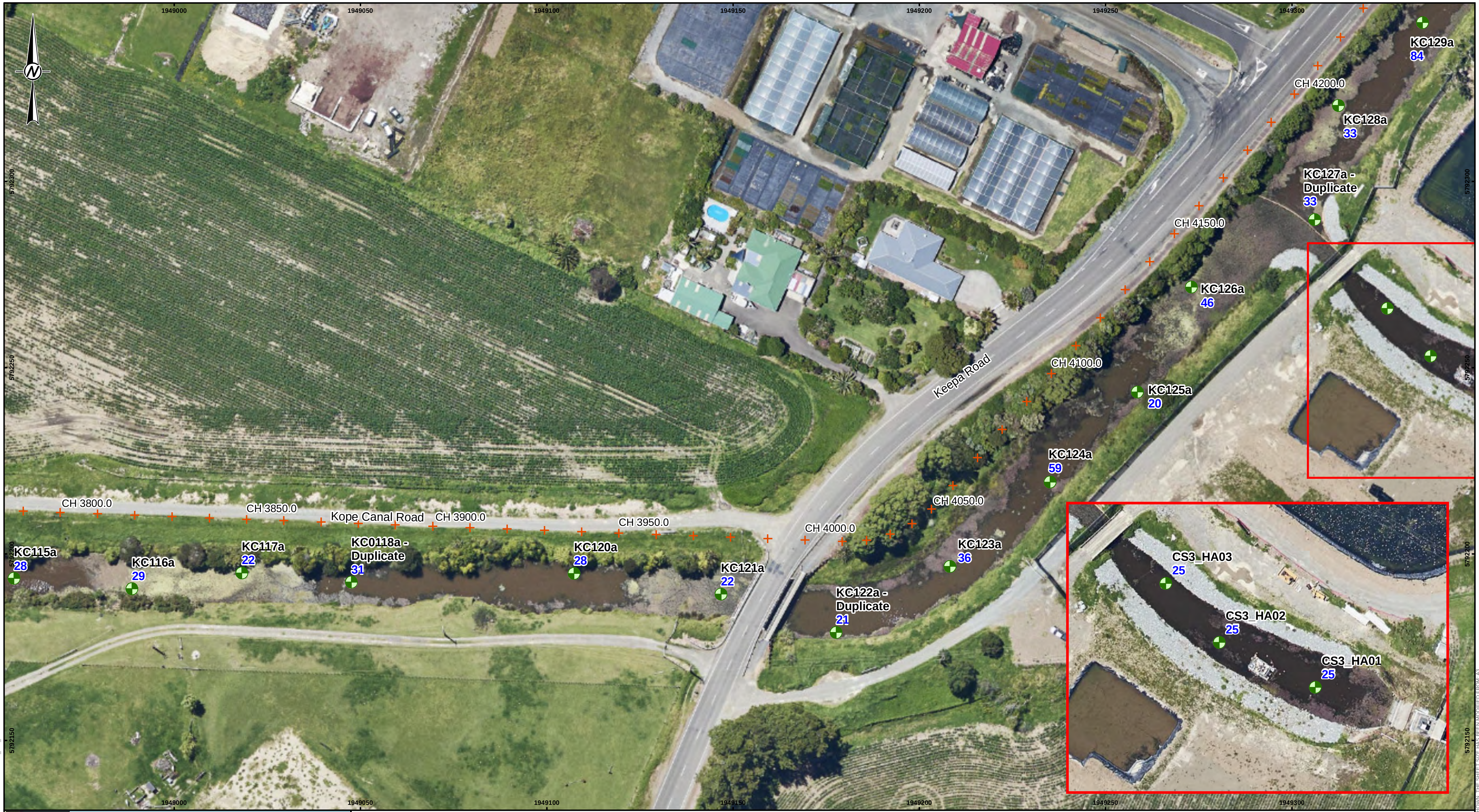
PROJECT
KOPEOPEO CANAL REMEDIATION

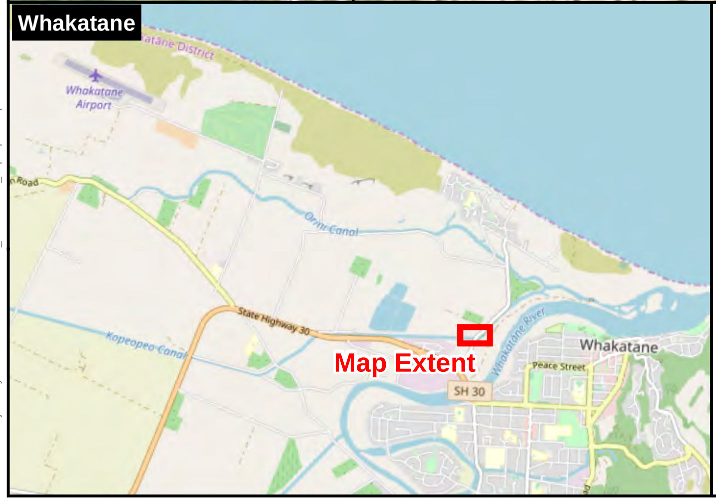
TITLE
SEDIMENT VALIDATION RESULTS - CH3410 TO CH3790

CONSULTANT
GOLDER

YYYY-MM-DD	2019-12-05
PREPARED	AE
REVIEW	AH
APPROVED	AH

PROJECT NO.	REPORT	REV.	FIGURE
1894562	005	0	14





LEGEND

- Sediment validation sample - Sediment dioxin concentration
- Chainage

NOTES
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2. Map image: © OpenStreetMap (and) contributors, CC-BY-SA Sourced from the LINZ Data Service and licensed for re-use under the Creative Commons Attribution 4.0 New Zealand licence
3. Schematic only, not to be interpreted as an engineering design or construction drawing.
4. Sediment dioxin concentrations as Total PCDD/F I-TEQ - Upperbound pg/g.

0 25 50
METRES

REFERENCE SCALE: 1:1,000 (at A3)
PROJECTION: NZGD 2000 New Zealand Transverse Mercator

CLIENT
ENVIRO (NZ) LIMITED

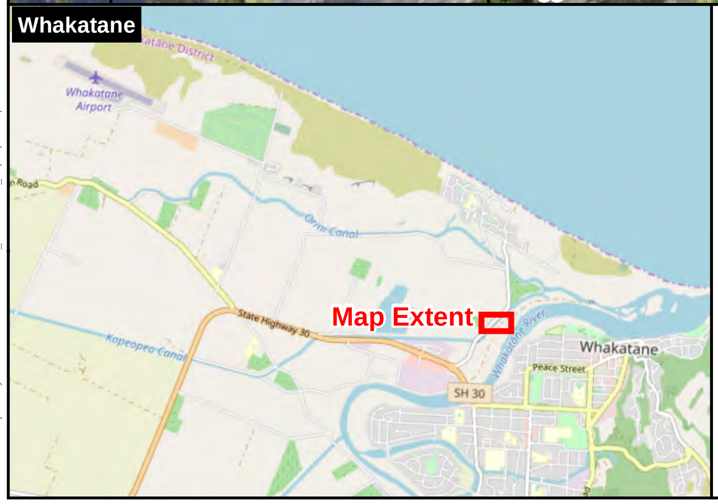
PROJECT
KOPEOPEO CANAL REMEDIATION

TITLE
SEDIMENT VALIDATION RESULTS - CH3790 TO CH4230

CONSULTANT
GOLDER

YYYY-MM-DD	2019-12-05
PREPARED	AE
REVIEW	AH
APPROVED	AH

PROJECT NO.	REPORT	REV.	FIGURE
1894562	005	0	15



LEGEND

- Sediment validation sample - Sediment dioxin concentration
- Chainage

NOTES
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3. Schematic only, not to be interpreted as an engineering design or construction drawing.
4. Sediment dioxin concentrations as Total PCDD/F I-TEQ - Upperbound pg/g.

0 25 50 METRES

REFERENCE SCALE: 1:1,000 (at A3)
PROJECTION: NZGD 2000 New Zealand Transverse Mercator

CLIENT
ENVIRO (NZ) LIMITED

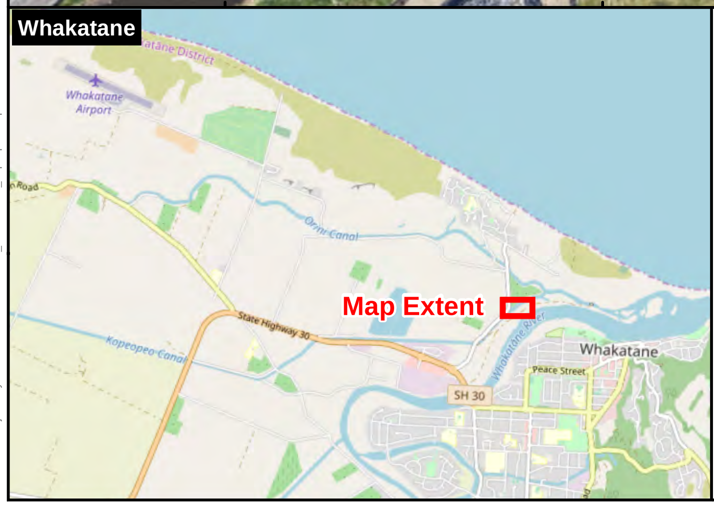
PROJECT
KOPEOPEO CANAL REMEDIATION

TITLE
SEDIMENT VALIDATION RESULTS - CH4230 TO CH4520

CONSULTANT
GOLDER

YYYY-MM-DD	2019-12-05
PREPARED	AE
REVIEW	AH
APPROVED	AH

PROJECT NO.	REPORT	REV.	FIGURE
1894562	005	0	16



LEGEND

Sediment validation sample - Sediment dioxin concentration

Chainage

NOTES
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3. Schematic only, not to be interpreted as an engineering design or construction drawing.
4. Sediment dioxin concentrations as Total PCDD/F I-TEQ - Upperbound pg/g.

0 25 50 METRES

REFERENCE SCALE: 1:1,000 (at A3)
PROJECTION: NZGD 2000 New Zealand Transverse Mercator

CLIENT
ENVIRO (NZ) LIMITED

PROJECT
KOPEOPEO CANAL REMEDIATION

TITLE
SEDIMENT VALIDATION RESULTS - CH4520 TO CH4870

CONSULTANT
GOLDER

YYYY-MM-DD	2019-12-05
PREPARED	AE
REVIEW	AH
APPROVED	AH

PROJECT NO.	REPORT	REV.	FIGURE
1894562	005	0	17

LEGEND

- Sediment validation sample - Sediment dioxin concentration
- Chainage

NOTES

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3. Schematic only, not to be interpreted as an engineering design or construction drawing.
4. Sediment dioxin concentrations as Total PCDD/F I-TEQ - Upperbound pg/g.

0 25 50 METRES

REFERENCE SCALE: 1:1,000 (at A3)
PROJECTION: NZGD 2000 New Zealand Transverse Mercator

CLIENT
ENVIRO (NZ) LIMITED

PROJECT
KOPEOPEO CANAL REMEDIATION

TITLE
SEDIMENT VALIDATION RESULTS - CH4840 TO CH5150

CONSULTANT
GOLDER

YYYY-MM-DD	2019-12-05
PREPARED	AE
REVIEW	AH
APPROVED	AH

PROJECT NO.	REPORT	REV.	FIGURE
1894562	005	0	18

6.0 QUALITY ASSURANCE AND QUALITY CONTROL

A quality assurance/quality control (QA/QC) program was implemented for the project to ensure that data collected during the remedial validation is scientifically valid, defensible and of known precision and accuracy.

Quality assurance (QA) pertains to the means to obtain representative data with the QA documentation developed prior to and during project works. QA documentation includes standard operating procedures (e.g., decontamination procedures, instrument calibration procedures, field sample collection procedures), field record sheets, sample integrity protocols (COC, calibration certificates), laboratory accreditation, and data quality indicators for field and laboratory data.

