Memo

From	**Doug Booker, Paul Franklin, Rick Stoffels**
To	Stephen Fragaszy
Date	12 March 2020
Subject	Contract 23184: Task 1 - Mapping CTG classes with few data to sediment classes

Background

A brief provided by the Ministry for the Environment (MfE) to Franklin et al. (2019) identified the requirement to set National Objective Framework (NOF) attribute thresholds for sediment classes that could be applied to all streams and rivers across New Zealand. Franklin et al. (2019) included the influence of landscape-scale variation on spatial patterns of sediment based on a pre-defined national classification mapped onto the national river network. This classification distinguished patterns in observed sediment states by aggregating groups defined by their climate, topography, and geology (CTG) as described by Franklin et al. (2019). Franklin et al. (2019) stipulated that a CTG class must have a pre-specified minimum number of observed sites to be included in the data-driven approach applied to estimate reference conditions. Some CTG classes did not meet this criterion. This was partly because some CTG classes are associated with very few river segments (e.g., 0.1% of national river network segments are classified as warm-wet/hill/soft-sedimentary; WW/H/SS). Any segments belonging to these data-poor CTG classes were not assigned to a sediment class by the data-driven approach. For example, WW/H/SS was not assigned to a suspended sediment class in the data-driven approach applied by Franklin et al. (2019) and, therefore, was missing from their table that mapped CTG classes to suspended sediment classes. It is very difficult to test the appropriateness of any method attempting to match unassigned CTG classes to sediment classes because no, or very few, observed data exist for each unassigned CTG class.

Franklin et al. (2019) applied a spatial searching algorithm to assign each segment belonging to an unassigned CTG to a sediment class. This method of associating unassigned CTG classes to sediment classes, and, therefore, deriving an estimated reference condition, is referred to here as the "nearest neighbour method". The nearest neighbour method had the advantage of allowing all segments of the national river network to be matched to an estimated reference condition without the need for arbitrary assignment of CTG classes to sediment classes. The nearest neighbour method had two main disadvantages. First, spatial searches from segments belonging to unassigned CTG classes might lead to contrasting estimates of reference condition. Second, the method created the possibility that segments belonging to the same unassigned CTG class could potentially be associated with different sediment classes. While all segment-to-sediment class associations could be displayed on a map, they could not be represented as a one-to-one mapping between CTG and sediment classes in a table.

MfE have requested that the following questions be investigated:

1. How consistently were segments within each unassigned CTG class associated with a common sediment class after having applied the nearest neighbour method?
2. If a clear majority of segments within an unassigned CTG class were associated with common sediment classes by the nearest neighbour method, could the mapping of CTG classes to sediment classes shown in Franklin et al. (2019) be updated to include unassigned CTG classes by identifying the majority sediment class that segments within each unassigned CTG class were mapped to? and

3. If unassigned CTG classes not mapped to sediment classes remained after this process, and it would require more than minor analysis to complete the work, what work would be needed to meet these requirements?

Method

For each of the separate suspended and deposited sediment classifications, all segments belonging to an unassigned CTG class were identified. The number of segments associated with each sediment class by the nearest neighbour method was tallied for each unassigned CTG class. Each unassigned CTG class was then assigned to the sediment class associated with the majority of its segments. This allowed identification of an estimated reference condition for that sediment class. This method of associating unassigned CTG classes to sediment classes and thereby deriving an estimated reference condition, is referred to here as the "majority vote method". The majority vote method is an extension of the nearest neighbour method. Labels of assigned CTG classes were compared against unassigned CTG classes placed in the same sediment class after having applied the majority vote method. The majority vote method was applied to the lowest level (12 classes) of both the suspended and deposited classifications. Matching of unassigned CTGs to the lowest level of sediment classes using the majority vote method allowed unassigned CTGs to be matched to sediment classes at all levels of the sediment classifications.

The results shown here for deposited sediment pertain to the deposited sediment classification from Franklin et al. (2019). The results shown here for suspended sediment pertain to the suspended sediment classification described in the memo for Task 7. This suspended classification was obtained by applying the method described by Franklin et al. (2019) to an improved suspended sediment input dataset. Both the nearest neighbour and majority vote method were applied to version 2.4 of the national digital river network.

