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Project Number: 1000713

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Dear Caitlin

RE: Lake Way Vadose Zone modelling

1 Introduction

Salt Lake Potash Limited (SO4) is conducting baseline studies for the Lake Way Potash Project. The project involves the extraction of sulphate of potash rich brines from sediments underlying Lake Way, near Wiluna, WA. The project requires the construction and operation of evaporation ponds, brine extraction (including trenches and production bores), transport infrastructure and salt disposal areas.

To support a draft Environmental Review Document (ERD) being prepared for the project, CDM Smith Australia Pty Ltd (CDM Smith) has been engaged by SO4 to undertake vadose zone modelling to inform an assessment of risk to samphire vegetation (*Tecticornia*) in the riparian zone and burrowing salt lake invertebrates from project activities. The project will likely cause groundwater levels to be lowered for a period of time. It is unclear whether these changes pose a risk to the *Tecticornia* or to the invertebrates, and whether these risks (if identified) require mitigation. To inform the risk assessment, the vadose zone modelling will examine the following hypotheses:

- Hypothesis 1: a reduction in groundwater levels will limit the availability of water to *Tecticornia* and impose an increased drought stress on the vegetation.
- Hypothesis 2: a reduction in groundwater levels will reduce the soil moisture (humidity) for salt lake invertebrates and affect their burrowing habitat which is correlated to the depth of the water table.

This report describes the vadose modelling undertaken to examine the above hypotheses. The modelling undertaken is largely conceptual in nature (recognising that there is limited data available to calibrate a model, and that there is significant spatial variability in soil conditions) but designed to provide a better understanding of the key processes that influence the vadose zone hydrology at Lake Way and any changes imposed by project activities that may impact water availability to *Tecticornia* and the soil moisture conditions for salt lake invertebrates.

2 Data review and conceptualisation

2.1 Data sources

Table 2-1 lists the data sources and reports that were reviewed to inform the vadose zone modelling.

Table 2-1 Reports and data sources reviewed

Reports	Data sources
• RPS (2015) Centipede-Millipede Groundwater Impact Assessment. Report prepared for Toro Energy • Emerge Associates (2020) Lake Way Flood Modelling Report. Prepared for Salt Lake Potash • SO4 (2020) H3 Groundwater modelling report. Prepared by Salt Lake Potash • Outback Ecology (2011) Baseline soil survey report. Lake Way, Centipede West Deposits and Haul Road Corridor. Wiluna Uranium Project. Prepared for Toro Energy Ltd. • Marchesini V. et al. (2014) Drought tolerances of three stem-succulent halophyte species of an inland semiarid salt lake system. Functional Plant Biology, 2014, 41, 1230-1238 • Moir-Barnetson L et al. (2016) Salinity tolerances of three succulent halophytes (*Tecticornia* spp.) differentially distributed along a salinity gradient. Functional Plant Biology, 2016, 43, 739–750. • Datson B. (2005) Understanding species zonation of samphires (*Salicornieae*) in the Goldfields of Western Australia. • Bennelongia (2020) Short Range Endemic species assessment. Prepared for Salt Lake Potash. Draft.	• Mapped extents of *Tecticornia* • Baseline groundwater level monitoring data • Project layout shapefiles • Climate data: rainfall from Wiluna and pan evaporation rates from Meekatharra, supported by SILO data • Groundwater drawdown contours and hydrographs from groundwater modelling • Data from soil infiltration tests • Floodwater sample analysis • Photos of *Tecticornia* at Lake Way • Soil logs from trenches dug at *Tecticornia* sites at Lake Way

2.2 Conceptualisation

2.2.1 Vadose zone hydrology supporting Tecticornia

The following notes present a conceptualisation of the typical soil conditions and hydrology inhabited by *Tecticornia* at Lake Way, recognising that several different species are likely to be present and occupy several different ecological niches, as outlined by Datson (2005).

Soil profile

- *Tecticornia* inhabit the fringes of the playa sediments at the transition between playa and dune sediments.
- Baseline soil report (Outback Ecology 2011) indicates that when dune sediments thicken, the soil profile becomes less saline and other species inhabit the dunes. So, in effect, the dune sediments are either absent or relatively thin (less than 20 to 30cm where *Tecticornia* occur).
- Based on soil logs, soil texture and morphology are highly variable in areas of *Tecticornia*.
- Rootzone salinity is variable, ranging from low (ECe 0 to 2 dS/m) to moderate (ECe 2 to 4 dS/m) to high (ECe 4 to 8 dS/m), with soil salinities increasing with depth.

Rooting depth and distribution

- *Tecticornia* roots in areas surveyed at Lake Way are concentrated in the very near surface horizons (upper 10 to 20 cm). This is evident in photos and baseline soils data: root counts and chemical markers (e.g. nitrate, organic carbon).
- Root growth appears to be limited by salinity of subsoil and hardpans (cemented layers).
- Some deeper roots have been observed but very few below 50 cm.

Groundwater

- The water table is about 1 m below surface or deeper in vegetated areas near the playa perimeter and is hosted by the lake bed sediments aquifer.
- Groundwater levels are driven by evapotranspiration (ET) and rainfall recharge from the surface. Water level fluctuations in groundwater monitoring data collected from vegetated areas in the lake bed sediments aquifer indicate recharge in the order of 50% of rainfall for major events, i.e. events greater than 5 mm (SO4 groundwater modelling report), and losses to ET in the order of 30 mm/y.
- Hydraulic conductivity for playa sediments is estimated to be about 5 m/d (approximately 20 mm/h) in the SO4 groundwater model, which is similar to the saturated hydraulic conductivity, K_s, listed for playa sediments in the Outback Ecology (2011) baseline soils report (18.6 mm/h for LW13).
- Groundwater is hypersaline, ranging from 250,000 mg/L underneath the playa to approximately 100,000 mg/L under areas of riparian vegetation.

Surface water

- Based on flood modelling (Emerge 2020), areas of *Tecticornia* are generally free from periods of inundation except for large events (e.g. 1 to 5% AEP), when it is possible that some (but not all) areas of *Tecticornia* will experience temporary submergence.
- Surface water salinity post-inundation is highly variable (TDS ranging from1,000 to 150,000 mg/L) and dependent on sampling location, with fresher water occurring in areas of surface water inflow and more saline water occurring on the Playa where salts have evapo-concentrated at the surface.

2.2.2 Vadose zone hydrology supporting salt lake invertebrates

Bennelongia (2020) reports that salt lake specialist invertebrates (e.g. beetles and spiders) use the lake sediments as refugia by constructing burrows whose depths are positively correlated with depth to water beneath the lake surface. A likely function of these burrows is the maintenance of a high-humidity environment with a relatively low ambient temperature, thus decreasing evaporative drive on the resident.

A survey undertaken by Bennelongia (2020) identified three species that may be affected by groundwater drawdown, some which were observed at the north-eastern edge of playa. A baseline soil survey report of Lake Way (Outback Ecology 2011) reports lake sediments in that part of the playa consisting of silty loam to light clay soil textures. There is no vegetation present at these locations and the surface consists of a thin, platy salt crust.

Depth to the water table is variable, but likely to be 50 cm or less in the areas inhabited by invertebrates. Groundwater modelling conducted by SO4 (2020) indicates project-related drawdown to be up to 2 m in parts of the playa, but not necessarily in the area where invertebrates have been observed.

3 Model set-up

3.1 Model platform

The model has been developed using the Soil Water Atmosphere Plant, SWAP, modelling code (Kroes et al. 2017). SWAP simulates the transport of water and solutes in the vadose zone and their interaction with the atmosphere and vegetation. The model uses the Richards equation and a sink term for root water extraction to simulate soil moisture movement in variably saturated soils.

