Rehabilitation of the Dawson Dam, Moura, Queensland

for
WestSide Corporation

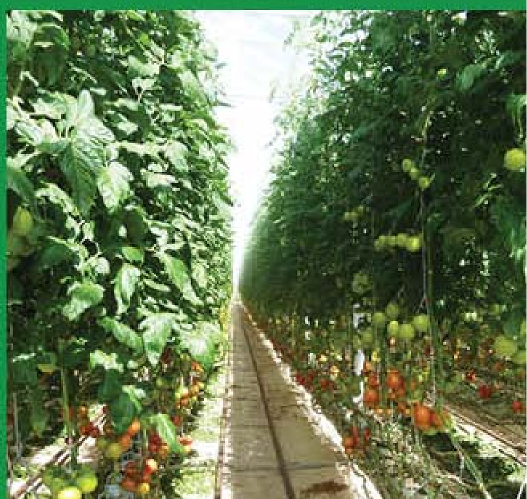
10th October 2017











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Abbreviations

Al	Aluminium
Ca	Calcium
CEC	Cation Exchange Capacity
cm	centimetre
CSG	Coal Seam Gas
Cu	Copper
dS/m	Deci siemens per metre
E	East
EA	Environmental Approval
EC	Electrical Conductivity
$EC_{1:5}$	Electrical Conductivity in a 1:5 soil:water solution
EC_{se}	Electrical Conductivity of a Saturated Extract
EP	Environmental Protection
ESP	Exchangeable Sodium Percentage
Fe	Iron
H_2O	Water
HC	Heavy Clay
K	Potassium
kg	kilogram
L	Loam
LC	Loamy Clay
m	meters
m^3	cubic metres
MC	Medium Clay
meq	milliequivalents
Mg	Magnesium
mg/kg	milligrams per kilogram
mm	millimetres
Mn	Manganese
N	Nitrogen
Na	Sodium
NE	North East
NH_4	Ammonium
NO_3	Nitrate Nitrogen
OC	Organic Carbon
pH_{CaCl2}	Soil pH in Calcium Chloride
S	Salinity
S	Sulfur
SC	Sandy Clay
SCL	Sandy Clay Loam
SiC	Silty Clay
SiCL	Silty Clay Loam
SiL	Silty Loam
SL	Sandy Loam
t/ha	Ton per hectare
TS	Transect
W	West
Zn	Zinc

2 Executive Summary

A practical interactive approach to rehabilitation of the Dawson Dam site has resulted in an outcome that meets the Queensland regulations (Analyses have determined that salt affected soils were mainly limited to the sediment and the underlaying basement materials of the dam. These materials were relocated to below the original subsoil (>1m). This ensures that the salinity would have minimum impact on pasture growth which was the species in existence during the land's previous use (and similar to the current use of surrounding land). Deep ripping and gypsum applications were used to minimise dispersion and ensure suitable water infiltration rates in the future. Low-salt soil materials from the dam walls were used to reconstruct the soil profile followed by grading the site into the existing landscape.

Table 1).

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Table 1 Outcomes of rehabilitation in terms of regulations for rehabilitation of dams in QLD

Regulation	Status	Comment
(X 28) After decommissioning, all significantly disturbed land caused by the carrying out of the environmentally relevant activity(ies) must be rehabilitated to meet the following final acceptance criteria:		
a) the landform is safe for humans and fauna	✓	Complete
b) the landform is stable with no subsidence or erosion gullies for at least three (3) years	✓	Ongoing will be completed over the following three (3) years
c) any contaminated land (e.g. contaminated soils) is remediated and rehabilitated	✓	Complete
d) not allowing for acid mine drainage	NA	No acid drainage
e) there is no ongoing contamination to waters (including groundwater)	✓	No impact to terrestrial waterways No significant impact to groundwater
f) rehabilitation is undertaken in a manner such that any actual or potential acid sulfate soils on the area of significant disturbance are treated to prevent or minimise environmental harm in accordance with the Instructions for the treatment and management of acid sulfate soils (2001)	NA	No evidence of acid sulfate soil in rehabilitation zone
g) all significantly disturbed land is reinstated to the pre-disturbed soil suitability class	✓	Complete
h) for land that is not being cultivated by the landholder	✓	Land restored to pasture species agreed to by the landholder
i. groundcover, that is not a declared pest species is established and self-sustaining	✓	Complete, will be monitored for three (3) years
ii. vegetation of similar species richness and species diversity to pre-selected analogue sites is established and self-sustaining	✓	Complete, will be monitored for three (3) years

Regulation	Status	Comment
iii. the maintenance requirements for rehabilitated land is no greater than that required for the land prior to its disturbance caused by carrying out the petroleum activity(ies)	✓	Complete, will be monitored for three (3) years
i) for land that is to be cultivated by the landholder, cover crop is revegetated, unless the landholder will be preparing the site for cropping within three (3) months of petroleum activities being completed	NA	Revegetation by WestSide

A final phase in 12 months time will be to mulch and seed the site with pasture species chosen by the land holder from pasture species already in use in the area.

3 Introduction

The Dawson dam has been used for CSG operations by WestSide Pty Ltd (WestSide) but is no longer required. Hence it must be decommissioned in accordance with the Environmental conditions agreed to with the regulator, i.e. rehabilitated and the site be brought back to productive agricultural soil.

The dam is situated between Moura and Theodore at 24°48’00.32’S; 150°00’41.85°E, near Moura, Queensland. The construction of the dams has been made using a cut and fill method where earth has been excavated and pushed up for the construction of banks of the dam. The dam base and walls are clay lined.

In consultation with WestSide, a rehabilitation plan was created by Arris (2017) from information gathered in June 2016 (Arris, 2016) and 2017 (Arris, 2017) and from the regulatory requirements of the Queensland Environmental Protection Act i.e.:

– Structures which are dams or levees constructed as part of environmentally relevant activities:

> "(X 28) After decommissioning, all significantly disturbed land caused by the carrying out of the environmentally relevant activity(ies) must be rehabilitated to meet the following final acceptance criteria:
>
> a) the landform is safe for humans and fauna;
> b) the landform is stable with no subsidence or erosion gullies for at least three (3) years;
> c) any contaminated land (e.g. contaminated soils) is remediated and rehabilitated;
> d) not allowing for acid mine drainage; or
> e) there is no ongoing contamination to waters (including groundwater);
> f) rehabilitation is undertaken in a manner such that any actual or potential acid sulfate soils on the area of significant disturbance are treated to prevent or minimise environmental harm in accordance with the Instructions for the treatment and management of acid sulfate soils (2001);
> g) all significantly disturbed land is reinstated to the pre-disturbed soil suitability class;
> h) for land that is not being cultivated by the landholder:
>   a. groundcover, which is not a declared pest species is established and self-sustaining
>   b. vegetation of similar **species richness** and **species diversity** to pre-selected **analogue sites** is established and self-sustaining, and
>   c. the maintenance requirements for rehabilitated land are no greater than that required for the land prior to its disturbance caused by carrying out the petroleum activity(ies).
> i) for land that is to be cultivated by the landholder, cover crop is revegetated, unless the landholder will be preparing the site for cropping within three (3) months of petroleum activities being completed."

Subsequently, the Department of Environment and Heritage Protection (EHP) has ruled that in all but exceptional circumstances, evaporation ponds have been banned for CSG water (EHP, 2014), and existing dams are to be either converted to other uses (such as farm dams if the landholder agrees) or decommissioned.

WestSide will meet its obligations and will ensure that rehabilitation areas are:

- safe for humans and animals;
- stable with no subsidence or erosion;
- free of contamination;
- able to sustain an agreed post-disturbance land use (productive grazing land); and
- equal in maintenance requirements to that required for the land prior to its disturbance.

An interactive management approach was adopted to ensure that the material identified as having the highest salinity be placed in the reformed profile as deeply as possible, so as to minimise the impact on plant growth.

4 Dam Rehabilitation Plan

The rehabilitation process (Table 2) was developed with the understanding of the following key elements:

- the only significant element of concern is salt in the sediments;
- disturbance of sediments will be minimised through in situ management and amelioration;
- the migration of salt over time presents an insignificant risk to the environment while improving the soil profile for plant root exploitation for water and nutrient;
- soil and vegetation disturbance will be kept to a minimum; the site has adequate clearance to be able to undertake proposed site rehabilitation.