Quality control (QC) pertains to the means to assess the reliability of data collected and the effectiveness of the data quality objectives set in QA actions. QC procedures include the collection of blind (field) duplicates, rinsate blanks, field blank and trip blank samples, in addition to internal laboratory testing of control samples, surrogates, matrix spikes and method blanks.

The quality of information is considered satisfactory when QC procedures demonstrate that the data quality objectives have been met.

The data quality objectives (DQO) for the sediment remediation works were established utilising the United States Environmental Protection Agency (USEPA) 2000a, 2000b and 2006a) seven-step DQO approach adopted in MfE (2011b) guidance. The DQOs outline QA and QC parameters for field and laboratory programs to ensure data of appropriate reliability is used to assess the environmental conditions. The seven-step process to develop DQOs is outlined in Table 7.

Table 7: Summary of data quality objectives.

DQO step	Detail
1. **State the problem**	Historical discharges into the canal from the timber treatment industry have led to contamination of the sediments with dioxins. Dioxin concentrations were identified to represent an unacceptable risk to human health, primarily through the consumption of eel harvested from Kopeopeo Canal. In addition to mitigating risks to human health, the remediation works were identified to be required to facilitate maintenance dredging of Kopeopeo Canal in order for it to continue to function as part of the Rangitaiki Drainage Scheme.
2. **Identify the decisions / goal of the study**	Undertake remediation work to remove dioxin contaminated sediment from Kopeopeo Canal to achieve the remedial goal as defined in the Consent (refer Section 2.4).
3. **Identify information inputs**	Media: Sediment within Kopeopeo Canal along with soil, sediment, surface water, groundwater and air in relation to the containment sites. Environmental parameters: Dioxins.
4. **Define the study boundaries (spatial and temporal)**	The study boundary comprises the 5.1 km section of Kopeopeo Canal between SH30 (at the intersection with Kope Drain Road) and the confluence with the Orini Stream. The study boundary has been defined based on previous investigations (BoPRC 2005a, 2005b; SKM 2006a; T&T 2015) and established through the resource consent process.
5. **Develop the analytical approach (decision rule)**	The analytical schedule was detailed in the EMVP (Golder 2017). This included the establishment of data quality indicators (DQIs) for assessing the quality of the data collected.

DQO step	Detail
6. **Specify the performance or acceptance criteria**	DQIs have been established to set acceptance limits on field and laboratory data. The DQIs are presented in Table 8 along with an assessment of compliance with the parameters.
7. **Develop the plan for obtaining the data**	The EMVP (Golder 2017) documented the plan for collecting data during the remedial programme.

As outlined in Step 6 of the DQO process (Table 7), DQIs have been established to assess the reliability of field procedures and analytical results based on the following metrics:

- **Representativeness** – The confidence (expressed qualitatively) that data are representative of each media present.
- **Comparability** – The confidence (expressed qualitatively) that data may be considered to be equivalent for each sampling and analytical event.
- **Accuracy** – A measure of the closeness of the results to the actual results. Accuracy is assessed through the comparison of results produced by the primary and secondary laboratories for the same sample and by measuring the extent to which an analytical result reflects the known concentration as measured by the recovery obtained from internal laboratory spikes.
- **Precision** – A measure of the repeatability of results by the laboratory. This is assessed through the analysis of duplicates both internally and externally and is calculated by using relative percentage differences (RPDs). In calculating RPD values, the following protocol types will be adopted according to the particular circumstance:
  - **Type 1:** Where the primary and duplicate samples have concentrations reported at levels below their laboratory limits of reporting (LORs), a RPD of <50 % was assigned.
  - **Type 2A:** Where one sample has a reported value below a LOR and the other has identified detectable contaminant concentration, a RPD was calculated. RPDs are calculated using the LOR for the undetected sample, and comparing that to the concentration of the detected sample.
  - **Type 2B:** Similar to Type 2A RPDs except that the primary and secondary laboratories have different LORs and a reported value from one laboratory may be below a LOR from the other and may result in an elevated RPD.
  - **Type 3:** Where both samples are reported with detectable contaminant concentrations, RPDs are calculated and tabulated.
- **Completeness** – The percentage of acceptable data obtained compared to the amount of data needed to achieve a particular level of confidence in the results.

Acceptance limits set to quantitatively assess DQIs are in accordance with MfE (2011b) and National Environment Protection Measure (NEPM) (National Environment Protection Council (NEPC) 2013) guidance, and Standards Australia (AS 4482.1–2005, and AS5567.1-1998). A summary of compliance with and assessment against the project DQOs is presented in Table 8.

Table 8: Summary of project data quality indicators.

Data quality indicator	Data quality indicator	Acceptance limit	Result
Representativeness	-	No quantifiable limit.	Samples were collected from residual canal base sediment following dredging using the same sampling methodology. Samples were collected using the methodology specified in the EMVP. All primary sediment samples were analysed by AsureQuality.
Comparability	LORs	Preferably below acceptance criteria.	The laboratory method provides a LOR for Total PCDD/F I-TEQ – Upperbound of 20 pg/g I-TEQ. This is below the remedial criteria of 60 pg/g I-TEQ.
Precision	Primary (field) Duplicates	Primary field duplicates to be collected at a rate of 1 in 10 primary samples[3]. RPD to be less than 50 % where concentrations detected above the laboratory LORs in both the primary and field duplicate samples.	A total of 37 field duplicate samples were collected. Based on the collection of 247 primary samples, this represents a collection rate of 15 %. RPDs above 50 % were calculated for a range of individual dioxin congeners in 17 of the 37 sample pairs (Table G2). Further review of these samples identified the following: ■ Greater variability (higher RPDs) typically occurred within the hexa- hepta- and octa- congeners which are considered to have relatively lower toxicity (compared to TCDD and TCDF). ■ RPDs of less than 50 % were achieved for the relatively more toxic TCDF and TCDD congeners. ■ Lower variability was evident in RPD values for the Total PCDD/F I-TEQ – Upperbound with only four samples pairs yielding RPDs above 50 %: ▪ KC038a/b (110 %) – these samples were subsequently re-dredged given the duplicate sample concentration of 110 pg/g I-TEQ. ▪ KC056a/b (58 %) – these samples were subsequently re-dredged given the duplicate sample concentration of 150 pg/g I-TEQ. ▪ KC072a/b (57 %) – dioxin concentrations were 35 pg/g I-TEQ in

[3] The EMVP (2017) noted that a collection rate of 20% for field duplicate samples. The rate documented in the EMVP was notably higher than collection rates for field (or blind) duplicate specified in contaminated land guidance – MfE (2011) recommends a rate of 1 in 10 samples (10%) and NEPC (2011) recommends a rate of at least 1 in 20 samples (5 %) (MfE 2011, NEPC 2013. The acceptance limits have been adjusted in line with industry guidance and in agreement with the Independent Monitor (A Kohlrush pers. comm., 6 November 2019).

Data quality indicator	Data quality indicator	Acceptance limit	Result
			the primary sample and 63 pg/g I-TEQ in the duplicate sample. ▪ KC142a/DUP03-25062019 (75 %) – this sample was subsequently re-dredged given the detected concentrations of 250 pg/g I-TEQ and 550 pg/g I-TEQ. ■ The variability in RPDs are indicative of inherent variability in natural conditions or field and laboratory methods. In particular, the variability likely reflects the discharge processes (stormwater discharges) to the canal of dioxin to the canal and sediment movement within the canal over time. ■ The variability is not considered to influence the overall assessment given that a conservative approach was adopted in calculating the UCL95 concentration. Specifically, the UCL95 was calculated using the higher of the primary or field duplicate concentration.
	Analysis of secondary (inter-laboratory) duplicate samples	Duplicates to be analysed at a rate of at least 5 % (1:20). RPD values to be less than 50 % for results reported by the primary and secondary laboratories.	A total of 14 sediment samples were analysed as part of the inter-laboratory duplicate process (Table G3). This satisfies the analysis rate of 1:20. AsureQuality submitted the inter-laboratory samples to the National Measurement Institute (NMI) laboratory in Sydney, Australia. BoPRC advised AsureQuality on which samples to submit to NMI for analysis. Comparison of the results identified variability in the laboratory LORs for individual congeners between AsureQuality and NMI. The variability reflects NMI analysing the samples using high resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS) compared to AsureQuality's in-house method (GC-MS/MS). The method used by NMI yields LORs between one and two orders of magnitude lower than AsureQuality. Comparison of the data reported by AsureQuality and NMI identified the following: ■ RPDs ranged between 0 % and 53 % where both AsureQuality and NMI

Data quality indicator	Data quality indicator	Acceptance limit	Result
			reported concentrations of individual congeners above the laboratory LORs. RPDs above 50 % were identified in two samples: - KC033 (123789-HxCDD) – 53 %. - KC067 (1234678-HpCDD) – 52 %. ■ RPDs of up to 198 % were calculated where individual congeners were reported below the laboratory LORs by AsureQuality but above the laboratory LORs by NMI. This variation was accounted for with the Type 2B RPD protocol outlined in the EMVP (Golder 2017a). It is noted that in each of the cases where this situation occurred the concentration reported by NMI was below the AsureQuality laboratory LORs for individual congeners. ■ RPDs were not calculated where both AsureQuality and NMI reported concentrations of individual congeners below the laboratory LORs. A RPD value of <50 % has been assigned to these results.
Accuracy	Rinsate Blanks	Analysed at a minimum rate of one per set of sampling equipment (sampling corer) per 10 samples collected for the analytes being requested for field samples. Results should be below LORs.	Rinsate blank samples were collected by pouring laboratory supplied rinsate water down the inside of the acrylic sampling tube. The water was collected and analysed by AsureQuality for dioxins. A total of 18 rinsate blank samples were submitted for analysis during the sediment validation sampling between April 2018 and July 2019 (Table G4). With the exception of the following six samples, concentrations of individual dioxin congeners were not detected above the laboratory LORs: ■ RQ1-180418 (OCDD). ■ RQ1-030918 (1234678-HpCDF, 1234678-HpCDD, OCDF and OCDD). ■ RQ1-240918 (OCDD). ■ RQ1-051118 (OCDD). ■ RQ01-281118 (OCDD). ■ RQ01-250619 (OCDD). The presence of these individual congeners is not considered to affect the integrity of the samples given:

Data quality indicator	Data quality indicator	Acceptance limit	Result
			■ These congeners have a relatively lower toxicity (compared to TCDD and TCDF) and hence have limited influence on the Total PCDD/F I-TEQ concentration. These represent the more common congeners, and are typically associated with a range of sources (including combustion).
	Trip Blanks	Analysed at a minimum rate of one per 10 samples collected where analyses are required. Results should be below LORs.	Trip blanks were laboratory supplied soil jars prefilled with sand. A total of 22 trip blank samples were submitted for analysis during the sediment validation sampling between April 2018 and July 2019 (Table G5). With the exception of the following two samples, concentrations of individual dioxin congeners were not detected above the laboratory LORs: ■ TQ01-270319 (OCDD – 24 pg/g). ■ TQ01-270319 (123478-HxCDF (11 pg/g), 123678-HxCDF (21 pg/g), 123678-HxCDD (83 pg/g), 123789-HxCDD (21 pg/g), 1234678-HpCDF (340 pg/g), 1234789-HpCDF (34 pg/g), 1234678-HpCDD (2,400 pg/g), OCDF (1,700 pg/g), OCDD (24,000 pg/g)). The presence of these individual congeners is not considered to affect the integrity of the samples given: ■ These congeners have a relatively lower toxicity (compared to TCDD and TCDF) and hence have limited influence on the Total PCDD/F I-TEQ concentration. These represent the more common congeners, and are typically associated with a range of sources (including combustion).
	Laboratory Method Blanks	Results should be below LORs.	AsureQuality included a laboratory method blank sample with every batch of samples analysed. The results are presented as the 'Blank' sample in the QC Results section of the Certificates of Analysis issued by AsureQuality. Concentration of individual dioxin congeners were below the LORs in each of the 'Blank' samples.

