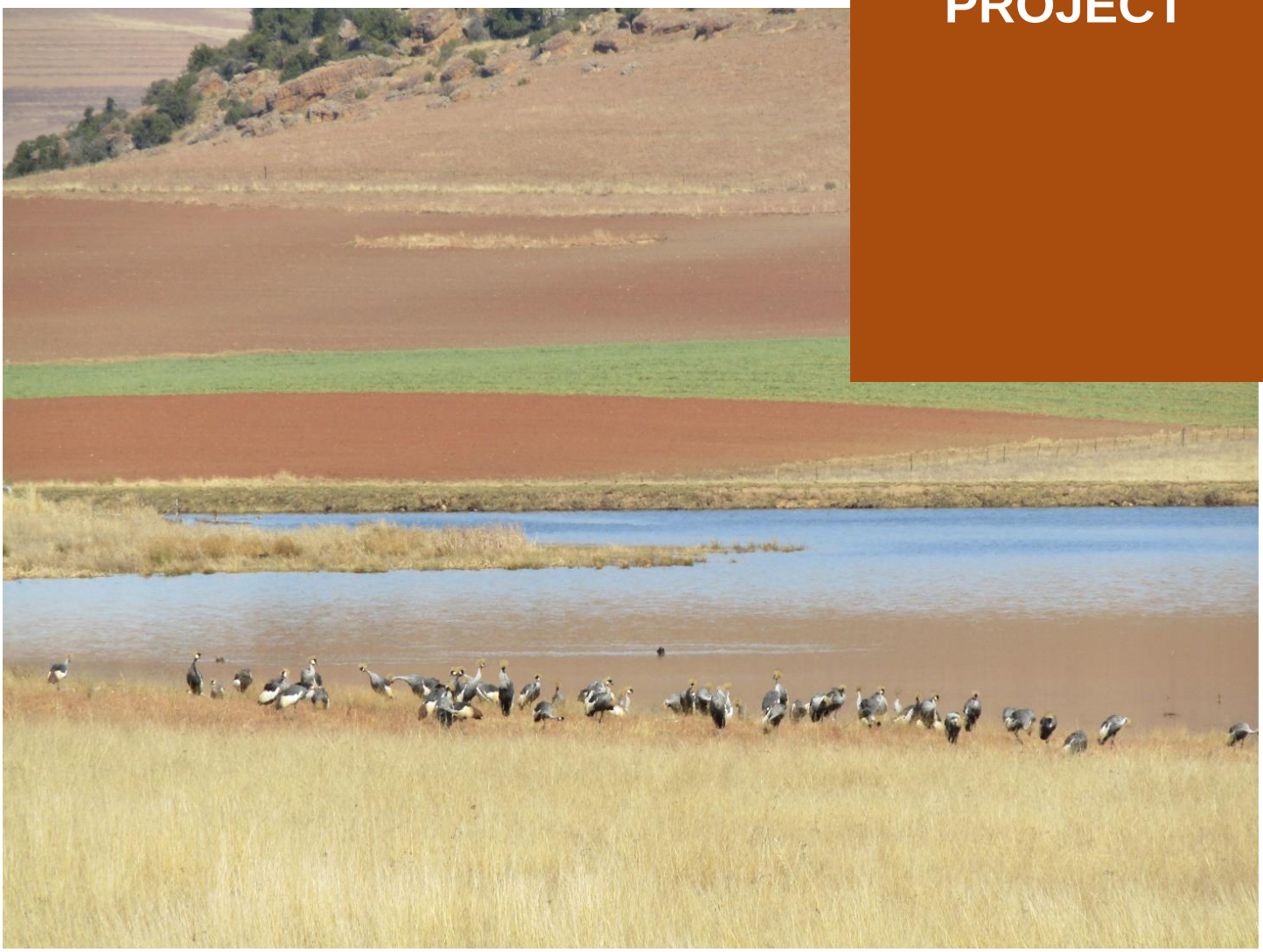
MANAGING SMALL RESERVOIRS IN THE UPPER TSITSA CATCHMENT

Catchment T35 A-E Prioritisation Plan

TSITSA PROJECT



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December 2018

environmental affairs
Department:
Environmental Affairs
REPUBLIC OF SOUTH AFRICA

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The research has been funded by the Department of Environmental Affairs: Environmental Programmes – Natural Resource Management Programmes. Directorate – Operational Support and Planning.

EXECUTIVE SUMMARY

Small earth dams are important parts of the landscape that provide both direct and indirect benefits to stakeholders in a catchment. Direct benefits include water for stock and nearby agriculture and indirect benefits include the trapping of sediments, nutrients and run-off.

The construction of new dams for the sole purpose of sediment trapping is economically unviable. However, by identifying and preserving the current dams in the catchment a significant advantage can be gained as these structures are already in place, are trapping sediment and might contain significant volumes of sediment that could potentially be released downstream.

Several of the existing small dams found in the Upper Tsitsa River Catchment (T35 A-E) are threatened by gully head erosion. Managers can target these areas to fix and maintain reservoirs that are breached or threatened by erosion at a lower cost than building new sediment trapping structures. In order to maintain their function to support livelihoods and trap sediments, site-specific interventions will need to be implemented. Interventions include gully head stabilisation, revegetation of bare areas, soil treatment and soil compaction where dam walls are at risk of erosion.