Table 2 Rehabilitation Plan for the Dawson Dam (Arris, 2017)

Activity	Responsibilities, Action and Rational
Phase 1 - Assessment	**Arris**
Soil and sediment analysis.	The Assessment process has been completed.
Phase 2 – Dam Liner Removal	**TBD**
Removal of dam liner	Mixing of the sediments with native soil will be undertaken in the basement of the dam. This process will disrupt the clay dam liner.
Phase 3 - Earthworks	**WestSide with technical assistance from Arris with respect to field soil analyses, their interpretation and development of an earthworks plan**
The goal of the earthworks is to rehabilitate the site so that it is returned to a condition that reflects the surrounding, environment and fit for the end land-use goals.	The regulator requires that dams at CSG sites either be transferred for reuse by a landholder, or fully rehabilitated to original land condition. This is a requirement of the WestSide Environmental Approval and is the driving goal behind the rehabilitation process. In this case, the goal is to return the site to productive grazing land.
Earthworks to be undertaken during the dry season.	This will help to mitigate the risk of compaction that could potentially lead to infiltration issues for the soil. Infiltration is important to leach salt from the profile post rehabilitation and assist with meeting the irrigation demand for revegetation. Further, the aim is not to create a perching layer in the

Activity	Responsibilities, Action and Rational
	profile that could lead to increased risk of water erosion and/or surface salinisation through capillary action with salt being redeposited in the surface soil.
Through on-site adaptive management Arris will manage the earth works so as to mitigate the costs and to ensure the best possible surface environment for plant growth across the portion of the dam being rehabilitated.	As the dam banks and lining have been formed with both surface and subsurface soil, active identification and segregation will be required to identify the lower salinity top soil to reinstate at the surface of the filled dam. Arris will use field assessment techniques for salinity and dispersion to assess soil as work is been undertaken for its suitability to support plant growth.
Any hyper-saline and sodic soil identified will be returned to the floor of the dam. The floor of the dam will then have gypsum applied at 10t/ha. The dam floor will be deep ripped to 1m to help improve drainage.	Relocate all hyper-saline and sodic material as deep as possible in the soil profile (at the basement of the dam) to limit interaction with plants. When areas of high salinity/sodicity are identified, the “Mix and Bury” procedure will be used to ameliorate the area (details given in Arris, 2016b). Such material is required to be <1m from the soil surface. The deep ripping process combined with the application of gypsum will flocculate the soil and assist with drainage through the base of the dam for movement of water and salt below the root zone of plants. The application of gypsum will be at a rate of 10t/ha, there will be no incorporation other than the deep ripping of the dam floor as movement of dissolved calcium will flocculate the soil and enable salt to be leached below the root zone over time. Arris strategy will be to manage all sediments and impacted soil in the dam rehabilitation phase in situ.
The identification and separation of soil contained in the bank into 'good' and 'poor' quality soil. The good soil will be actively identified during the earthworks and set aside.	Where possible, topsoil will be identified for reuse as topsoil. Poor quality soil will be returned to the floor of the dam to cover sediment.
Depending on the condition of the soil retained for the surface rehabilitation, soil may require further amendment.	As gypsum is a salt and can impact the osmotic (salt) effect on plants that are being established, timing of application will be critical. For this reason organic matter will be used to improve the soil condition, soil structure and moisture holding capacity, and through decomposition provide nutrients for the replanted vegetation. If conditions require that gypsum be applied for the correction for surface sodicity, it will be undertaken post replanting. This is to mitigate risk of increased salt in the surface soil that could negatively impact plant germination and performance. If and when appropriate, the required soil amendments will be spread and incorporated by rain.
Phase 4 - Re-sowing	**WestSide with technical assistance from Arris with respect**

Activity	Responsibilities, Action and Rational
	to plant choices and soil bed preparation
Re-sowing of pasture and/or native vegetation	The first step in the rehabilitation process will be the undertaking and industry specific soil test to establish nutrient and other chemistry levels against Industry established thresholds. It is important that the soil profile is wet during germination as this helps lower the soil salinity (dilution effect) that is experienced by the sensitive seedlings during germination. Depending on the soil condition and seasonal conditions (high temperatures and rainfall), supplementary watering may be required.
Species and varieties of plants selection Recommended plant species that at yet to be agreed to agreed to for planting	On the basis of: • the requirements of the landholder and the EA requirements; • the salt tolerance of pasture species to be included; and • the species that make up the background analogue sites; a range of suitable plant species that have increased salt and water logging tolerance are included in Table 13. Note: these are suitable examples of pasture plants with increased salt tolerance and not a recommendation for selection. It is important to understand that the soil condition at planting will be the most hostile experienced post rehabilitation. Rainfall and time will create increasingly favourable conditions. Good coverage of actively growing plants will be essential for improving the soil environment. The species selected for direct seeding will be guided by the final land use (grazing), pre-clearance vegetation, soil conditions, micro-climate and aspect of the new landform, and determined in consultation with the landholder. Preference has been given to the use of native species; however the final land use of grazing dictates that some non-native species are required. Native trees and shrubs may also be required should the landholder agree. Seeding is to be undertaken as soon as practicable after the topsoil has been reinstated and nature profile restored, but before spreading mulch. The grass seed mix to be applied is a mix of Agricote USA Buffel (45 percent), Agricote Urochloa (15 percent), Agricote Bisset Blue Grass (10 percent) and Agricote Seca/Siran/Amiga Stylo (30 percent) and has already been agreed upon by Westside and the Landowner. It may also be appropriate to plant some tree and shrub seedlings. Recommended species (dependent upon seedling availability and landholder agreement) include the following: • Eucalyptus crebra (Narrow-leaved ironbark); • Corymbia clarksoniana (Grey bloodwood); • E. moluccanna (Gum-topped box); • E. populnea (Poplar box); • E. melanophloia (Silver-leaved ironbark);

Activity	Responsibilities, Action and Rational
	• Eremophila mitchellii (False sandalwood); • Geijera parviflora (Wilga) • Archidendropsis basaltica (Dead finish); • Carissa ovata (Currant bush); • Erythroxylum australe; and • Capparis lasiantha (Native orange).
Soil water management Soil water management Soil water management (cont.)	It will be important to manage soil at a level that does not impact plant germination and productivity. • Sowing should take place to maximise the benefit of potential rainfall (early in the wet season). • In the event of poor rainfall a watering strategy should be developed to ensure that water applied exceeds plant demand. • Water salinity of between 250-500mg/L (TDS) should be used. It s likely that the plants will have higher tolerance to salt in water but due to likely background levels, 'good quality' water should be used. • When watering it will be an advantage to keep equipment and vehicles off the site to avoid compaction and associated issues. However, if this is not possible then vehicles should follow the designated tracks. A surface application of compost, applied post planting will create a barrier to reduce surface drying. This in turn will have positive effect on soil moisture and help mitigate the potential impact of retained salt. Applying compost will help to hold water and improve infiltration, reduce water loss, reduce erosion potential and provide nutrients for plant growth. Organic matter applied should not be greater than 50mm deep as it could impact seed emergence.
Site to be fenced for protection. It is anticipated that the fencing be retained until successful revegetation has been achieved. This is likely to be up to three years.	Fencing of the site will be an important part of the process as this will help prevent livestock access. Cattle traffic when soils are wet will compact soils. This effect will be more severe for salt affected saline soils. Cattle will pull young plants from the soil when grazing, thinning plant density. By fencing the site, all organic matter grown will be retained and form part of organic carbon and nutrient cycles. When good ground cover is achieved, the fence will be removed so 'normal' land management can be undertaken.
Phase 5 - Monitoring,	**WetSide with assistance from Arris with respect to soil**

Activity	Responsibilities, Action and Rational
Reporting and Ongoing Maintenance	**analyses and interpretation and further remediation plans if necessary**
Monitoring and reporting will be undertaken as per regulatory requirements. A monitoring plan will be developed following the completion of re-sowing and will be informed by rehabilitated condition, plant species and climatic conditions.	It is likely a monitoring plan will be required over the three years following revegetation to ensure satisfactory vegetation, with development soil salinity and structural stability: • Site inspection and report at 3 months; • Site inspection and report at 6 months; • Site inspection and report at 12 months; • Site inspection and report at 24 months; • Site inspection and report at 36 months. Assessment will include soil analysis of areas with poor revegetation. The revegetation assessment will be photographic. Soil assessment will be laboratory and field soil analysis.
Erosion and Sediment Control Plan (ESCP).	Although it is not envisaged that erosion and sediment will be an issue, rehabilitation works for this pond should be conducted to comply with the ESCP including aligning with drainage lines. Plan to be prepared by WestSide.
Weed and pest management.	It is not anticipated that weeds and pests will be a significant issue, however: • declared weeds under the Land Protection (Pest and Stock Route Management) Act 2002 (Qld) (LP Act) should be controlled as required throughout the rehabilitation activities duration; • pest animals have the potential to cause severe land degradation by promoting soil erosion, stream turbidity and the spread of weeds and can impact rehabilitation success; under the LP Act it is a legal requirement of all landowners and landowning State agencies to control declared pests.
Bushfire management.	The rehabilitation of this site will not increase the risk of bushfire. However, it should be managed in accordance with WestSide's Bushfire Management Plan.