Results

Suspended sediment classification

For the suspended classification, 22 of 39 possible CTG classes were unassigned to a sediment class by the data-driven approach described by Franklin et al. (2019) (Figure 1). This meant that 88% of segments were associated with a sediment class using the data-driven approach directly. The remaining 12% of segments were associated with sediment classes using the nearest neighbour method and then the majority vote method.

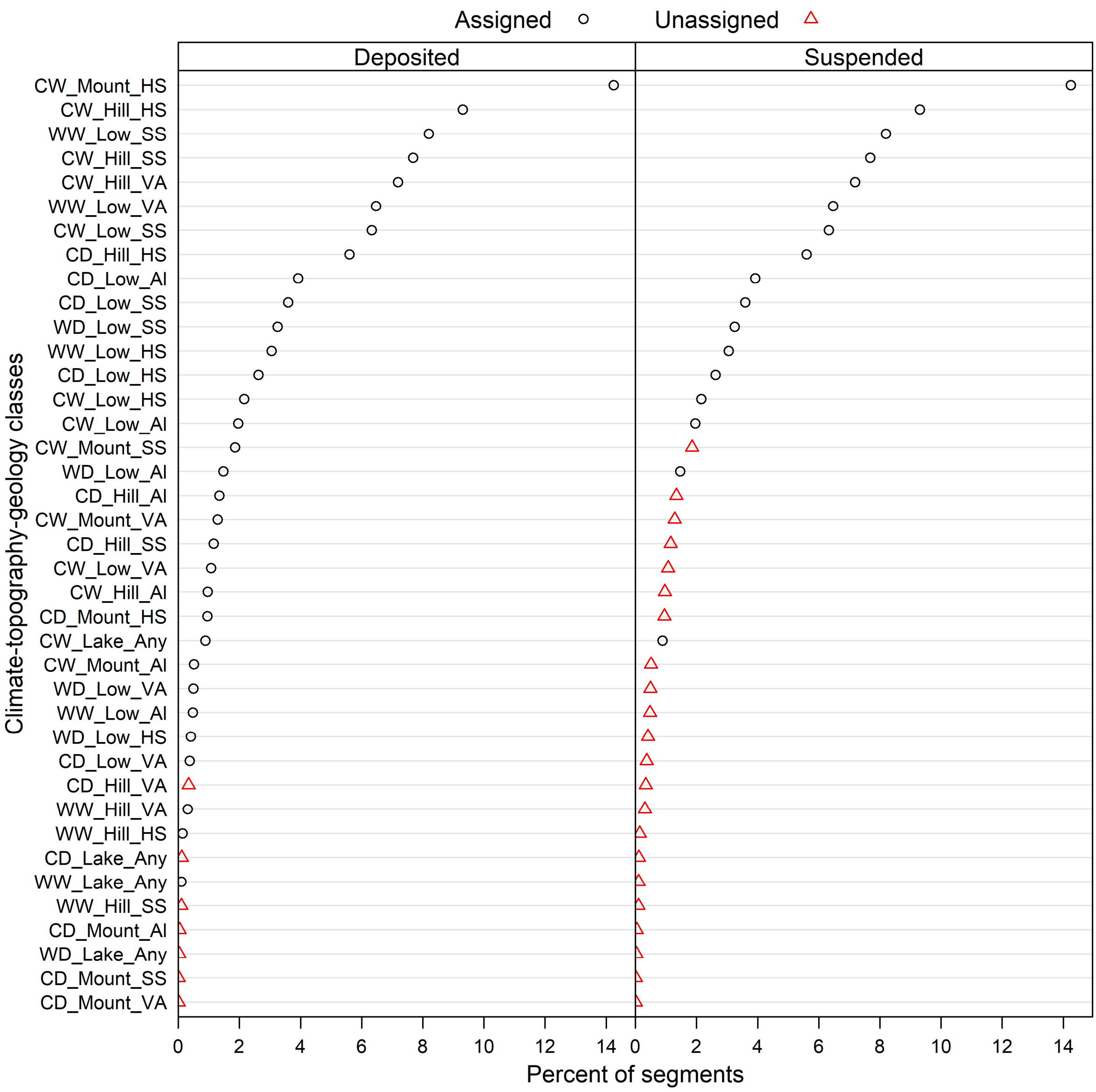

Figure 1. Percent of national river network segments (regardless of stream order) belonging to each amended Climate-Topography-Geology class. "Assigned" indicates included in the data-driven method. "Unassigned" indicates insufficient data for inclusion in the data-driven method.

