Environment Waikato Technical Report 2005/40

Peat Subsidence Near Drains in the Waikato Region

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ISSN: 1172-4005

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Document #1009733

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Date June 2005

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Acknowledgements

We would like to thank Robbie Price for advice on modelling, and Mark Smale who provided useful comment on the draft report. Many land owners and managers allowed access to private property and this is greatly appreciated.

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Summary

Project and Client

During February and March 2005, Landcare Research, Hamilton, measured land surface profiles of farmed peat soils in the Waikato Region and modelled the relationship between peat subsidence, drain depth, and distance from drain, for Environment Waikato (Waikato Regional Council).

Objective

To model peat subsidence in relation to drains of various depths so that the lateral influence of drain depth on peat subsidence can be estimated, as well as the amount of subsidence at any distance from the drain.

Methods

- Vertical peat surface height was measured with a laser level and receivers.
- Horizontal distance from drains was measured by tape measure.
- Regression analysis of measured data was used to construct a model of peat subsidence away from drains of various depths.

Results

- Fourteen transects were measured with an average length of 481 m, and 21 sections of these transects were used to develop a subsidence model.

- The logarithmic model:

  Subsidence = (-0.1202 × *drain depth* + 0.0162) × Ln(*distance from drain*) + (0.8102 × *drain depth* - 0.4079)

  was found to be an acceptable predictor of the amount and lateral extent of subsidence. Subsidence and depth measurements are in metres. The model is strongly influenced by the accuracy of drain depth measurement, which can be difficult to achieve.

- The peat subsidence model can be used to estimate drain depth—which is required for surface subsidence modelling—from depth measurements made relatively close to a drain. Appropriate conversion formula are:

  Drain depth = 1.7340 × *depth25* - 0.6169

  where *depth25* is the depth (m) of the drain relative to the peat surface 25 m away.

  Drain depth = 1.5151 × *depth50* - 0.522

  where *depth50* is the depth (m) of the drain relative to the peat surface 50 m away.

  Drain depth = 1.3453 × *depth100* - 0.4484

  where *depth100* is the depth (m) of the drain relative to the peat surface 100 m away.

Conclusions

- Peat subsidence is strongly related to drain depth .
- Peat subsidence away from drains can be estimated by a logarithmic model.
- Drain depth—which is needed for subsidence modelling—can be estimated from measurements made relative to points close to the drain, removing the need to measure the level of the highest peat which may be hundreds of metres further away.

1 Introduction

The majority of the once extensive peat wetlands in the Waikato have been drained and converted to agriculture and horticulture (Davoren 1978), a process that inevitably leads to peat shrinkage and surface subsidence. Subsidence occurs due to mineralisation of the organic material and consolidation (Schipper & McLeod 2002) and is most pronounced close to deep drains where the drainage effect is greatest.

Obtaining information on subsidence rates and the extent of subsidence from drains is important for future land-use management and the development of mitigation strategies to reduce subsidence rates and CO^2 emissions from peat mineralisation, and to protect sensitive wetlands set aside for nature conservation.

2 Background

Peat soils cover approximately 78000 ha of the Waikato Region, North Island, New Zealand (New Zealand Land Resources Inventory 2001), most of which has been converted to pasture.

McKenzie and McLeod (2002), McLeod et al. (2003), and Fitzgerald and McLeod (2004) reported general rates of peat subsidence at various locations in the Waikato Region and noted difficulties in assessing overall subsidence rates due to increased subsidence near drains. While subsidence of the peat surface near drains is often clearly visible to the unaided eye, the distance from drains to which the effect extends into adjacent paddocks and neighbouring wetlands is largely unknown.

3 Objective

To model peat surface subsidence in relation to drains of various depths so that the lateral influence of drainage on peat subsidence can be estimated, as well as the amount of subsidence at any distance from the drain.

4 Methods

Sites for surface profile transects were identified on the main areas of deep peat that have been drained and converted for several years (the Hauraki, Komakorau, Moanatuatua, and Rukuhia deposits,) and are estimated to have reached equilibrium with the drainage system. Sites with widely spaced drains were preferred so that long transects could be measured and subsidence could be reasonably associated with a single drain. Transects were measured from, and perpendicular to, main and secondary drains. Transects were measured in February and March 2005 when drain water levels were low and the drainage effect at approximate maximum.

Transect locations were recorded using a handheld GPS (Garmin® eTrex™).

Height measurements were made using a Spectra-Physics Laserplane® 220 and measuring-staff mounted Laser-Eye™ receivers. A tape measure was used to measure horizontal distances. The Laserplane was tripod mounted mid-transect and repositioned if measurements were required more than 250 m away (i.e. >500 m transect). The Laserplane 220 has a specified accuracy of ±15 arc seconds (±0.02 m @ 250 m). All distance and subsidence measurements are in metres.

The vertical distance between the ground surface and the laser was measured to the nearest 0.01 m at various distances from the drain depending on the slope of the land (more frequent on steeper slopes). The depth to the base of the drain at each transect origin, and depth and location of any paddock drains and ditches bisected by the transect were recorded. Drain water levels were recorded where present.

Surface height measurements were plotted against horizontal distance, and the subsidence datum for each transect determined. The datum is assumed to approximate the height of the peat in the absence of any drainage (subsidence = 0), because the actual peat height before drainage is unknown. The datum is typically the highest point on each transect. Some transects that crossed drains were divided into sections and treated separately, with adjusted drain depth, distance from drain, and datum (e.g., the nearest inflection point) for each section where appropriate.

Regression analysis was used to model the shape of each subsidence profile and the relationship between profile shape and drain depth.

5 Results

Fourteen transects were measured in the Hauraki, Komakorau, Moanatuatua, and Rukuhia areas (Fig. 1, Appendix 1 & 2). The target transect length was 500 m. However, actual length was governed by drain spacing, property boundaries, major land management differences, and thick hedges, and other objects which the laser could not pass through.

Mean transect length was 481 m (218–733 m) but due to the influence of other drains only shorter sections (denoted by a decimal suffix) of most were used for analysis. Two entire transects (transects 1 and 7) were excluded from subsidence modelling due to anomalous subsidence profiles, probably caused by frequent soil cultivation and contouring for hump and hollow drainage. In total, 21 transect sections with a mean length of 109 m (23–382.5 m) and drain depths of 0.35–5.51 m were used to model peat subsidence.

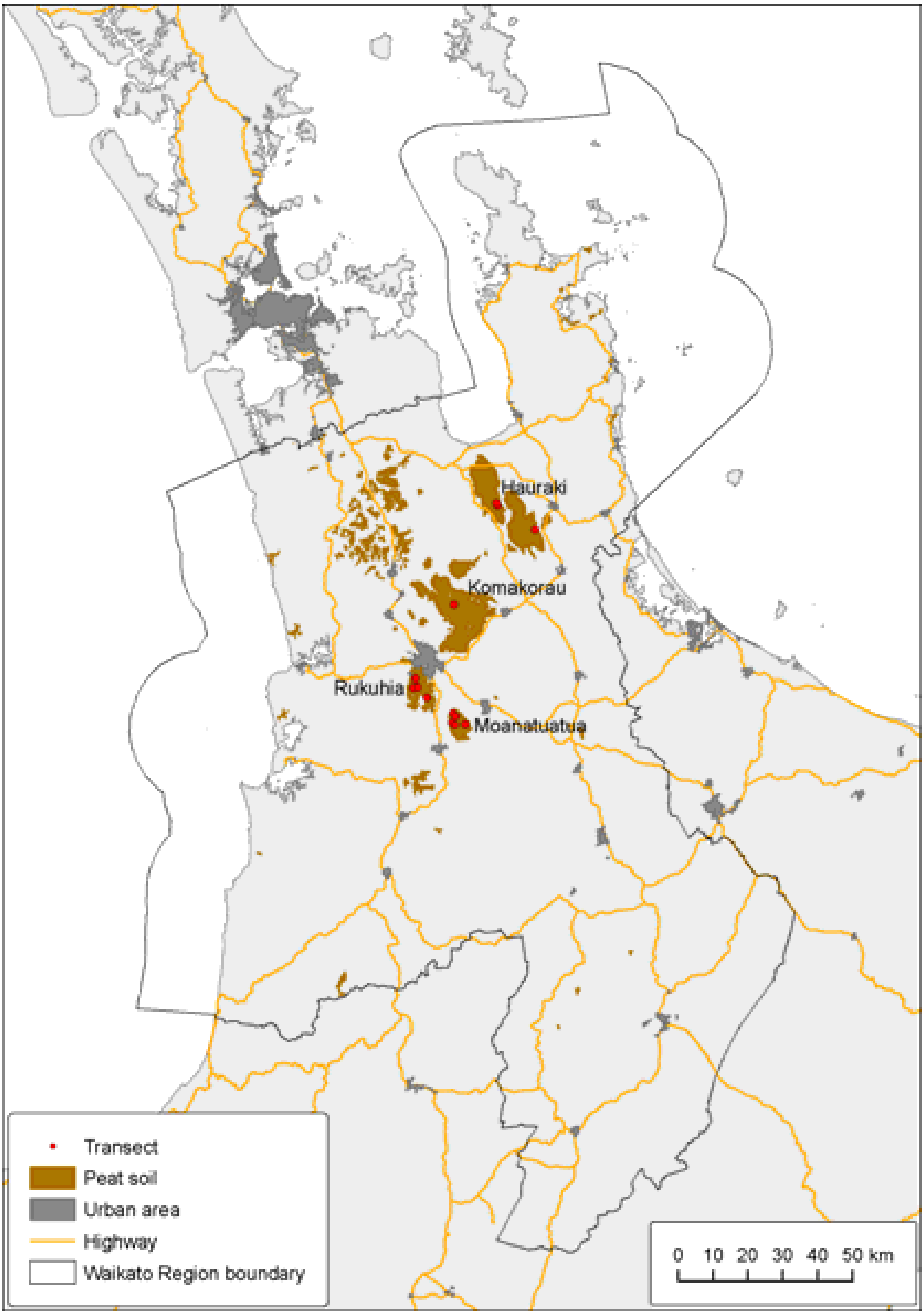

Figure 1: Peat deposits in the Waikato Region and location of peat subsidence transects.

5.1 Model development

Peat subsidence associated with drainage along a transect away from a drain is described well by y = a×Ln(x)+b (Table 1, Appendix 3), where y = subsidence (m) and x = distance from drain (m). Formula of this format fitted to each transect section account for 71–99% of the measured variance.

Table 1: Transect sections and best fit equations

Transect section	Transect length (m)	Drain depth (m)	Regression equation	R^2
2.0	270	1.8	y = -0.0861Ln(x) + 0.8414	0.9001
3.0	69	2.18	y = -0.2488Ln(x) + 1.1703	0.9546
3.1	42	0.41	y = -0.0646Ln(x) + 0.246	0.844
3.2	32	0.38	y = -0.0483Ln(x) + 0.2136	0.7102
3.3	23	0.35	y = -0.0668Ln(x) + 0.2149	0.8409
4.0	255	2.02	y = -0.2728Ln(x) + 1.4827	0.9753
5.0	40	2.06	y = -0.2457Ln(x) + 0.956	0.9616
5.1	197	2.29	y = -0.1831Ln(x) + 0.9487	0.9472
6.0	45	2.56	y = -0.2159Ln(x) + 0.8176	0.9734
6.1	382	1.81	y = -0.1563Ln(x) + 0.9643	0.9669
8.0	50	5.51	y = -0.6944Ln(x) + 4.6166	0.8964
9.0	125	3.17	y = -0.2625Ln(x) + 1.2696	0.9844
10.0	105	3.75	y = -0.4159Ln(x) + 2.589	0.9914
11.0	82	3.95	y = -0.6729Ln(x) + 3.2936	0.9768
11.1	94	1.45	y = -0.199Ln(x) + 0.9502	0.9716
11.2	61	1.7	y = -0.1758Ln(x) + 0.8996	0.9722
11.3	40	0.8	y = -0.0572Ln(x) + 0.2503	0.8896
12.0	90	3.44	y = -0.3723Ln(x) + 1.6891	0.9774
12.2	72	1.205	y = -0.2404Ln(x) + 1.2187	0.9774
13.0	185	1.24	y = -0.112Ln(x) + 0.5922	0.9647
14.0	127	4.77	y = -0.5013Ln(x) + 4.163	0.958

The constants '*a*'and '*b*' determine the shape of the subsidence curve; determining the relationship between the constants and drain depth enables the final model to account for the effect of drains of various depths. The linear relationship between the constants '*a*' and '*b*' and drain depth (Fig. 2) is described by the equations:

'*a*' = -0.1202 × *drain depth* + 0.0162 (R^2 = 0.84)
'b' = 0.8102 × *drain depth* - 0.4079 (R^2 = 0.86)

The resulting model of peat surface subsidence thus becomes:
Subsidence = (-0.1202 × *drain depth* + 0.0162) × Ln(*distance from drain*) + (0.8102 × *drain depth* - 0.4079)

Figure 3 shows the peat subsidence with distance from drain predicted by this model for drains 1 m, 2 m, 3 m, 4 m, and 5 m deep. The amount of subsidence predicted for drains ranging from 1 to 5m deep is also shown in table 2. The model predicts subsidence will extend for 500 m from deep (5 m) drains.