Visible dams in Catchment T35 A-E were digitised using 2013 digital aerial photographs. Aerial photographs were made available by National Geo-Spatial Information, Cape Town. These photographs have a suitable resolution (1:10 000 orthophotos, with 50 cm resolution) in the area of interest. Digitizing was done at a scale of 1:2000.

A reservoir breach risk score was given to each reservoir based on visible signs of erosion. The ratings are given below:

- No threat: reservoir wall well vegetated, no erosion near wall and no headcut within 100 m downstream of dam.
- Moderate threat: reservoir wall showing signs of erosion/bare patches and/or headcut within 100m downstream of wall.
- High threat: extensive erosion of wall/spillway and/or headcut within 50m downstream of wall (likely to be breached in the near future)
- Dam breached/broken

Catchment areas for each of the dams were delineated using ARC GIS hydro tools and a 28.8m DEM that was derived from 20m contour lines. Statistics for the reservoir area and risk were calculated.

GroundTruth (2018) were tasked to carry out site assessments of areas based on the desktop assessment and to determine appropriate interventions to mitigate soil erosion. This required the designing of structures that function effectively to rehabilitate eroded areas and reduce erosion to ensure the protection of the current dams. In addition a number of weirs were proposed to reduce sediment input into the proposed Ntabelanga Dam.

A total of 455 dams were identified. The area covered by dam catchments and in which dams are trapping sediment is 77 km^2 and is about 4% of the catchment area for Catchment T35A-E. Dams that are not currently threatened by erosion make up 68% of the dams. Dams that will need maintenance to ensure that they keep trapping sediment and do not release sediment when dams are breached make up 29% of the dams. Only 3% of the dams are currently breached.

These results are desktop based and have not been verified on the ground. It is important to note that not all of the mapped dams will be effective sediment traps. The size of the dam catchments and the amount of sediment that it can potentially be catching needs to be balanced against the cost of ensuring that the dam remains a sediment sink.

A total of 22 small dams were prioritised by GroundTruth (2018) after visiting a number of dams in the catchment. Recommended intervention types including hard and soft interventions with a corresponding cost estimate are given. The total estimated cost to fix 22 small dams is R 4 721 035.45.

A total of 5 weirs were proposed as erosion control proximal to the proposed Ntabelanga Dam inundation. Cost estimates and priorities for each hard structure are given. The total cost estimate to build 5 weirs is R4 243 406.00.

It is important to note that the proposed weirs which will help mitigate soil erosion are very expensive to implement and only affect small catchment areas. Therefore these are not seen as viable to landscape restoration with limited resources and focus should rather shift to doing more interventions on small dams which are already functional in the landscape.

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1. INTRODUCTION

Small earth dams have many direct and indirect benefits to the local stakeholders in a catchment. Small earth dams provide direct benefits such as water to stock and nearby agriculture and indirect benefits such as trapping sediment, nutrients and run-off (Boardman & Foster, 2008; Boardman & Foster, 2011; Blanc & Strobl, 2013).

From an economical perspective the construction of small dams to reduce catchment sediment yield was found to be more expensive and shorter lived than other restoration methods such as revegetation (Quiñonero-Rubio *et al*., 2016). The optimisation of the distribution of small dam locations relative to land use patterns is crucial for managing sediment yields effectively (Quiñonero-Rubio *et al*., 2016).

Several of the existing small dams found in the Upper Tsitsa River Catchment (T35 A-E) are threatened by gully head erosion. As these structures are already in place, are trapping sediment and might contain significant volumes of sediment, managers can:

Fix and maintain reservoirs that are breached or threatened by erosion at a lower cost than building new sediment trapping structures.

Reduce soil erosion rates and sediment export from highly eroding catchments.

Exclude the catchments of these dams from intervention planning over the short term (5 years - up to 2022).

Those dams vulnerable to erosion/breaching will require attention in order to maintain their function to support livelihoods and trap sediment. This will be site-specific, but is likely to include gully head stabilisation, revegetation of bare areas, soil treatment, and soil compaction where the dam wall is showing signs of erosion.

Figure 1: A dam and catchment exhibiting low vulnerability to erosion

Figure 2: A dam exhibiting an erosional nick point on the dam wall which could result in dam wall breaching

Figure 3: Dams acting as sediment traps

Figure 4: A well maintained and vegetated spillway

2. METHODS

2.1. Digitising dams

Visible dams in Catchment T35 A-E were digitised using 2013 digital aerial photographs. Aerial photographs were made available by National Geo-Spatial Information, Cape Town. These photographs have a suitable resolution (1:10 000 orthophotos, with 50 cm resolution) in the area of interest. Digitizing was done at a scale of 1:2000. A reservoir breach risk score was given to each reservoir based on visible signs of erosion. The ratings are given below:

- No threat: reservoir wall well vegetated, no erosion near wall and no headcut within 100 m downstream of dam.
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Catchment areas for each of the dams were delineated using ARC GIS hydro tools and a 28.8m DEM that was derived from 20m contour lines. Statistics for the reservoir area and risk were calculated.