Segments belonging to an unassigned CTG were sometimes associated with different suspended sediment classes by the nearest neighbour method (Figure 2). For many unassigned CTG classes, a large majority of segments were associated with a single sediment class. For example, a large majority of segments within the CW/M/SS, CW/M/VA, CW/L/VA, and CW/M/Al CTG classes were associated with Class 1 of the Level 2 suspended sediment classification (L2.1). This class contained several assigned CTG classes with similar CTG labelling such as CW for climate, M for topography, and either VA, SS, or Al for geology. A similar situation occurred for the unassigned WD/L/HS class for which a large majority of segments were associated with L2.2 of the suspended sediment classification. This suspended sediment class contained assigned CTG classes with similar CTG labelling such as either WW or WD for climate, L for topography, and HS for geology.

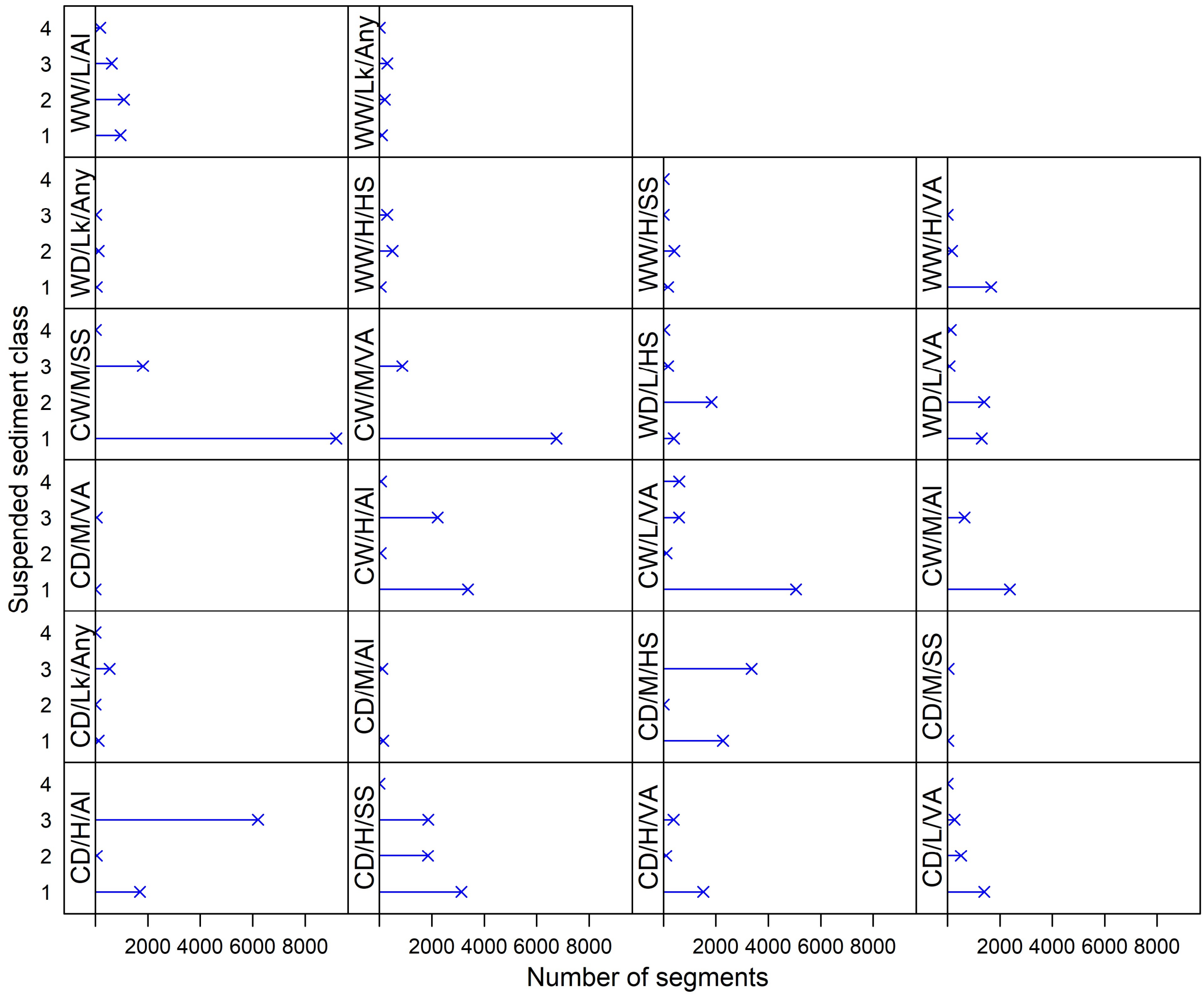

Figure 2. Suspended sediment classes (level 2, 4 classes) associated with each unassigned CTG class using the nearest neighbour method. Panel headings (vertical labels) indicate the unassigned CTG name.

Some unassigned CTG classes had a smaller majority of segments associated with a single sediment class. For example, a majority of segments within the unassigned CD/M/HS class were associated with L2.1, but many segments with unassigned CTG were associated with L2.3 by the nearest neighbour method. Of the six assigned CTGs contained within L2.1 there were two CD's for climate, a M for topography, and a HS for geology. Of the five assigned CTGs contained within L2.3 there was one CD for climate, no M for topography and no HS for Geology. In terms of CTG labelling, the majority vote method therefore matched the unassigned CD/M/HS class most appropriately with L2.1.