5 Dam Rehabilitation: Earthworks Process

The dam rehabilitation was a stepwise process with eight elements:

1. Identification of material with high salt concentration. This is critical to the successful rehabilitation is to separate clean and high salt materials to ensure appropriate material is placed in the rootzone of the rehabilitation plants.
2. Apply gypsum to allow for drainage over time to mitigate risk of erosion and salt build up in the rootzone of rehabilitation plants.
3. Deep rip to maximise water flow down layers with high clay content
4. Use the mix and bury method to relocate saline material to below the base of the dam and top make the dam trafficable to support earthworks for the rehabilitation. This is undertaken to ensure the reconstructed profile has the materials that are most likely to negatively impact plant growth at greatest depth.
5. Separate the topsoil on the outer surfaces of the dam walls from the subsoil which forms the internal portion of the dam walls
6. Redistribute the subsoil over the mix and bury layer
7. Redistribute the topsoil over the subsoil
8. Revegetation of site, to be conducted by WestSide.

WestSide managed the earthworks process and Arris was onsite to provide the required soil science capability to identify saline materials and recommend their safe incorporation in the soil profile not accessed by pasture species. In addition, Arris signed off on the earth works as being completed in line with the plan.

The rehabilitation process occurred in late August at the end of the dry season.

6 General Site Characteristics

The dam is approximately 200 x 230m and empty of water even thought the Google Earth shot shows water (Figure 1). This is because the Google Earth image comes from 2015. It was constructed using a cut and fill approach, using the soil from the cutting process to create the dam walls.

Figure 1 Dawson Dam near Moura, QLD (Google Earth snapshot, accessed on 10 August 2017 but image taken in 2015, hence the presence of water in the dam)

The main elements of the area to be rehabilitated included the dam walls and base (Figure 2).

Figure 2 General views of the Dawson Dam site before rehabilitation started

When the dam walls were created, the topsoil was separated from the subsoil and placed over the outside of the wall formed by piling up the subsoil ()Figure 3.

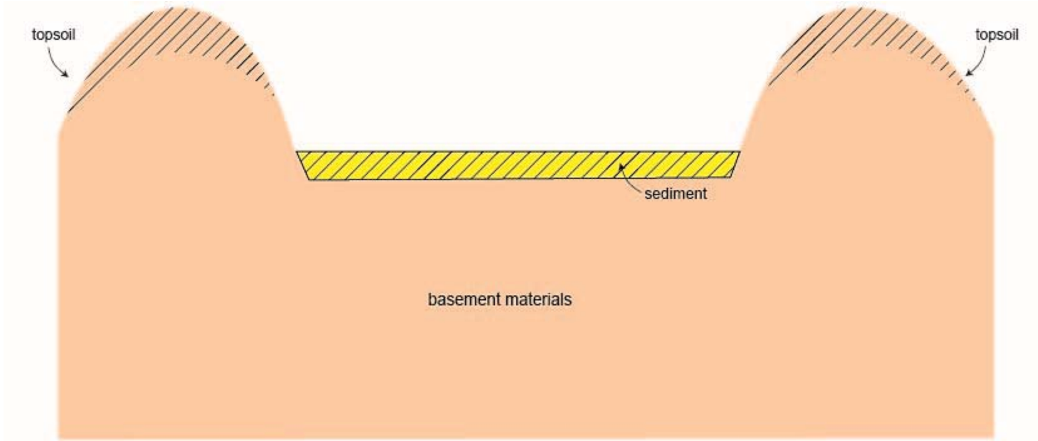


Figure 3 Cross section of the Nipan Dam showing dam walls and base

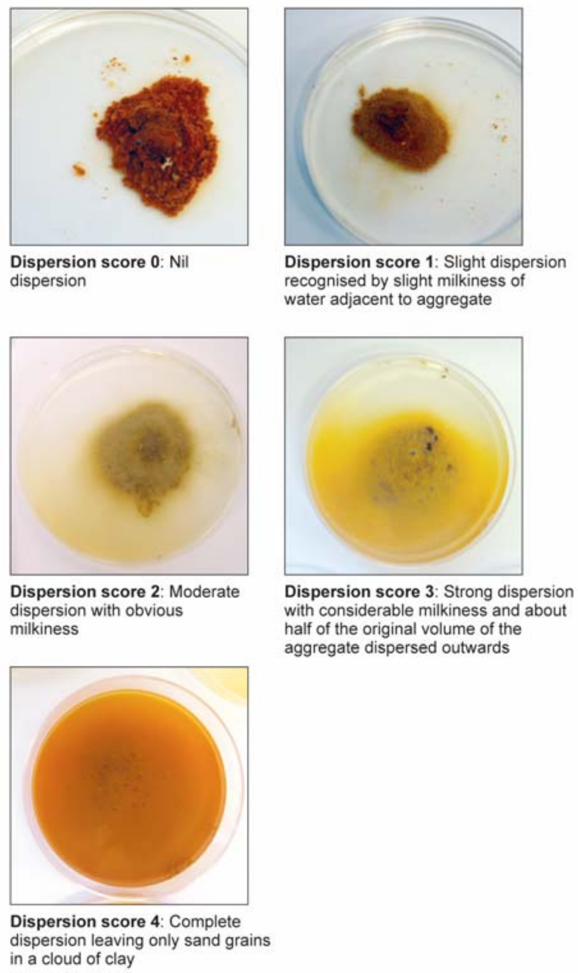
7 Methodology

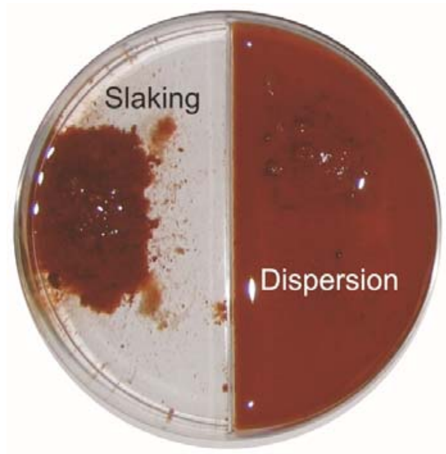
Rehabilitation commenced on 8th August 2017.

During the earthworks, soils were field assessed for texture, slaking, dispersion, pH and electrical conductivity in a 1:5 water suspension.

Soil texture was determined in the field by moistening some soil and creating a bolus (McKenzie et al., 2004). The ball of soil is then rolled into a sausage and its flexibility (i.e. how easily it cracks when bending it) and length are used to classify the texture (Anderson et al., 2007).

Slaking and dispersion were estimated by placing aggregates into deionised water and assessing the level of dispersion using a visual score of the extent of dispersion (Anderson et al., 2007). Slaking was assessed as either: very evident (VE), evident (E), slightly evident (SE) or non evident (NE).





Above: Dispersion and slaking (Anderson et al (2007)

Left: Dispersion score (Anderson et al 2007)

Figure 4 Scoring of soil dispersion and slaking assessment (Anderson et al., 2007)

During and after rehabilitation, samples were taken from finished topsoils (before gypsum application) and from the basement layer (after mix and bury but before gypsum application). Soil samples were sent to the CSBP Laboratory in Western Australia and the chemical and physical characteristics analysed are given in Table 3. The data was used to confirm field analyses and assess the suitability of soils for plant growth.