Data quality indicator	Data quality indicator	Acceptance limit	Result
	Laboratory Control Sample Spikes (LCS)	Analysed at a frequency of 10 % of total samples analysed by the laboratory. Recoveries to be within the range of 70 % to 130 %[4]. This spike refers to a certified reference material or an independently prepared interference free matrix spiked with target analytes. Organic LCS are almost exclusively blank water spiked with target analytes.	'Ongoing Precision and Recovery' (OPR) samples are included with every batch of samples analysed by the primary (AsureQuality) and secondary (NMI) laboratories used during the project in accordance with the analytical method. The OPR is a laboratory blank spiked with known quantities of isotopically ($^{13}C_{12}$) labelled surrogate standards (40 pg/g for Tetra Dioxins and Furans, 200 pg/g for Penta – Hepta Dioxins and Furans and 400 pg/g for Octa Dioxins and Furans). The OPR is analysed exactly like a sample. Its purpose is to assure that the results produced by the laboratory remain within the limits specified in this method for precision and recovery. Recoverability is based on the percent recovery of the isotopically labelled surrogates against the recover standard. Recovery rates for the majority of samples were within the acceptable range specified in AsureQuality's analytical method (25-150 %). AsureQuality's reports note a number of occasions where the recovery rate was outside of the acceptable range. Given the recovery rates were slightly outside of the acceptable range, and these were for congeners consistently reported below the laboratory LORs in both primary and duplicate samples, this is not considered to affect the integrity of the data. NMI reported recovery rates within the acceptable range of 25-125 % for the analytical method.
	Matrix Spikes	Analysed at a frequency of 10 % of total samples analysed by the laboratory. Recoveries for most analytes should generally be within the range of 70 % to 130 %.	Based on the analytical method and the use of OPR samples, additional matrix spikes were not used by the analytical laboratories.

[4] The arbitrary selection of acceptance criteria that are too narrow can lead to unnecessary data rejection. The USEPA recommends advisory recovery acceptance criteria for laboratory control sample spikes of 70-130 % to be used until laboratory control limits become available. The acceptable recovery limits for spikes will vary between analytes, analytical methods, day to day/month etc. and laboratory to laboratory. Laboratories usually assess accuracy by using control charts built up over time based on the total historical data for all client analyses.

Data quality indicator	Data quality indicator	Acceptance limit	Result
	COC Documentation	All COC documentation to be completed and included within validation report.	COC documentation is included in Appendix F.
	Sample analysis and extraction holding times	An overall target of 100 % of samples analysed within recommended holding times.	All samples extracted within recommended holding times.
Completeness	Overall Completeness	95 %.	Overall it is considered that the target for 95 % overall completeness has been achieved on the basis that: - All samples collected were collected in accordance with the methodology outlined in the EMVP; standard sampling procedures were used and complied with; samples were collected by experienced samplers; and sampling documentation is correct. - Samples were analysed for the target analyte in accordance with the specified analytical method with appropriate LORs and analysed within the analyte specific holding times. - Sample documentation is complete. - Variation occurred with respect to the precision DQIs particularly in relation to the target RPD of 50 %. However, the variation is considered to reflect natural variability in the distribution of dioxin within the sediments. - The DQI of 50 % was achieved in the majority of the inter-laboratory samples. - Given the overall UCL_{95} concentration (39 pg/g I-TEQ), was well below the target of 60 pg/g I-TEQ, variability in the reported concentrations (as indicated by RPDs above 50 %), and that a conservative approach was adopted in calculating the UCL_{95} (calculated using the higher of the primary or field duplicate result) the is not considered to affect the quality of the data.

7.0 CONTAINMENT SITE 1 MONITORING

7.1 Overview

The following section provides a summary of the monitoring undertaken at CS1 as part of the remedial works programme. The monitoring programme comprised baseline soil and groundwater, groundwater during and post-sediment placement and post-closure soil sampling.

The pre-construction soil and groundwater monitoring is documented in detail in the 'Containment Site 1 (CS1) Environmental Monitoring' report (Golder 2019a) provided in Appendix I.

This section provides a summary of the key monitoring data. The monitoring locations are shown on Figure 19.

7.2 Monitoring Programme

The Consent includes conditions for the sampling of groundwater, soil and sediment prior to, during and post-construction and placement of sediment within the containment cell. The relevant conditions of the Consent that relate to both CS1 and CS3 are summarised in Table 9.

Conditions 36.4 and 36.7 of the Consent requires ongoing monitoring of groundwater levels and quality for the duration of the Consent. This report only includes monitoring data up to completion of the remedial dredging works and closure of CS1 and CS3.

Table 9: Relevant consent conditions for pre-construction soil sampling, groundwater monitoring, and perimeter drain sediment sampling (CS1 only).

Condition	Description
Groundwater Monitoring	
36.1	From the first deposit of contaminated sediments at each Containment Site authorised under this consent, the Consent Holder shall carry out groundwater monitoring at the containment site in accordance with conditions 36.2 to 36.9 of this consent.
36.2	Groundwater monitoring shall be undertaken at all of the locations described in the Groundwater Monitoring Programme referred to in condition 4.5 of this consent. As recommended by the Monitoring Programme, no monitoring is required at MW3.
36.4	The static groundwater level shall be measured at all monitoring locations at bi-monthly intervals from the first deposit of contaminated sediment and for the duration of the consent in accordance with the methods set out in the Groundwater Monitoring Programme referred to in condition 4.5 of this consent.
36.5	At least two background groundwater quality monitoring events shall be undertaken prior to the deposition of sediment in the containment sites in accordance with the methods set out in the Groundwater Monitoring Programme referred to in condition 4.5 of this consent and for the following parameters: a) pH; b) Electrical Conductivity (EC); c) Dissolved Oxygen (DO); d) Redox Potential (ORP);

Condition	Description
	e) Dissolved Metals (Heavy Metal Suite, As, Cd, Cr, Cu, Pb, Ni, Zn and Fe); f) Anion/Cat ion Profile (Ca, Mg, Na, K, Alkalinity, Bicarbonate, NO3, NO2, SO4, Cl); and g) Dioxins.
36.6	Ongoing groundwater quality monitoring shall be undertaken upon the first deposition of sediment in the containment sites in accordance with the methods set out in the Groundwater Monitoring Programme referred to in condition 4.5 of this consent and for the following parameters: a) pH; a) Electrical Conductivity (EC); h) Dissolved Oxygen (DO); i) Redox Potential (ORP); j) Dioxins.
36.7	Groundwater quality monitoring shall be undertaken at CS1 and CS2[5] following the deposition of contaminated sediment as follows: a) For the first 12 months following the first deposition of sediment in the containment sites (expected duration of the conditioning phase), sampling shall be undertaken at 3-monthly (i.e., quarterly) intervals; b) If, following the first 12 months of monitoring, results show that a dioxin concentration of 30 pg I- TEQ/L has not been exceeded, sampling shall continue at annual intervals for the remainder of the consent. c) In the event that any monitoring undertaken after 12 months produces a dioxin concentration of 30 pg I-TEQ/L or more, monitoring shall be undertaken at the frequencies referred to in conditions 36.7(a), until the dioxin concentration is equal to or less than 30 pg I-TEQ/L. Conditions 36.7d and 36.7e do not apply.
36.8	The Consent Holder shall carry out groundwater quality monitoring at CS3 from the first deposit of contaminated sediment at annual intervals, or until three consecutive monitoring results show that the dioxin concentration of groundwater is at or below 30 pg I-TEQ/L at which time groundwater quality monitoring at CS3 may cease.
36.9	If the groundwater quality Trigger Level 2 of 30 pg I-TEQ/L is exceeded at any of the containment sites a Corrective Action Plan shall be implemented. The Corrective Action Plan shall be detailed in the Environmental Monitoring Plan required by condition 4.5 and will include: a) Further investigation and sampling of the groundwater exceeding the trigger level; b) Possible installation of additional wells; c) Undertaking a risk assessment to determine whether the exceedance poses a risk to human health; d) Any risk assessment shall be carried out by an appropriately qualified expert. The Containment Site(s) shall be managed in accordance with the recommendations contained within the risk assessment.

[5] C2 was not constructed and the alternative site CS3 was used.

Condition	Description
Pre-construction Soil Sampling	
44.1	Prior to the deposition of contaminated sediment at the containment sites, the Consent Holder shall undertake background soil sampling at the containment sites in accordance with the methods set out in the Environmental Monitoring and Validation Plan (including the Soil Sampling Protocols of the Environmental Monitoring and Validation Plan) referred to in condition 4.5 of this consent for the following parameters: a) Dioxins (full congener analysis, - Polychlorinated dibenzo-p-dioxins (PCDDs), Polychlorinated dibenzofurans (PCDFs), reported as I-TEQ; b) Heavy Metals (As, Cd, Cr, Cu, Ni, Pb, Zn); c) Acid Herbicides (Screen); and d) Organochlorine Pesticides (Screen).
Perimeter Drain Sediment Sampling	
44.2	After the first placement of sediment in the CS1 containment cells, the Consent Holder shall undertake sediment sampling in the CS1 Perimeter Drain at the following locations: a) The mid-point of the northern cut-off drain; b) The mid-point of the eastern cut-off drain; c) The mid-point of the southern cut-off drain. A composite sample of locations a to c (above) shall be analysed to determine dioxin concentration. Samples shall be collected and analysed at three monthly intervals for the first two years following the placement of sediment in CS1.

Environmental assessment and monitoring works for CS1 were undertaken between August 2014 and March 2019. A summary of the various activities and timing for completion of monitoring events is presented in Table 10.

Table 10: CS1 monitoring dates.

Date	Groundwater sampling	Groundwater gauging	Perimeter drain sampling
20 August 2014	Monitoring wells installed.		
17 January 2017	X	X	
16 February 2017	X	X	
22 January 2018	Sediment placement started at CS1.		
15 February 2018			X
16 March 2018	X	X	
22 May 2018		X	X
14 June 2018	X	X	
25 July 2018		X	
13 August 2018			X

Date	Groundwater sampling	Groundwater gauging	Perimeter drain sampling
24 September 2018	X	X	
5 November 2018		X	X
12 December 2018	X	X	
19 December 2018	Sediment placement at CS1 completed.		
27 February 2019		X	X
27 and 28 March 2019	X	X	

7.3 Pre-construction Soil Sampling

Prior to the deposition of contaminated sediment at CS1, background soil sampling was undertaken across the area where CS1 would be constructed. Nine surficial soil samples were collected on 17 January 2017 in a grid across the site. The soil samples were composited into three composite samples comprising three discrete samples for laboratory analysis.

As required by condition 44.1 of the Consent, the samples were analysed for the following:

- Total recoverable metals/metalloids including arsenic, cadmium, chromium, copper, lead, nickel and zinc.
- Acid herbicides.
- Organochlorine pesticides.
- Dioxins.

Dioxin analysis was undertaken by AsureQuality. RJ Hill Laboratories Limited (Hills) was contracted to undertake the analysis for metals/metalloids, acid herbicides and OCPs. AsureQuality and Hills hold IANZ accreditation for the analysis undertaken.

The results of the baseline soil sampling are summarised in Table 11. Dioxin, as Total PCDD/F I-TEQ Upperbound was not reported above the laboratory LOR of 20 pg/g in each of the three composite samples. With respect to the individual congeners, OCDD was detected in each of the three composite samples at concentrations between 21 pg/g and 48 pg/g. All other congeners were not detected above the laboratory LORs.