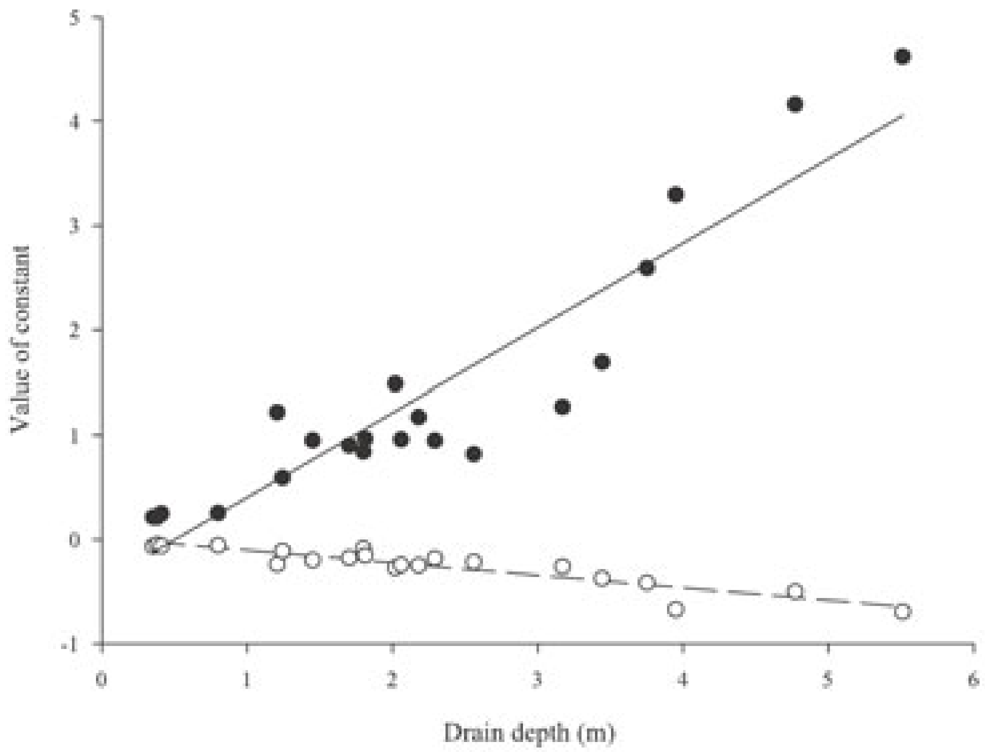

Figure 2: Relationship between the equation constants *a* (○) and *b* (●) and drain depth.

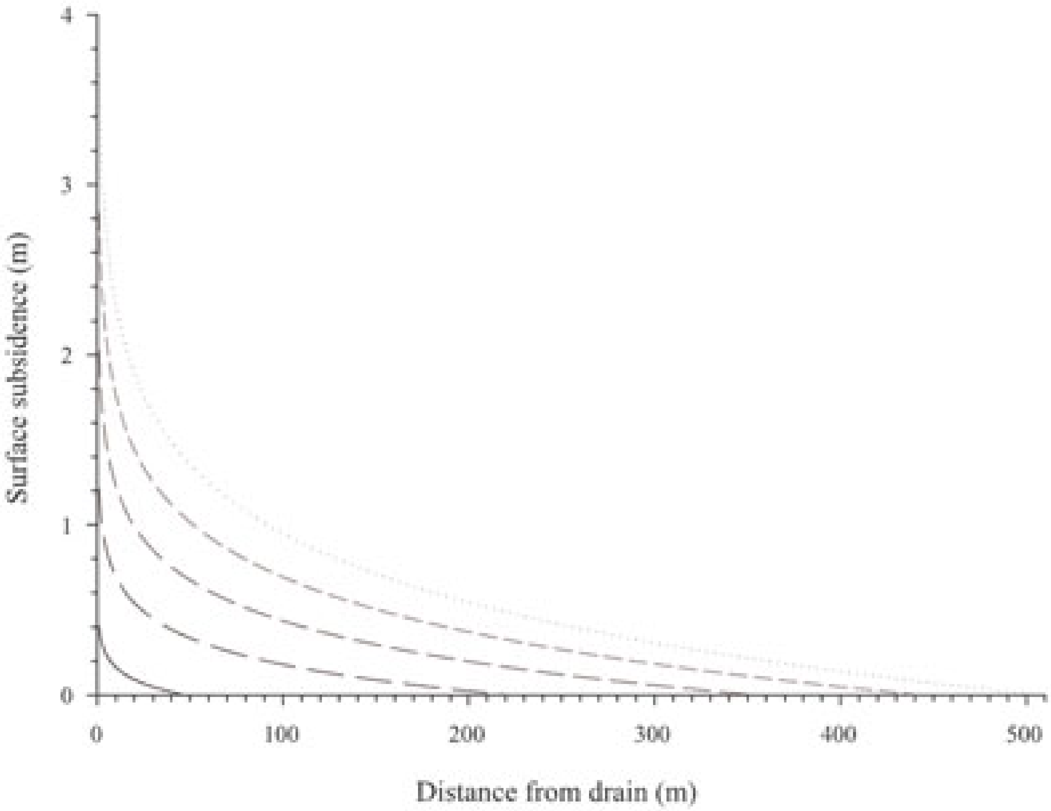

Figure 3: Predicted peat subsidence in response to drains1 m ( ), 2 m ( ), 3 m ( ), 4 m ( ), and 5 m deep ( ).

Table 2: Predicted peat subsidence (m) away from drains of different depths.

	Distance from drain (m)							
Drain Depth (m)	**25**	**50**	**100**	**150**	**200**	**300**	**400**	**500**
1	0.07	0.00	-	-	-	-	-	-
1.5	0.28	0.17	0.05	-	-	-	-	-
2	0.49	0.34	0.18	0.09	0.02	-	-	-
2.5	0.70	0.51	0.31	0.19	0.11	0.00	-	-
3	0.91	0.68	0.44	0.30	0.20	0.06	-	-
3.5	1.13	0.85	0.57	0.40	0.28	0.12	0.00	-
4	1.34	1.02	0.69	0.50	0.37	0.18	0.05	-
4.5	1.55	1.19	0.82	0.61	0.46	0.25	0.09	-
5	1.76	1.36	0.95	0.71	0.54	0.31	0.14	0.01

By re-arranging this equation, the distance from a drain at which a specified amount of subsidence is expected to occur can be calculated:

$$\textit{Distance from drain} = e^{\left(\frac{subsidence-(0.8102\times drain\_depth-0.4079)}{(-0.1202\times drain\_depth-0.4079)}\right)}$$

Figure 4 uses this model to illustrate the distance from drains of various depths at which subsidence thresholds of 0.5 m, 0.25 m, 0.1 m, and 0.05 m are reached.

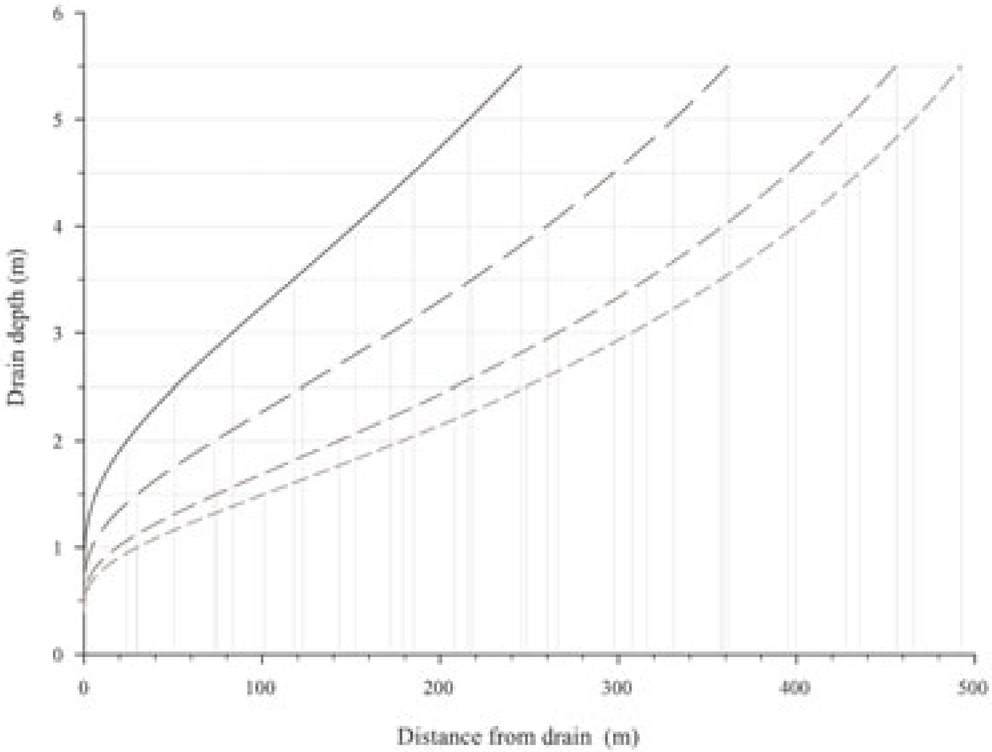

Figure 4: Predicted distance from drains at which surface subsidence of 0.5 m (————), 0.25 m (— — —), 0.1 m (— — — —), and 0.05 m (– – – – –) are reached.

The logarithmic model is not greatly affected by errors in the measurement of the lateral distance from drain, but is very susceptible to errors in drain depth estimation (i.e. datum selection).

5.2 Correlation of the model with measured subsidence profiles

The peat subsidence model was overlain on plots of measured peat subsidence for each transect to identify likely causes of discrepancies. Measured surface subsidence along transect one (Fig. 5) is not well replicated by the model ($R^2 = 0.33$). This may be due a number of factors such as atypical drainage regimes related to the adjacent Moanatuatua Scientific Reserve wetland, or cultivation history (surrounding paddocks were planted in maize at the time of sampling).

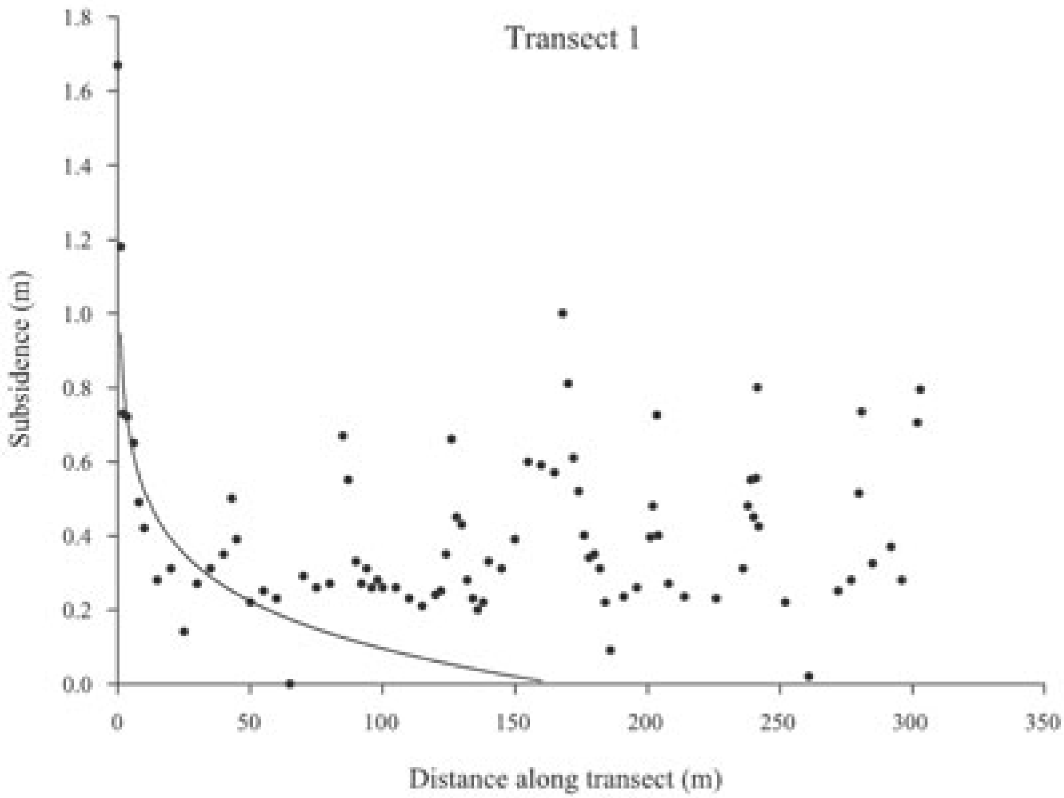

Figure 5: Transect 1, showing poor correlation between measured (•) and predicted (——) peat subsidence. No transect 1 data were used to construct the model.