Table 3 Analyses conducted on topsoil and basement layer samples after rehabilitation but before gypsum application at the Dawson dam site

						Exchangeable Cations							DTPA Trace Elements									
Sample	pH water	pH_{CaCl2}	$EC_{1:5}$	EC_e	Boron	K	Ca	Mg	Na	Al	H	Effective CEC	Cu	Zn	Mn	Fe	Nitrate NO3	Ammonium NH4	Colwell K	Organic Carbon	Colwell P	KCL S
S1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S4	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S5	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S6	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S7	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S8	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S9	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S10	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
B1	X	X	X	X	X	X	X	X	X	X	X	X										
B2	X	X	X	X	X	X	X	X	X	X	X	X										
B3	X	X	X	X	X	X	X	X	X	X	X	X										
B4	X	X	X	X	X	X	X	X	X	X	X	X										
B5	X	X	X	X	X	X	X	X	X	X	X	X										
B6	X	X	X	X	X	X	X	X	X	X	X	X										

S = topsoil
B= Basement layer

8 Identification of Contaminated Material

Two samples were taken from the dam base and 28 samples from the dam walls (Figure 5) and were then field assessed using the methods described in the previous section.

Figure 5 Sampling sites for the Dawson Dam

9 Dam Wall Assessment (0-10cm)

The dam walls were approximately 5m high. Samples were taken at a 25m spacing along each of the four walls, resulting in 28 sites (Figure 5). The soil materials making up the 0-10cm layer of the inside of the dam wall were assessed because it was considered it would be the most prone to an increase in salt concentrations due to contact with the CSG waters.

Samples were taken on the inside of the dam wall to a depth of 10cm, 1m above the dam base and 1m below the top of the dam wall. They were assessed for pH and electrical conductivity in a 1:5 mixture of soil and water ($EC_{1:5}$), soil texture and aggregate stability (slaking and dispersion).

The texture of the samples varied from a clay loam to a heavy clay (Table 7).

9.1 Salinity in the dam wall

The $EC_{1:5}$ measured in the field was converted to the electrical conductivity in a saturated extract (Field EC_e) by using a multiplying factor (Cass et al., 1996) given in Table 4. The conversion enables the identification of soils that would be a barrier to plant germination and/or growth.

Table 4 Classification of soil texture and the conversion factors to estimate EC_{se} from $EC_{1:5}$

Texture	Factor (R)
Sand (S), loamy sand (LS)	13
Silty loam (SiL)	12
Sandy Loam (SL), loam (L)	11
Sandy clay loam (SCL), clay loam (CL), silt clay loam (SiCL)	9
Sandy clay (SC), silty clay (SiC), loamy clay (LC)	7
Medium clay (MC), heavy clay (HC)	5

(Adapted from Cass et al., 1996)

The resulting EC_e was then classified according to its potential impact on plant growth using Table 5.

Table 5 Classification of soil EC_{se} according to its potential impact on plant growth (adapted from Cass et al., 1996)

EC_{se} dS/m	Salinity hazard	Effects on plant yield
<2	Non-saline	Negligible effect
2-4	Slightly saline	Very sensitive plants affected
4-8	Moderately saline	Many plants affected
8-16	Very saline	Salt tolerant plants unaffected
>16	Highly saline	Salt tolerant plants affected

The calculated EC_e (Table 7) indicate that the CSG water has not impacted the salinity of the dam wall materials very much. One exception was in the region of site 4 where unsuccessful attempts had been made to increase the evaporation of the CSG water by spraying it onto the dam walls. This had led to the 0-10cm layer of the dam wall being very saline (Table 5) and only salt tolerant plants might be unaffected.

It is appropriate to consider an average salinity as there will be significant mixing of soil contained in the dam wall during the land reformation process. Using a bulldozer to transport soil and further tillage will further increase soil mixing. The average salinities in the lower portion of the dam wall show the same trend as the individual samples (Table 6), i.e. there is a slightly higher salinity lower down the dam wall presumably because there is more likelihood that the lower portion would have been in contact with CSG water. Nevertheless, the average values both at the top and bottom of the dam wall were only slightly saline for plant growth (Table 5).

Table 6 Average salinity of all dams walls at two places on the wall

Position of sampling	Mean EC_e for all dam walls (dS/m)
1m down from top of dam wall	2.10
1m up from bottom of dam wall	1.57

Table 7 Field analyses of samples taken from 1m above the dam base (lower bank) and 1m below the top of the dam wall (upper bank) at 28 sites around the Dawson dam

Site	Material	Ribbon length (cm)	Texture	Slaking	Dispersion	Effer-vescence w HCl addition	Effer-vescence w H_2O_2 addition	EC 1:5 water (dS/m)	EC_e Calculated (dS/m)	pH
1	Lower bank	7	Light clay	VE	3	none	none	0.65	4.55	7.1
	Upper Bank	>10	Heavy clay	NE	0	none	none	0.17	0.85	7.15
2	Lower bank	>10	Heavy clay	SE	1	none	none	0.67	3.35	7.96
	Upper Bank	12	Heavy clay	NE	0	none	none	0.15	0.75	7.5
3	Lower bank	11	Heavy clay	SE	1	none	none	1.21	6.05	7.45
	Upper Bank	12	Heavy clay	NE	0	none	none	0.17	0.85	7.56
4	Lower bank	8.5	clay loam	E	1	none	none	1.24	8.68	7.23
	Upper Bank	8	clay loam	NE	0	none	none	1.21	8.47	7.17
5	Lower bank	12	Heavy clay	E	1	none	none	1	5	7.71
	Upper Bank	7	clay loam	SE	0	none	none	0.91	6.37	7.68
6	Lower bank	11.5	Heavy clay	SE	0	none	none	0.43	2.15	7.8
	Upper Bank	13	Heavy clay	E	0	none	none	0.33	1.65	7.72
7	Lower bank	8	clay loam	NE	0	none	none	0.08	0.56	7.53
	Upper Bank	10	medium clay	E	0	none	none	0.14	0.7	6.92
8	Lower bank	12	Heavy clay	SE	0	none	none	0.23	1.15	7.47
	Upper Bank	11.5	Heavy clay	E	0	none	none	0.12	0.6	7.72
9	Lower bank	9.5	medium clay	VE	0	none	none	0.2	1	7.79
	Upper Bank	9	medium clay	SE	0	slight	none	0.12	0.6	7.44
10	Lower bank	9	medium clay	VE	0	slight	none	0.11	0.55	7.43
	Upper Bank	9	medium clay	E	1	none	none	0.15	0.75	7.24
11	Lower bank	9.5	medium clay	VE	0	none	none	0.1	0.5	7
	Upper Bank	12	Heavy clay	E	2	none	none	0.2	1	7.74

Site	Material	Ribbon length (cm)	Texture	Slaking	Dispersion	Effer-vescence w HCl addition	Effer-vescence w H_2O_2 addition	EC 1:5 water (dS/m)	EC_e Calculated (dS/m)	pH
12	Lower bank	8.5	clay loam	SE	0	none	none	0.11	0.77	8.5
	Upper Bank	12	Heavy clay	SE	1	none	none	0.14	0.7	7.43
13	Lower bank	8.5	clay loam	SE	0	none	none	0.13	0.91	7.1
	Upper Bank	13	Heavy clay	NE	0	none	none	0.22	1.1	7.65
14	Lower bank	13	Heavy clay	E	3	none	none	0.15	0.75	7.24
	Upper Bank	12	Heavy clay	E	2	none	none	0.25	1.25	8.03
15	Lower bank	4	sandy clay loam	E	1	none	none	0.08	0.72	7.44
	Upper Bank	8.5	clay loam	E	0	none	none	0.17	1.19	7.39
16	Lower bank	10	medium clay	VE	4	none	none	0.55	2.75	8.97
	Upper Bank	11	Heavy clay	VE	1	slight	none	0.35	1.75	8.02
17	Lower bank	12	Heavy clay	E	4	none	none	0.27	1.35	8.04
	Upper Bank	13.5	Heavy clay	SE	0	none	none	0.18	0.9	7.79
18	Lower bank	12	Heavy clay	VE	1	none	none	0.29	1.45	7.71
	Upper Bank	11.5	Heavy clay	VE	0	none	none	0.14	0.7	6.72
19	Lower bank	12	Heavy clay	VE	3	none	none	0.26	1.3	7.48
	Upper Bank	13	Heavy clay	NE	2	Slight	none	0.18	0.9	7.64
20	Lower bank	13	Heavy clay	SE	3	none	none	0.68	3.4	8.16
	Upper Bank	15	Heavy clay	E	3	none	none	0.13	0.65	7.16
21	Lower bank	11	Heavy clay	VE	1	none	none	0.2	1	7.78
	Upper Bank	12	Heavy clay	VE	4	none	none	0.28	1.4	7.42
22	Lower bank	13	Heavy clay	VE	2	none	none	0.28	1.4	7.86
	Upper Bank	12	Heavy clay	VE	0	none	none	0.36	1.8	7.01
23	Lower bank	10	medium clay	VE	0	none	none	0.28	1.4	8.02
	Upper Bank	12	Heavy clay	E	2	none	none	0.08	0.4	7.37
24	Lower bank	10	medium clay	E	1	none	none	0.21	1.05	8.14
	Upper Bank	14	Heavy clay	E	3	none	none	0.44	2.2	8