The model domain is represented by a column of soil, extending from the ground surface to the water table. In this zone, the transport processes are predominantly vertical, making a 1D modelling approach a reasonable simplification. SWAP typically runs off a daily timestep, but shorter timesteps can be incorporated if required. The model domain is split into a series of horizontal compartments (model cells) of varying thicknesses, with finer discretisation (thinner compartments) required near model boundaries for numerical stability and to appropriately represent sudden changes in soil moisture over short distances.

While SWAP is capable of simulating heat transport and macropore flow, neither of these options were implemented in the modelling undertaken. Thus, the modelling undertaken represents matrix flow of a porous medium under conditions of uniform temperature.

3.2 Soil profile and properties

As outlined in the conceptualisation, soil properties in the areas of *Tecticornia* can be highly variable (ranging from sands to clays), with no generic soil type apparent. Rather than modelling every single type of soil, two different soil types have been selected: a loamy sand (representing a more coarsely textured soil) and a loam (representing a moderately coarse soil). A more clayey soil was not modelled because a clayey soil over a shallow water table will have a capillary fringe that extends to the surface and create waterlogged and saline conditions in the rootzone that are unfavourable for root water uptake.

For the model scenarios that investigate effects on salt lake invertebrates, silt loam and clay loam soils have been selected to approximate the range in soil textures of playa sediments described by Outback Ecology (2011).

The soil hydraulic parameters used in the modelling are listed in Table 3-1. The Mualem-Van Genuchten functions (Mualem 1976; Van Genuchten 1980) are used for calculation of relative permeability and degree of saturation with a modification near saturation implemented according to Schaap and Van Genuchten (2006) to avoid numerical instabilities. The parameters selected are based on average soil water retention and hydraulic conductivity parameters for major soil textural classes according to Rawls et al. (1982).

The soil water retention and hydraulic conductivity functions based on the parameters selected are shown in Figure 3-1 and Figure 3-2. Note the differences in the hydraulic conductivity functions which is related to the different pore size distributions. These have important consequences for the modelling undertaken, as follows:

- For the scenarios investigating drawdown effects on Tecticornia: While the loamy sand has a higher saturated hydraulic conductivity K_s, it has a lower hydraulic conductivity at soil suctions in excess of 10 cm (compared to the loam). Thus, for the pore pressure of a soil profile in equilibrium with a water table, the hydraulic conductivity of the loam would be greater than the loamy sand at soil depths more than 10 cm above water table. In this manner, the loam soil is able to conduct more water from the groundwater table to the land surface in response to ET for water tables deeper than 10 cm.
- For the scenarios investigating drawdown effects on salt lake invertebrates, the silt loam has a hydraulic conductivity about 6 times that of the clay loam for any given soil suction.

Table 3-1 Soil hydraulic parameters

Parameter	Symbol	Units	Soil properties for Tecticornia simulations		Soil properties for salt lake invertebrate simulations	
			Loamy sand	Loam	Silt Loam	Clay Loam
Saturated water content	Θ_S	cm³/cm³	0.4	0.45	0.49	0.39
Residual water content	Θ_R	cm³/cm³	0.03	0.03	0.02	0.08
alpha shape parameter (related to air-entry)	α	1/cm	0.12	0.09	0.05	0.04
n shape parameter (related to steepness of water retention curve)	n	-	1.5	1.2	1.2	1.2
m shape parameter	m (1 – 1/n)	-	0.3	0.2	0.2	0.2
Capillary pressure head	h_c	cm	1	2	2	2
Exponent	λ	-	0.5	0.2	0.2	0.2
Saturated hydraulic conductivity	K_s	cm/d	40	15	30	5

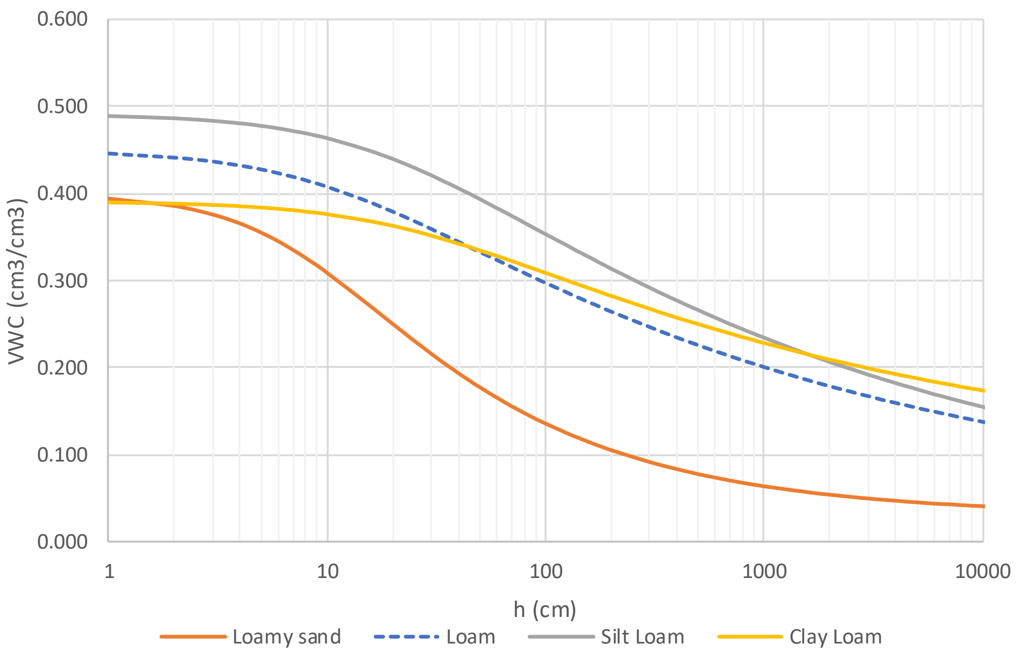


Figure 3-1 Soil water retention curves for the Loam and Loamy Sand materials modelled, showing the volumetric water content (VWC) with respect to soil suction (h)

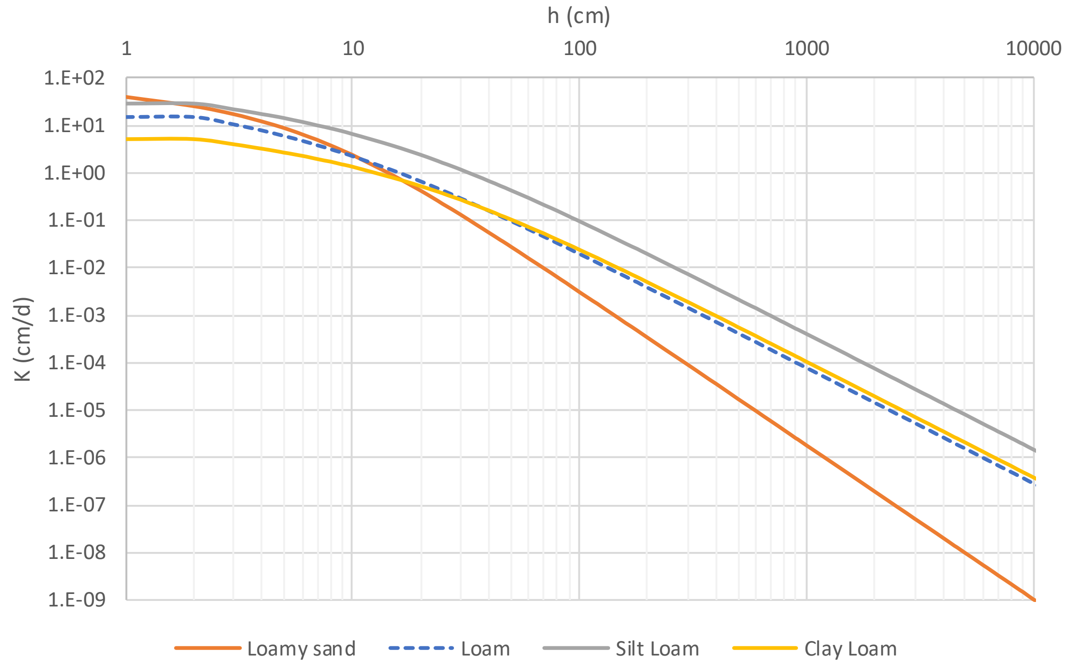


Figure 3-2 Soil hydraulic conductivity functions for the Loam and Loamy Sand materials modelled, showing the hydraulic conductivity (K) with respect to soil suction (h)