LEGEND

- Groundwater monitoring well
- Monitoring well - decommissioned
- Site boundary
- Soil validation sample (GHD 2019)
- Perimeter drain sample

NOTES

1. Aerial: Eastern Bay Aerial Imaging, 7 January 2019.
2. Map image: © OpenStreetMap (and) contributors, CC-BY-SA Sourced from the LINZ Data Service and licensed for re-use under the Creative Commons Attribution 4.0 New Zealand licence Eagle Technology, LINZ
3. 2016 machine core hole position for monitoring wells is from a hand held GPS and is an estimate only.
4. Schematic only, not to be interpreted as an engineering design or construction drawing.
5. Soil validation samples based on GHD Figure 1 - Validation Sample Plan: CS1 Bulk Bag Storage and Water Treatment Area (Ref: 51-33279, Rev A).

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0 25 50
METRES

REFERENCE SCALE: 1:1,000 (at A3)

PROJECTION: NZGD 2000 New Zealand Transverse Mercator

CLIENT
ENVIRO (NZ) LIMITED

PROJECT
KOPEOPEO CANAL REMEDIATION

TITLE
CS1 - MONITORING LOCATIONS

CONSULTANT		
GOLDER	YYYY-MM-DD	2019-12-05
	PREPARED	AE
	REVIEW	AH
	APPROVED	AH

PROJECT NO.	REPORT	REV.	FIGURE
1894562	005	0	**19**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: A3
25mm

Table 11: Summary of pre-construction soil quality data at CS1.

Compound	Concentration range
Arsenic	5.0-8.0
Cadmium	0.13-0.15
Chromium	7-9
Copper	11-14
Lead	10.8-12.6
Nickel	5-7
Zinc	39-50
Herbicides	<LORs
OCPs	<LORs
Dioxins (Total PCDD/F I-TEQ)	20

Notes: Concentrations expressed as mg/kg dry weight except dioxin (pg/g).

7.4 Groundwater Quality

7.4.1 Sampling

During the design for the containment site and prior to the construction, six groundwater monitoring wells (MW01 to MW06) were installed at CS1 on 20 August 2014. Prior to the construction of CS1, on 20 March 2017, monitoring wells MW02 through MW06 were decommissioned, removed and backfilled with a cement bentonite grout. On 23 May 2017, monitoring wells MW02 through MW06 were re-installed within the vicinity of their previous locations, around the outside of the bunded CS1 area. Monitoring well MW03 was not re-installed due to it being located centrally within the area of the containment cell.

Groundwater sampling was completed across monitoring wells MW01 through MW06 on seven occasions between 17 January 2017 and 28 March 2019. Monitoring well MW03 was only gauged and sampled in January and February 2017.

Two sampling events were undertaken prior to the placement of sediment on 17 January 2017 and 16 February 2017. Sampling was then undertaken at a frequency of every three months after the start of placement of sediment in the containment site (Table 10).

7.4.2 Analytical results

Dioxins

Total PCDD/F I-TEQ – Upperbound concentrations ranged between 3.09 pg/L and 6.79 pg/L in the pre-construction monitoring rounds (Figure 20). Monitoring undertaken following completion of construction activities and placement of sediment detected dioxin concentrations ranging between 3.07 pg/L and 8.61 pg/L (Figure 20). Total PCDD/F I-TEQ – Upperbound concentrations in the pre- and post-sediment placement samples did not exceed the 30 pg/L I-TEQ trigger specified in the Consent (condition 36.7(b)).

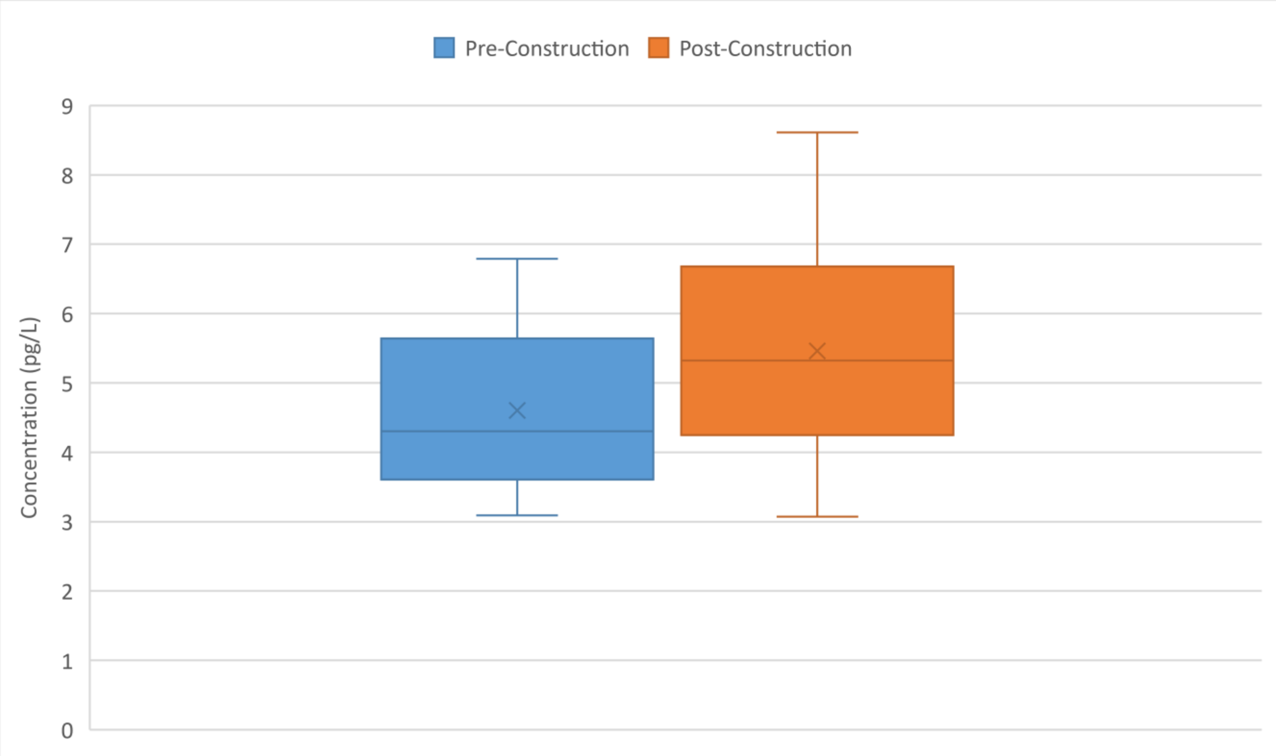

Figure 20: Comparison of pre- and post-construction CS1 groundwater dioxin (Total PCDD/F I-TEQ Upperbound) concentrations (data for all monitoring wells aggregated).

A limited range of individual dioxin congeners were detected in each of the monitoring wells sampled pre- and post-construction of CS1. OCDD was the predominant congener detected in each of the wells with the exception of MW4 where the 1234678-HpCDF and 1234678-HpCDD congeners were detected. Given the presence of dioxin congeners, and in particular the predominance of OCDD in each of the wells, these detections are likely to reflect a background or ambient source. This is also supported by the presence of higher OCDD higher concentrations in the pre-sediment placement sampling compared to the post-sediment placement data (Figure 21).

Metals/Metalloids and Cations/Anions

Groundwater quality samples collected prior to sediment placement were analysed for a suite of anions and cations and dissolved metals/metalloids. Full results are presented in the Containment Site 1 (CS1) Environmental Monitoring report (Golder 2019a) included in Appendix I.

Concentrations of dissolved metals/metalloids detected during the baseline groundwater sampling at CS1 are presented in Figure 22. A summary of the baseline groundwater geochemistry at CS1 is presented in Table 12.

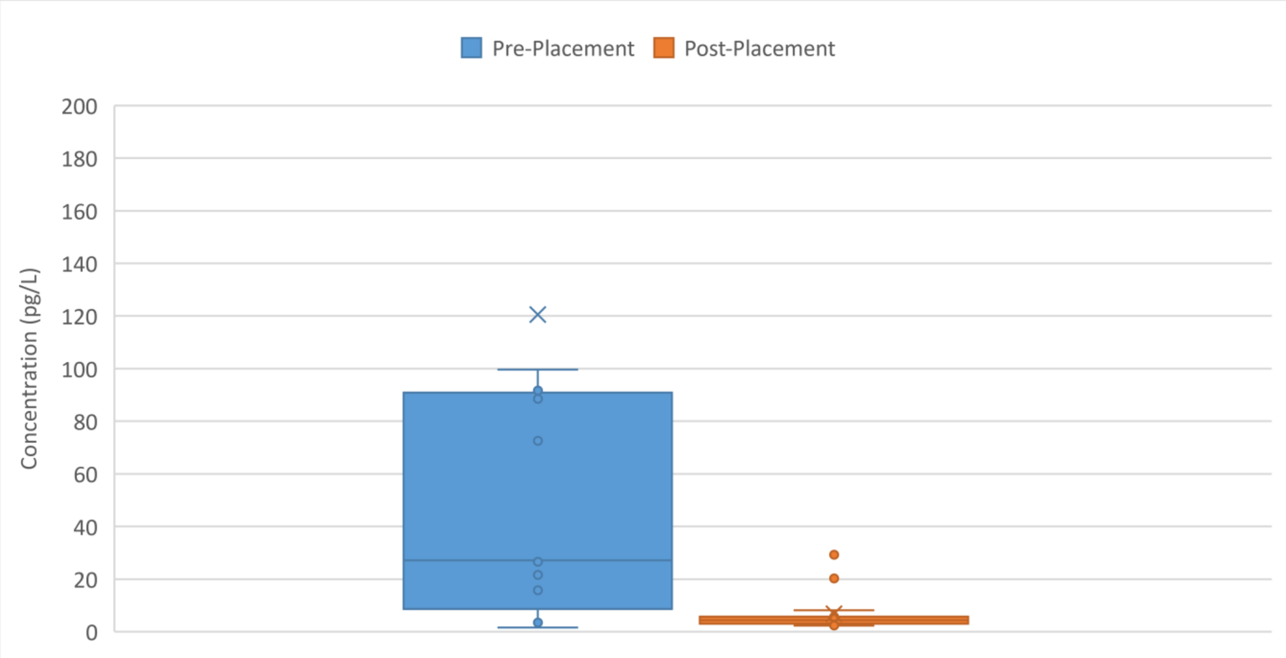

Figure 21: Comparison of pre- and post-construction CS1 groundwater OCDD concentrations (data for all monitoring wells aggregated). An outlier concentration of 991 pg/L at MW4 measured in February 2017 has been excluded for display purposes.