2.2. Sediment mitigation plan for the Ntabelanga area (GroundTruth, 2018)

2.2.1. Existing sediment trapping structures

GroundTruth (2018) were tasked to carry out site assessments of areas based on the desktop assessment and to determine appropriate interventions to mitigate soil erosion. This required the designing of structures that function effectively to rehabilitate eroded areas and reduce erosion to ensure the protection of the current dams. The design interventions were also required to include methods of construction that are labour intensive and which maximise job creation and socio-economic growth. More details can be found in the GroundTruth report in Appendix 2.

GroundTruth (2018) prioritised dam interventions based on the size of the dam, the catchment area of the dam and the risk of the dam breaching following an infield inspection. Priority is therefore based on dam functionality and risk of failure (Table 1).

Table 1: Dam intervention prioritisation (GroundTruth, 2018)

Priority	Description
Low	- Small dam - Small catchment - Medium to low risk of failure at current state
Medium	- Medium dam - Medium catchment - Medium to high risk of failure
High	- Medium to large dam - Medium to large catchment - High risk of failure

2.2.2. Proposed weir construction

A number of weirs were proposed to reduce sediment input into the proposed Ntabelanga Dam. Proposed weirs were prioritised by taking into account the cost of the structure, the structures capacity to trap sediment and the size of the catchment above the structure (Table 2).

Table 2: Proposed weir prioritisation (GroundTruth, 2018)

Priority	Description
Low	- Expensive to implement - Low sediment trapping capacity
Medium	- Moderately expensive to implement - Moderate sediment trapping capacity
High	- Relative cost is low compared to the sediment trapping capability

3. RESULTS

3.1. Digitised dams

A total of 455 dams were identified. The locations of the dams and their catchments can be seen in Figure 5 and Figure 6. The area covered by dam catchments and in which dams are trapping sediment is 77 km^2 and is about 4% of the catchment area for Catchment T35A-E (Table 3). These dams are mostly on private land (Figure 5).