Transect 2 (Fig. 6) was measured along the crest of a hump of a hump and hollow drainage system, as there were few suitable sites in the Moanatuatua area that did not use this system and as the degree to which this would affect subsidence was unknown. The model underestimated the amount of surface subsidence ($R^2 = 0.87$). The slope of the actual subsidence profile is less than the average for that drain depth, suggesting contouring of the land has created an artificial subsidence profile. Subsidence data were only used in model construction to 270 m from the drain, due to an access road that possibly affected subsidence beyond that point.

Transect 3 crossed several paddocks of rough pasture with rushes (*Juncus effusus*), uneven soil surface, and shallow paddock drains spaced approximately 70 m apart (Fig. 7). The predicted subsidence closely matches that measured from the transect origin to 69 m away ($R^2 = 0.95$) as well as from 210 m to the relatively deep mid-transect drain ($R^2 = 0.88$) and the mid-transect drain to 406 m ($R^2 = 0.89$). Subsidence was not as well predicted for the end section of the transect sloping down to the drain at the end ($R^2 = 0.67$). The divergence of the predicted and actual subsidence is likely to be due to the paddock drains and highlights the difficulty of predicting subsidence where complex inter-related drainage systems are operating. In the absence of the deep mid-transect drain, the peat surface would undoubtedly be higher along much of the transect length. Sections of the transect used to construct the model were selected from near drains of various depths.

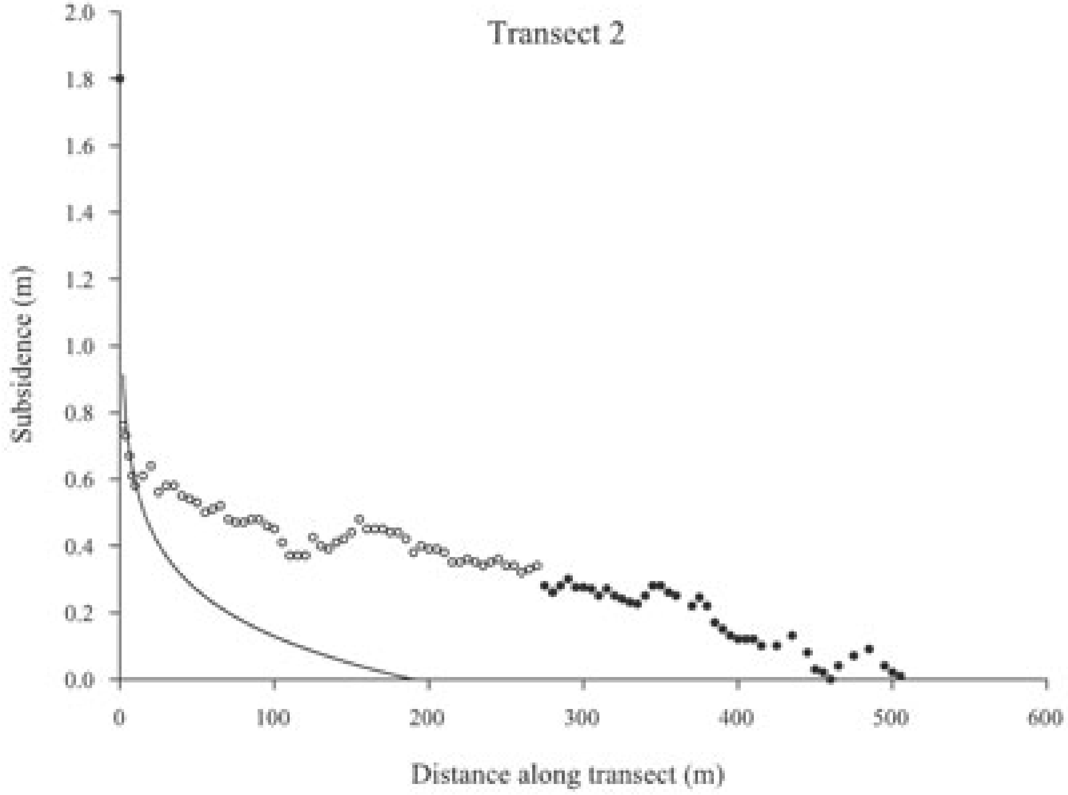

Figure 6: Transect 2 measured peat subsidence used to construct model—section 2.0 (◦). Data not used to construct the model (•) and predicted peat subsidence (——).

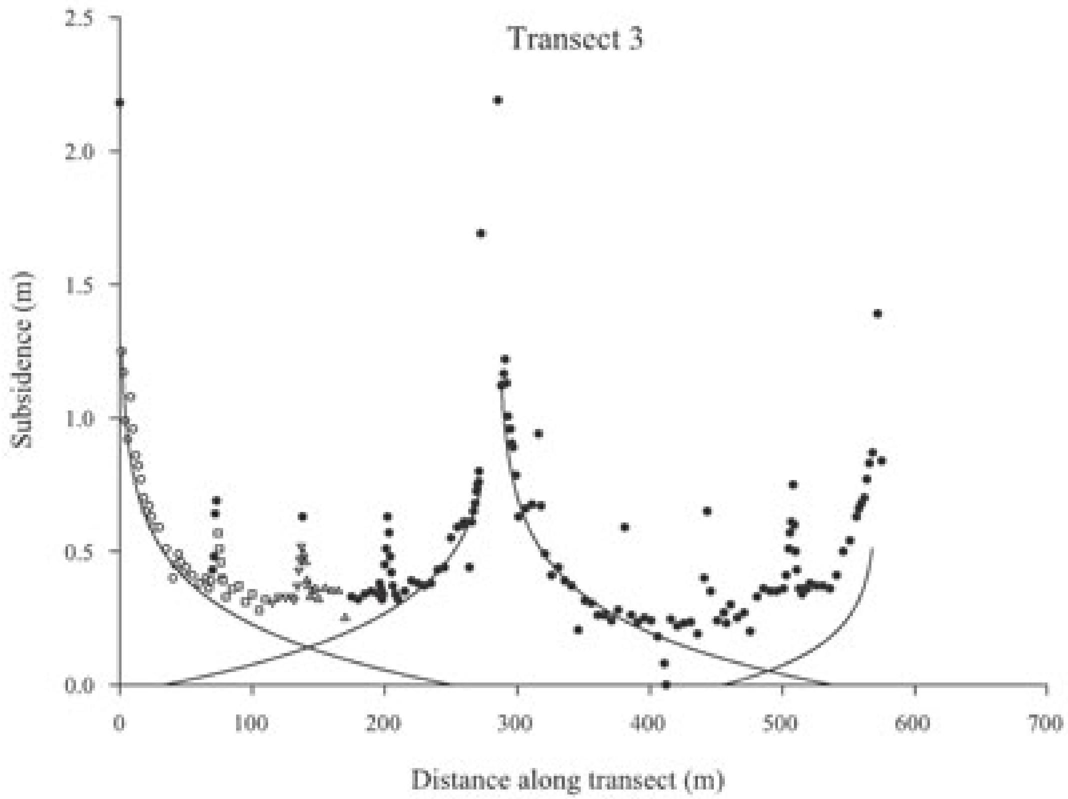

Figure 7: Transect 3 measured peat subsidence used to construct the model—sections 3.0 (◦), 3.1 (▫), 3.2 (▵) and 3.3 (▿). Data not used to construct model (•) and predicted peat subsidence (——).

Measured subsidence along transect 4 is precisely matched by modelled subsidence (R^2 = 0.98) for approximately 225 m from a deep roadside drain to zero subsidence

(Fig. 8). Modelled subsidence back from the end drain is less accurate (R^2 = 0.82). This could indicate that the farm drain at the end of the transect is not as effective as the roadside drain, and is effectively shallower than the measured drain depth (e.g., it may be blocked with vegetation). For this reason data from the end of the transect were not used in model construction. Measured and modelled subsidence would be very similar if the end drain was measured 0.4 m shallower.

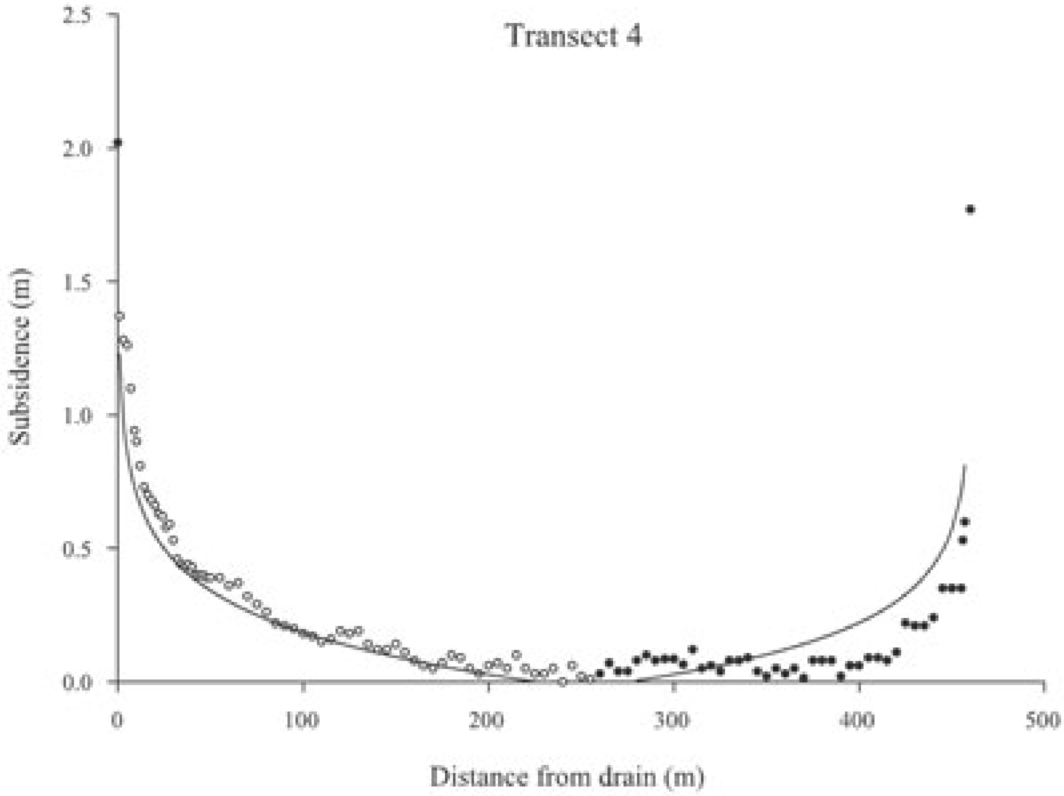

Figure 8: Transect 4 measured peat subsidence used to construct the model—section 4.0 (◦). Data not used to construct the model (•) and predicted peat subsidence (——).

Transects 5 and 6 (Figs 9 & 10) were located on a Moanatuatua blueberry farm. The model tended to over-predict subsidence compared to the measured data for transect 5 (modelled in relation to the drain at the start of the transect R^2 = 0.84, and from the end drain R^2 = 0.94). Subsidence in transect 6 was similarly over-predicted (modelled in relation to the drain at the start of the transect R^2 = 0.48, and from the end drain R^2 = 0.96).The correlation between measured and predicted subsidence in relation to the drain at the start of transect 6 was better if the water level was used as the effective drain depth (R^2 = 0.81), suggesting this level more closely represents maximum drainage of the drain. The general overestimation suggests blueberry cultivation, which involves infrequent soil disturbance and generally higher soil water levels than other types of farming, causes less peat subsidence. The relatively flat section of transect 5 was not used in subsidence model construction because there is essentially no subsidence there.