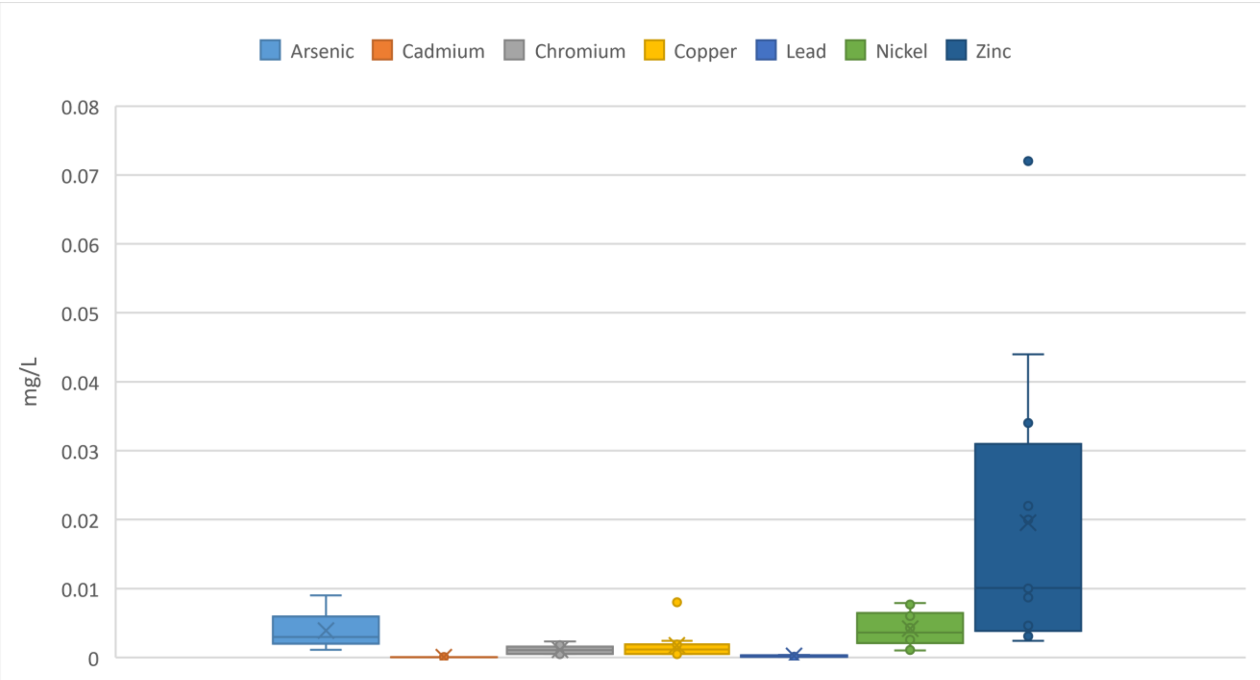

Figure 22: Baseline dissolved metals/metalloids in groundwater at CS1.

Table 12: Summary of baseline groundwater geochemistry at CS1.

Compound	Concentration range	Mean
Sum of Anions	3.3-16.3	8.4
Sum of Cations	3.3-15.3	8.0
pH	5.6-7.0	6.4
Total Alkalinity	52-198	105
Bicarbonate	63-240	128
Total Hardness	96-52	240
Electrical Conductivity	32.5-169.2	86
Calcium	14.7-79	45
Magnesium	13.3-85	31
Potassium	2.6-95	22
Sodium	30-107	60
Chloride	29-310	99
Nitrite-N	<0.02-0.006	0.005
Nitrate-N	<0.02-0.037	0.01
Sulfate	3.5-350	168

Notes: Concentrations expressed as mg/L except pH (pH units) and electrical conductivity (mS/m).

7.5 Perimeter Drain Sampling

After the first placement of sediment in the CS1 containment cells, sediment sampling within the CS1 Perimeter Drain was undertaken. Sediment samples were collected at three-monthly intervals at the following locations and analysed for dioxins by AsureQuality:

- The mid-point of the northern cut-off drain.
- The mid-point of the eastern cut-off drain.
- The mid-point of the southern cut-off drain.

The results from the five sampling events, undertaken between February 2018 and February 2019, indicated that there was no variability in dioxin concentrations within the CS1 perimeter drain samples. Total PCDD/F I-TEQ – Upperbound concentrations were reported at the laboratory LOR of 20 pg/g I-TEQ during each sampling round. Individual dioxin congeners were detected in May 2018 (OCDD (45 pg/g)), August 2018 (OCDD (29 pg/g)), and March 2019 (OCDD (25 pg/g)).

7.6 Post-closure Sampling

Soil validation sampling was undertaken at CS1 following completion of the sediment dredging works and decommissioning of plant as outlined in Section 14.2 of the EMVP (Golder 2017a).

Soil samples were collected from ground surfaces in area used for oversize bag storage and around the water treatment plant. The oversize bags were relocated into the lined containment cell prior to sampling. Samples were collected following the removal of surface soils to a depth of approximately 50 mm. The surface soils were removed using a machine excavator and placed into the containment cell.

Three samples (CS1_VAL_03, CS1_VAL_04 and CS1_VAL_05) were collected from the oversize bag storage area in the south of CS1 (adjacent to Kope Drain Road). Two samples were collected from the water treatment plant area (CS1_VAL_01 and CS1_VAL_02). One duplicate sample (CS1_DUPE) was collected from a sample location in the oversize bag storage area (CS1_VAL_04). The sample locations are shown on Figure 19.

The samples were collected on 10 June 2019 by a GHD Environmental Scientist at the request of BoPRC. Samples were submitted to AsureQuality in Wellington and analysed for dioxins. The laboratory analytical reports are reproduced in Appendix F.

Dioxin, as Total PCDD/F I-TEQ Upperbound, were reported at the laboratory LOR of 20 pg/g in four of the six samples (Table 13). The further two samples were reported with Total PCDD/F I-TEQ Upperbound concentrations of 21 pg/g. A range of individual dioxin congeners were detected in each of the samples with the exception of sample CS1_VAL_01.

Table 13: Dioxin concentrations in additional samples collected at CS1.

Sample ID	Laboratory reference	Location	Dioxin (as Total PCDD/F I-TEQ Upperbound)	Dioxin congeners detected (concentration)
CS1_VAL_01	19/1067-1	Water Treatment Plant	20	-
CS1_VAL_02	19/1067-2	Water Treatment Plant	21	1234678-HpCDD (47) OCDF (24) OCDD (530)
CS1_VAL_03	19/1067-3	Oversize Bag Storage	20	OCDD (67)
CS1_VAL_04	19/1067-4	Oversize Bag Storage	20	1234678-HpCDD (26) OCDF (24) OCDD (240)
CS1_DUPE (Duplicate of VAL_04)	19/1067-5	Oversize Bag Storage	21	1234678-HpCDD (30) OCDF (26) OCDD (290)
CS1_VAL_05	19/1067-6	Oversize Bag Storage	20	OCDD (33)

Notes: Concentrations expressed as pg/g.

7.7 Air Dioxin Air Quality Monitoring

Condition 39 of the Consent required air quality monitoring for dioxins. Specifically, condition 39.1(a) required the collection of three air quality samples during the initial phase of depositing sediment within the geotextile bags at the first containment site to be filled. Given this, air quality monitoring was undertaken during the placement of sediment at CS1.

Source Testing New Zealand Limited (STNZ) was commissioned by BoPRC to undertake ambient air dioxin quality monitoring. Ambient air dioxin monitoring was carried out over the period 8 March to 20 April 2018. STNZ prepared a report, included in Appendix J, documenting the ambient dioxin sampling methodology, the monitoring site and the results of the air quality monitoring.

STNZ (2018) reported the following ambient air dioxin results[6] for three monitoring events between 8 March 2018 and 20 April 2018:

- 12.4 fg/m^3 Total I-TEQ Upper Bound for the period 8 March to 22 March 2018.
- 5.89 fg/m^3 Total I-TEQ Upper Bound for the period 22 March 2018 to 5 April 2018.
- 9.42 fg/m^3 Total I-TEQ Upper Bound for the period 5 April to 20 April 2018.

The reported concentrations are below the dioxin concentration trigger of 0.03 pg/m^3 I-TEQ (30 fg/m^3).

7.8 Discharge Water Quality Monitoring

Condition 12.1 of the Consent provided for filtrate and stormwater that accumulated on the liners within the containment sites to be discharged to Kopeopeo Canal subject to the discharge water meeting the water quality standards set out in condition 12.3 (including via a turbidity or Total Suspended Solids (TSS) proxy as per condition 12.8).

Turbidity monitoring was undertaken at seven locations within the Kopeopeo Canal remediation area, one location upstream of the western control structure adjacent to the SH30 bridge, and two locations within Orini Canal. Monitoring was undertaken by the Principal using real-time monitors. As outlined in the Independent Monitor reports (e.g., GHD 2018a, 2018b, 2019), no exceedances of the triggers associated with the discharges from the containment sites occurred for the duration of the sediment remediation and dredging works.

[6] Ambient air dioxin concentrations reported in units of femtogram per cubic metre (fg/m^3); 1 picogram (pg) equals 1,000 femtograms (fg).

8.0 CONTAINMENT SITE 3 MONITORING

8.1 Overview

The following section provides a summary of the monitoring undertaken at CS3 as part of the remedial works programme. The monitoring programme comprised baseline soil and groundwater, groundwater during and post-sediment placement and post-closure soil sampling.

The pre-construction soil and groundwater monitoring is documented in detail the 'Containment Site 3 (CS3) Pre-Construction Soil and Groundwater Monitoring' report (Golder 2019b) included in Appendix K. Environmental monitoring undertaken following commencement of sediment placement is presented in the following sections. The monitoring locations are shown on Figure 23.

8.2 Monitoring Programme

The Consent includes conditions for the sampling of groundwater, soil and sediment prior to, during and post-construction and placement of sediment within the containment cell. The relevant conditions of the Consent that relate to CS3, and addressed by this report, are summarised in Table 9 (refer Section 7.2).

8.3 Pre-construction Soil Quality

Soil sampling was undertaken at CS3 during the initial stages of construction on 17 and 23 April 2018. One of the composite samples was collected from surface (0.0-0.1 m bgl), with the other four composite samples collected from the base of constructed lateral drains at a depth of 0.3-0.4 m bgl. The results of the baseline soil sampling are summarised in Table 14.

Table 14: Summary of pre-construction soil quality data at CS3.

Compound	Concentration range
Arsenic	2.8-6.1
Cadmium	<0.4
Chromium	6.5-11
Copper	9.6-19
Lead	16-48
Nickel	<5-7.8
Zinc	37-140
Herbicides	<LORs
OCPs	<LORs
Dioxins (Total PCDD/F I-TEQ)	21-52

Notes: Concentrations expressed as mg/kg dry weight except dioxin (pg/g).

LEGEND

- CS3 Area
- Soil sample locations
- Monitoring well
- Composite 1A 17 April
- Composite 1A 23 April
- Composite 2A 17 April
- Composite 2A 23 April
- Composite 3A 17 April
- Canal outline
- Pump station

NOTES

1. Aerial: LINZ and Eagle Technology, CC-BY-3.0-NZ.
2. Map image: © OpenStreetMap (and) contributors, CC-BY-SA Sourced from the LINZ Data Service and licensed for re-use under the Creative Commons Attribution 4.0 New Zealand licence
3. Based on Golder Report figure 1660799-006-R-F002-RevA.
4. Schematic only, not to be interpreted as an engineering design or construction drawing.

0 50 100 METRES

REFERENCE SCALE: 1:1,600 (at A3)

PROJECTION: NZGD 2000 New Zealand Transverse Mercator

CLIENT
ENVIRO (NZ) LIMITED

PROJECT
KOPEOPEO CANAL REMEDIATION

TITLE
CS3 LOCATION AND SITE LAYOUT

CONSULTANT		
GOLDER	YYYY-MM-DD	2019-12-05
	PREPARED	AE
	REVIEW	AE
	APPROVED	ST

PROJECT NO.	REPORT	REV.	FIGURE
1894562	005	0	23

The variation in Total PCDD/F I-TEQ concentrations reflects the detection of a range of individual dioxin congeners (primarily hepta- and octa-congeners) in each of the five composite samples. The detected concentrations of Total PCDD/F I-TEQ were below the soil contaminant standard (SCS_{health}) of 600 pg/g[7] for a recreational land use exposure scenario previously adopted as part of the Kopeopeo Canal Remediation Project (GHD 2019).

8.4 Groundwater Quality

Two rounds of pre-construction groundwater sampling were completed across monitoring wells MW301 through MW307 (noting MW303 does not exist) in June 2018 and July 2018. The results of the pre-construction monitoring are presented in Golder (2019b) (included in Appendix K).

Groundwater monitoring was also undertaken in February 2019, June 2019 and August 2019 following commencement of placement of sediment at CS3. Data collected during these three monitoring events is presented in this report along with the pre-construction monitoring data.