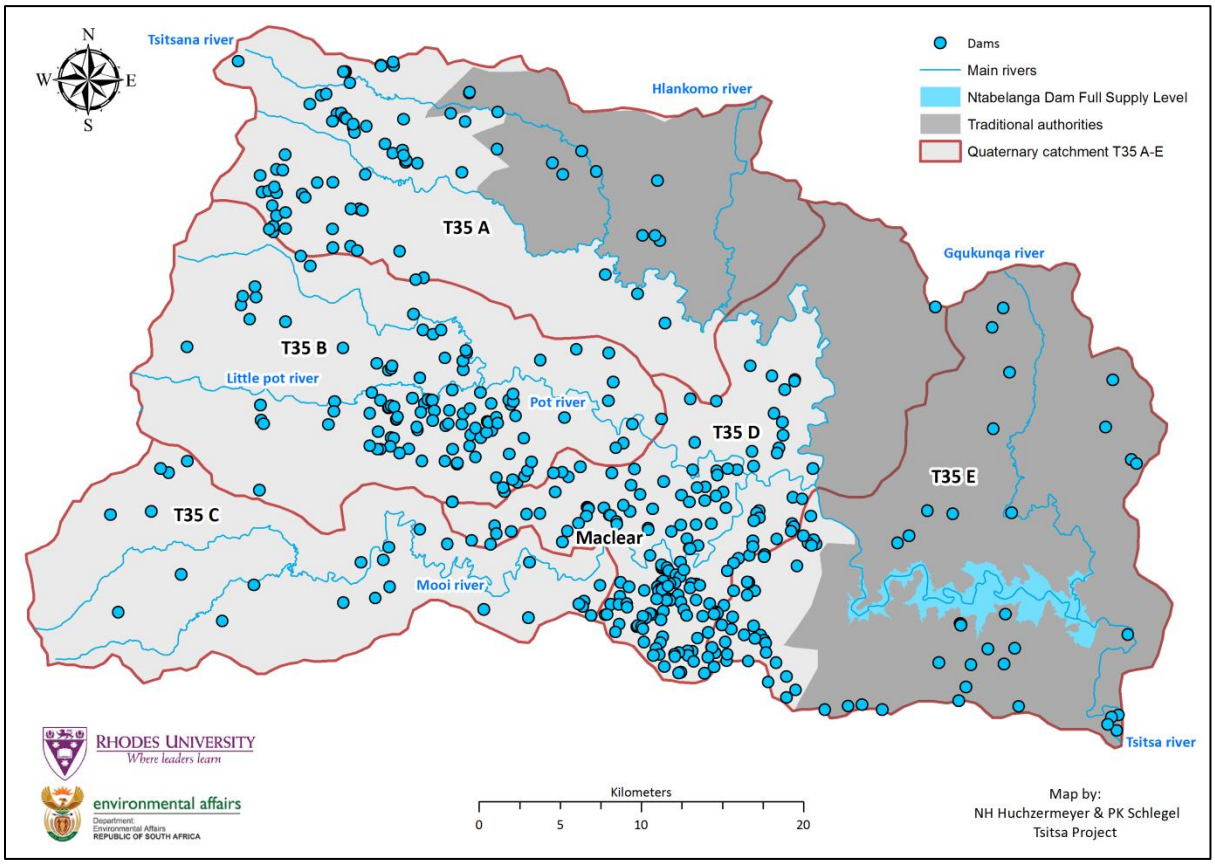

Figure 5: Location of dams in Catchment T35 A-E

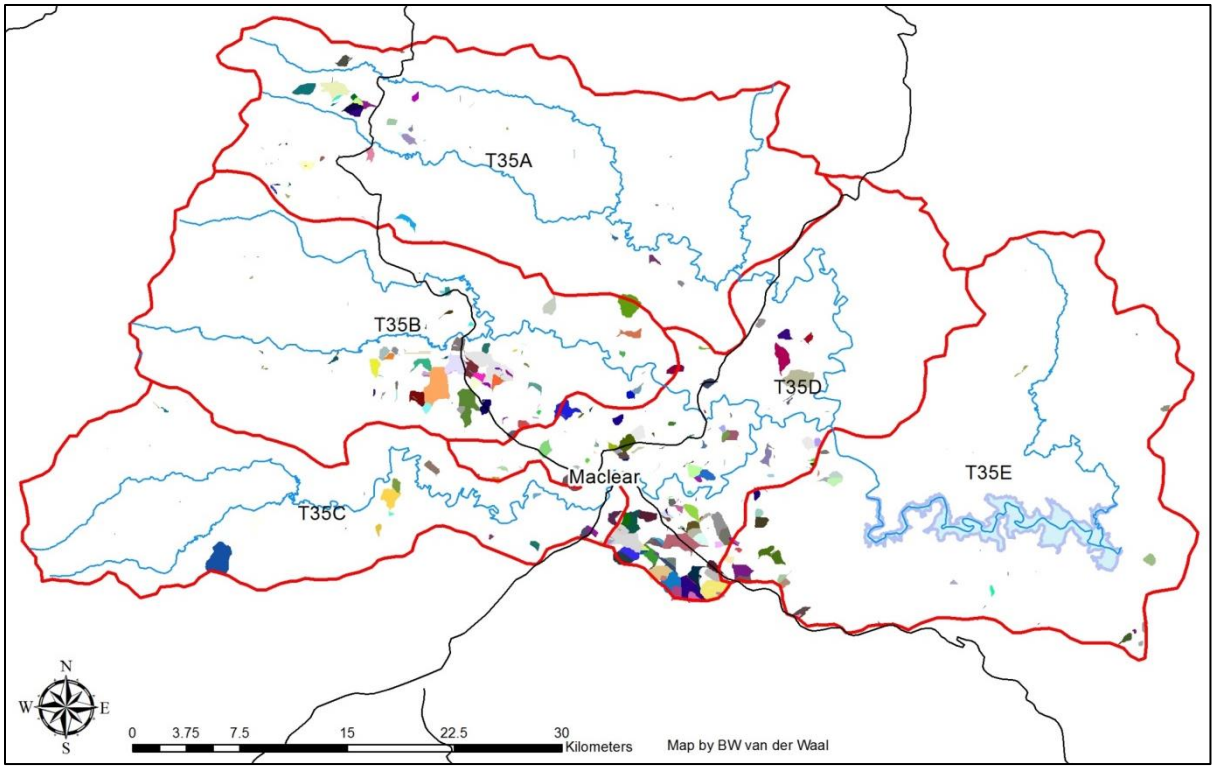

Figure 6: Map of the catchment areas for dams in Catchment T35 A-E

Figure 7 shows the status of dams in terms of their vulnerability to erosion. Dams that are not currently threatened by erosion make up 68% of the dams. Dams that will need maintenance to ensure that they keep trapping sediment and do not release sediment when dams are breached make up 29% of the dams. Only 3% of the dams are currently breached.

Table 3: A summary of the number of tams, their current risk of failure and the catchment area per risk class

Risk	Count of reservoirs	Catchment area km2	Percentage area (%) of T35A-E
Low	308	49	2
Medium	97	17	1
High	37	9	1
Breached	13	2	<1
Total	**455**	**77**	**4**