3.3 Upper boundary condition

3.3.1 Tecticornia model simulations

The upper boundary to the model is an atmospheric boundary which is driven by daily reference evapotranspiration (ET_{ref}) and rainfall data that is input to the model. ET_{ref} is a measure of potential ET and is the key driver of actual ET, which is comprised of soil evaporation (E) and root water uptake or transpiration (T). Soil evaporation occurs through the upper boundary of the model (at the land surface) and transpiration occurs via root water uptake from soil compartments where roots are present and there is moisture available.

ET_{ref} is partitioned into a potential soil evaporation rate and a potential transpiration rate using the Leaf Area Index (LAI). In this study, a LAI of 1.3 m^2/m^2 has been selected based on the global average for the desert biome (Asner et al. 2003). The ET_{ref} and LAI is used to calculate a potential soil evaporation rate, with actual soil evaporation determined by the rate at which water can be supplied to the surface via unsaturated flow, with the flux further limited by an empirical relationship devised by Black et al. (1969).

ET_{ref} can be scaled by a crop factor (κ_c), which has been used by this study to calibrate the fluxes at the base of the model domain to be similar to those observed and to provide for a range of scenarios representing different rates of root water uptake (T) in response to atmospheric conditions. When used in this manner, κ_c can be used to scale the transpiration demand of vegetation and mimic either a more conservative or less conservative approach to accessing soil moisture. Plants vary in their responses to increased soil moisture conditions from rainfall events. Less conservative species will consume the moisture rapidly and respond by rapid shoot growth and increased transpiration with the downside to this strategy being that the soil moisture will be exhausted quickly. More conservative species will maintain stomatal control to consume the water gradually with the payoff being that the soil moisture is available for a longer period. Further definition to simulated transpiration is provided in the following section.

3.3.2 Salt lake invertebrate model simulations

The models set up to investigate drawdown influence on salt lake invertebrates do not include any plants. Thus, transpiration/root water uptake is set to zero (by assigning a LAI of 0 m^2/m^2) and only soil evaporation is modelled.

3.4 Root water uptake/transpiration

SWAP simulates root water uptake as a sink term to the Richards equation where soil moisture is extracted from each soil compartment based on the level of atmospheric demand (κ_c *ET_{ref}), the relative density of roots within the soil compartment and the soil moisture and salinity conditions which define the moisture availability to the plant.

In this study, the rooting depth is assumed to be 50 cm, with 80% of the roots concentrated into the upper 20 cm of soil.

Soil moisture availability is defined using stress functions to limit root water uptake when the soil becomes too wet, too dry or too saline. The following assumptions have been made to define these functions in this study:

- Three separate functions are defined to calculate stress factors for saturation stress, drought stress and salinity stress. The stress factors vary between 0 and 100%, where 0% results in zero root water uptake and 100% represents non-limiting conditions. The stresses are assumed to be multiplicative.
- Saturation stress: Root water uptake is assumed to be zero when the soil compartment is saturated with non-limiting conditions occurring when the air-filled porosity is 10% or greater. For example, in the loam soil, the porosity is 0.4 cm^3/cm^3 and 10% air-filled porosity is reached at a soil suction of 10 cm. In the loamy sand, the 10% air-filled porosity is reached at a soil suction of 5 cm. The threshold of 10% air-filled porosity is a default assumption for soil physics studies examining plant water availability but will likely vary between species.
- Drought stress: based on the studies into the drought response of *Tecticornia*, it is assumed the drought stress increases linearly with respect to soil suction from 0% at a point near saturation to 100% at a permanent wilting point. Marchesini et al. (2014) indicates a permanent wilting point at a soil suction of around 10 MPa (1,000 m water head) for different species of *Tecticornia*. This is a very high wilting point and indicates a plant that is able to tolerate extremely dry environments. For comparison, the wilting point for agronomic crops is nominally set at a soil suction of 1.5 MPa (150 m water head). Indeed, SWAP only has a maximum wilting point of 2 MPa, which has been used in this study. While this differs considerably from the literature threshold, the use of a much lower wilting point is a conservative assumption when evaluating the drought stress imposed by lowering the water table and is therefore appropriate.
- Salt stress: Moir-Barnetson et al. (2016) indicates that *Tecticornia* can tolerate salinities of up to around 1,750 mM NaCl, which is roughly equivalent to a TDS of 100,000 mg/L. Thus, for the modelling undertaken here, salt stress is assumed to increase linearly from non-saline conditions to a TDS of 100,000 mg/L with zero root water uptake at salinities greater than 100,000 mg/L.

3.5 Solute transport

SWAP models solute transport via convective, dispersive and diffusive processes. The parameters used in the modelling were a dispersion length of 10 cm and a diffusion coefficient of 1 cm^2/d. Adsorption processes and solute uptake by roots were not modelled. Initial conditions were set as a soil solute concentration of 1,000 mg/L in the rootzone, grading to 100,000 mg/L at the base of the model where groundwater occurs.

3.6 Lower boundary condition

A head dependent boundary has been set at the base of model representing a water table at either 0.5 m, 1 m or 2 m below surface depending on the scenario run. The water table is fixed (it does not rise and fall with time) for all scenarios, except for those implemented to examine the drawdown influence on salt lake invertebrates. Depending on the hydraulic gradients at the base of model, water can either flow from the groundwater table upwards into the soil profile or downwards from the soil profile to groundwater (representing a recharge flux).

3.7 Time-stepping

All models were run using a daily timestep and over the 20-year period from 1 January 2000 to 31 March 2020, using the climate data files for this period.

3.8 Model calibration

For the Tecticornia analysis, a base case model was set up using the loam soil texture with the water table set at 1 m below surface and it was loosely calibrated by varying the κ_c until the fluxes to and from groundwater gave a reasonable match to those observed in the groundwater monitoring data for 2019 and 2020, noting that the water table fluctuations evident in the monitoring record occur in response to 3D processes in the groundwater domain and are not solely determined by the vertical processes occurring in the above soil column. Thus, the calibration target is a loose one. A loose calibration process is, however, appropriate given that the purpose of the modelling is not to replicate the exact vadose environment at Lake Way in all its complexity but to investigate the key processes influencing plant water availability and how they may vary in response to project stresses. Using this process, it was determined that the κ_c within the model had to be adjusted to between 0.5 and 0.6 to provide a reasonable approximation of fluxes to and from groundwater.

There was no calibration conducted for models used to investigate drawdown influences on salt lake invertebrates.

4 Scenario analysis

4.1 Investigating drawdown influences on Tecticornia

4.1.1 Scenarios

The 12 scenarios listed in Table 4-1 were run to investigate potential drought stress in response to two levels of water table drawdown. The four base cases have a water table set at 1 m below the surface and cover the two different soil types and the two different levels of transpiration demand which is set by varying the κ_c. The eight project cases are identical, except that the water table is 1 m or 3 m deeper. The 1 m and 3 m drawdowns are conservative representations of drawdown, which will likely be less than 0.5 m in most areas of *Tecticornia*-dominated vegetation, based on groundwater modelling being conducted by SO4.