The origin of transect 7 was at a deep board drain and the transect oriented perpendicular to hump and hollow drainage. Due to the largely artificial surface contour, data from this transect were not used in model construction, and the subsidence model bears little resemblance to the measured profile (R^2 = 0.32; Fig. 11).

The land where transect 8 was located is contoured to some extent annually (P. Reymer, pers. comm.). However, the extent of the surface subsidence from the deep (roadside) drain is still accurately predicted (R^2 = 0.88; Fig. 12). The highest point recorded on the transect was 503 m from the drain and it is possible surface subsidence extended further, though this could not be measured due to a dense hedge obstructing the laser. Data for model construction were taken from the drain to the first inflection point because artificial contouring is likely to have proportionately more effect on the shallower drains, making them unsuitable.

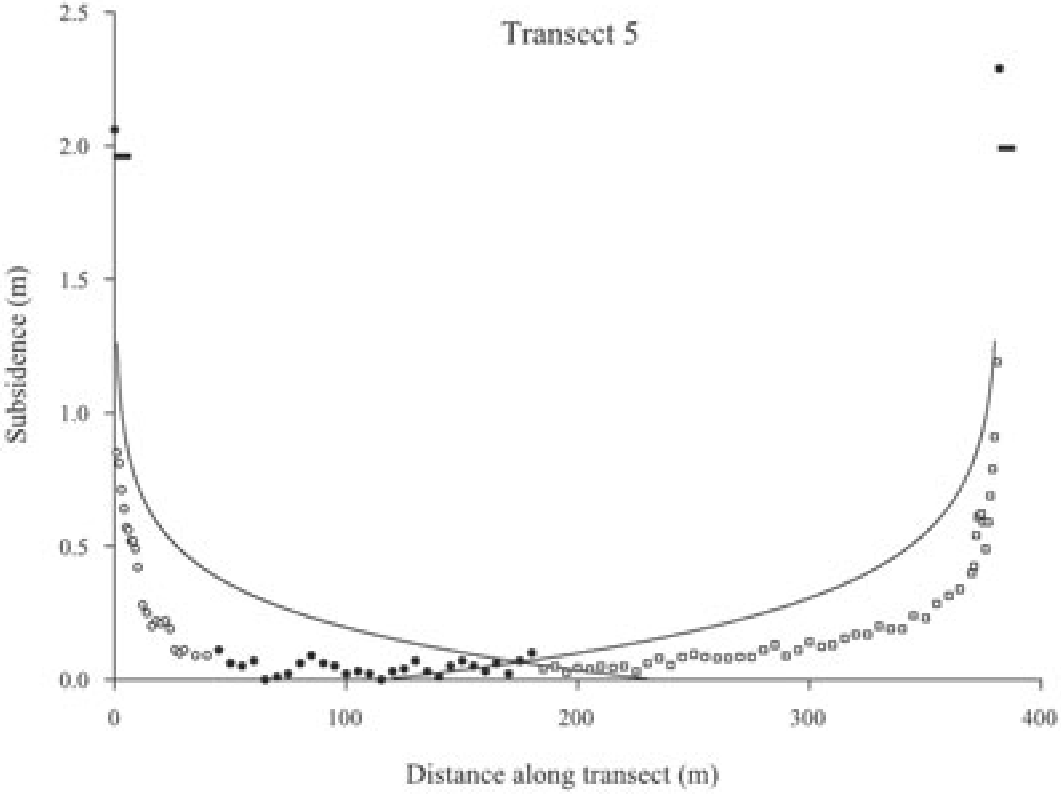

Figure 9: Transect 5 measured peat subsidence used to construct the model—sections 5.0 (∘) and 5.1 (▫). Data not used to construct the model (•), predicted peat subsidence (——) and drain water level (▬).

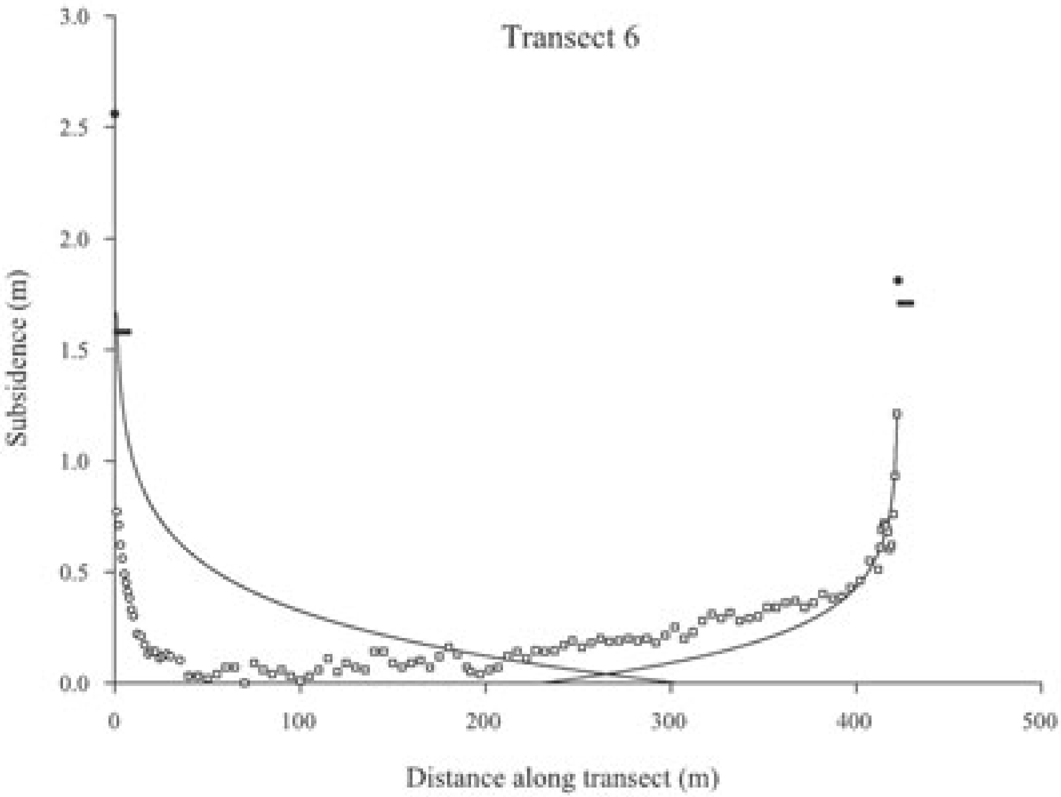

Figure 10: Transect 6 measured peat subsidence used to construct the model—sections 6.0 (◦)and 6.1 (◦). Data not used to construct the model (•), predicted peat subsidence (——) and drain water level (▬).

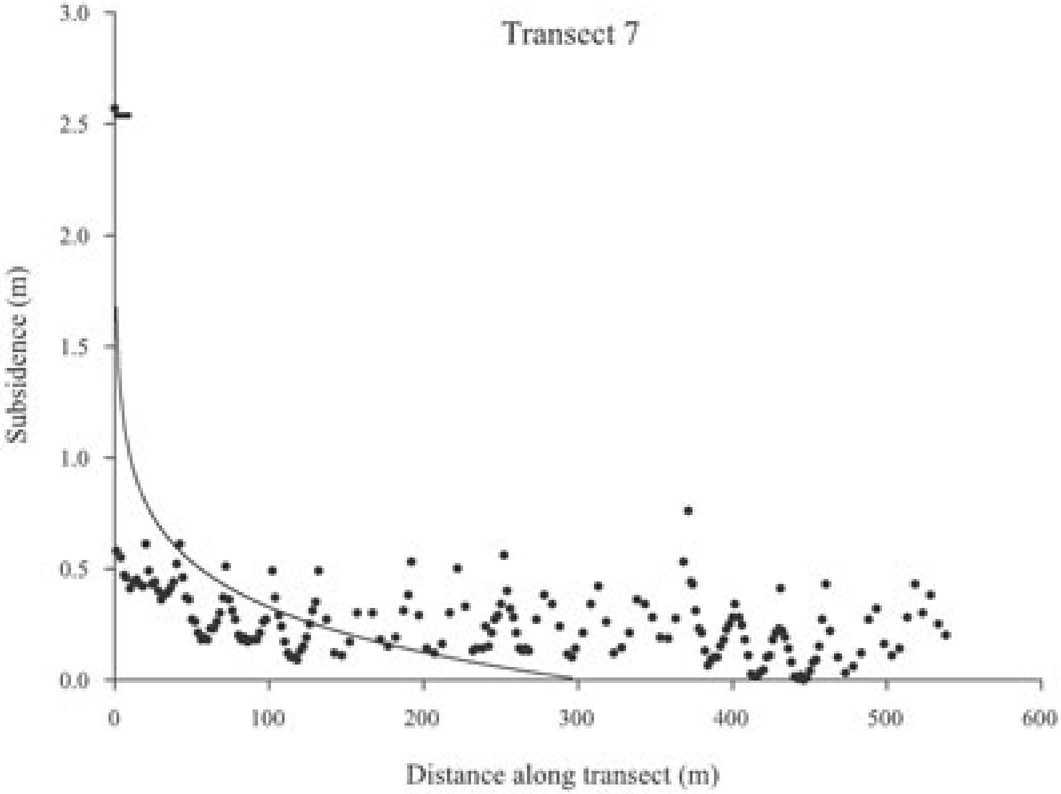

Figure 11: Transect 7, measured (•) and predicted peat subsidence (——), and drain water level (▬). No data from this transect were used to construct the model because of artificial surface contouring.

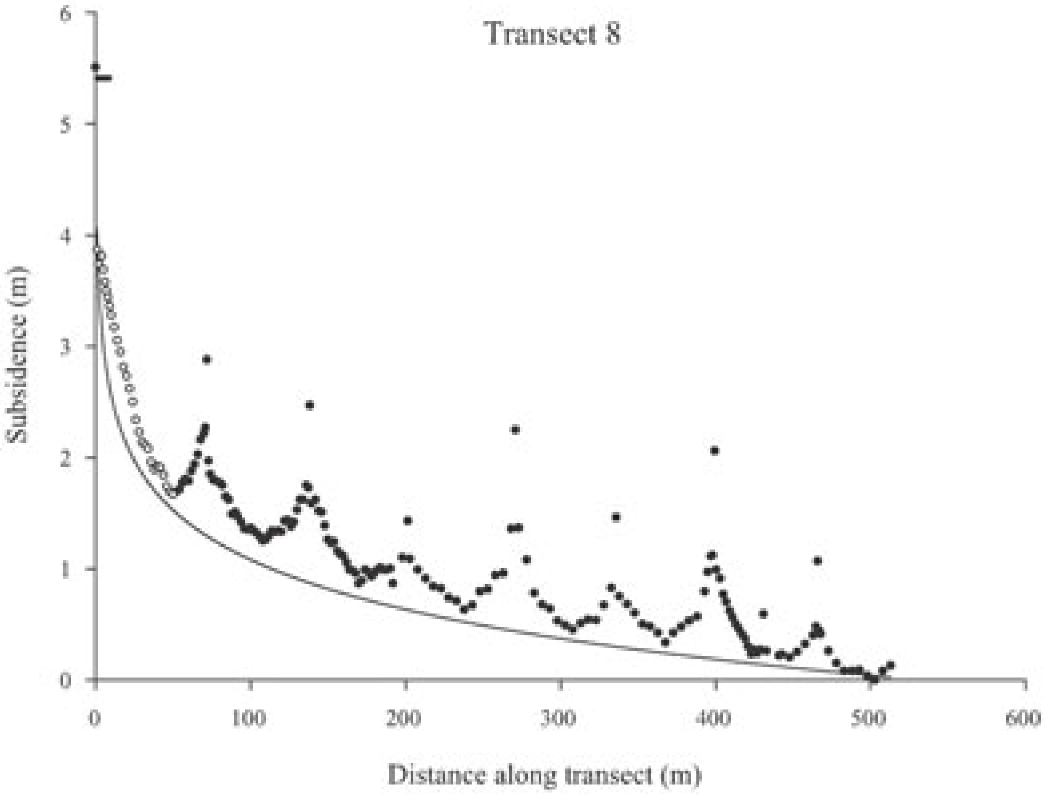

Figure 12: Transect 8 measured peat subsidence used to construct the model—section 8.0 (○). Data not used to construct the model (•), predicted peat subsidence (——) and drain water level (▬). Paddocks bisected by this transect are frequently artificially contoured.