Very few segments belong to selected unassigned CTG classes (e.g. CD/Lk/Any, WW/Lk/Any, WD/Lk/Any, CD/M/SS, and CD/M/VA; Figure 1). It was, therefore, very hard to assess the spread of sediment classes within segments allocated to these classes by the nearest neighbour method (Figure 2). However, the majority vote method again associated unassigned CTG classes with similarly labelled assigned CTG classes (Table 1). For example, CD/Lk/Any and WW/Lk/Any were associated with a sediment class containing CW/Lk/Any.

Table 1. Membership of CTG classes within the hierarchical structure of the suspended sediment classification. "Assigned" indicates CTG classes included in the data-driven approach of Franklin et al. (2019). "Unassigned" indicates CTG classes associated with sediment classes using the majority vote method.

CTG	SSC Level 1	SSC Level 2	SSC Level 3	SSC Level 4	Percent of network	Assignment Method
CD_Low_HS	1	1	1	1	2.62	Assigned
WW_Low_VA	1	1	1	1	6.47	Assigned
WW_Hill_VA	1	1	1	1	0.31	Unassigned
CD_Low_Al	1	1	3	7	3.92	Assigned
CW_Hill_SS	1	1	3	7	7.69	Assigned
CW_Mount_SS	1	1	3	7	1.85	Unassigned
CW_Hill_VA	1	1	3	9	7.19	Assigned
CD_Hill_SS	1	1	3	9	1.15	Unassigned
CD_Hill_VA	1	1	3	9	0.34	Unassigned
CD_Low_VA	1	1	3	9	0.37	Unassigned
CW_Low_VA	1	1	3	9	1.07	Unassigned
CW_Mount_VA	1	1	3	9	1.29	Unassigned
CW_Mount_HS	1	1	6	12	14.25	Assigned
CD_Mount_Al	1	1	6	12	0.04	Unassigned
CW_Hill_Al	1	1	6	12	0.96	Unassigned
CW_Mount_Al	1	1	6	12	0.51	Unassigned
WD_Low_Al	1	1	7	2	1.47	Assigned
CW_Hill_HS	1	3	4	8	9.31	Assigned
CW_Lake_Any	1	3	4	8	0.89	Assigned
CD_Lake_Any	1	3	4	8	0.11	Unassigned
WW_Lake_Any	1	3	4	8	0.10	Unassigned
CW_Low_HS	1	3	4	10	2.15	Assigned
CW_Low_Al	1	3	5	4	1.96	Assigned
CD_Hill_HS	1	3	5	11	5.60	Assigned
CD_Hill_Al	1	3	5	11	1.34	Unassigned
CD_Mount_HS	1	3	5	11	0.95	Unassigned
CD_Mount_SS	1	3	5	11	0.01	Unassigned
CD_Mount_VA	1	3	5	11	0.01	Unassigned
CD_Low_SS	2	2	2	5	3.59	Assigned
WW_Low_HS	2	2	2	5	3.05	Assigned
WW_Low_SS	2	2	2	5	8.20	Assigned
WW_Hill_HS	2	2	2	5	0.14	Unassigned
WW_Hill_SS	2	2	2	5	0.10	Unassigned
WW_Low_Al	2	2	2	5	0.48	Unassigned
WD_Low_SS	2	2	2	6	3.25	Assigned
WD_Lake_Any	2	2	2	6	0.03	Unassigned
WD_Low_HS	2	2	2	6	0.41	Unassigned
WD_Low_VA	2	2	2	6	0.49	Unassigned
CW_Low_SS	2	4	8	3	6.33	Assigned