Site	Material	Ribbon length (cm)	Texture	Slaking	Dispersion	Effer-vescence w HCl addition	Effer-vescence w H_2O_2 addition	EC 1:5 water (dS/m)	EC_e Calculated (dS/m)	pH
25	Lower bank	12	Heavy clay	E	0	none	none	0.35	1.75	7.48
	Upper Bank	14	Heavy clay	E	0	none	none	0.23	1.15	7.62
26	Lower bank	14.5	Heavy clay	VE	0	none	none	0.4	2	8.26
	Upper Bank	13	Heavy clay	NE	0	none	none	0.29	1.45	7.47
27	Lower bank	13	Heavy clay	-	-	none	none	-	-	6.19
	Upper Bank	12	Heavy clay	-	-	none	none	-	-	5.82
28	Lower bank	13	Heavy clay	-	-	none	none	0.21	1.05	-
	Upper Bank	13	Heavy clay	-	-	none	none	0.44	2.2	8.14

9.2 Slaking and Dispersion of dam wall samples (0-10cm)

Dispersion is caused by high soil sodicity (a high percentage of sodium on clay surfaces) which can contribute to structural decline creating erosion and drainage issues in the future.

Slaking was quite variable within the 52 samples taken (Table 7). Approximately one third of samples did not slake or there was only slight evidence of it. Slaking in the other samples was evident or very evident. Examples of no slaking (NE), slight evidence (SE) and evident (E) are given in Figure 6 whereas Figure 7 includes an example of very evident (VE) slaking.

Out of the 52 samples tested, 52% did not disperse (score = 0, Table 7) and another 21% only slightly dispersed (Score = 1, Table 7). The remaining samples had between scores of 2-4. Examples of scores of 0, 2 and 3 are given in Figure 6 for samples 13 and 14.

Figure 6 Slaking and dispersion in dam wall samples 13 and 14

Figure 7 shows examples of dispersion with scores of 0, 1 or 4 from samples 15-17.

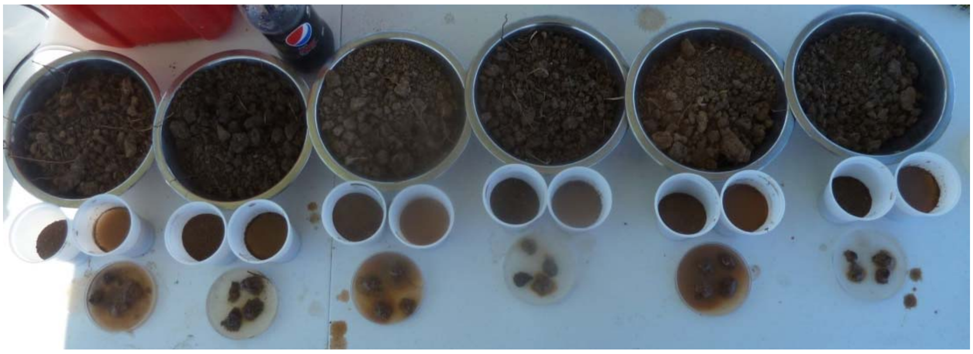


Figure 7 Slaking and dispersion in dam wall samples 15-17

10 Dam Base Assessment

Pits were dug in the dam base and typical examples of the profiles are given in Figure 8. At the surface, there was a layer of red brown sediment that varied in thickness from 30 – 150cm. Below this were mainly clay materials which varied in colour from grey, yellow and red to green (Figure 8).

The texture of the soils varied from a sandy clay loam to a heavy clay (Table 8; Figure 9).

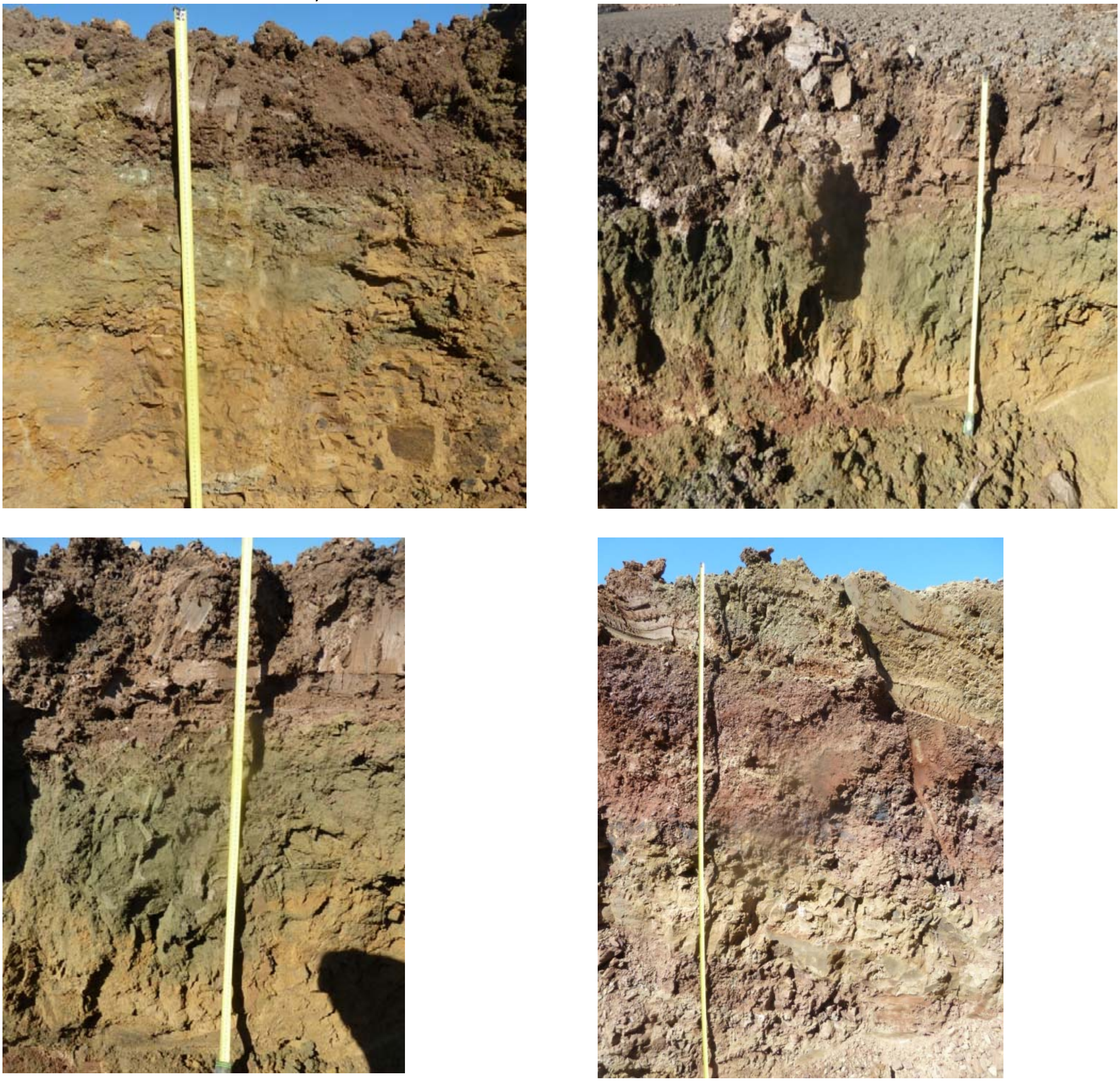


Figure 8 Example of materials found in the dam basement

10.1 Salinity and pH

Field analyses indicated that pH values varied from 8.4-9.5 whereas EC_e would support plant growth except sensitive plants may have difficulty with the salinity of the green clay found at Site 2 (Table 8).