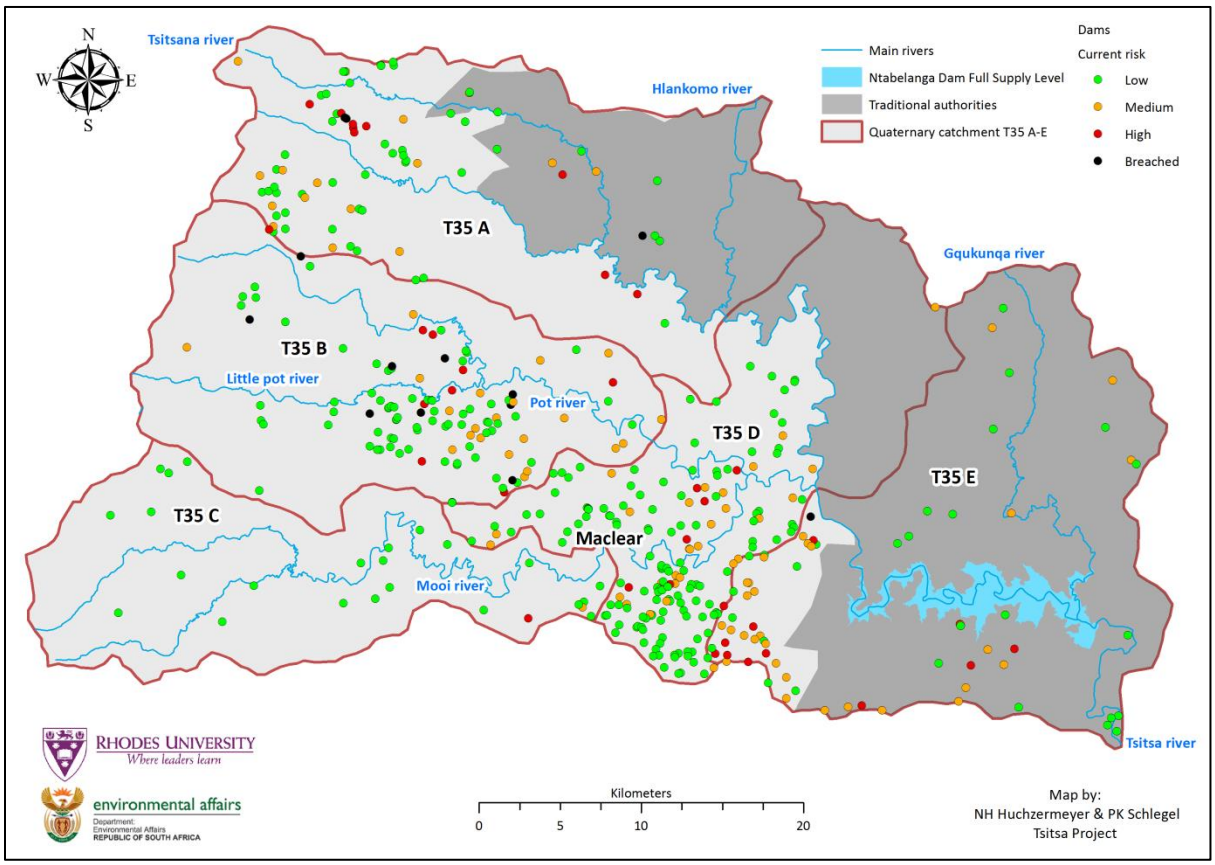

Figure 7: Status of dams in terms of vulnerability to erosion in Catchment T35 A-E

These results are desktop based and have not been verified on the ground. It is important to note that not all of the mapped dams will be effective sediment traps. The size of the dam catchments and the amount of sediment that it can potentially be catching needs to be balanced against the cost of ensuring that the dam remains a sediment sink.

3.2. Sediment mitigation plan for the Ntabelanga area (GroundTruth, 2018)

3.2.1. Existing sediment trapping structures

A total of 22 small dams were prioritised (Table 4) by GroundTruth (2018) after visiting a number of dams in the catchment. Recommended intervention types including hard and soft interventions are given in Table 4 with a corresponding cost estimate.

The total estimated cost to fix 22 small dams is R 4 721 035.45.

Table 4: Cost estimate and prioritisation of dam interventions in Catchment T35 A-E (GroundTruth, 2018)

Intervention number	Intervention description	Cost estimate (R) per structure	Total cost estimate (R) per dam	Prioritisation
T35E-061-002	Rock packs	2 924.00	**6 367.50**	Low
T35E-061-001	Rock packs	3 443.50		
T35B-022-001	Rock pack chute	8 225.00	**8 225.00**	Low
T35A-009-001	Minor concrete maintenance	17 600.00	**17 600.00**	Low
T35E-023-001	Rock packs	71 465.00	**71 465.00**	Medium
T35E-044-001	Rock packs	71 465.00	**71 465.00**	Medium
T35E-021-001	Earthworks/gravelling	112 000.00	**112 000.00**	Low
T35B-021-001	Slope, bio-jute blankets and erosion control logs	121 275.00	**121 275.00**	Low
T35D-0A6-001	Block chute	121 308.40	**121 308.40**	Medium
T35B-021-002	Geo-cell concrete chute	124 085.00	**124 085.00**	Low
T35B-017-001	Earthworks	126 250.00	**126 250.00**	Medium
T35D-0A5-001	Earthworks	127 750.00	**127 750.00**	Low
T35B-020-001	Geo-cell concrete chute	134 860.00	**134 860.00**	Low
T35B-015-001	Concrete weir	143 636.80	**143 636.80**	Low
T35E-045-001	Concrete chute	197 787.90	**197 787.90**	Medium
T35B-0A3-001	Concrete drop inlet weir	218 661.25	**218 661.25**	High
T35B-036-001	Concrete drop inlet weir	225 018.25	**225 018.25**	Medium
T35B-028-001	Concrete chute	253 246.50	**253 246.50**	High
T35E-027-001	Concrete drop inlet weir	275 982.00	**275 982.00**	High
T35C-031-001	Concrete drop inlet weir and concrete road crossing	470 824.20	**470 824.20**	High
T35D-075-001	Concrete chute with stone pitching	476 952.55	**476 952.55**	Medium
T35E-025-001	Concrete base-flow chute	483 000.80	**483 000.80**	High
T35B-018-001A	Concrete drop inlet weir	621 122.00	**933 274.30**	Medium
T35B-018-001B	Slope out and rock pack	12 982.50		
T35B-018-001C	Slope out and rock pack	45 820.00		
T35B-018-001D	Concrete drop inlet weir	253 349.80		
		Grand Total	**4 721 035.45**	