Deposited sediment classification

For the deposited classification, 7 of 39 possible CTG classes were unassigned to a sediment class by the data-driven approach (Figure 1). This meant that 99.4% of segments were directly associated with a sediment class using the data-driven approach. The remaining 0.6% of segments were associated with a sediment class using the nearest neighbour method.

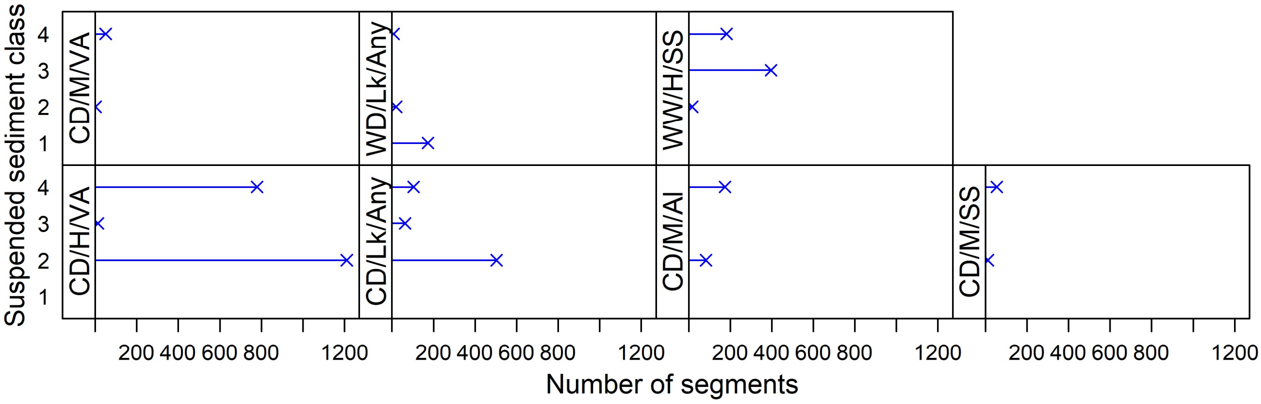

Figure 3. Deposited sediment classes (level 2, 4 classes) associated with each unassigned CTG class using the nearest neighbour method. Panel headings (vertical labels) indicate the unassigned CTG name.

Segments belonging to an unassigned CTG were sometimes associated with different deposited sediment classes by the nearest neighbour method (Figure 3). Some unassigned CTG classes had a large majority of segments associated with a single sediment class. For example, a large majority of segments within the CD/M/VA, CD/M/Al and CD/M/SS CTG classes were associated with Class 4 of the Level 2 (4 classes) deposited sediment classification (L2.4). This class contained a single assigned CTG class with very similar CTG labelling (CD/M/HS). Other unassigned CTG classes were also associated with similarly labelled CTG classes by the majority vote method (Table 2).

Table 2. Membership of CTG classes within the hierarchical structure of the deposited sediment classification. "Assigned" indicates CTG classes included in the data-driven approach of Franklin et al. (2019). "Unassigned" indicates CTG classes associated with sediment classes using the majority vote method.