There is poor correlation (R^2 = 0.61) between measured and predicted surface subsidence along transect 9 (Fig. 13). Possible causes of this might be unusual characteristics of the roadside drain at the start of the transect or the influence of other drains not bisected by the transect. Data for model construction were taken from the drain to the inflection point.

The model initially predicts subsidence along transect 10 accurately (0–105 m, R^2 = 0.99) until secondary and paddock drains are encountered (Fig. 14). The combined effect of these drains creates significantly more subsidence than the origin drain alone. Predicted extent of subsidence is approximately 400 m, while measured extent is nearly 650 m. Data for model construction were taken to the first inflection point.

Less-than-predicted subsidence was measured along transect 11 (R^2 = 0.38; Fig. 15). The drain at the beginning of this transect was several metres wide and deep, with a mineral soil base. The base of the peat appeared to be close to the water level, 19 cm above the drain base. This drain is not typical of those generally present on peatland. Subsidence from 200 m to the shallower drain at 341 m on the transect is strongly correlated with the model (R^2 = 0.92). Data for model construction were taken from the deep drain at the start of the transect to the first inflection point, and in both directions from some of the smaller paddock drains to provide a range of drain depth data for the model.

Subsidence is overestimated for transect 12 for most of its length (R^2 = 0.37; Fig. 16). This could be caused by inappropriate datum selection and hence drain depth, or drain characteristics resulting in an effectively shallower than measured drain (e.g., impeded water flow). The drains at this site contained long grass, rushes, moss and lichen. Data for model construction were taken from the two main drains from which sufficient points were measured.

Transect 13 (Fig. 17) is oriented perpendicular to, and crosses, transect 12 and is reasonably approximated by modelled surface subsidence relative to the drains at both the start and end of the transect (R^2 = 0.99 and 0.91 respectively). Data for model construction were taken from the start drain to the inflection point. Data were not used from the drain at the end of the transect due to insufficient measurement points for regression.

The lateral extent of surface subsidence was well predicted for transect 14 relative to both the start drain (R^2 = 0.86) and the paddock drain at 494 m from the start (R^2 = 0.87). However, the amount of surface subsidence was generally underestimated, most likely caused by the paddock drains bisected by the transect. Data for model construction were taken from the start drain to the inflection point before the first paddock drain. Remaining measurements were not used due to uncertainties about the interactions of the other drains.

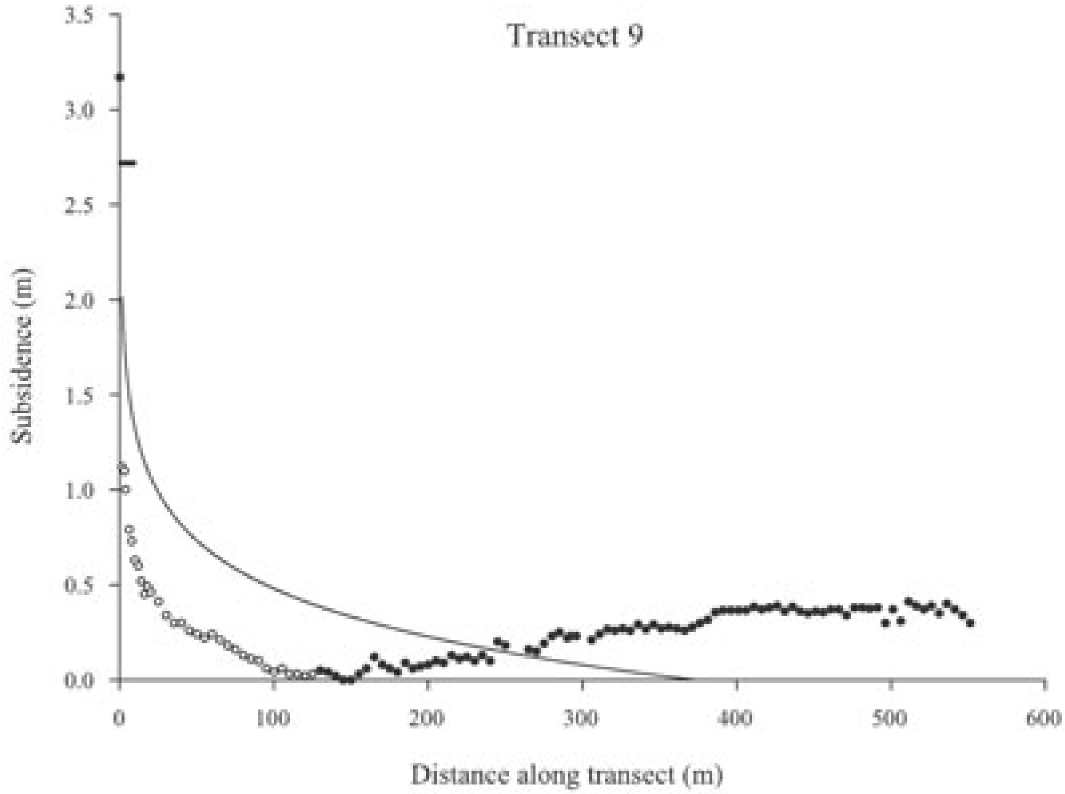

Figure 13: Transect 9 measured peat subsidence used to construct the model—section 9.0 (◦). Data not used to construct the model (•), predicted peat subsidence (——) and drain water level (▬).

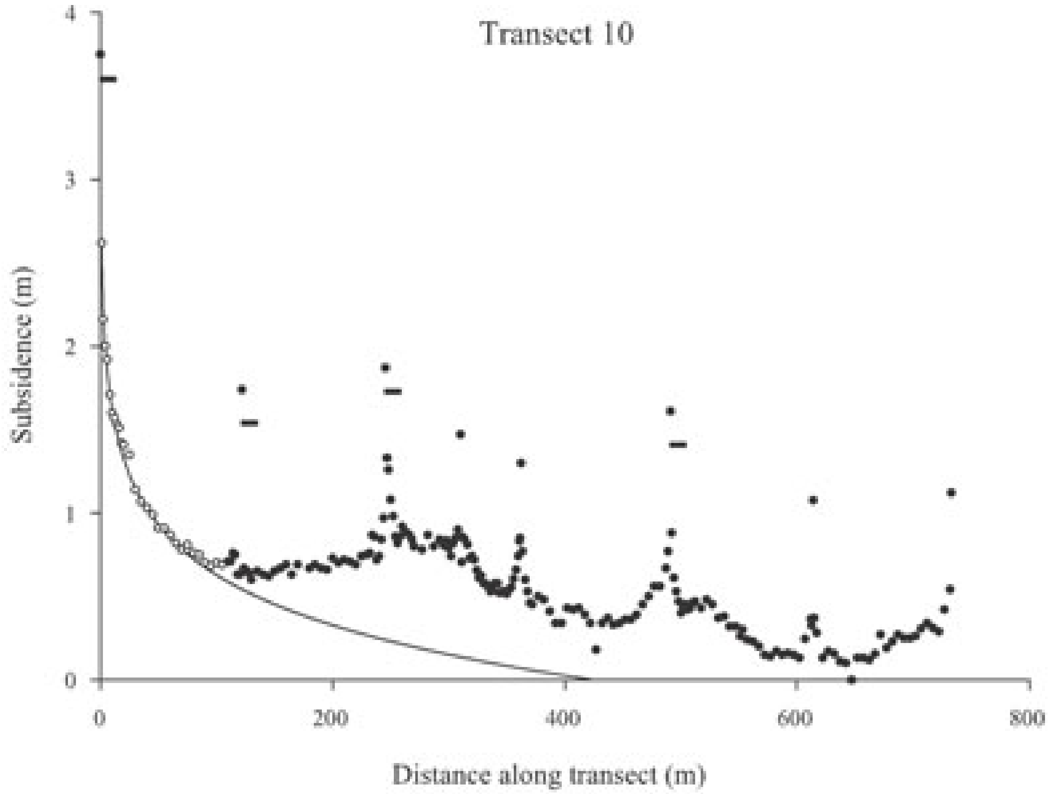

Figure 14 Transect 10 measured peat subsidence used to construct the model—section 10.0 (◦). Data not used to construct the model (•), predicted peat subsidence (——) and drain water level (▬) .

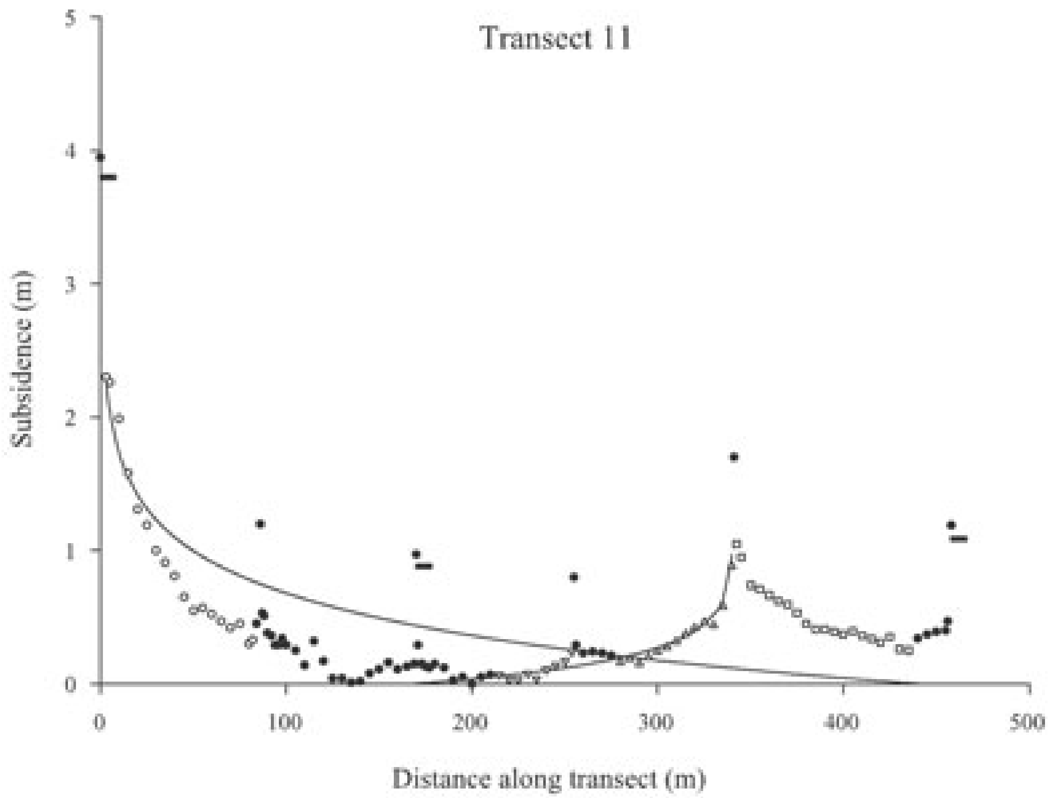

Figure 15: Transect 11 measured peat subsidence used to construct the model—sections 11.0 (◦), 11.1 (▫), 11.2 (▵), 11.3 (▿). Data not used to construct the model (•), predicted peat subsidence (——) and drain water level (▬).