Each scenario has been named according to the differences in the model set up for ease of interpretation, as follows: 'Soil type'_'Depth to water table'_'crop factor'. For example, L_100_50 represents a loam soil with a water table 100 cm below the surface and a crop factor of 0.5.

Table 4-1 Model scenarios run to investigate drought stress

Crop Factor (Kc)	Loam (Depth to water table)			Loamy sand (Depth to water table)		
	100 cm	200 cm	400 cm	100 cm	200 cm	400 cm
0.5	L_100_50	L_200_50	L_400_50	LS_100_50	LS_200_50	LS_400_50
0.6	L_100_60	L_200_60	L_400_60	LS_100_60	LS_200_60	LS_400_60

4.1.2 Results

Figure 4-1 and Figure 4-2 show the annual water balances for the scenarios modelled showing the fluxes into and out of the model domain.

Annual total rainfall depth is highly variable, ranging from 105 mm in 2019 to 556 mm in 2006, with the other components of the water balance tending to fluctuate in response to this key driver.

Soil evaporation fluctuates in response to rainfall with some differences apparent in the scenarios run. It is highest in loam soils where the water table is 100 cm and is not especially sensitive to changes to water table depth and crop factor in the loam soils. Similar trends are observed in the loamy sand scenarios, albeit with slightly lower soil evaporation rates.

Transpiration rates are seen to be especially sensitive to the crop factor. The lower κ_c (0.5) results in reasonably uniform transpiration rates from year to year, corresponding to a plant that is using soil moisture conservatively. The higher κ_c (0.6) results in significant inter-annual variability in transpiration in response to rainfall and at mostly higher rates, corresponding to a plant more profligate in its water use. However, there are some cases where the higher crop factor results in very low transpiration rates, e.g. L_100_60 in 2011 and 2019.

The net fluxes to and from groundwater are inversely related to rainfall and while they display a similar pattern, the absolute values vary considerably between scenarios. In most years, there tends to be a net flux from the soil profile to the groundwater table but in the drier years there can be a net flux from the groundwater table to the soil profile. These upwards fluxes occur much more commonly in the loam soil and in the cases where the crop factor is high. They are also reduced by increasing the depth of the water table.

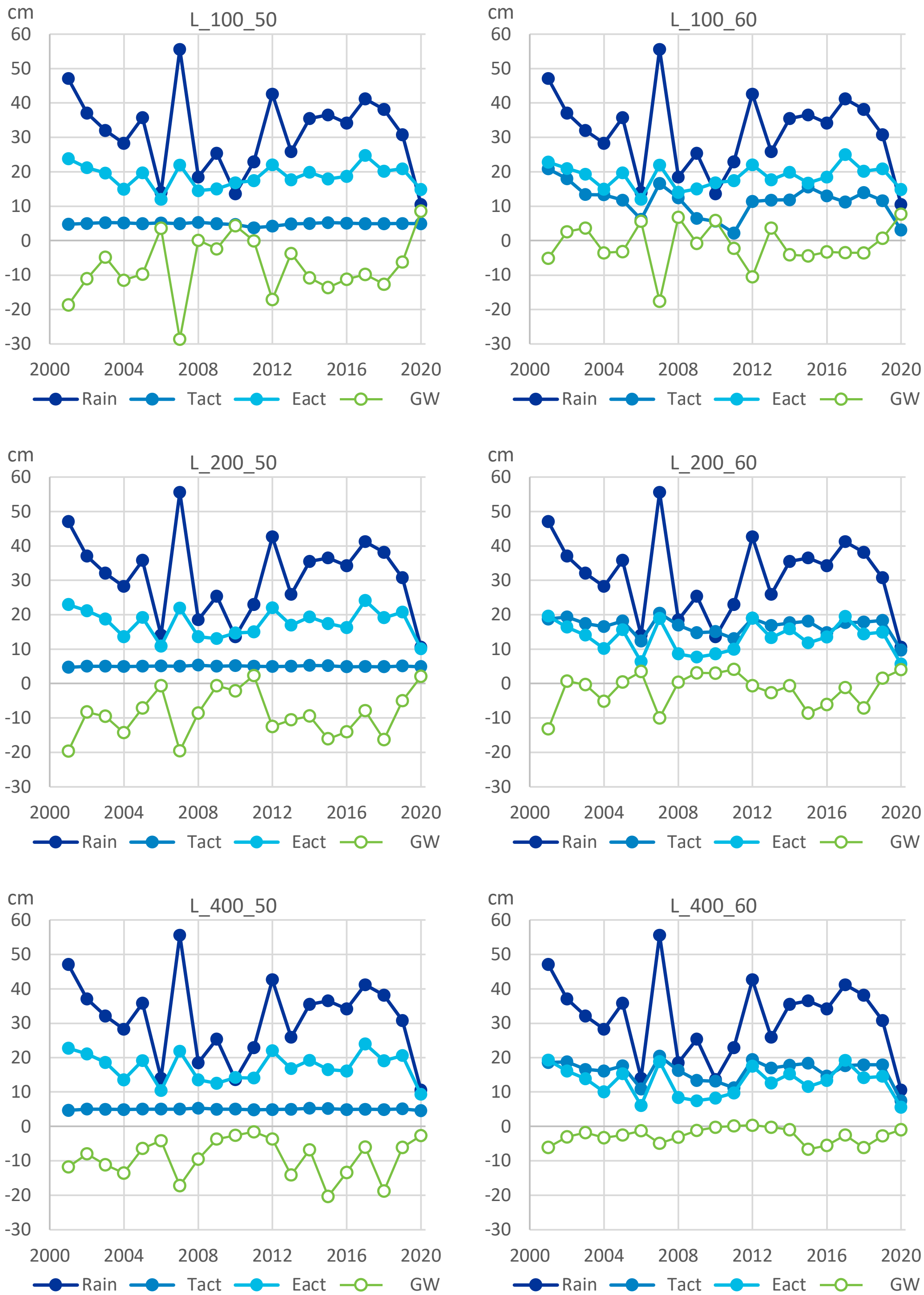


Figure 4-1 Modelled annual water balance fluxes (shown as an equivalent depth of water, cm) for loam scenarios showing rainfall, actual transpiration (T_{act}), actual soil evaporation (E_{act}) and fluxes to and from groundwater (GW) where a positive GW flux indicates an upwards flux from groundwater to the soil profile and a negative GW flux indicates a downwards flux from the soil profile to groundwater