Groundwater gauging and sampling between February and August 2019 was undertaken using the same methodology as for the pre-construction monitoring as documented in the pre-construction monitoring report (Golder 2019b). Field sampling sheets, laboratory reports and the full dataset of groundwater quality parameters are presented in Appendix L.

The network of groundwater monitoring wells was gauged on five separate events between June 2018 and August 2019. Groundwater elevations measured during this period are shown on Figure 24. Groundwater elevations are presented with respect to the Moturiki vertical datum as surveyed in August 2018 (Golder 2019b).

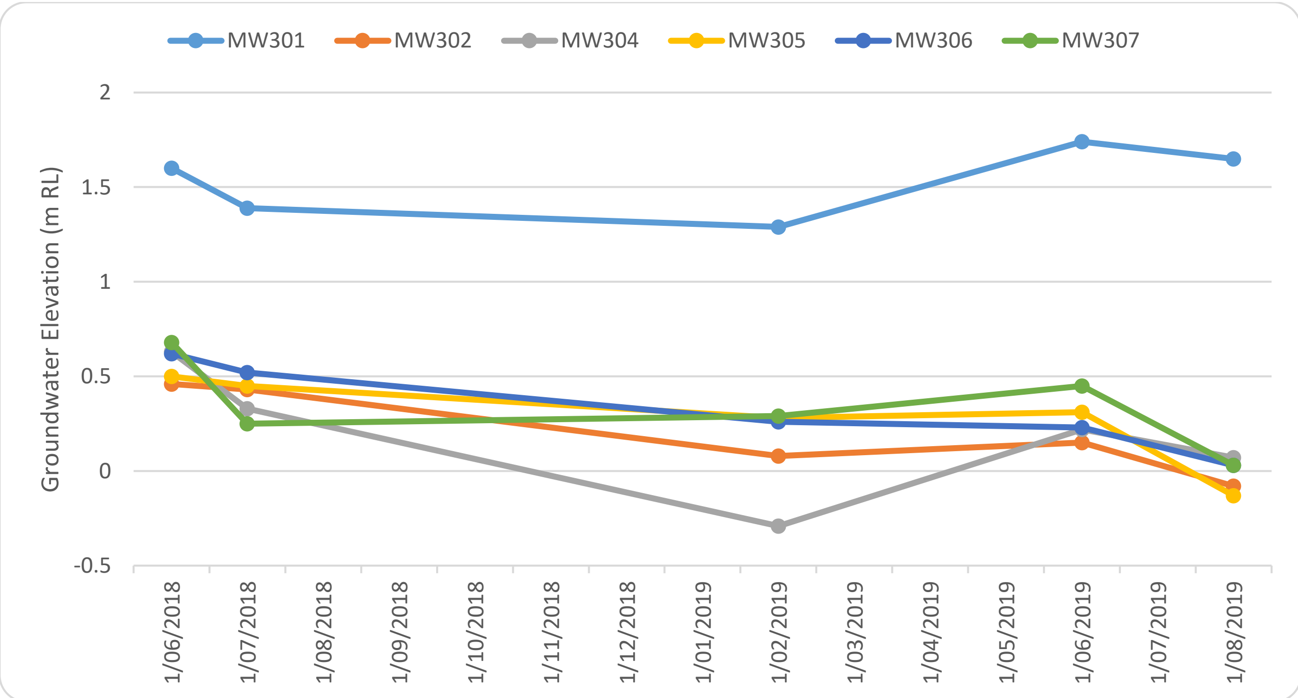

Figure 24: Groundwater elevations at CS3 between June 2018 and August 2019.

[7] It is noted that the SCS_{health} of 600 pg/g is based on the toxic equivalency to 2,3,7,8-TCDD using the World Health Organization toxic equivalency factors.

Groundwater quality parameters were measured during groundwater sampling (Table L1 (Appendix L)). Comparison of the data indicated measured field parameters were similar between the pre- and post-sediment placement monitoring (Table 15).

Table 15: Summary of groundwater field parameters measured pre- and post-sediment placement.

Field parameters		Pre-sediment placement	Post-sediment placement
pH	Minimum	5.86	5.83
	Maximum	6.49	6.65
Conductivity (µS/cm)	Minimum	724	722
	Maximum	15,014	12,295
Redox potential (mV)	Minimum	-58	-98
	Maximum	148	76
Dissolved oxygen (mg/L)	Minimum	0.2	0.21
	Maximum	2.0	0.59
Temperature (°C)	Minimum	13.8	13.5
	Maximum	16.4	24.8

Notes: µS/cm = microsiemens per centimetre. mV = millivolt. mg/L = milligrams per litre. °C = degrees Celsius

Groundwater samples were collected for laboratory analysis as follows:

- Dioxins (all monitoring rounds).
- A suite of dissolved metals/metalloids and major anions and cations (pre-construction samples only).

Dioxin analysis was undertaken by AsureQuality. Hills was contracted to undertake the analysis for dissolved metals/metalloids and the cation/anion suite.

Dioxins, as Total PCDD/F I-TEQ Upperbound were reported between 4.11 pg/L and 10.6 pg/L prior to sediment placement and between 3.74 pg/L and 8.3 pg/L following commencement of sediment placement at CS3 (Figure 25). Total PCDD/F I-TEQ – Upperbound concentrations in the pre- and post-sediment placement samples did not exceed the 30 pg/L I-TEQ trigger specified in the Consent (condition 36.7(b)).

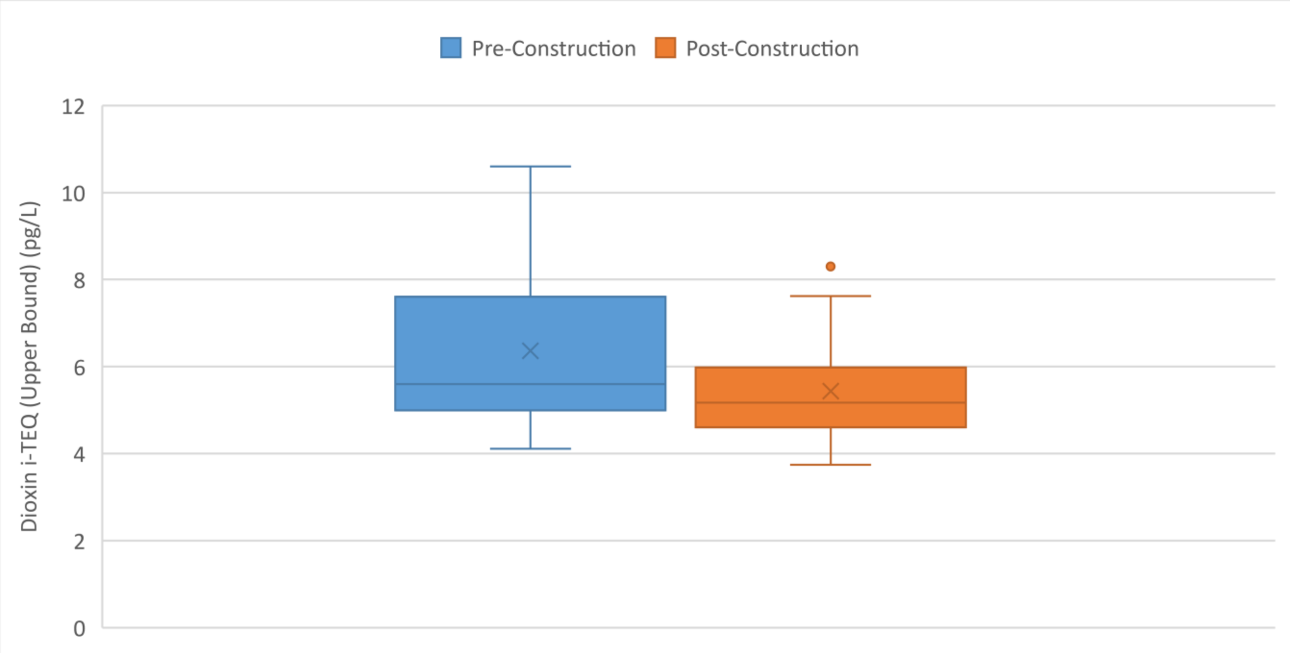

Figure 25: Comparison of pre- and post-construction CS3 groundwater dioxin concentrations (data for all monitoring wells aggregated).

The variation in the Total PCDD/F I-TEQ Upperbound reflects differences in the laboratory LORs for individual dioxin congeners between each monitoring round and differing concentrations of individual dioxin congeners (where detected). Individual dioxin congeners, where detected, primarily comprised hepta- and octa-dioxin congeners.

Dissolved iron was detected in each of the CS3 monitoring wells. A range of dissolved metals/metalloids were detected above the laboratory LORs in monitoring wells MW301 and MW305, and to a lesser degree in MW307 during both pre-construction monitoring rounds. Dissolved metals/metalloids were generally consistent in each of the six monitoring wells across the two monitoring rounds (Figure 26).

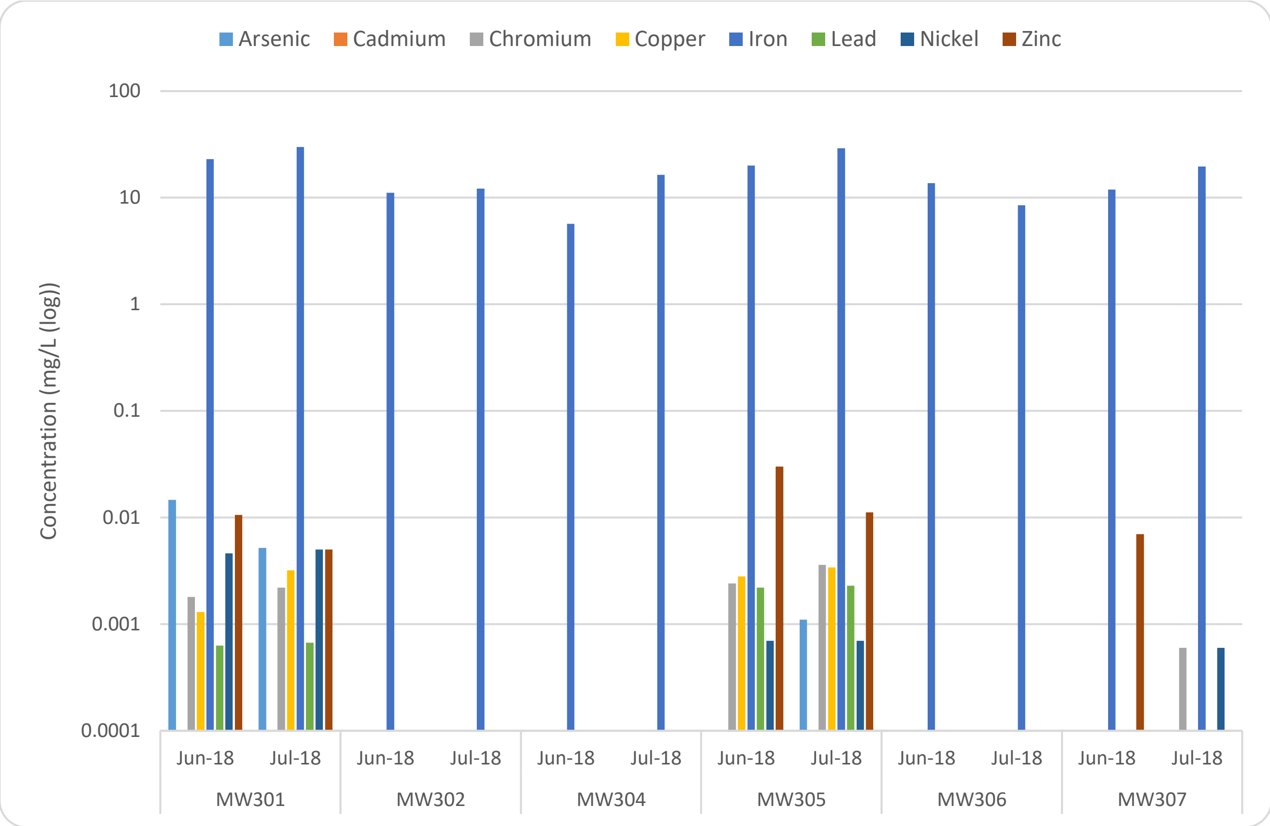

Figure 26: Pre-construction dissolved metal/metalloid concentrations in groundwater at CS3. Data only shown where concentrations reported above laboratory LORs.