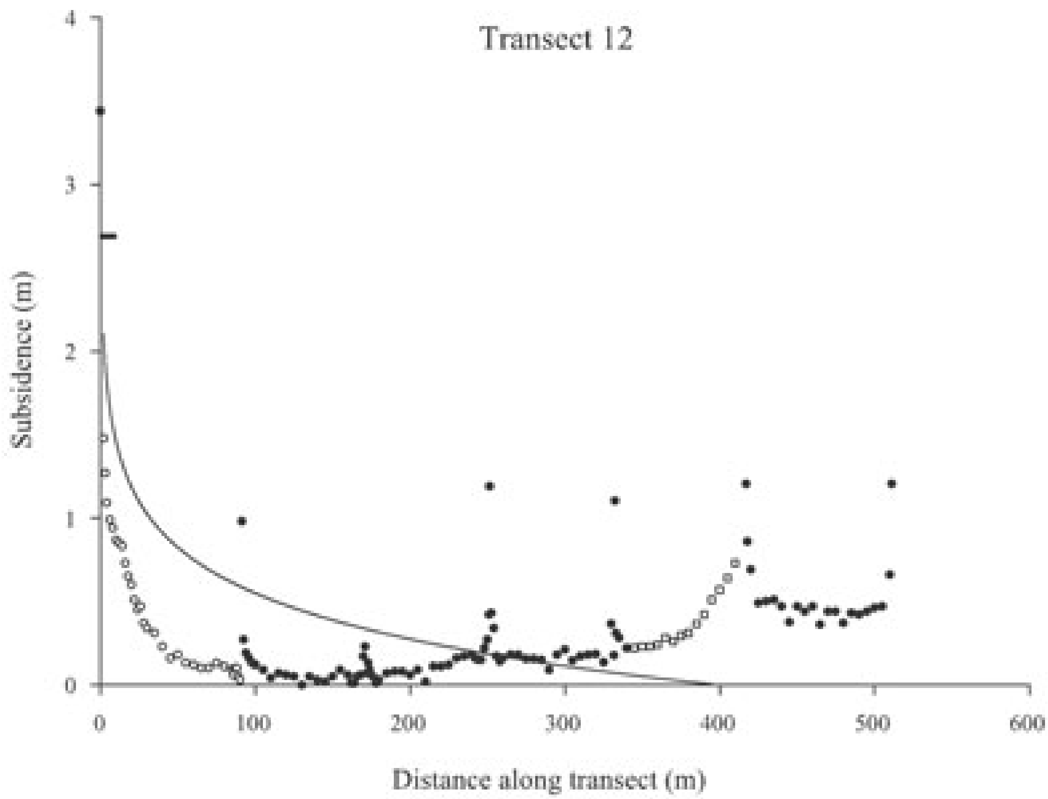

Figure 16: Transect 12 measured peat subsidence used to construct the model—sections 12.0 (◦), 12.2 (▫). Data not used to construct the model (•), predicted peat subsidence (——) and drain water level (▬).

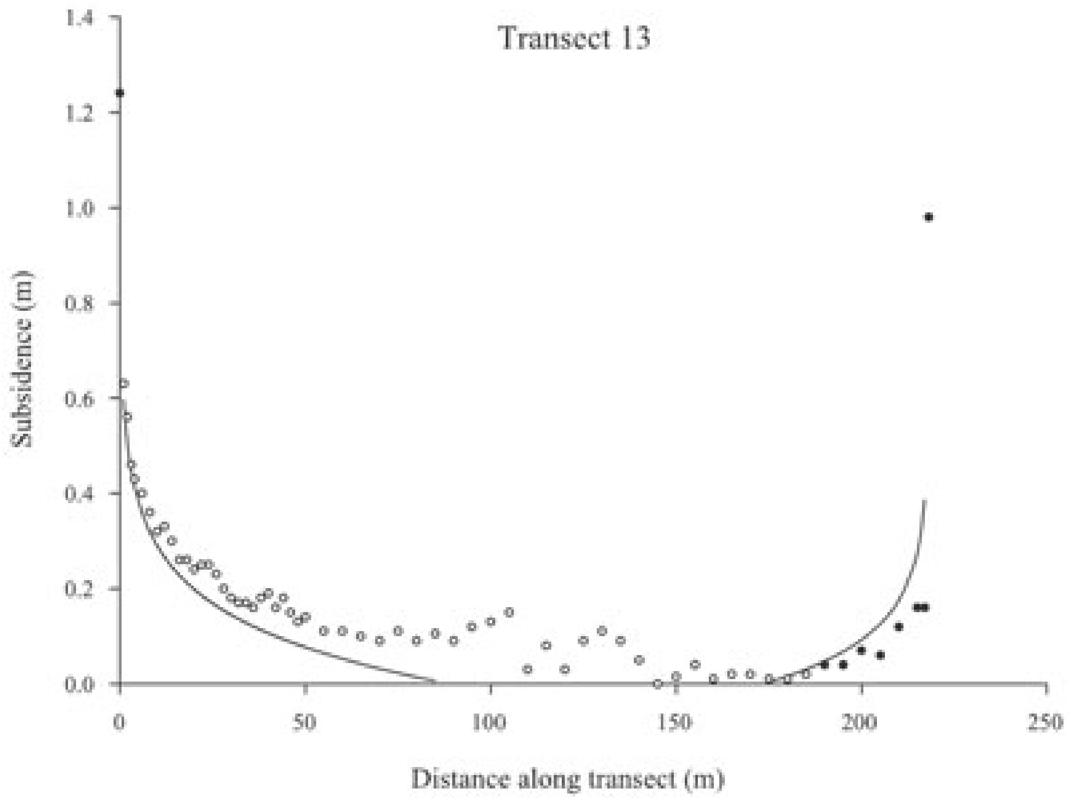

Figure 17: Transect 13 measured peat subsidence used to construct the model—section 13.0 (◦). Data not used to construct the model (•) and predicted peat subsidence (——).

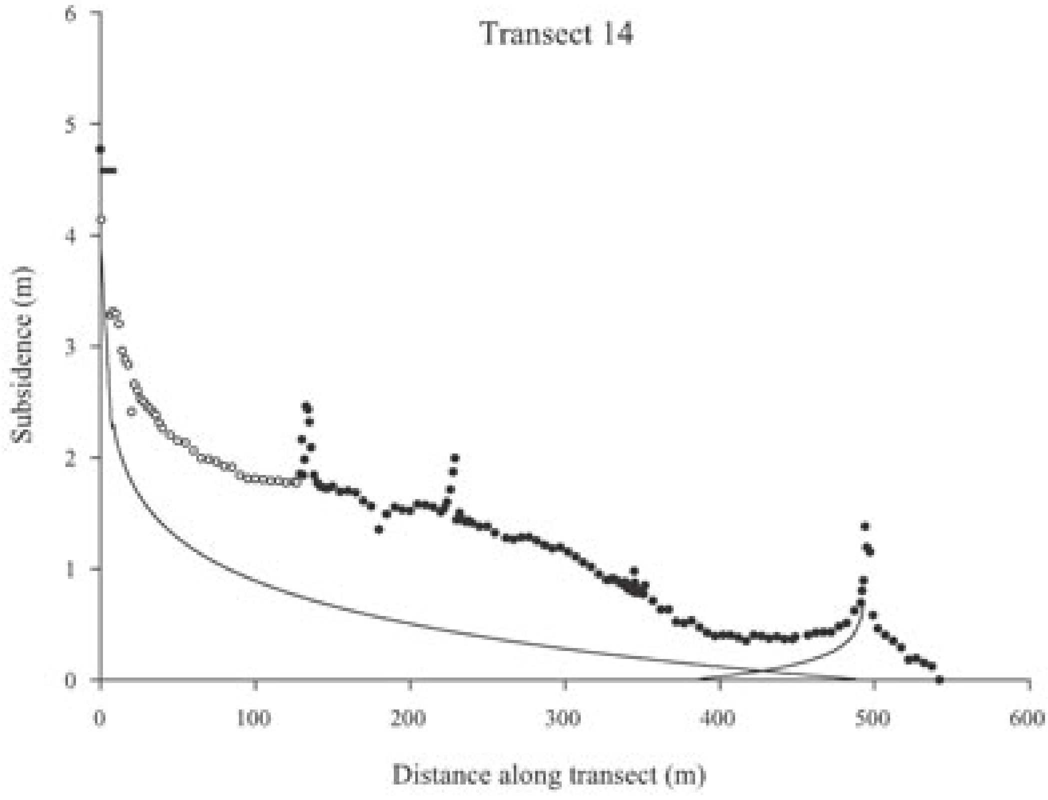

Figure 18: Transect 14 measured peat subsidence used to construct the model—section 14.0 (◦). Data not used to construct the model (•), predicted peat subsidence (——) and drain water level (▬).

Excluding transects 1 and 7, and sections of other transects obviously effected by bisected drains, the subsidence model accounts for 37–99% (mean 81%) of the variance in measured peat subsidence.

5.3 Drain depth estimation

In future, the depth of many drains may need to be measured so that subsidence can be predicted. As the zero subsidence datum against which drain depth is measured can be hundreds of metres away, it is useful to be able to estimate the actual depth of a drain from a depth measurement made relative to the peat surface closer to the drain.

It is possible to solve the subsidence model to estimate 'drain depth' based on a drain depth measurement made relative to a known distance from the drain. This estimated drain depth can then be incorporated into the subsidence model. For example, if depth of a drain is measured in relation to the peat surface height (measured in metres) 50 m distant (*depth50*), 'drain depth' (m) is predicted by the equation:

$y = 1.5151 \times depth50 - 0.522$

If the depth is measured relative to the surface 25 m away (possibly useful where drains are shallow or closely spaced), the equivalent formula is:

$y = 1.7340 \times depth25 - 0.6169$

The equivalent formula if depth is measured relative to the surface 100 m away is:

$y = 1.3453 \times depth100 - 0.4484$

Figure 19 illustrates an example where the depth of a drain is measured relative to the peat surface 50 m away as 1.99 m (*depth50*). In this situation, the zero subsidence datum is approximately 300 m from the drain, and 'drain depth' (which can then be incorporated into the model and used to predict subsidence) is 2.49 m.

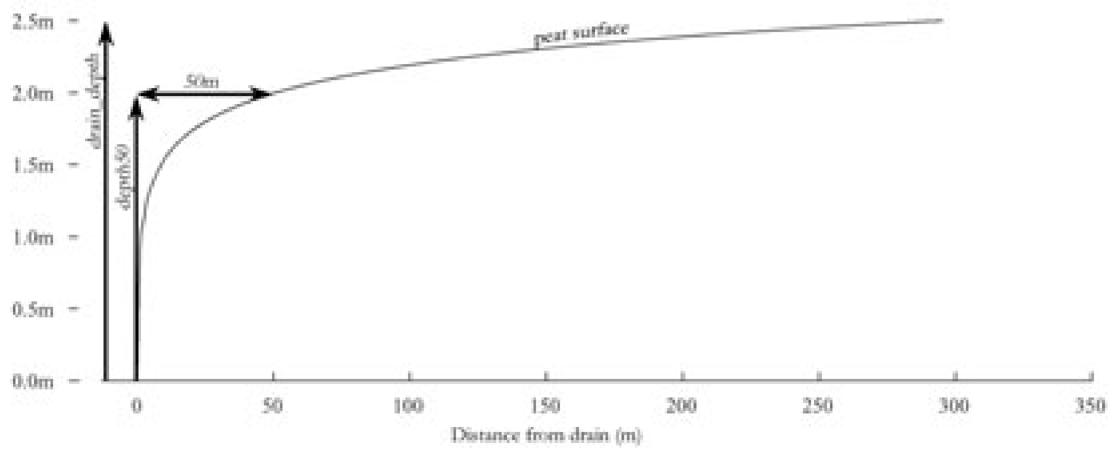

Figure 19: Illustration of drain depth estimation from a depth measurement made relatively close to the drain.

6 Conclusions

Peat subsidence away from drains of various depths can be estimated by the equation (all measurement units in metres):

Subsidence = (-0.1202×*drain depth*+0.0162)×Ln(*distance from drain*)+(0.8102×*drain_depth*-0.4079)

This equation can be rearranged to give the distance from a drain to which a certain amount of subsidence is likely to occur.

$$\textit{Distance from drain} = e^{\left(\frac{depression-(0.8102\times drain\_depth-0.4079)}{(-0.1202\times drain\_depth-0.4079)}\right)}$$

The amount of peat subsidence and the distance to which the effect extends is strongly correlated with drain depth, deep drains having much greater effect than shallow drains.

The model is based on the effects of single, independent drains only. Where these criteria are met in the sampled transects, the model accounts for an average of 81% of the measured variance in subsidence. The model will generally underestimate subsidence caused by many closely spaced drains.

The shape of the predicted subsidence curve is such that small measurement errors or paddock unevenness could have considerable effect on predicted extent of subsidence. It may be appropriate to calculate the lateral extent of subsidence for subsidence values either more or less than zero to allow a margin of error if required.

The peat surface against which drain depth should be measured (the subsidence datum) may be hundreds of metres from the drain, and complicated by the effects of other drains. In many instances it will be more appropriate to estimate drain depth from a depth measurement (or average of several measurements) made relative to a point closer to the drain by the equations (all depth measurements in metres):

Drain depth = 1.7340 × *depth25* - 0.6169

where *depth25* is the depth (m) of the drain relative to the peat surface 25 m away.