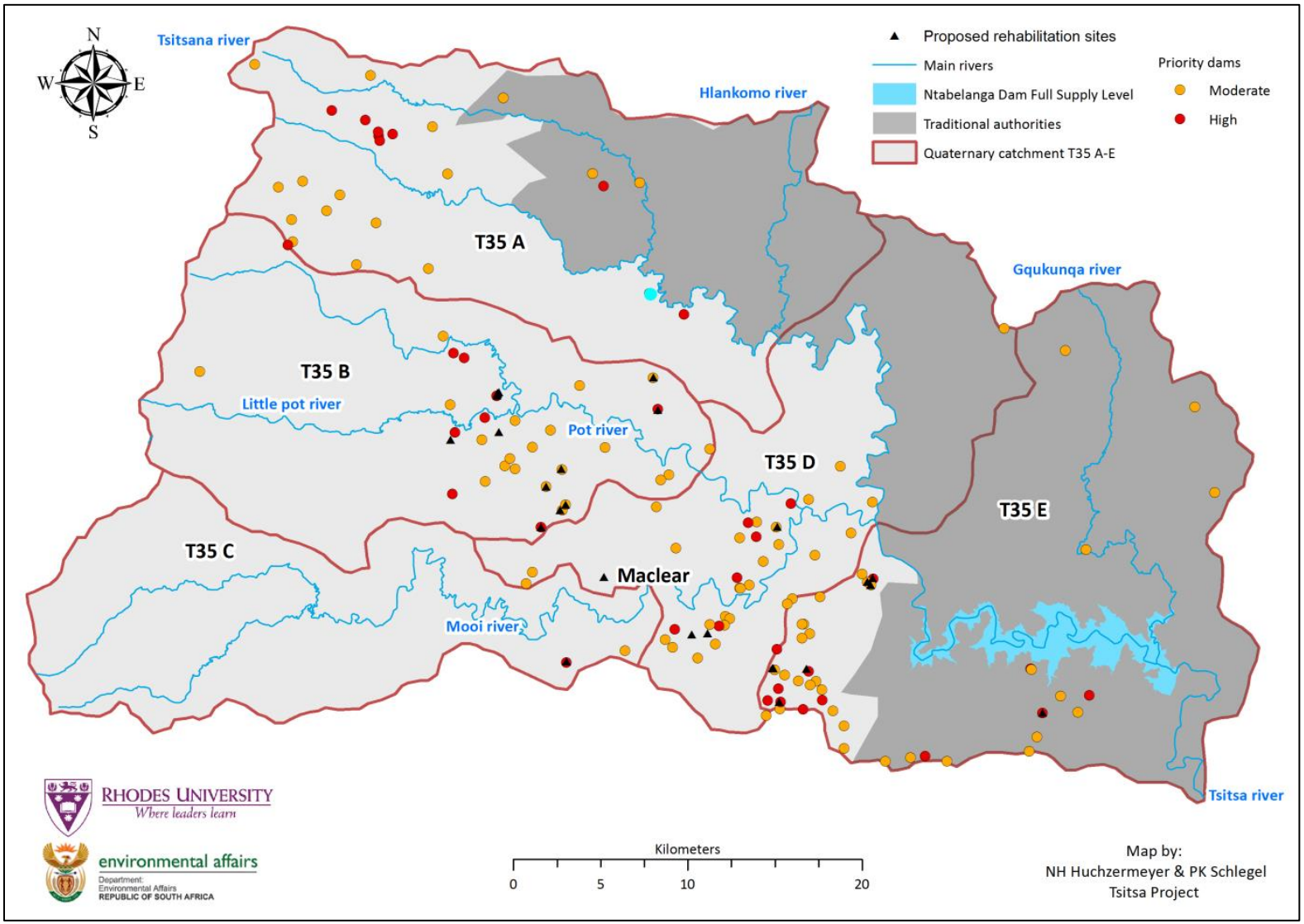

Figure 8: Location of proposed dam rehabilitation sites in relation to moderate and high priority dams

3.2.2. Erosion control structures

A total of 5 weirs were proposed as erosion control proximal to the proposed Ntabelanga Dam inundation (Figure 9).