Table 8 Field analyses of two dam base sites at Dawson dam

Site	Material	Colour	Depth of sample (cm)	Ribbon length (cm)	Texture	Slaking	Dispersion	Effer-vescence w HCl addition	EC 1:5 water (dS/m)	EC_e Calculated (dS/m)	pH
1	Sediment		0-30	9	Medium clay	E	3	-	-	-	-
	Soil		30-45	9	Medium clay	SE	2	-	0.9	4.5	9.24
	Soil		45-100	7	Light clay	NE	1	-	0.54	3.78	8.52.
	Soil		>100	12	Heavy clay	SE	4	-	0.47	2.35	8.41
2	Sediment		0-34		Light clay	NE	0	High	-	-	-
	Soil	Green	34-74	3	Sandy clay loam	VE	3	-	1.02	9.18	9.5
	Soil	Yellow	74-120	4	Clay loam	SE	2	-	0.43	3.87	8.7
	Soil	Red	>100	6.5	Light clay	SE	5	-	0.45	3.15	8.5

10.2 Slaking and dispersion

(a) **Site 1**: 0-30, 30-45, 45-100cm and >100cm (left to right in photo)

(b) **Site 2**: 0-34, 34-74, 74-120cm and >100cm (left to right in photo)

Figure 9 Texture, slaking and dispersion at the two sites in the dam basement

Slaking and dispersion varied but not in a consistent manner with depth.

11 Saline soil placement

Two sources of saline soil were identified:

- The sediment (30-150cm deep) on top of the dam base;
- The dam basement (up to 10m deep below the sediment).

The sediment thickness varied quite widely. At the southern end of the dam base, it was 30cm thick while at the northern end it was only 1.5m deep.

Pits, 3-10m in depth, were dug into the base of the dam. The sediment was mixed with the soil taken from the pits and relocated in a pit (Figure 10).

The contaminated soil were placed at a depth sufficient to ensure that the subsequent profile reconstruction would cover saline material to a depth of ≈ 2m so as to provide adequate protection for pasture re-establishment.

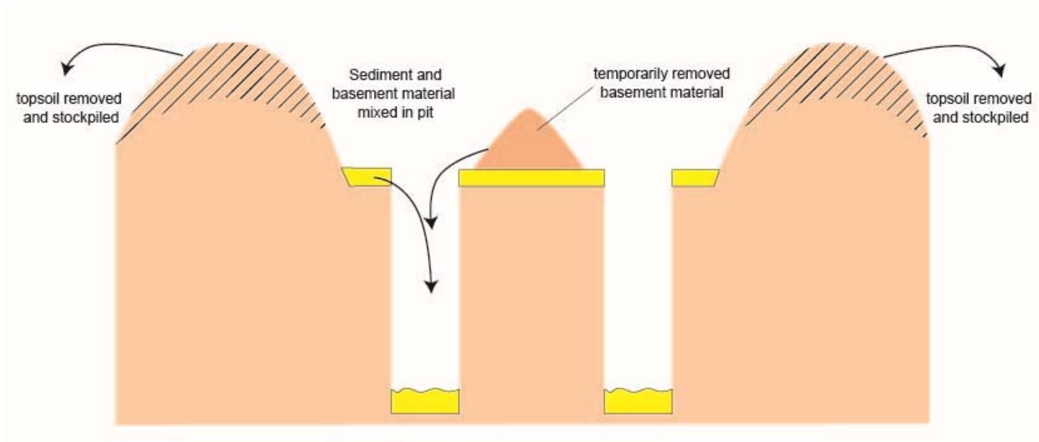


Figure 10 Cross section of the Dawson Dam showing the mix and bury process

After the mix and bury process was completed, materials from the dam walls were spread over the top of the reformed basement surface (Figure 11).

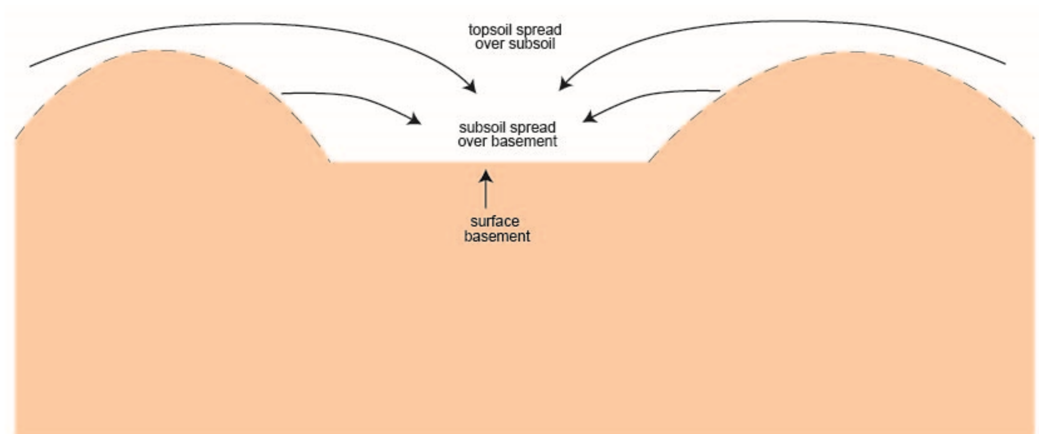


Figure 11 Cross section of the Dawson dam showing the spreading of the dam wall materials over the reformed basement

12 Reformation of the Pasture Land

This was undertaken in a stepwise process where a pit was excavated down 3-10m, saline material was added and then the excavated material replaced on top of the saline material and the two materials were mixed together (Figure 12). This process was repeated until all saline material was buried to depths of greater than 1m as required in the rehabilitation plan (Figure 13).

a) A pit being excavated during the mix and bury process

b) Pits and stockpiled material that has been excavated

Figure 12 General views of the mix and bury process underway

Figure 13 Reformed basement surface after the mix and bury process was completed

Gypsum was applied to the surface of the mix and bury layer (Figure 14) and then it was deep ripped to a depth of 1m (Figure 15) before subsoil (~2m deep) was placed over it.

Figure 14 Spreading gypsum onto the reformed basement layer after completion of the mix and bury process

Figure 15 Ripping the reformed basement layer formed after the mix and bury process

The topsoil on the outer surface of the dam walls was then scraped off into a temporary stockpile (Figure 16).

Figure 16 Topsoil that had been scraped of the outside of the dam walls and stockpiled temporarily

The subsoil exposed in the dam walls was then spread over the reformed basement surface (Figure 17) and deep ripped to 1m (Figure 18).

Figure 17 Spreading the subsoil over the reformed dam basement

Figure 18 Deep ripping the subsoil to a depth of 1m

Subsequently, topsoil was spread over the subsoil to a depth of ~20cm (Figure 19).

Figure 19 Spreading the topsoil over the ripped subsoil during rehabilitation of the Dawson dam

Gypsum was then applied to the surface and cultivated into the topsoil (Figure 20).

Figure 20 Cultivating gypsum into the 20cm depth of topsoil

The finished surface after the rehabilitation earthworks were completed is shown in Figure 21, illustrating that the reformation was continuous with the adjacent native land.

Figure 21 The finished surface after the rehabilitation earthworks were completed

It is not envisaged that the expression of sodicity will be a significant issue in the soil due to the application of gypsum and the electrolyte effect. Over time it is expected that the soil will increasingly reflect the condition of the native soil.

Before rehabilitation commenced, it was very evident that the clays in the basement material were high swelling and produced large cracks when dried (Figure 2). In addition, the depth of the pits dug for the mix and bury process varied from 2-10m. Consequently, it was decided to leave the site as it is for 12 months to allow for any subsidence to occur, if any. At the end of the resting period, reparations in the surface topography will be made if necessary and mulch will be spread on the surface and cultivated in before pastures species are sown. The 12 month period will also provide time for the gypsum to dissolve and for Ca to displace Na from exchange sites and be washed down the soil profile out of the root zone.

WestSide will apply the mulch and then cultivate it into the soil. The mulch will help increase the general fertility of the soil and enhance soil structure in the long term. It will help increase organic carbon which tended to be on the lower side. Organic carbon increases soil structure and nutrient retention as well as increasing the soil microbiome. The sol microbes will then increase soil fertility in the long term by recycling some nutrients into more available forms for plant uptake.

13 Analyses of Basement layer after mix and bury process was completed

After the basement layer was reformed, six samples were taken from a depth of 0-10cm as shown in Figure 22.

Figure 22 Location of sampling sites in the reformed basement before deep ripping

The samples were sent to CSBP in West Australia for analysis of the parameters given in Table 3.