Drain depth = 1.5151 × *depth50* - 0.522

where *depth50* is the depth (m) of the drain relative to the peat surface 50 m away.

Drain depth = 1.3453 × *depth100* - 0.4484

where *depth100* is the depth (m) of the drain relative to the peat surface 100 m away.

References

Davoren A. 1978. A survey of New Zealand peat resources. Water and Soil Technical Publication No. 14.

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McKenzie S, McLeod M. 2002. Subsidence rates of peat since 1925 in the Moanatuatua swamp area. Landcare Research Contract Report LC0102/128.

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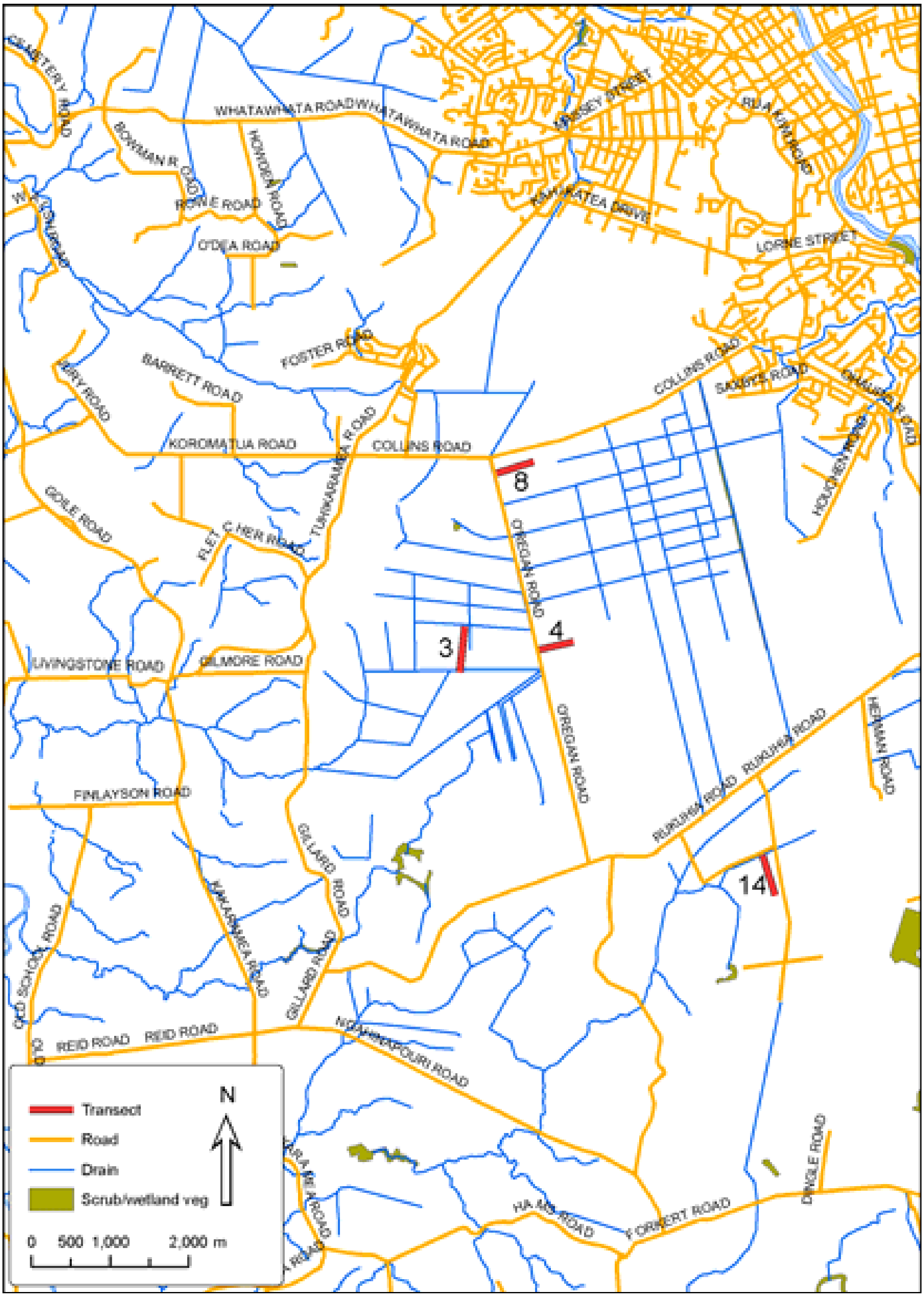
Appendix I: Transect grid references

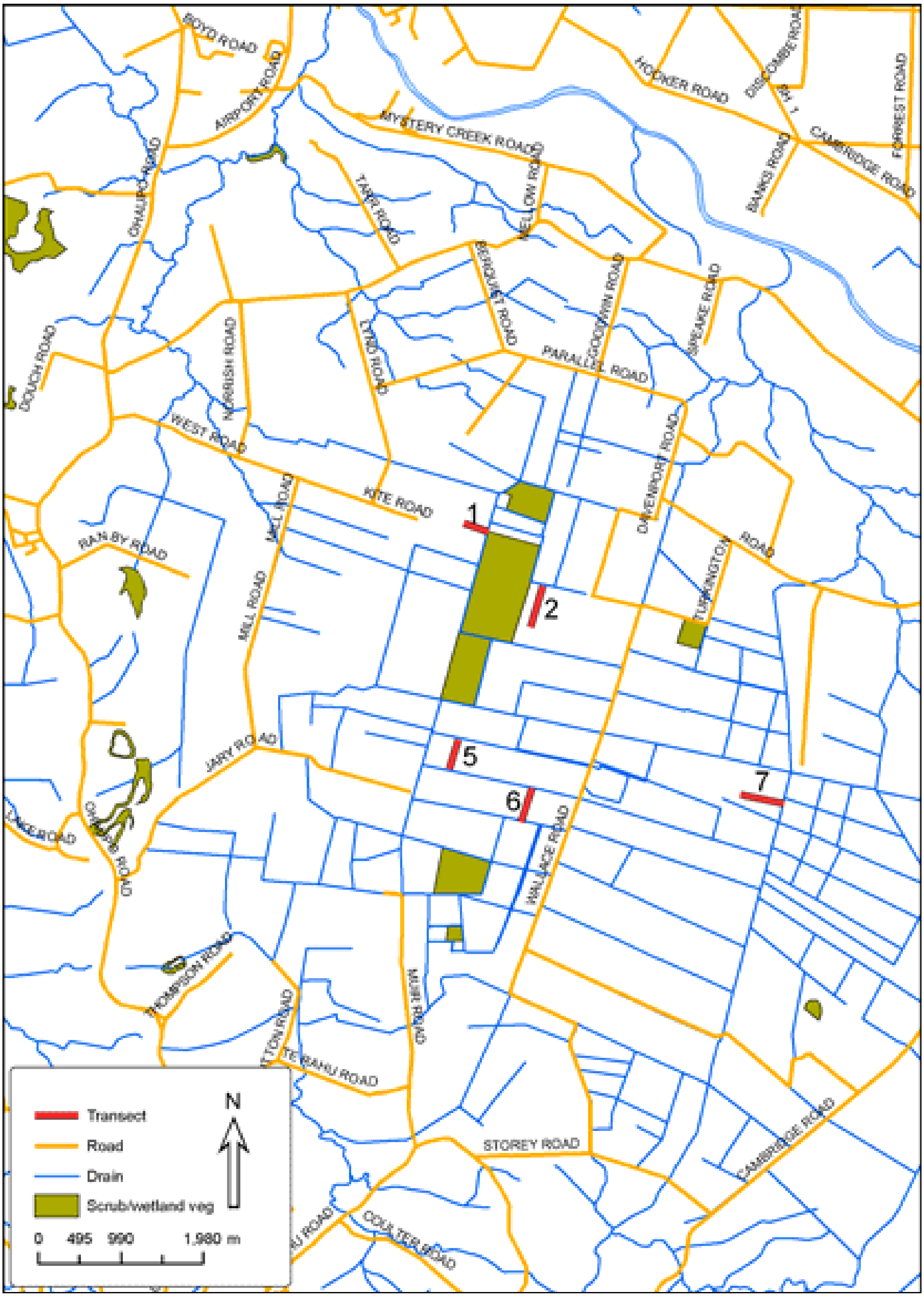
Start and end point coordinates (NZMG, Geodetic Datum 1949) of 14 peat subsidence transects.

Transect	Start point		End point	
1	E2718398	N6362284	E2718099	N6362391
2	E2719051	N6361631	E2718902	N6361133
3	E2706852	N6369940	E2706795	N6369365
4	E2707803	N6369641	E2708244	N6369744
5	E2717926	N6359436	E2718030	N6359800
6	E2718922	N6359217	E2718787	N6358797
7	E2721957	N6359022	E2721426	N6359134
8	E2707259	N6371889	E2707734	N6372042
9	E2718603	N6392917	E2718398	N6393426
10	E2731121	N6421331	E2730838	N6422006
11	E2730607	N6422541	E2730782	N6422127
12	E2742041	N6414869	E2741579	N6414659
13	E2741738	N6414840	E2741837	N6414647
14	E2710648	N6367038	E2710809	N6366518