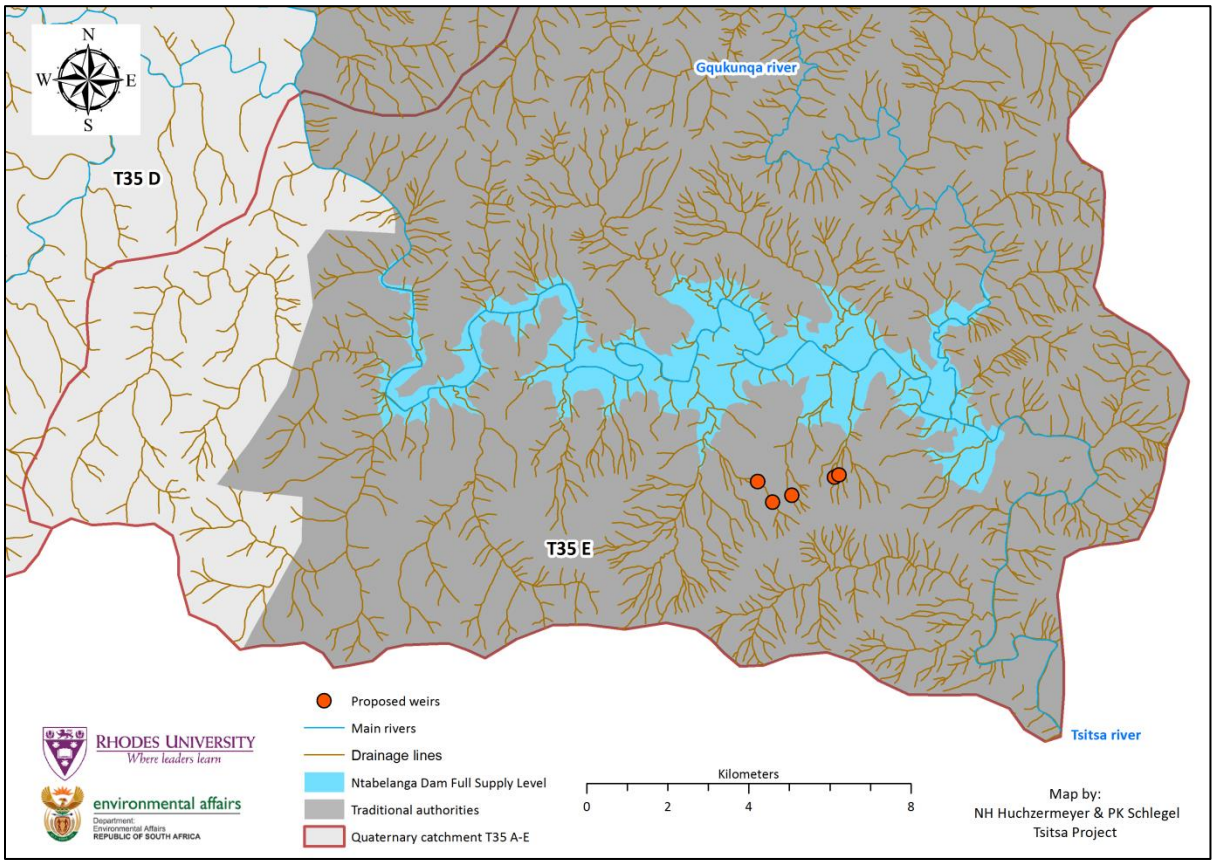

Figure 9: Location of proposed concrete weirs

Cost estimates and priorities for hard structures are given in Table 5. The total cost estimate to build five weirs is R4 243 406.00

Table 5: Cost estimate and prioritisation of proposed weirs in Catchment T35 A-E (GroundTruth, 2018)

Intervention number	Intervention description	Cost estimate (R)	Prioritisation
JW003	Concrete buttress weir	342 498.50	Low
JW001	Concrete buttress weir	447 571.00	Medium
JW005	Concrete buttress weir	895 363.00	Medium
JW006	Concrete buttress weir	1 107 079.00	Low
JW007	Concrete buttress weir	1 450 894.50	Low
Grand total		**4 243 406.00**	

Figure 9 Figure 10 show the relation of the proposed structures to the drainage network in Catchment T35 A-E. The cost estimate of the structures and the amount of sediment they will be trapping in the catchment make them an unviable option.