The results in Table 9 indicate that the pH measured in $CaCl_2$ varied from 7.4-8.6. and the salinity was marginally high in three samples. The ESP was very high presumable because the soil was not prewashed before measuring the exchangeable cations. This results in soluble Na being counted as exchangeable Na, resulting in artificially high ESPs. Nevertheless, the addition of gypsum to the reformed basement will mitigate the high ESPs when calcium from the gypsum displaces Na off the exchange sites.

Table 9 Laboratory soil analyses of the 0-10cm layer of the basement after mix and berry and before deep ripping

Site	Soil Depth (cm)	Conductivity (dS/m)		pH		Exchangeable Cations (meq/100g)											ESP %	CEC (meq/100g)
		1:5 water	EC_e	$CaCl_2$	H_2O	Al	%Ex Al	H	% Ex H	Ca	%Ex Ca	Mg	%Ex Mg	K	%Ex K	Na		
1	0-10	1.546	9.30	8.6	9.4	0.05	0.15	0.04	0.12	8.0	24.92	5.2	16.2	1.6	5.1	17.2	53.5	32.1
2	0-10	1.124	8.50	7.8	8.6	0.03	0.09	0.03	0.09	9.6	28.23	11.6	34.1	0.6	1.8	12.1	35.7	34.0
3	0-10	1.147	8.20	7.9	8.8	0.03	0.10	0.05	0.15	9.8	29.6	10.7	32.1	0.6	1.8	12.0	36.2	33.2
4	0-10	0.480	3.30	8.2	9.4	0.03	0.11	0.03	0.10	7.1	23.1	10.3	33.7	0.6	1.9	12.6	41.1	30.6
5	0-10	0.404	3.00	8	9.3	0.04	0.12	0.03	0.10	8.0	26.1	10.6	34.7	0.6	1.9	11.4	37.2	30.6
6	0-10	1.021	7.50	7.4	8.4	0.03	0.08	0.02	0.06	7.1	22.0	10.4	32.1	0.7	2.2	14.1	43.6	32.3

14 Analyses of Reformed Topsoil

After completing the earthworks but before applying gypsum, ten samples were taken from the 0-10cm depth in the rehabilitated area (Figure 23).

Figure 23 Location of soil sampling sites in rehabilitated topsoil of dam site

The soils were sent to the CSBP Laboratory in Western Australia for independent, ASPAC accredited, analysis of chemical and physical properties (Table 12).

One cannot determine plant growth from soils analyses alone. Levels of some soil parameters need to be interpreted in conjunction with other parameters, e.g. extractable copper needs to be considered with pH and organic matter content. Hence the statements below are an indication only of the likelihood of issues with plant growth. Further analyses would have to be done if a particular parameter appears to be at a level that impacts plant growth.

Preliminary assessment (Arris, 2016) of two adjacent native soils (Figure 24) indicated that that the topsoils were low in nitrogen, phosphorus, and sulphur but were adequate to high in potassium (Table 10). The topsoil pH (H_2O) values were 8 and 7.7 which could limit some sensitive pasture species. This is compounded by pH values of 9 and 8.8 in the subsoil. The soils had marginal salinity in the topsoil and high salinity in the subsoils. The topsoils were not sodic but the northern subsoil was sodic and the southern subsoil was marginally sodic (Table 11).

(a) (b)

Figure 24 Native soil profiles (a) north of dam and (b) south of dam

Table 10 Soil chemical fertility characteristics of native soils adjacent to the Dawson dam rehabilitation area

Site	Ammonium Nitrogen	Nitrate Nitrogen	Phosphorus Colwell	Potassium Colwell	Sulphur	Organic Carbon
	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	%
Dawson Native Soil N 0-10cm	1	3	10	221	2.3	1.14
Dawson Native Soil S 0-10cm	2	4	6	190	6.2	1.62

Table 11 Laboratory analyses of native soils adjacent to the Dawson dam rehabilitation area

Site	Conductivity (1:5)	Conductivity ECe	pH ($CaCl_2$)	pH (H_2O)	OM	Boron	Top soil Chloride	Sub Soil Chloride
	dS/m	dS/m	pH	pH	%	mg/kg	mg/kg	mg/kg
Dawson Native Soil N 0-10cm	0.088	0.53	6.9	8	1.96	0.44	18.1	
Dawson Native Soil N 15-25cm	0.246	1.14	7.9	9	-	1.16	-	303.1
Dawson Native Soil S 0-10cm	0.11	0.71	6.5	7.7	2.79	0.86	53	-
Dawson Native Soil S 30-45cm	0.386	1.68	7.8	8.8	-	0.53	-	295.5

Table contd.

Site	Exc. Al	%Ex Al	Exc. H	% exc H	Exc. Ca	%Ex Ca	Exc. Mg	%Ex Mg	Exc. K	%Ex K	Exc. NA	ESP	CEC
	meq/100g	%	meq/100g	%	meq/100g	%	meq/100g	%	meq/100g	%	meq/100g	%	meq/100g
Dawson Native Soil N 0-10cm	0.056	0.24	0.0	0.0	16.16	69.0	6.25	26.7	0.54	2.3	0.4	1.71	23.42
Dawson Native Soil N 15-25cm	0.068	0.23	0.0	0.0	14.33	48.2	10.47	35.2	0.28	0.9	4.56	15.34	29.72
Dawson Native Soil S 0-10cm	0.085	0.33	0.0	0.0	17.48	67.0	7.26	27.8	0.48	1.8	0.78	2.99	26.10
Dawson Native Soil S 30-45cm	0.075	0.23	0.0	0.0	16.37	50.9	9.45	29.4	3.12	9.7	3.12	9.71	32.15

The main aim of the rehabilitation process was to ensure that the salinity and/or sodicity of the topsoil were not increased by soil movements and any contamination within the dam. Salinity is indicated by the electrical conductivity of a saturated extract (EC_e). The EC_e concentrations in the rehabilitated soils do not present any problems for plant growth (2-4.75dS/m) even though they were higher than the control (0.53-0.71dS/m). An exception was found in TS2 which had an EC_e of 6.17Ds/m but that is not considered excessive.

In contrast, all the reformed topsoil samples had ESP percentages similar to the native subsoil and hence were sodic (ESP were >6%, Table 12). This suggests that some mixing of the original top- and subsoils could have occurred during the construction of the dam.

Organic matter (OM) was lower than in the native soil (Table 10) but not outside the range of values that have been found in agricultural soils. pH and exchangeable cations in the rehabilitated soils were similar to the native subsoil and slightly higher than the native topsoil (Table 10). The pH_{CaCl2} is in the upper range considered to be adequate for plant growth. Organic matter concentrations are low and the soils may benefit from a compost application at a later date. However as the site produces vegetative matter in the future OM may self correct.

DTPA extractable copper (Cu), iron (Fe) and manganese (Mn) were in a range of values considered adequate for plant (Table 10). In contrast, zinc (Zn) appeared to be deficient in two of the reconstituted topsoil samples and marginal in the rest. Zinc deficient soils are not uncommon in the region and can easily be ameliorated with the addition of a zinc fertiliser.

The nitrate nitrogen (NO_3-N) in the rehabilitated soil varied quite widely from 2-60mg/kg but tended to be higher than in the native soil (Table 10). Disturbance of the reconstructed soil in combination with rainfall could have increased microbial activity leading to an increase in nitrification and the production of NO_3-N. The ammonium concentration in the rehabilitated topsoil samples were similar to the concentrations found in the native soils. The Colwell extractable phosphorous (P) was higher in the reformed topsoils than in the native soil but would still need augmentation as the concentrations were still low

The sulphate in the rehabilitated soil samples varied from 6-28mg/kg (Table 12). The soils with concentrations < 7mg/kg may benefit from an S application. The Colwell extractable potassium values were similar to the native soil concentrations (Table 12).

The chemical parameters of the soils are not of concern because they can all be augmented by addition of fertilisers.

The ESPs of the reformed topsoils appear to be higher than what one might expect from observing the EC_e values. This might be partly because of not pre-washing the soil before measuring exchangeable cations. This results in soluble Na contributing to the estimate of the exchangeable Na and so the estimated ESP is higher than in reality. In addition, there might have been some mixing of the subsoil with the topsoil which would have resulted in a true increase in the ESPs. Nevertheless, the addition of gypsum to the topsoil will lead to the displacement of the Na by Ca from the gypsum and thereby lower the ESP.