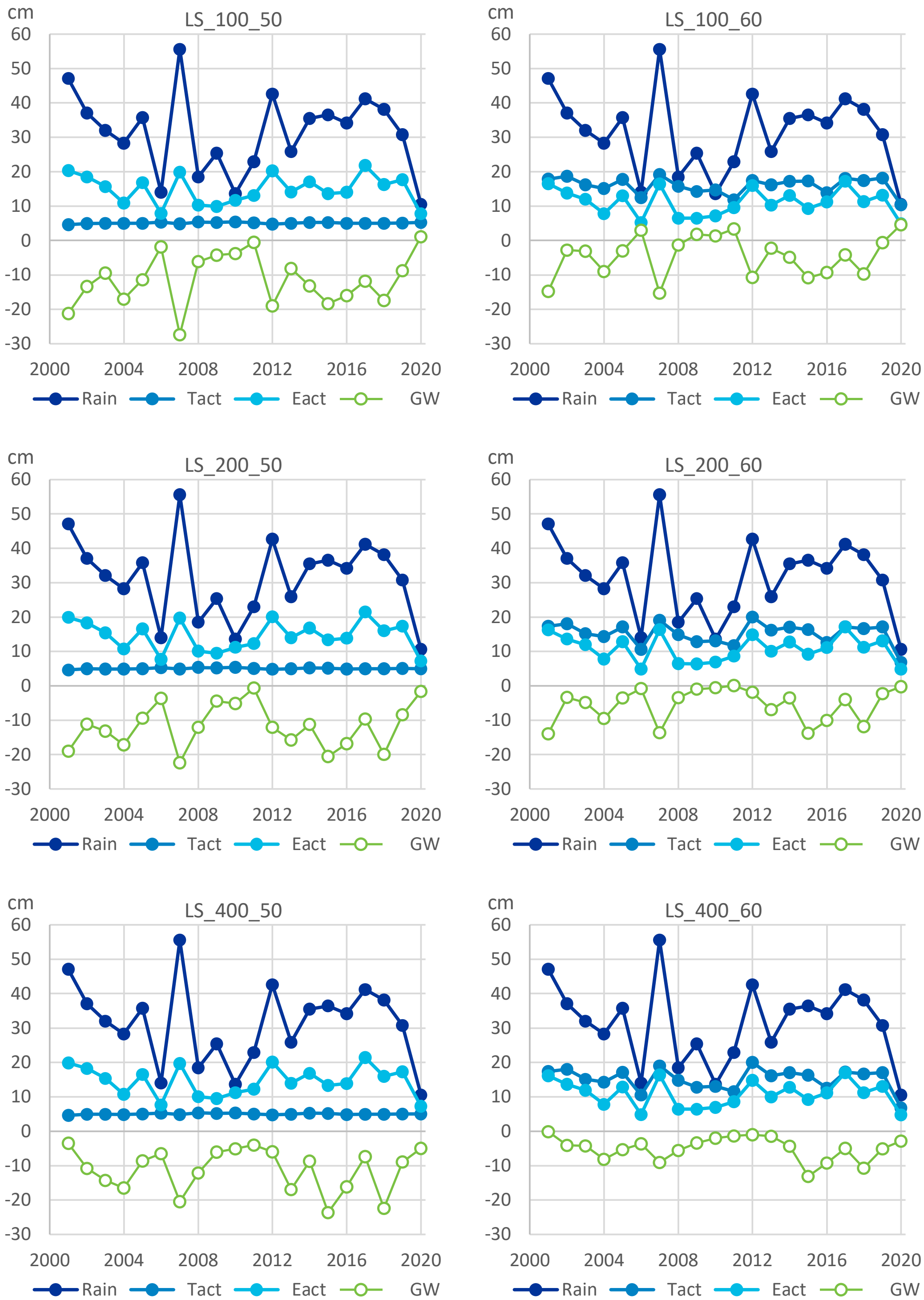
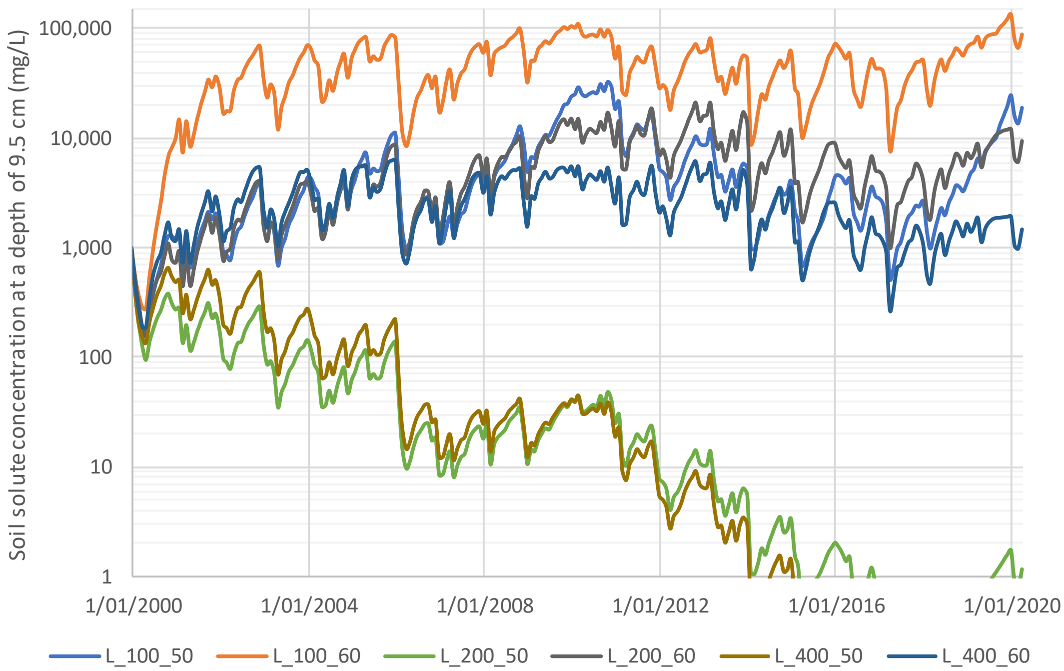


Figure 4-2 **Modelled annual water balance fluxes (shown as an equivalent depth of water, cm) for loamy sand scenarios showing rainfall, actual transpiration (T_{act}), actual soil evaporation (E_{act}) and fluxes to and from groundwater (GW) where a positive GW flux indicates an upwards flux from groundwater to the soil profile and a negative GW flux indicates a downwards flux from the soil profile to groundwater**



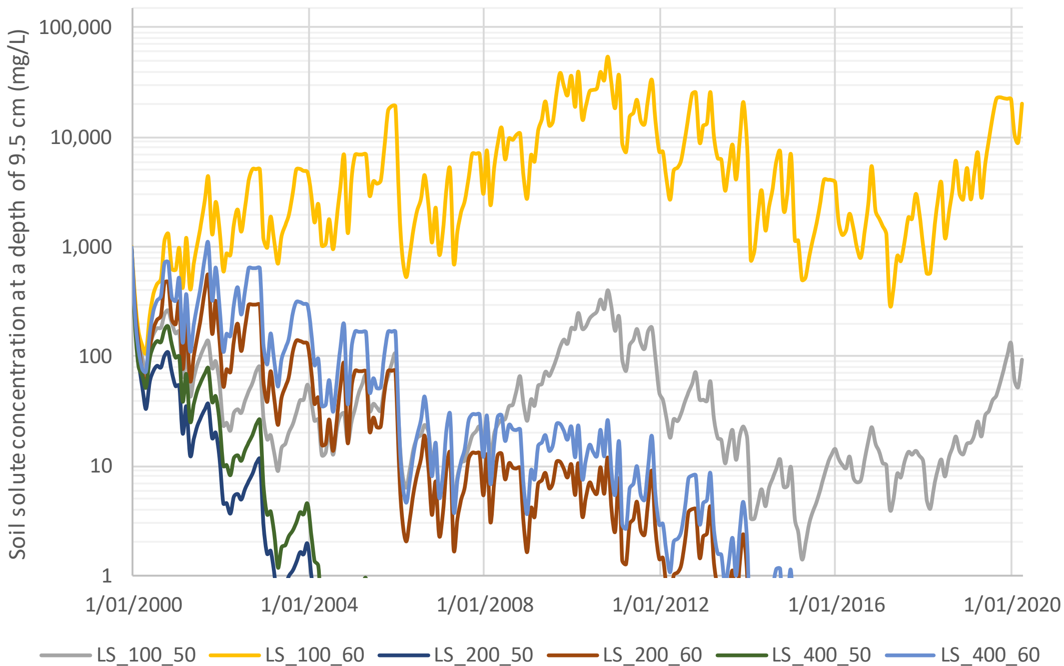
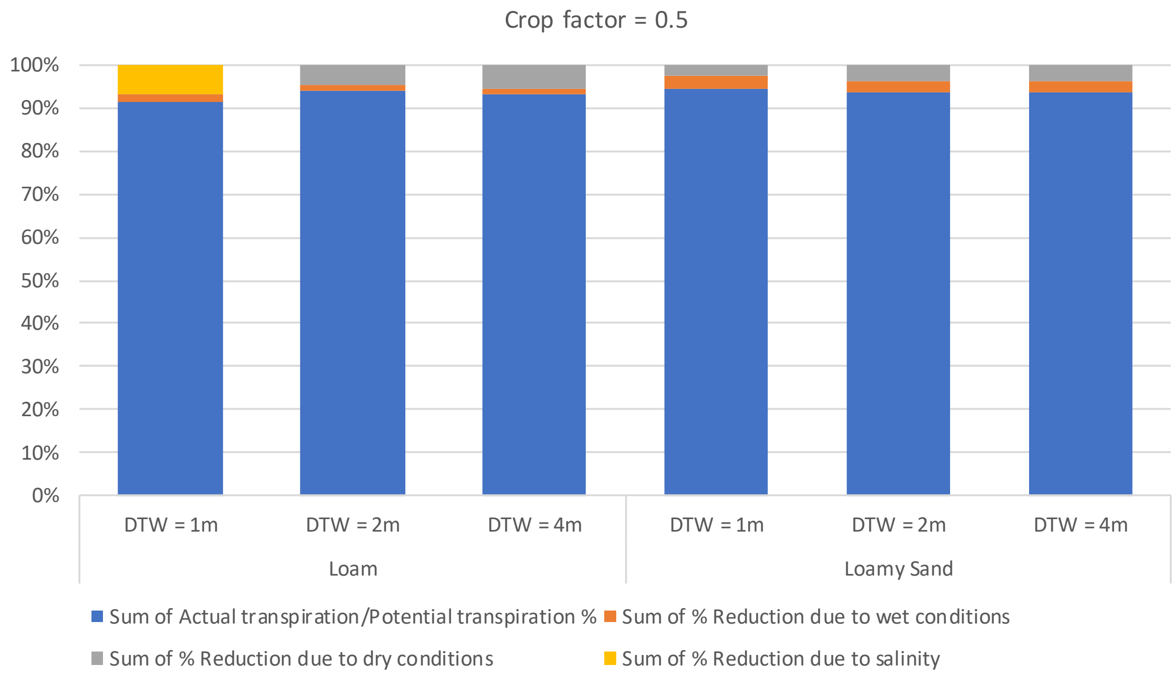