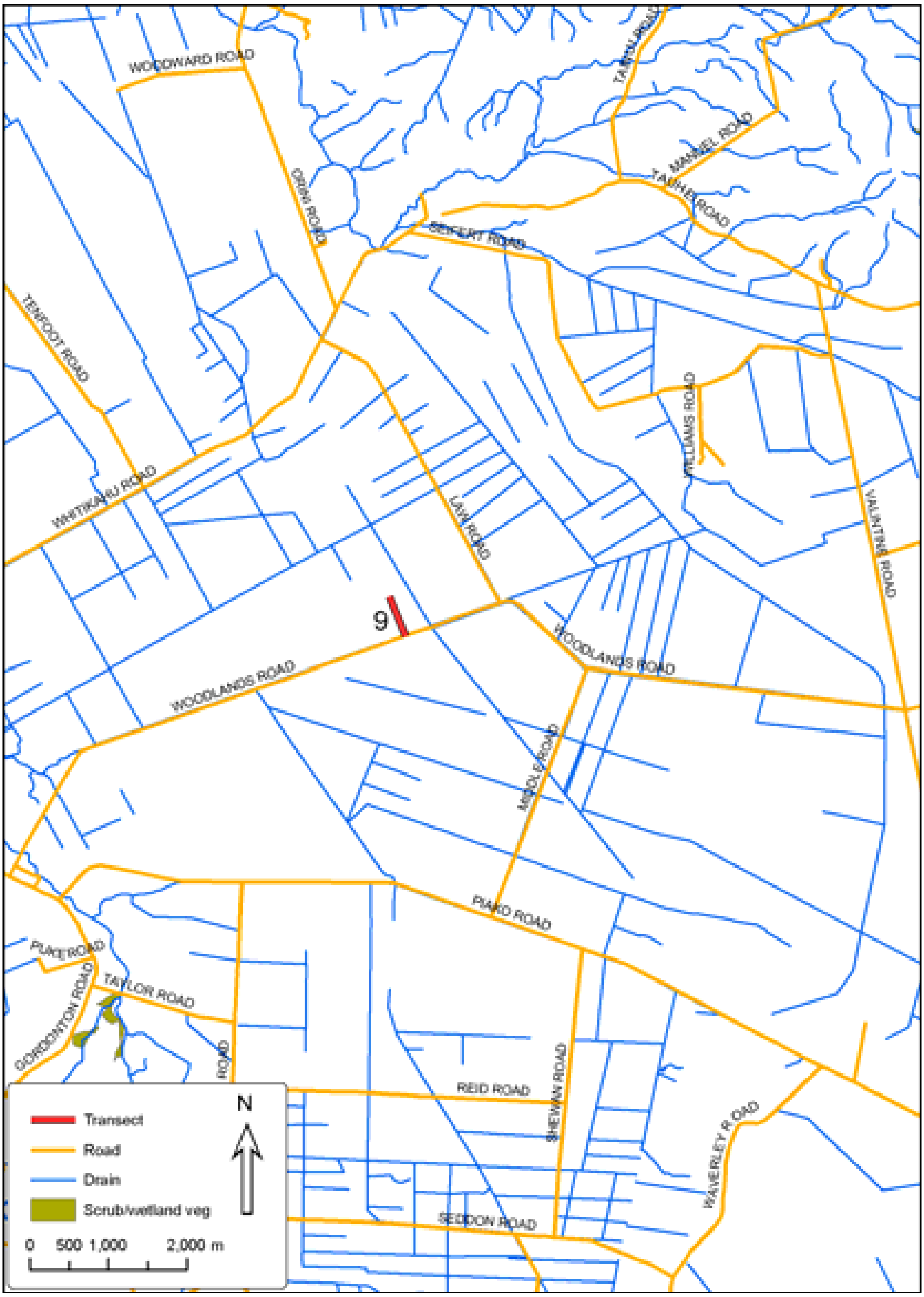
Appendix II: Transect location maps



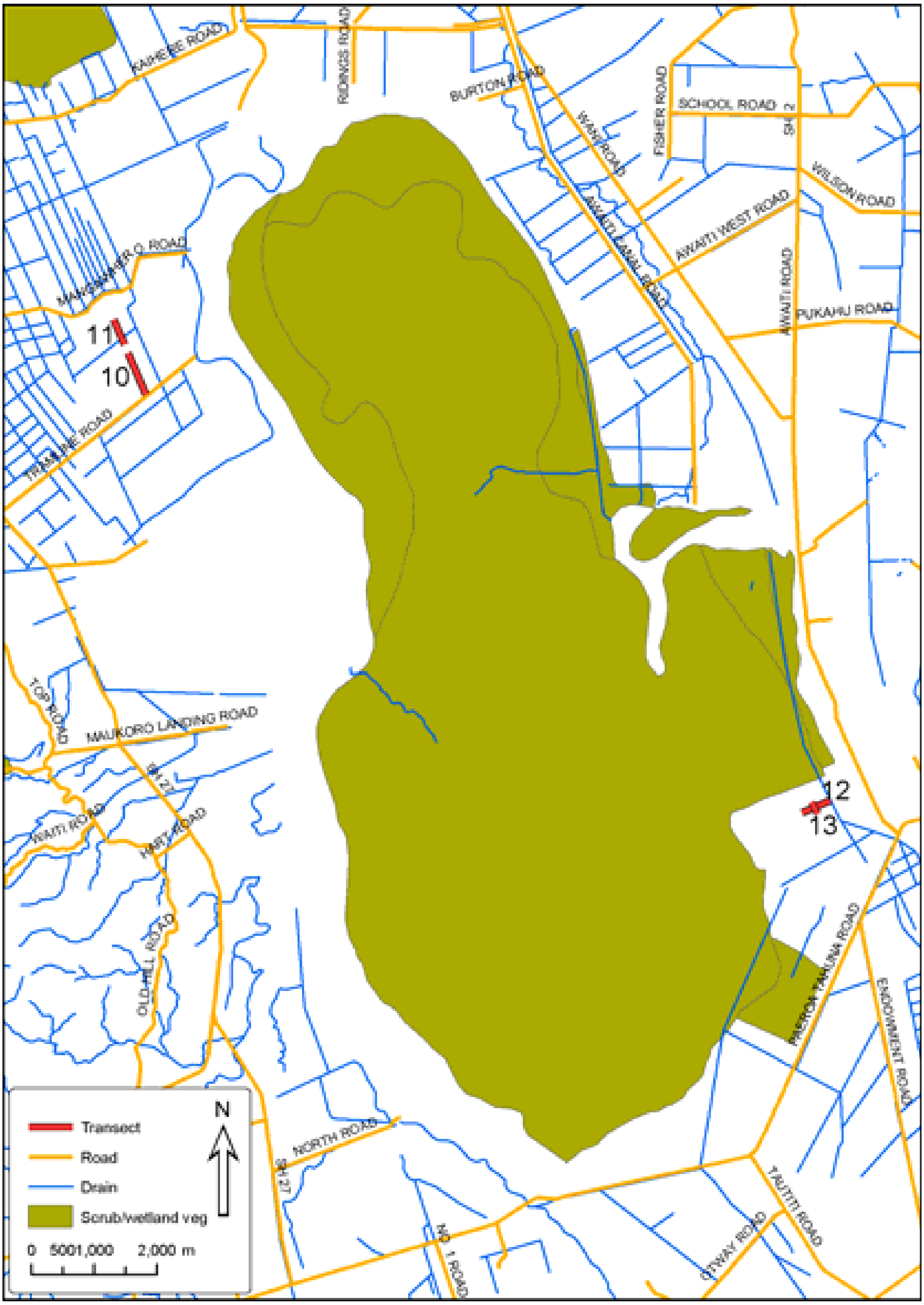
Location of peat subsidence transects in the Rukuhia area.



Location of peat subsidence transects in the Moanatuatua area.

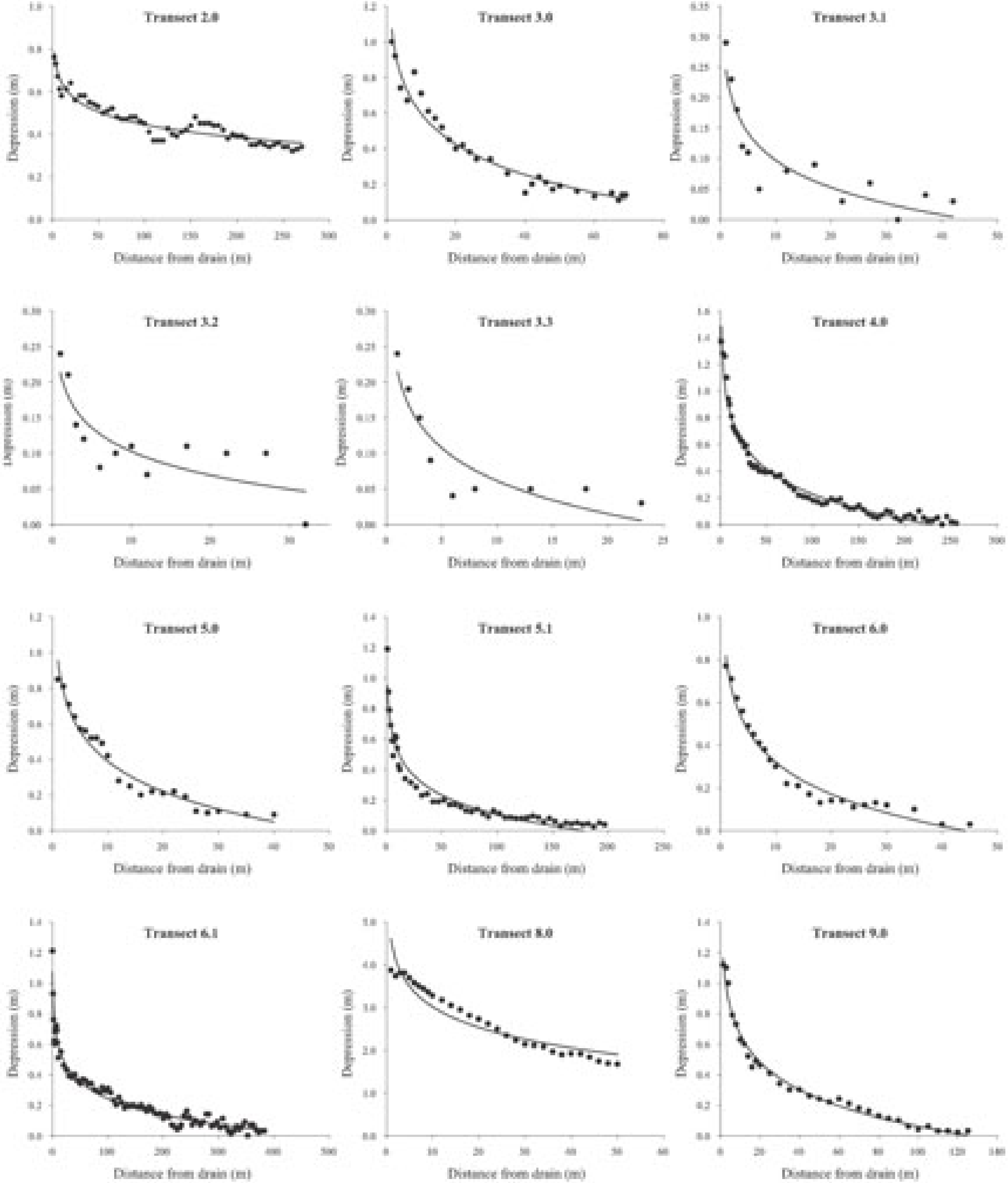


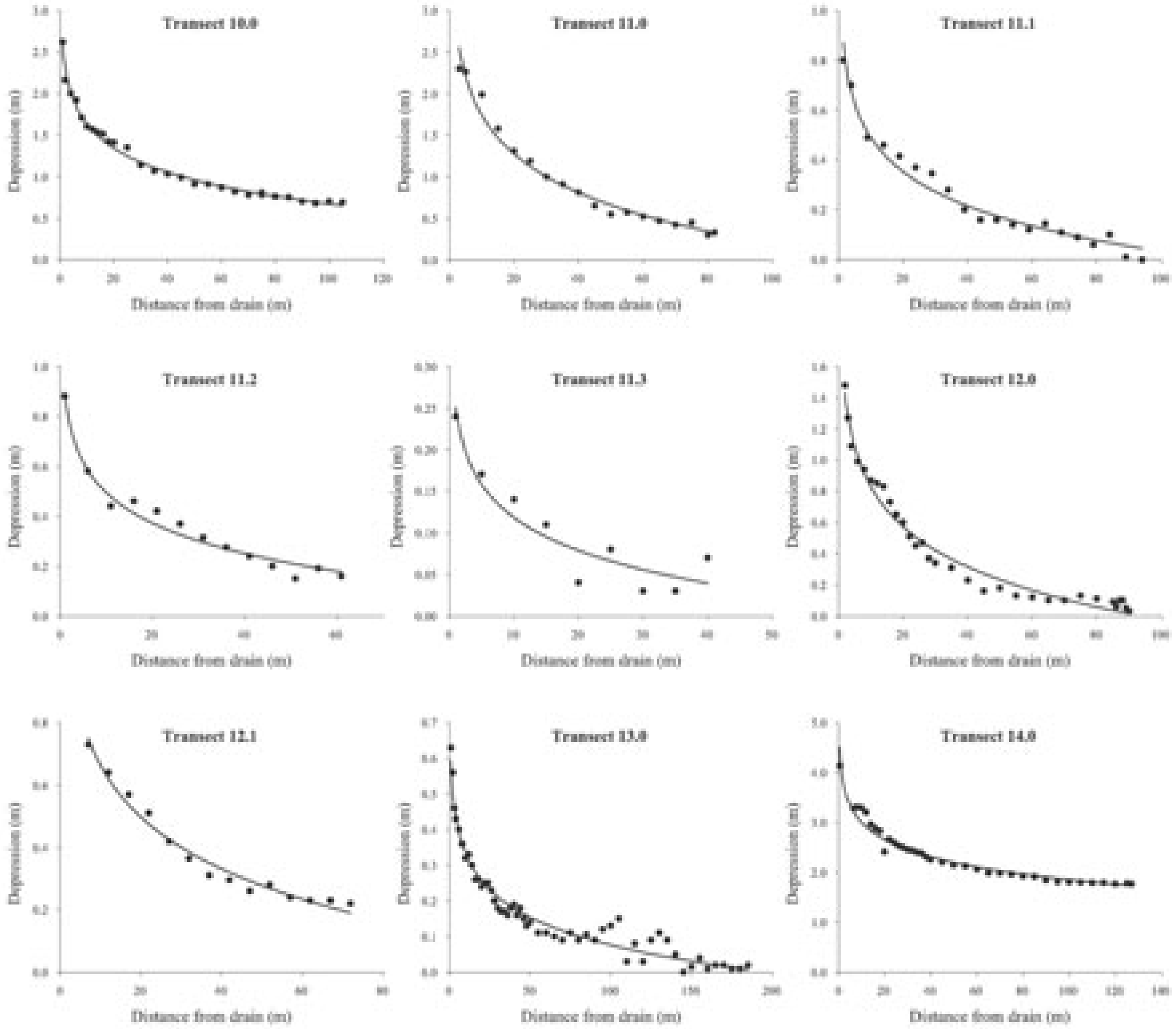
Location of peat subsidence transects in the Komakorau area.



Location of peat subsidence transects in the Hauraki area.

Appendix III: Subsidence profiles and regression curves of 21 transect sections





Transect sections and regression curves used in the peat subsidence model development. Regression equations are given in Table 1.