CTG	SSC Level 1	SSC Level 2	SSC Level 3	SSC Level 4	Percent of network	Assignment Method
WD_Low_Al	1	1	1	1	1.47	Assigned
WD_Low_VA	1	1	1	1	0.49	Assigned
WD_Lake_Any	1	1	2	5	0.03	Unassigned
WD_Low_SS	1	1	2	5	3.25	Assigned
WD_Low_HS	1	1	2	9	0.41	Assigned
WW_Lake_Any	1	1	5	8	0.10	Assigned
WW_Low_Al	1	1	7	11	0.48	Assigned
CD_Hill_Al	2	2	3	6	1.34	Assigned
CD_Low_HS	2	2	3	6	2.62	Assigned
CD_Low_VA	2	2	3	6	0.37	Assigned
WW_Low_HS	2	2	3	6	3.05	Assigned
WW_Low_VA	2	2	3	6	6.47	Assigned
CD_Hill_SS	2	2	8	3	1.15	Assigned
CD_Lake_Any	2	2	8	3	0.11	Unassigned
CW_Lake_Any	2	2	8	3	0.89	Assigned
CW_Low_Al	2	2	8	3	1.96	Assigned
CD_Hill_HS	2	2	8	12	5.60	Assigned
CW_Hill_VA	2	2	8	12	7.19	Assigned
CW_Low_SS	2	2	8	12	6.33	Assigned
CW_Low_VA	2	2	8	12	1.07	Assigned
CD_Low_Al	2	3	4	7	3.92	Assigned
CD_Low_SS	2	3	4	7	3.59	Assigned
WW_Hill_SS	2	3	4	7	0.10	Unassigned
WW_Low_SS	2	3	4	7	8.20	Assigned
CD_Hill_VA	2	4	6	2	0.34	Unassigned
CW_Mount_VA	2	4	6	2	1.29	Assigned
WW_Hill_HS	2	4	6	2	0.14	Assigned
CW_Mount_SS	2	4	6	4	1.85	Assigned
CD_Mount_Al	2	4	6	10	0.04	Unassigned
CD_Mount_HS	2	4	6	10	0.95	Assigned
CD_Mount_SS	2	4	6	10	0.01	Unassigned
CD_Mount_VA	2	4	6	10	0.01	Unassigned
CW_Hill_Al	2	4	6	10	0.96	Assigned
CW_Hill_HS	2	4	6	10	9.31	Assigned
CW_Hill_SS	2	4	6	10	7.69	Assigned
CW_Low_HS	2	4	6	10	2.15	Assigned
CW_Mount_Al	2	4	6	10	0.51	Assigned
CW_Mount_HS	2	4	6	10	14.25	Assigned
WW_Hill_VA	2	4	6	10	0.31	Assigned

Conclusion and recommendations

Spatial searches from segments belonging to unassigned CTG classes using the nearest neighbour approach led to some contrasting sediment classes and, therefore, different estimates of reference condition within the same CTG class. A lack of data for the unassigned CTG classes means that it is very difficult to test the appropriateness of methods used to match unassigned CTG classes to sediment classes. However, the majority vote method did place unassigned CTG classes into sediment classes comprising assigned CTG classes with similar labels. Given the requirement to establish threshold bands that could be applied to all streams and rivers across New Zealand, and the inability to include the unassigned CTG classes in the data-driven approach because of data inadequacy, the majority vote method represents the best available method for assigning CTG classes to a sediment class.

It should be noted that use of the majority vote method to assign CTG classes was only necessary for a small proportion of segments. This was especially the case for the deposited sediment classification. Table 1 and Table 2 show membership of unassigned CTG classes to sediment classes at all levels of aggregation (2, 4, 8 and 12 sediment classes). Table 1 and Table 2, therefore, describe a direct mapping of all amended CTG classes to sediment classes obtained using the methods described by Franklin et al. (2019). These tables include mapping of unassigned CTG classes to sediment classes after having applied the majority vote method. We recommend that the mapping of CTG to sediment classes shown in Table 1 and Table 2 be applied.

References

Franklin, P., Stoffels, R., Clapcott, J., Booker, D., Wagenhoff, A., Hickey, C. (2019) Deriving potential fine sediment attribute thresholds for the National Objectives Framework. Client report to the Ministry for the Environment, 2019039HN. 290pp.