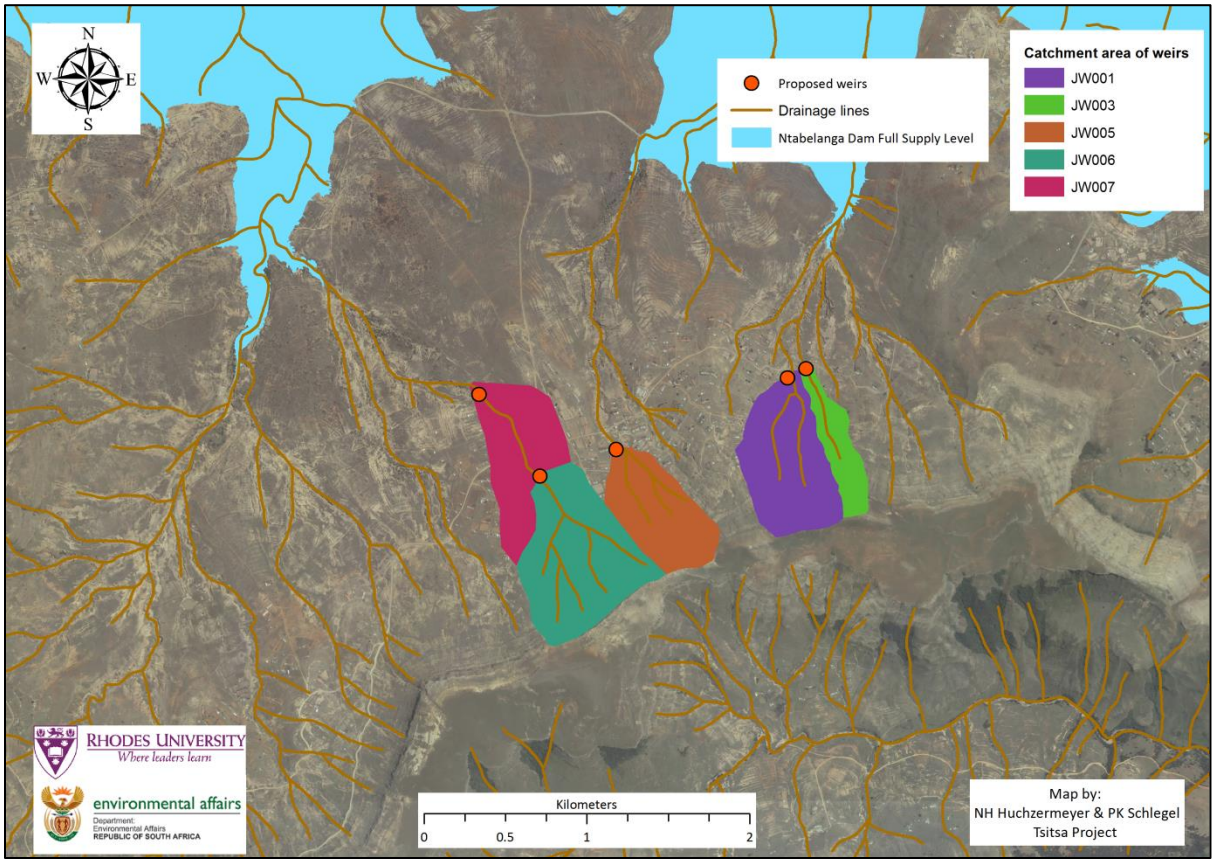

Figure 10: Catchment area of proposed weirs in Catchment T35 A-E

4. CONCLUDING REMARKS

Existing sediment trapping structures such as small dams can be targeted to ensure that they remain sediment sinks in the environment. A total of 22 dams were prioritised for management and cost estimates for each dam were calculated (GroundTruth, 2018).

Proposed weirs to help mitigate soil erosion are very expensive to implement and only affect small catchment areas. Therefore these are not seen as viable to landscape restoration with limited resources.

Appendix 2 gives the full report from GroundTruth (2018).

REFERENCES

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GroundTruth. 2018. *Sediment mitigation plan for the Ntabelanga area*. Report no. GTE130-160418-01. Prepared for Department of Environmental Affairs.

Quiñonero-Rubio, J.M., Nadeu, E., Boix-Fayos, C. & de Vente, J. 2016. Evaluation of the effectiveness of forest restoration and check-dams to reduce catchment sediment yield. *Land Degradation & Development* 27: 1018–1031.

APPENDICES

Appendix 1: Spatial dataset

This data is available in .shp and .kml format to allow the user to interact with the data at various scales and run queries. The database column headings and units are given below.

File name: Dams T35 A_E point/polygon	
Description	Mapped and classified dams in Catchment T35 A-E
Data Origin	Tsitsa Sediment Group
Scale Captured	- Digitising at a scale of 1: 2 000
Date Captured	- Digitising: Off 2013 aerial images
Layer Properties	
Feature Type	Vector format (point or polygon)
Projection	
Projection Name	Geographic Coordinate System – GCS_WGS_1984
Datum	D_WGS_1984
Prime Meridian	Greenwich
Angular Unit	Degree

Attribute Fields	
Field Name	**Description**
FID	Feature Identification
Shape	Point/Polygon
Rating_1	Vulnerability score to erosion (1=low; 4=high)

File name: Dams GroundTruth	
Description	Proposed dams for intervention methods
Data Origin	GroundTruth (2018)
Scale Captured	- Handheld GPS
Date Captured	- 2018
Layer Properties	
Feature Type	Vector format (point)
Projection	
Projection Name	Geographic Coordinate System – GCS_WGS_1984
Datum	D_WGS_1984
Prime Meridian	Greenwich
Angular Unit	Degree

Attribute Fields	
Field Name	**Description**
FID	Feature Identification
Shape	Point
X	Latitude
Y	Longitude
Tag	Intervention code (GroundTruth, 2018)
Interventi	Intervention type

File name: Weirs GroundTruth	
Description	Proposed weirs proximal to the Ntabelanga dam inundation
Data Origin	GroundTruth (2018)
Scale Captured	- Handheld GPS
Date Captured	- 2018
Layer Properties	
Feature Type	Vector format (point)
Projection	
Projection Name	Geographic Coordinate System – GCS_WGS_1984
Datum	D_WGS_1984
Prime Meridian	Greenwich
Angular Unit	Degree

Attribute Fields	
Field Name	**Description**
FID	Feature Identification
Shape	Point
X	Latitude
Y	Longitude
Tag	Intervention code (GroundTruth, 2018)
Interventi	Intervention type

Appendix 2: Sediment mitigation plan for the Ntabelanga area (GroundTruth, 2018)