Figure 4-3 Soil solute concentrations in the root zone at a depth of 9.5 cm shown for loam (L) and loamy sand (LS) scenarios

Figure 4-3 shows the soil solute concentration in the shallow root zone where the majority of plant roots occur. There are four cases (L_100_50, L_100_60, L_200_60 and LS_100_60) where there is appreciable build up of salinity in the rootzone due to upwards fluxes from the groundwater table.



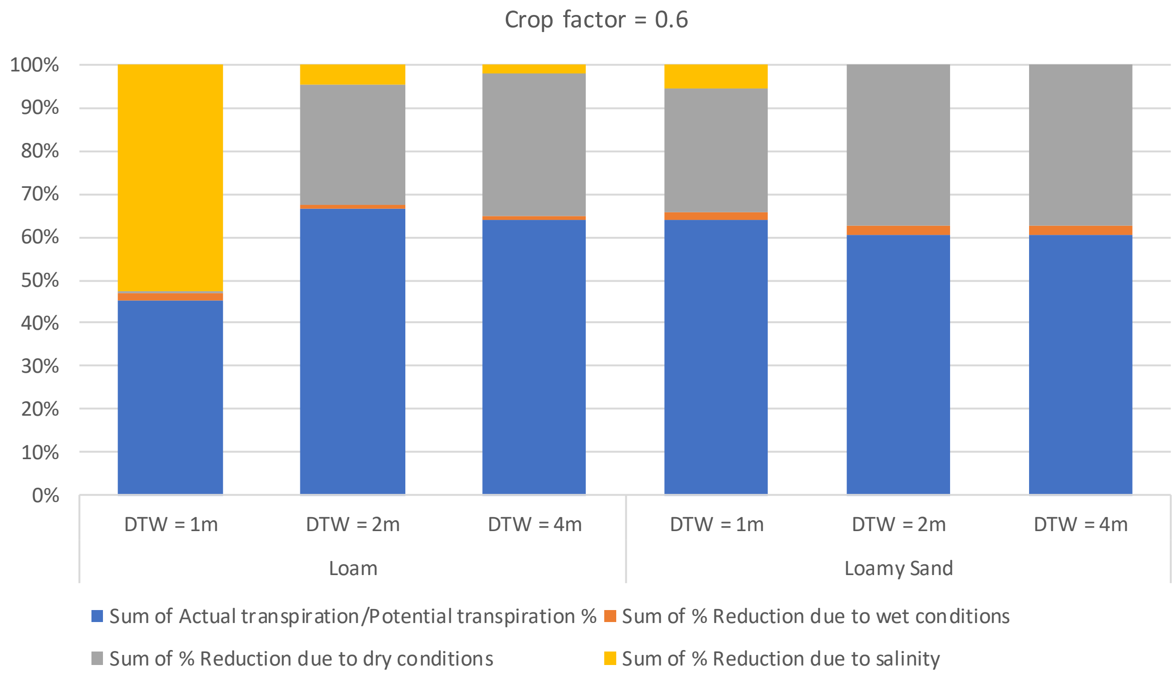


Figure 4-4 Comparison of transpiration efficiency (T_{act}/T_{pot}) and stress factors responsible for reductions between scenarios

Figure 4-4 plots the transpiration efficiency which is a measure of the ratio between actual and potential transpiration rates. This is reduced from 100% by the stress factors related to the soil conditions being too wet, too dry or too saline. Comparing the scenarios, the highest transpiration efficiency occurs when the crop factor is low; i.e. if the plants lower their transpiration demands, they are able to use the soil moisture available more efficiently. By comparison, the influence of lowering the water table is minor, which is evident in comparing the scenarios which have the same κ_c and soil types but different depths to groundwater.

Salinity is the dominant stress in shallow loam soils but is also evident in other examples of upwards flux from groundwater (L_200_60 and LS_100_60). Drought stress is most common in the cases where the κ_c is high. Stress due to saturation is low under all scenarios.

The salinity stress is variable over time and corresponds to the changes in soil salinity (Figure 4-5). In the case of a loam soil with a shallow water table and a high crop factor (L_100_60), there are periods of time where the salinity exceeds 100,000 mg/L and it is unlikely that plants would be able to survive such high salinities.