8.5 Additional Soil Sampling

8.5.1 Overview

Additional sampling was undertaken at CS3 during and following completion of the sediment placement works as outlined in Section 14.2 of the EMVP (Golder 2017a). The following sections document the results of soil sampling following a spillage of oversize material from the shakers (Section 8.5.2) and following decommissioning of plant at CS3 (Section 8.5.3).

8.5.2 Spillage from shakers

Soil samples were collected at CS3 on 20 May 2019 following a spillage of material from the shakers (Figure 27). Samples were collected by a Golder contaminated land consultant in conjunction with Enviro NZ as follows:

- Five samples were collected from the oversized bags (327, 291, 316, 317 and 323). The five individual samples were composited into a single sample ('Composite') at the laboratory for analysis.
- Three samples were collected from the operational areas where the spillage flowed including behind mobile plant (SS1), near the corner of the liner in the area of the main flow of the spillage (SS2), and in the lowest point in the swale (SS3).
- One sample was collected from the main driveway area (SS4).
- One sample was collected from the shaker chute of the current oversize material (shakers).

The samples were submitted by BoPRC to AsureQuality in Wellington and analysed for dioxins. The laboratory analytical reports are reproduced in Appendix E.

Dioxin concentrations ranged between 20 pg/g and 25 pg/g I-TEQ in the four samples collected from ground surfaces in the area of the spillage (Table 13). This compared to concentrations of 150 pg/g I-TEQ detected in the two samples of oversize material. The detected concentrations of Total PCDD/F I-TEQ were below the SCS_{health} of 600 pg/g for a recreational land use exposure scenario previously adopted as part of the Kopeopeo Canal Remediation Project (GHD 2019).

Table 16: Dioxin concentrations in additional soil samples collected at CS3.

Sample reference	Laboratory reference	Dioxin	Location
Shaker Spillage			
SS1-200519	19-116985-1	22	Behind mobile plant.
SS2-200519	19-116985-2	21	Corner of liner – main flow area.
SS3-200519	19-116985-3	20	Low point of swale.
SS4-200519	19-116985-4	25	Main driveway area.
Shakers-200519	19-116982-1	150	Shaker chute of the current oversize material.
Composite	19-116986-1	150	Oversize material in bags 327, 291, 316, 317 and 323.
Post-Closure			
S1-CS3-WTA	19-211799-1	20	Water treatment area.
S2-CS3-WTA	19-211799-2	20	

Notes: Concentrations expressed as pg/g Total PCDD/F I-TEQ Upperbound.

8.5.3 Post-closure sampling

Soil validation sampling was undertaken at CS3 following completion of the sediment dredging works and decommissioning of plant. Soil samples were collected from ground surfaces in area beneath the water treatment plant.

Two samples (S1-CS3-WTA and S2-CS3-WTA) were collected from the oversize bag storage area in the south of CS1 (adjacent to Kope Drain Road). The sample locations are shown on Figure 25.

The samples were collected on 9 September 2019 by Enviro NZ. Samples were submitted by BoPRC to AsureQuality in Wellington and analysed for dioxins. The laboratory analytical reports are reproduced in Appendix F.

Dioxins, as Total PCDD/F I-TEQ Upperbound, were reported at the laboratory LOR of 20 pg/g I-TEQ (Table 16). The detected concentrations of Total PCDD/F I-TEQ were below the SCS_{health} of 600 pg/g for a recreational land use exposure scenario previously adopted as part of the Kopeopeo Canal Remediation Project (GHD 2019).

LEGEND

- CS3 boundary
- Spillage soil validation sample
- Water treatment plant validation sample

NOTES

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0 20 40 METRES

REFERENCE SCALE: 1:700 (at A3)

PROJECTION: NZGD 2000 New Zealand Transverse Mercator

CLIENT
ENVIRO (NZ) LIMITED

PROJECT
KOPEOPEO CANAL REMEDIATION

TITLE
CS3 SOIL VALIDATION SAMPLES

CONSULTANT

GOLDER

YYYY-MM-DD	2019-12-05
PREPARED	AE
REVIEW	CV
APPROVED	AH

PROJECT NO.	REPORT	REV.	FIGURE
1894562	005	0	27

9.0 CONCEPTUAL SITE MODEL

9.1 Overview

The Kopeopeo Canal Remediation Project involved the dredging of dioxin contaminated sediment from a 5.1 km length of the canal between SH30 in the west and the confluence with Orini Stream in the east. Dredged sediment was transferred to two purpose-built containment sites for storage and bioremediation. The remediation works were undertaken under resource consent (Consent Number: 67173) issued by BoPRC.

This section presents an updated CSM including a revised evaluation of the source-pathway-receptor linkages for Kopeopeo Canal following completion of the sediment dredging and containment remedial programme. The following sections present an overview of the pre-remedial condition of the canal, a summary of the remedial dredging and containment works, an assessment of the post-remedial conditions and a re-evaluation of potential risks from residual contamination.

9.2 Pre-remedial Condition of Kopeopeo Canal

The sediment remediation was undertaken to mitigate risks associated with the presence of dioxin contaminated sediment within Kopeopeo Canal. The source of the contamination has been linked to historical stormwater discharges from the local timber treatment plant which formerly used dioxin contaminated PCP for timber treatment.

Previous investigations (BoPRC 2005a, 2005b; SKM 2006a; T&T 2015) documented the pre-remedial condition of Kopeopeo Canal comprised:

- Sediment dioxin concentrations ranging between 12 pg/g WHO-TEQ and 2,300 pg/g WHO-TEQ (BoPRC 2005b) and 0.17 pg/g I-TEQ to 1,950 pg/g I-TEQ (SKM 2006a) with the most elevated concentrations found close by to the stormwater outfall (BoPRC 2005b).
- Concentrations of dioxins within sediments in the remediation area ranged between 0.17 pg/g I-TEQ to 1,950 pg/g I-TEQ (SKM 2006a). Eel tissue concentrations ranged between 0.11 pg/g WHO-TEQ and 3.56 pg/g WHO-TEQ (BoPRC 2005b) and 0.016 pg/g I-TEQ to 0.344 pg/g I-TEQ (SKM 2006a). Dioxin concentrations in eel tissue were generally higher in the eastern reaches of the canal and also reduced with distance from the outfall.

9.3 Sediment Dredging and Containment

The remedial dredging was undertaken with a barge mounted excavator fitted with a cutter suction head and Dragflow® sludge pump mounted to the dipper arm. The dredged sediment was transferred via a slurry pipe to one of two containment sites (CS1 and CS3). At each containment site, the sediment was screened to remove oversize material and dosed with flocculant. Once screened and treated, the sediment was transferred to Geotube® bags located within the designated containment sites. The Geotube® bags allowed for the sediment to be dewatered prior to the sediments being inoculated for bioremediation.

The sediment remediation was undertaken in seven sections along of the canal defined by the presence of structures crossing the canal. The sections and the associated sediment containment locations comprised the following:

- Sections 1 to 5 comprised the canal remediation zone between SH30 in the west and the wastewater pipeline across the canal at Chainage 2800. Sediment within these sections was dredged and transferred to CS1. CS1 is located on the northern side of the canal at the intersection of SH30 and Kope Drain Road.

- Sections 6 and 7 of the canal remediation zone comprised the area between the wastewater pipeline at Chainage 2800 and the end of Kopeopeo Canal at the confluence with Orini Canal. Dredging activities within Section 7 also included the pump channel on the true right bank of Kopeopeo Canal at Chainage 4170. Sediment within these sections was dredged and transferred to CS3. CS3 is located on a narrow peninsula of land lying between Kopeopeo Canal and the Whakatane River at the eastern end of the remediation area.

Sediment dredging was undertaken between January 2018 and July 2019. Section 1 was dredged between January 2018 and December 2018 with Section 2 dredged between January 2019 and July 2019.

Sediment volumes removed from the canal have been calculated from hydrographic surveys of the canal and geo-processing of images captured from drone flight images undertaken pre- and post-filling of the Geotube® bags and oversize bags.

Based on the processed data, a total of 35,707 m^3 of sediment was dredged and placed into the Geotube® bags. This comprises 25,707 m^3 of sediment at CS1 and 10,000 m^3 at CS3. Analysis of the pre- and post-hydrographic survey data yielded a dredged sediment volume 34,465 $m^{3.}$

In addition to the sediment contained within the Geotube® bags, the dredging also removed an additional 1,608 m^3 of oversize material stored separately to the Geotube® bags. This comprised approximately 1,018 m^3 at CS1 and 590 m^3 at CS3.

Remedial dredging was undertaken within the dredge corridor which comprised a nominal 20 m width along the length of the canal. Dredging was undertaken to an agreed survey level (-0.2 m RL based on the Moturiki Vertical Datum (MVD)) and by feel controlled by the presence of marine sediments and clays which are more compact compared to the sediment targeted for remediation. Dredging was constrained/limited by the following:

- The edges of the canal outside the dredge corridor due to the potential to compromise the integrity of the stopbanks along the edge of the canal.
- The bridge abutments at the Paroa Road bridge at Chainage 1200.
- The bridge abutments of the SH30 bridge at Chainage 1870 to 1880.
- The entrance to a small canal connecting the Kopeopeo Canal to the Whakatane River via a pump station. The canal is located along the southern side of CS3 at Chainage 4160.
- The bridge abutments of the Keepa Road bridge at Chainage 3980.

9.4 Assessment of Post-remedial Condition

9.4.1 Kopeopeo Canal

Validation of the remedial dredging was undertaken sequentially following completion of dredging works within discrete lengths of the canal. Validation was undertaken based on the methodology prescribed in the EMVP (Golder 2017a) and comprised:

- A visual inspection of residual canal base sediments to evaluate the composition and thickness of residual canal base sediment following completion of the dredging works.
- Collection of sediment validation samples from residual canal base sediments. Samples were collected from the upper 100 mm of recovered sediment core and submitted to AsureQuality for dioxin analysis.

- Sediment validation was undertaken in a staged manner in accordance with the EMVP (Golder 2017a). This involved re-dredging of subsections of the canal where sediment dioxin concentrations were such that the remedial criteria were not achieved. Additional sediment validation samples were collected for analysis from re-dredged areas to evaluate residual canal sediment concentrations.

Sediment concentrations were used to assess whether the dredging was successfully removing dioxin contaminated sediment to a level where the remedial criterion (UCL_{95} of 60 pg/g I-TEQ) was being achieved. During the initial stages of the remedial dredging works, Phase 1 validation was considered to be satisfied where each individual sample was below 60 pg/g I-TEQ. Where sediment concentrations exceeded 60 pg/g I-TEQ, the area was re-dredged and subjected to further sampling under the Phase 2 validation methodology.

In May 2019, the Consent Authority provided clarification regarding interpretation and use of the UCL_{95}. The clarification referred to the application of a UCL_{95} as outlined in MfE (2011b) guidance in that "*the result will be acceptable if the 95% upper confidence limit is at or below the guideline, provided no result is more than twice the guideline value*". The implication of this clarification was that the sediment remediation was achieved where the sediment dioxin concentration UCL_{95} is at or below 60 pg/g I-TEQ and no individual concentration exceeded 120 pg/g I-TEQ.