Table 12 Soil analyses from ten, 0-10cm samples of the rehabilitated soil before gypsum application

Site	Conductivity (dS/m)		pH		Exchangeable Cations (meq/100g)											ESP %	CEC (meq/100g)
	1:5 water	EC_e	$CaCl_2$	H_2O	Al	%Ex Al	H	% Ex H	Ca	%Ex Ca	Mg	%Ex Mg	K	%Ex K	Na		
TS1	0.677	3.88	7.7	8.5	0.08	0.25	0.02	0.1	15.70	48.5	10.69	33.0	0.47	1.5	5.39	16.66	32.35
TS2	0.812	6.17	7.6	8.4	0.09	0.26	0.02	0.1	13.45	38.3	12.77	36.4	0.4	1.1	8.37	23.85	35.10
TS3	0.95	4.63	7.8	8.5	0.068	0.19	0.01	0.1	16.11	45.2	12.09	33.9	0.48	1.3	6.91	19.37	35.67
TS4	0.636	3.47	7.8	8.5	0.082	0.25	0.01	0.0	17.41	52.4	10.66	32.1	0.51	1.5	4.57	13.75	33.24
TS5	0.741	3.44	7.9	8.6	0.088	0.26	0.02	0.1	16.75	49.4	10.98	32.4	0.46	1.4	5.63	16.59	33.93
TS6	0.477	1.89	7.9	8.9	0.104	0.35	0.02	0.1	14.61	49.5	9.55	32.4	0.43	1.5	4.79	16.24	29.50
TS7	0.573	2.84	7.9	8.8	0.094	0.30	0.02	0.1	14.65	47.4	10.52	34.1	0.4	1.3	5.21	16.86	30.89
TS8	0.722	4.75	7.9	8.8	0.097	0.31	0.01	0.0	14.33	45.3	10.83	34.2	0.38	1.2	5.98	18.91	31.63
TS9	0.806	4.58	7.8	8.6	0.086	0.26	0.02	0.1	16.13	48.9	10.62	32.2	0.54	1.6	5.59	16.95	32.99
TS10	0.71	4.66	7.9	8.7	0.099	0.32	0.01	0.0	14.49	46.2	10.7	34.1	0.4	1.3	5.64	18.00	31.34

Table 12 Soil analyses from ten, 0-10cm samples of the rehabilitated soil before gypsum application (contd.)

Site	Ammonium Nitrogen	Nitrate Nitrogen	Phosphorus Colwell	Potassium Colwell	Sulphur	Organic Carbon	DTPA Trace metals (mg/Kg)				
	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	%	Copper	Iron	Manganes e	Zinc	Boron
TS1	2	14	11	232	8.9	0.93	1.65	26.5	16.3	0.6	1.16
TS2	1	37	7	191	5.7	0.56	1.72	21.07	7.45	0.38	1.15
TS3	1	60	10	222	7.2	0.89	1.84	18.21	6.29	0.42	1.49
TS4	1	41	15	220	6.1	1.17	1.38	25.63	11.09	0.64	1.11
TS5	2	5	9	201	7	0.93	1.94	15.1	8.13	0.81	1.4
TS6	2	2	9	198	10.8	0.91	1.47	30.18	15.45	0.45	1.05
TS7	2	3	7	178	7	0.87	1.38	24.29	9.23	0.68	1.05
TS8	<1	10	5	259	7.7	0.73	1.25	15.16	5.03	0.54	1.26
TS9	2	8	9	188	10	0.93	1.64	18.08	8.14	0.53	1.45
TS10	1	13	7		21.8	0.76	1.4	12.41	5.99	0.5	1.25

15 Soil Preparation and Revegetation

As discussed, reseeding of the site with pasture species to meet the rehabilitation requirements of WestSide's EA and the needs of the farmer has not been undertaken at this point. This decision has been made to ensure a high level of germination and survival of pasture species. A list of pasture species has been provided in Table 13.

Table 13 Pasture species to be used in final rehabilitation planting

Pasture Species	Soil Requirements*
USA Buffel *Cenchrus ciliaris* Cv *American* (30% of mix)	A medium-short, early maturing, non-rhizomatous type, with fine stems, dense green foliage, and purple inflorescence, suitable for light to medium textured soils. Similar to Gayndah, but earlier flowering. Better seedling survival on acid soils than other cultivars. Selected for drought tolerance and forage production. Rapid growth from very early spring through late summer. Growth continues during hottest part of summer with brief showers. Fast recovery from grazing and drought. Susceptible to buffel grass blight (*Pyricularia grisea*). Moderate tolerance of salinity.
Toro Rhodes Grass *Poaceae (alt. Gramineae)* (25% of mix)	While preferring well-structured loams and clays of volcanic origin, it grows on most well drained soils, except very heavy clays, provided fertility is adequate. Very tolerant of high soil Na levels (conductivity >10 dS/m), particularly as HCO3- and SO4--, but less so as Cl- or NO3-. Also tolerant of high Li+ but not Mg++ . More tolerant of high than low pH, growing best in soils with pH between about 5.5 and 7.5, but will grow down to pH 4.5 and up to 10. Intolerant of high soil manganese.
Bambatsi Panic *Bothriochloa insculpta* Cv *Bisset* (25% of mix)	Found on sandy or clay soils in river beds, drainage courses, around pans or in depressions. It occurs mainly on seasonally waterlogged soils, rarely on heavy clays that are waterlogged for long periods. Var. makarikariense occurs on seasonally waterlogged or flooded heavy clays, often with significant salinity, suggesting why some types can produce up 50% maximum yield at an EC of 16.4 dS/m. Salt tolerance varies among genotypes (see 'Klein Verde'). While some types have been collected on low fertility soils, cultivars of both varieties have largely been selected for performance on fertile soils.
Desmanthus *Desmanthus sp* (20% of mix)	Occurs naturally on rocky limestone soils and occasionally on soils of volcanic origin. In exotic locations, *Desmanthus* spp. are generally selected for their persistence on duplex podzolics and cracking clays, including alkaline and sodic soils, but will grow productively on lighter soils of neutral to alkaline reaction.

* Taken from http://www.tropicalforages.info and http://keys.lucidcentral.org/keys/v3/pastures/Html/Stylo.htm and equivalent sites

16 Conclusions

A practical interactive approach to rehabilitation of the Dawson Dam site has resulted in an outcome that meets the Queensland regulations for rehabilitation of dams (Table 14).

Analyses have determined that salt affected soils were mainly limited to the sediment and the underlaying basement materials of the dam. These materials were relocated to below the original subsoil (>1m). This ensures that the salinity would have minimum impact on pasture growth which was the species in existence during the land's previous use (and similar to the current use of surrounding land). Deep ripping and gypsum applications were used to minimise dispersion and ensure suitable water infiltration rates in the future. Low-salt soil materials from the dam walls were used to reconstruct the soil profile followed by grading the site into the existing landscape.

Table 14 Outcomes of rehabilitation in terms of regulations for rehabilitation of dams in QLD

Regulation	Status	Comment
(X 28) After decommissioning, all significantly disturbed land caused by the carrying out of the environmentally relevant activity(ies) must be rehabilitated to meet the following final acceptance criteria:		
a) the landform is safe for humans and fauna	✓	Complete
b) the landform is stable with no subsidence or erosion gullies for at least three (3) years	✓	Ongoing will be completed over the following 3 years
c) any contaminated land (e.g. contaminated soils) is remediated and rehabilitated	✓	Complete
d) not allowing for acid mine drainage	NA	No acid drainage
e) there is no ongoing contamination to waters (including groundwater)	✓	No impact to terrestrial waterways No significant impact to groundwater
f) rehabilitation is undertaken in a manner such that any actual or potential acid sulfate soils on the area of significant disturbance are treated to prevent or minimise environmental harm in accordance with the Instructions for the treatment and management of acid sulfate soils (2001)	NA	No evidence of acid sulfate soil in rehabilitation zone
g) all significantly disturbed land is reinstated to the pre-disturbed soil suitability class	✓	Complete
h) for land that is not being cultivated by the landholder	✓	Land restored to pasture species agreed to by the landholder
a. groundcover, that is not a declared pest species is established and self-sustaining	✓	Complete, will be monitored for three years
b. vegetation of similar species richness and species diversity to pre-selected analogue sites is established and self-sustaining	✓	Complete, will be monitored for three years
c. the maintenance requirements for rehabilitated land is no greater than that required for the land prior to its disturbance caused by carrying out the petroleum activity(ies)	✓	Complete, will be monitored for three years
i) for land that is to be cultivated by the landholder, cover crop is revegetated, unless the landholder will be preparing the site for cropping within 3 months of petroleum activities being completed	NA	Revegetation by WestSide

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