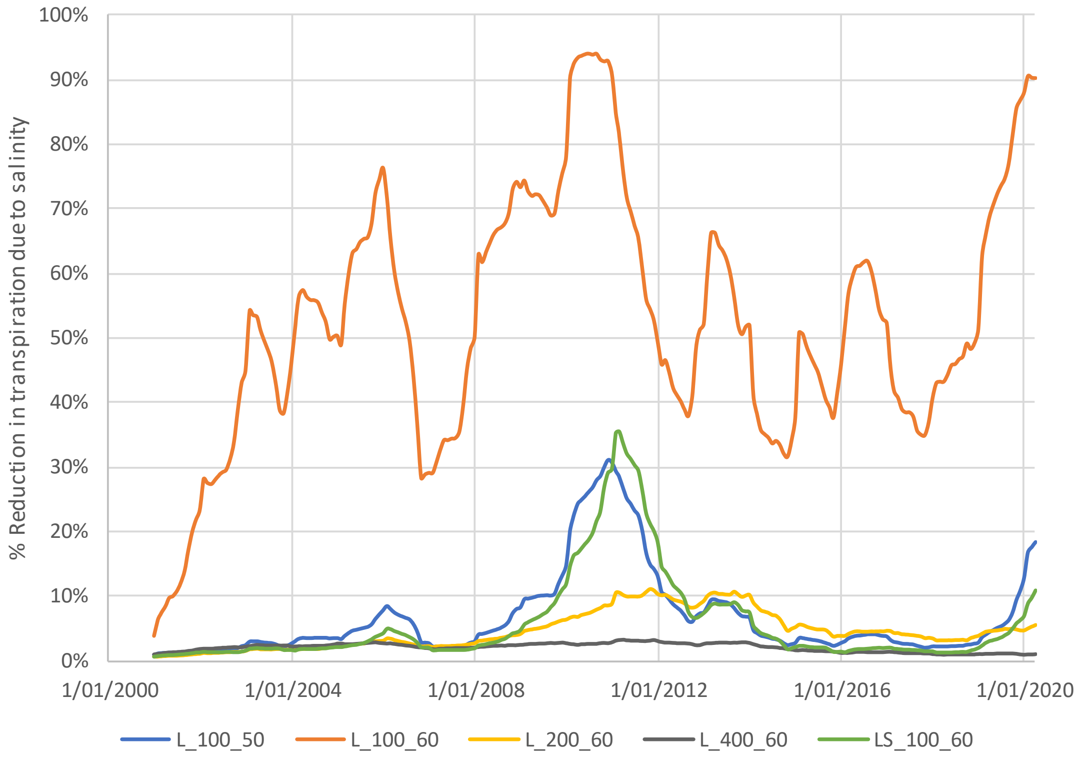


Figure 4-5 Scenarios where there is a reduction in transpiration due to soil salinity

4.1.3 Summary

Based on the results presented, the influence of lowering the water table is minor compared to other factors. Because the groundwater is highly saline, the plants cannot consume appreciable quantities of water by being profligate water users and imposing a high transpiration demand. This strategy results in salt from groundwater being brought to the surface and concentrating in the rootzone. For example, in the loam soils modelled with a crop factor of 0.6, transpiration actually increases as the water table is lowered because their root zones become less saline. While this effect is not as evident on loamy sand soils, the overall effect of lowering the water table has little adverse influence on transpiration rates.

4.2 Investigating drawdown influences on salt lake invertebrates

4.2.1 Scenario descriptions

Four model scenarios were run to investigate potential drawdown influences on salt lake invertebrates, as listed in Table 4-2. For each soil type, there was a base case scenario in which the water table is held constant at 50 cm below surface and two drawdown scenarios.

Table 4-2 Model scenarios run to investigate drawdown influences on salt lake invertebrates

Scenario	Soil type	Depth to water table (mbgl)
CL – base case	Clay loam	0.5 m
CL – 1 m drawdown		1.5 m
CL – 2 m drawdown		2.5 m
SL – base case	Silt loam	0.5 m
SL – 1 m drawdown		1.5 m
SL – 2 m drawdown		2.5 m

4.2.2 Results

The key metric tracked by the model of relevance to salt lake invertebrates is the soil moisture status which can be plotted as the degree of saturation (the percentage of the available pore space that is filled with water). Figure 4-6 and Figure 4-7 plots the range in the degree of saturation by depth in the soil profile for the silt loam and clay loam scenario runs. Figure 4-8 and Figure 4-9 plots the degree of saturation by time at a depth of 9.5 cm for the silt loam and clay loam scenarios (a depth of 9.5 cm was selected as a point within the expected depth range of the invertebrate burrows, 0–25 cm).

Regarding the soil moisture profiles by depth over all time periods (Figure 4-6 and Figure 4-7):

- Under base case scenarios (water table at 50 cm), moist conditions are maintained near the surface for both soils. The silt loam is particularly moist at the surface because the hydraulic conductivity of the soil is high. The soil surface dries out slightly more in clay loam soil due to its lower hydraulic conductivity.
- With drawdown, drier conditions occur within the soil because the flux from the water table is lower and unable to support the evaporation demand of the atmosphere.

Similar trends are borne out when temporal changes in soil moisture are viewed in Figure 4-8 and Figure 4-9, with the fluctuations in soil moisture being greater when drawdown occurs.

The implications of these trends for potential effects of drawdown on salt lake invertebrate habitats are as follows:

- A relative reduction in soil moisture is an inevitable consequence of drawdown.
- Soil moisture conditions will also fluctuate more with drawdown.
- The changes will be greatest in near-surface environments which are already very moist due to the presence of a shallow water table, and the level of drawdown is such that the upwards flux from groundwater can no longer sustain the atmospheric evaporative demand.
- The changes will be less significant where the near-surface is already somewhat dry due to evaporation.
- The modelling does not incorporate any natural fluctuations in the position of the water table which would be expected in response to rainfall. This natural variability would influence soil moisture status and is something that the invertebrates would have to respond to.

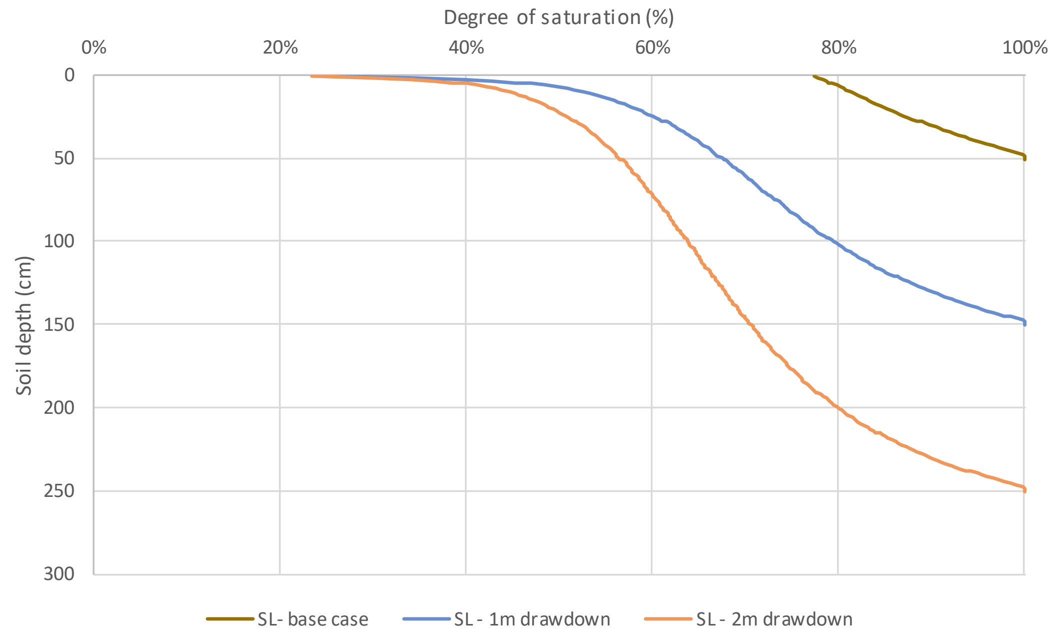


Figure 4-6 Minimum degree of soil saturation by depth for the base case and drawdown scenarios for silt loam soils