Based on this clarification to the validation criteria, Phase 1 validation was considered to be satisfied where the rolling UCL_{95} was at or below 60 pg/g I-TEQ and no individual concentration exceeded 120 pg/g I-TEQ. Additional dredging and validation sampling (Phase 2 and Phase 3 validation) was only undertaken where individual concentrations exceeding 120 pg/g I-TEQ were detected during the Phase 1 validation.

The overall UCL_{95} for sediment dioxin was calculated based on a total of 213 samples considered representative of residual sediment quality and suitable for calculating the UCL_{95}. Concentrations in the samples used to calculate the UCL_{95} ranged between 20 pg/g I-TEQ and 160 pg/g I-TEQ with an average concentration of 37 pg/g I-TEQ. The calculated UCL_{95} for the data set is **39 pg/g I-TEQ**.

One sample (KC084e2) reported a concentration (160 pg/g) exceeding the 120 pg/g I-TEQ maximum. The sample was collected from the upstream side of the wastewater pipe at Chainage 2800. While the reported concentration does not strictly satisfy the remedial criterion of no concentration exceeding 120 pg/g I-TEQ, it is considered that the area was remediated to the extent practicable given the following:

- The area was dredged on three separate occasions with the dredge operator noting that the area had been dredged to a hard base.
- Cores recovered during the validation sampling showed no visible evidence of the target material remaining.
- Further assessment was undertaken by the Independent Monitor using multiple push tube cores following the third dredging phase. The Independent Monitor concurred that the area had been remediated to the extent practicable and there was no visible evidence of target material remaining.

9.4.2 Containment sites

In addition to the sediment validation, monitoring was undertaken at CS1 and CS3 in accordance with the Consent to assess potential impacts from the placement and storage of the dioxin contaminated sediment within the containment sites.

Monitoring of pre- and post-placement soil and groundwater quality at CS1 and CS3, and sediment in perimeter drains at CS1 did not identify a material change in dioxin concentrations. Monitoring of discharge water quality did not identify exceedances of the triggers associated with the discharges from the containment sites occurred for the duration of the sediment remediation and dredging works.

On this basis it is considered that placement of the sediment in the containment cells has not impacted soil and groundwater quality at CS1 and CS3 during and up to completion of the sediment dredging and containment phase of the remedial project.

9.4.3 Summary

Overall, the validation undertaken during the project has documented that the Kopeopeo Canal remedial area has been successfully remediated to a standard that satisfies the remedial criteria. Specifically, sediment dioxin concentrations in the residual canal base sediments post-dredging have a UCL_{95} of 39 pg/g I-TEQ and with the exception of one sample, sediment dioxin concentrations were below 120 pg/g I-TEQ. Based on further assessment of residual sediment conditions in the area of this exceedance, and in consultation with the Independent Monitor, it is considered that the area was remediated to the extent practicable.

9.5 Assessment of Source-Pathway-Receptor Linkages

For a risk to a receptor to occur, a complete pathway must exist between the source of contamination and the receptor. Where the contaminant pathway is incomplete, there is no exposure and hence no risk via that pathway. Based on the potential contaminant sources, and in consideration of the pathways and receptors present at the site and surrounding land, the potential CSM linkages are presented in Table 17.

Based on the assessment, it is considered that the majority of the pathways with respect to exposure to dioxins are incomplete based on the remediation works completed and the ongoing management controls to eliminate exposure. Where the pathway was considered incomplete, the exposure was also considered incomplete. The presence of residual dioxin concentrations within the canal sediment and within the soils along the stopbanks of Kopeopeo Canal has been identified as a potentially complete pathway. Where the pathway was considered potentially complete, the risk associated with the exposure pathway was assessed to be low, however, in some cases, it is recognised that there is limited data to confirm this (long-term update by eels) or formal management is required (stopbank soils).

Table 17: Revised CSM following completion of sediment removal from Kopeopeo Canal.

Source	Media	Exposure mode	Receptor	Commentary
Historical stormwater discharges containing dioxin	Sediment	Eel consumption	Human Health	■ Validation sampling has documented that the remedial works have reduced canal bed sediments dioxin concentrations below the risk-based remedial criteria considered to be protective of eel consumption and dermal contact (SKM 2006b). ■ Eel population to be re-established in Kopeopeo Canal. Ongoing monitoring to be undertaken (as per condition 25.6 of Consent) to assess potential exposure risks from uptake of residual dioxin in canal sediment.
		Dermal Contact	Human Health	
		Uptake by Biota	Eels	
	Soil	Dermal Contact	Human Health	■ Previous sampling has documented the presence of dioxin contamination of stopbanks. While there is likely to be a low risk given the exposure would be limited given the physical setting of the stopbanks, ongoing management is required to ensure risks to the public are mitigated.
Containment of contaminated media at CS1 and CS3	Sediment	Dermal Contact	Human Health	■ Dioxin contaminated sediment stored in Geotube® bags located in purpose built lined containment sites. Inoculation of the sediment during placement was undertaken to facilitate bioremediation of the dioxin contaminated sediment. ■ Monitoring of groundwater (CS1 and CS3) and perimeter drain (CS1) during placement of sediment has not identified the presence of dioxin contamination associated with the placement of sediment. Further monitoring of groundwater is required under condition 36 of the Consent. ■ Geotube® bags covered by soil as part of completion of sediment dredging and containment phase of Kopeopeo Canal Remediation Project. Soil covering provides a barrier to direct exposure to sediment stored at containment sites. ■ Presence of dioxin contaminated sediment within the Geotube® bags at CS1 and CS3 requires implementation of management controls to ensure the long-term integrity of the containment sites.
	Soil	Dermal Contact	Human Health	
	Groundwater	Discharge to aquatic ecosystems (Kopeopeo Canal)	Contact Recreation	
			Ecosystem health	
		Uptake by Biota	Eels	

Pathway Incomplete Pathway Partially Complete Pathway Complete

9.6 Future Monitoring and Management

The sediment removal and containment, and associated validation of residual canal base sediments, represents one element of the overall approach to achieving the human heath objectives for the Project. The sediment dredging and containment works comprises the first stage of the overall Kopeopeo Canal Remediation Project. Further work as part of the Kopeopeo Canal Remediation Project includes:

- Containment of sediment provided for the sediment to be inoculated to facilitate bioremediation within the Geotube® bags as part of the next phase of the project. Given the anticipated timeframe (up to 15 years) for the bioremediation (Anderson and Kelly 2012), ongoing management and monitoring is required. This is considered to include:
  - groundwater monitoring at CS1 and CS3 as required under condition 36 of the Consent for the purpose of monitoring that the storage of dioxin contaminated sediment is not resulting in the discharge of contaminants to the environment; and
  - implementation of management controls to ensure that the integrity of the containment sites is maintained for the duration of the bioremediation phase and long term once the remediation target (UCL_{95} of 40 pg/g I-TEQ for Total PCDD/F I-TEQ – Upperbound as defined by condition 24 of the Consent) has been achieved.
- A primary driver for the remediation works was to mitigate risks to human health via the consumption of dioxin contaminated eels harvested from Kopeopeo Canal. Eels (along with other fish species) were removed from Kopeopeo Canal prior to the remedial dredging works. Given the dredging works have been completed and the control structure removed, re-population of the canal will occur over time. Given the presence of residual dioxin concentrations within canal sediments, further monitoring (in the form of eel tissue sampling or passive samplers within the water column) is to be undertaken, as per condition 25.6 of the Consent to evaluate exposure and uptake of dioxins by the re-established eel population.

10.0 SUMMARY

BoPRC has undertaken a programme of remedial works to remove dioxin contaminated sediment along a 5.1 km stretch of the canal, between SH30 (at the intersection with Kope Drain Road) and the confluence with the Orini Stream. The primary driver for the remediation works was to address unacceptable risks to human health, primarily via the consumption of dioxin contaminated eel tissue harvested from the canal, associated with the presence of dioxins within Kopeopeo Canal.

The remedial project comprised the dredging of dioxin contaminated sediments from the canal and containment of dredged sediment in Geotube® bags at two purpose-built containment sites (CS1 and CS3). The containment sites provide for long-term containment and bioremediation of the dredged sediment.

The sediment dredging and containment was undertaken to the extent practicable and to achieve the remedial criterion for in-situ canal sediments. The dioxin sediment remedial criterion was defined as the UCL_{95} for dioxin (as Total PCDD/F I-TEQ – Upperbound) being equal to or below 60 pg/g I- TEQ with no individual concentration exceeded 120 pg/g I-TEQ.

The key elements of the sediment dredging and containment remedial programme are summarised as follows:

- Sediment dredging was undertaken between January 2018 and July 2019. Sections 1 to 5 were dredged between January 2018 and December 2018 with this material transferred to CS1. Sections 6 and 7 were dredged between January 2019 and July 2019 with this material transferred to CS3.
- Approximately 37,300 m^3 of dioxin contaminated sediment was dredged from Kopeopeo Canal and transferred to CS1 and CS3 for long-term containment and bioremediation.
- Sediment validation samples (287 in total) were collected at 155 individual sampling transects (KC001 to KC155) along the length of Kopeopeo Canal between SH30 and the confluence with Orini Canal. Samples were also collected following dredging of the pump channel at Chainage 4170.
- Following additional dredging works to remove sections of sediment that failed the remedial criterion, a total of 241 samples represent the quality of residual in-situ sediment.
- The overall UCL_{95} for sediment dioxin was calculated based on a total of 213 samples representative of residual sediment quality. Concentrations in the samples used to calculate the UCL_{95} ranged between 20 pg/g I-TEQ and 160 pg/g I-TEQ with a mean concentration of 37 pg/g I-TEQ. The calculated UCL_{95} for the data set is **39 pg/g I-TEQ**.

Overall, the validation undertaken during the project has documented that the Kopeopeo Canal remedial area has been successfully remediated to a standard that satisfies the remedial criteria. Specifically, sediment dioxin concentrations in the residual canal base sediments post-dredging have a UCL_{95} of 39 pg/g I-TEQ and with the exception of one sample (KC084e2 collected from the upstream side of the wastewater pipeline at Chainage 2800), sediment dioxin concentrations were below 120 pg/g I-TEQ. Based on further assessment of residual sediment conditions in the area of this exceedance, and in consultation with the Independent Monitor, it is considered that the area was remediated to the extent practicable.

In addition to the sediment validation, monitoring was undertaken at CS1 and CS3 in accordance with the Consent to assess potential impacts from the placement and storage of the dioxin contaminated sediment within the containment sites. Monitoring of the containment sites up to the completion of the sediment placement work did not record exceedances of the triggers specified in the Consent. On this basis it is considered that placement of the sediment in the containment cells has not impacted the receiving environment around CS1 and CS3 during and up to completion of the sediment dredging and containment phase of the remedial project.

11.0 LIMITATIONS

Your attention is drawn to the document, “Report Limitations”, as attached in Appendix M. The statements presented in that document are intended to advise you of what your realistic expectations of this report should be, and to present you with recommendations on how to minimise the risks to which this report relates which are associated with this project. The document is not intended to exclude or otherwise limit the obligations necessarily imposed by law on Golder Associates (NZ) Limited, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.

12.0 REFERENCES

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APPENDIX A

Sediment Dredging Exception Log

APPENDIX B

As-built Plans for Containment Sites

APPENDIX C

Sediment Volume Calculations from Geotube® Bags

APPENDIX D

Hydrographic Survey Data

APPENDIX E

Visual Inspection Records of Sediment Cores

APPENDIX F

Laboratory Analytical Reports

Sediment

Intra-lab

Rinsate

COCs

APPENDIX G

Sediment Quality Data

APPENDIX H

UCL_{95} Calculation

APPENDIX I

CS1 Closure Report

APPENDIX J

Ambient Air Monitoring Data

APPENDIX K

CS3 Pre-construction Monitoring Report

APPENDIX L

CS3 Monitoring Data

APPENDIX M

Report Limitations

Report Limitations

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