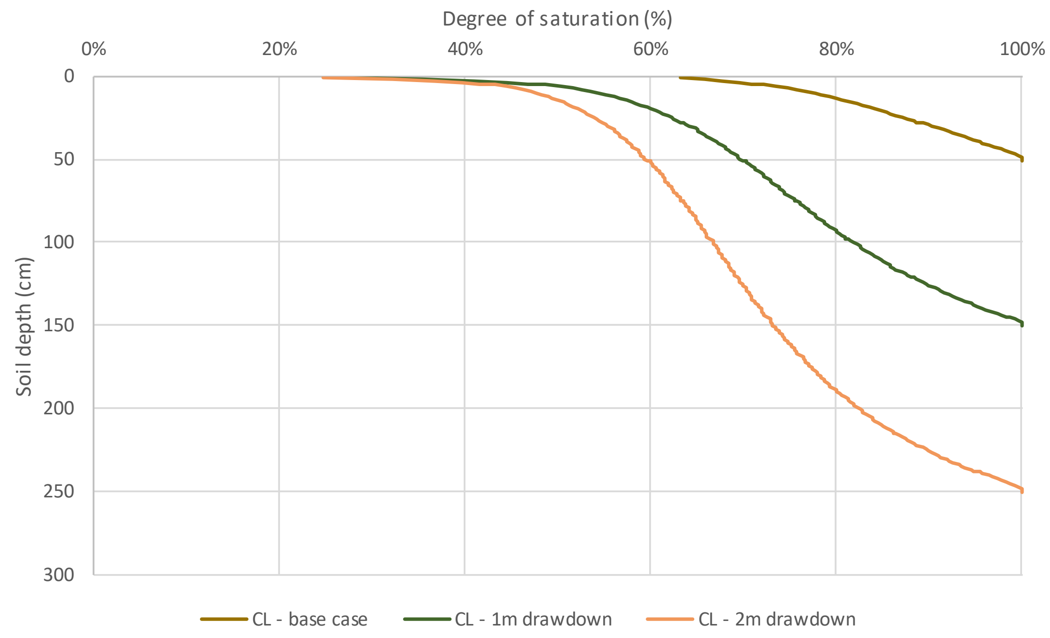


Figure 4-7 Minimum degree of soil saturation) by depth for the base case and drawdown scenarios for clay loam soils

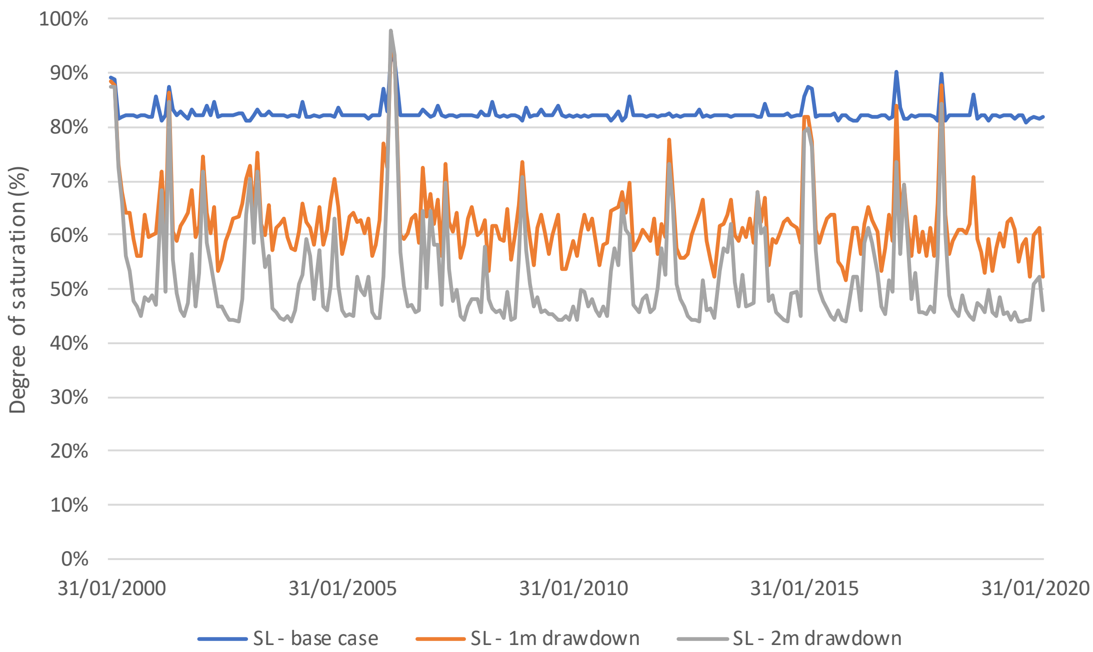


Figure 4-8 **Changes in soil moisture (degree of saturation) with time at a depth of 9.5 cm for the base case (SL_base) and drawdown (SL_ddn) scenarios for silt loam soils**

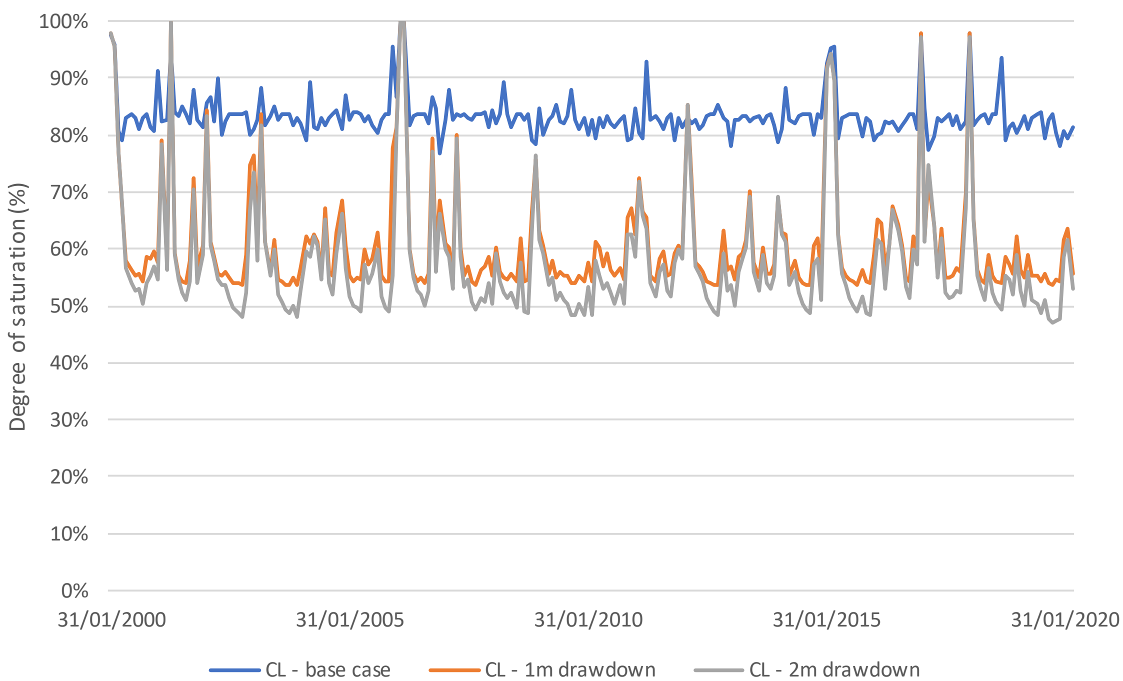


Figure 4-9 **Changes in soil moisture (degree of saturation) with time at a depth of 9.5 cm for the base case (CL_base) and drawdown (CL_ddn) scenarios for clay loam soils**

5 Conclusions

Reflecting on the hypotheses posed in the introduction to this paper, the first hypothesis (that a reduction in groundwater levels will limit the availability of water to *Tecticornia* and impose and increased drought stress on the vegetation) is generally not supported. While a reduction in groundwater levels can increase the drought stress to *Tecticornia*, this only happens under certain circumstances and its influence is minor compared to other factors like salinity which impose a greater influence on soil water availability. Indeed, a lowering of the water table can potentially increase the water availability to vegetation if this allows for salts to be leached through the soil profile.

The second hypothesis that concerns drawdown and its influence of soil moisture for salt lake invertebrates is generally supported. Relative changes in soil moisture are an inevitable consequence of drawdown in shallow water table settings and these changes can be significant in cases where the soil surface does not experience any appreciable evaporative drying. Whether or not these changes in soil moisture are consequential to the salt lake invertebrate habitats is beyond the scope of this study.

6 References

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