74-80 (Buried topsoil) uA1	Black (10YR1.7/1) sandy loam. Very friable. Moderately developed very fine to fine nut with some fine to very fine blocky structure. Few roots, few fine and medium charcoal fragments, many fine and few medium lapilli. Indistinct wavy boundary.
80-91 uB	Brownish-black (10YR3/2) sandy loam with many faint, medium to coarse mottles ranging in colour from dull yellow-brown (10YR5/4) to greyish yellow-brown (10YR4/2). Moderately developed very fine to fine nut with some very fine to fine blocky structure. Friable. Few roots, few lapilli. Distinct to diffuse wavy boundary.
91+ C	Dull yellow-orange (10YR6/3) sand with many fine to coarse distinct brown (10YR4/4) mottles. Single grain, loose. Few roots.

SWALE 3

DEPTH (cm)	DESCRIPTION
0-30 (Forestry disturbed deposits)	Well-defined layers and lenses of dark and light coloured sand. Sharp irregular boundary.
30-41 (Garden soil) uAp	Brownish-black (10YR2/3) sandy loam with many faint fine brownish-black (10YR3/2) and few distinct medium yellow-brown (2.5Y5/3) mottles. Moderately developed very fine to fine nut structure. Friable to firm. Few roots, few fine and medium charcoal fragments, few fine lapilli, many lumps of Kaharoa Tephra. Indistinct smooth boundary.
41-49 (Buried topsoil) uA1	Dull yellowish-brown (10YR4/3) sandy loam with many faint medium dull yellowish-brown (10YR4/3-5/3) mottles. Moderately developed very fine to fine nut structure. Friable. Few roots, few fine charcoal fragments, many fine lapilli near top of horizon. Indistinct wavy boundary.
49-58 uA_2(?)	Dull yellow-brown (10YR5/3) sandy loam with many faint fine to medium dull yellow-orange (10YR6/3) mottles. Moderately developed very fine to fine blocky and nut structure. Friable. Few roots. Distinct wavy boundary.
58-64 uB	Yellowish-brown (10YR5/6) loamy sand with many faint medium bright yellowish-brown (10YR6/6) mottles, grading down to sand. Loamy sand breaks to a moderately developed very fine to fine blocky and nut structure. Sand breaks to a weakly developed very fine to fine blocky and nut structure with single grain. Friable to loose. Few roots. Indistinct wavy boundary.
64-90+ C	Bright yellowish-brown (10YR6/6) sand with many faint medium to coarse brown (10YR4/6) mottles. Single grain. Loose. Few roots.

SWALE 2

DEPTH (cm)	DESCRIPTION
0-11 (Soil disturbed by forestry)	Brownish-black (10YR2/3) loamy sand, with many faint coarse dark brown (10YR3/3) mottles. Weakly developed medium granular and fine nut structure with single grain. Very friable. Few roots, pieces of wood (*Pinus* sp.). Sharp wavy boundary.
11-31 (Garden soil) uAp	Black (10YR2/1) sandy loam with few faint medium to coarse brownish-black (10YR3/2) and many distinct fine to coarse dull yellow (2.5Y6/3) mottles of Kaharoa Tephra. Moderately developed fine to medium blocky and very fine nut structure. Friable. Few roots. Few fine and medium charcoal fragments, few fine and medium lapilli. Sharp irregular boundary.
31-37 (Kaharoa Tephra)	Kaharoa Tephra. Discontinuous graded layer, fine at top and coarse at bottom. Dull yellow (2.5Y6/3). Distinct smooth boundary.
37-50 (Buried topsoil) uA1	Brownish-black (10YR3/2) paling downwards to greyish-yellow-brown (10YR4/2) sandy loam with many faint fine to medium brownish-black (10YR3/2) mottles. Moderately developed very fine to medium blocky and very fine nut structure. Friable. Few roots. Many fine lapilli, few fine charcoal fragments. Indistinct wavy boundary.

50-54 uA2(?)	Dull yellowish-brown (10YR5/3) sandy loam with many faint fine to medium dull yellow brown (10YR4/3) mottles. Moderately developed very fine blocky and fine nut structure. Very friable. Few roots. Indistinct smooth boundary.
54-63 uB	Yellowish-brown (10YR5/6) sandy loam with many distinct fine and medium dull yellow orange (10YR6/4) to dark brown (10YR3/4) mottles. Moderately developed very fine blocky and fine nut structure grading down to sand with weakly developed very fine and fine nut structure and single grain. Friable. Few roots. Indistinct smooth boundary.
63+ C	Dull yellowish-brown (10YR5/4) sand with many medium to coarse dull yellow-orange (10YR6/4) mottles. Single grain. Loose. Few roots.

SWALE 1

DEPTH (cm)	DESCRIPTION
0-37 Ap(?)	Brownish-black (10YR2/2) sandy loam with faint, medium and coarse dark brown (10YR3/3) mottles, few increasing downwards to abundant at the boundary with the underlying Kaharoa Tephra. Weakly developed fine to very fine nut structure. Firm. Few roots, few fine charcoal fragments, few fine lapilli. Sharp to distinct irregular boundary.
37-47 (Kaharoa Tephra)	Kaharoa Tephra. Fine component (*c.* 2cm thick layer) generally on top with coarse at the bottom, but also mixed in places. Dull yellow (2.5Y6/3). Firm. Distinct wavy boundary.
47-52 (Buried topsoil) uA1	Dull yellowish - brown (10YR5/3) sand. Weakly developed fine to very fine nut structure. Friable. Few roots, few coarse rounded pumice fragments up to 10cm long, many fine and very fine lapilli, few fine charcoal fragments. Indistinct wavy boundary.
52-69 uA2	Dull yellow - orange (10YR7/3) sand with few faint medium dull yellow - orange (10YR6/3) mottles. Single grain. Very friable. Few roots. Distinct smooth boundary.
69-81 uB	Dull yellowish-brown (10YR5/3) loamy sand with many fine and medium faint brown (10YR4/4) mottles. Weakly developed very fine to coarse nut and blocky structure. Firm. Few roots. Indistinct smooth boundary.
81-100 C	Dull yellowish-brown (10YR5/4) sand with many medium and coarse distinct brown (7.5YR4/4) mottles. Single grain. Very friable. Few roots. Distinct irregular boundary.
100-110+ D	Dark reddish-brown (5YR3/3) sand with profuse faint medium brown (7.5YR4/4) mottles. Weakly developed very fine to fine nut and fine blocky structure with single grain. Firm.

TABLE A3.2. CHEMISTRY' OF THE SOILS BURIED BY KAHAROA *TEPHRA IN* SWALES 1 TO 5, AND OF THE GARDEN SOIL IN SWALE 5.

PROPERTY	SOIL HORIZON	SWALE 1	SWALE 2	SWALE 3	SWALE 4	SWALE 5	SWALE 5 GARDEN SOIL
pH	A1	5.3	5.8	6.1	8.1	6.2	5.8
	A2	5.4	5.7	6.2		6.3	
	B	5.1	5.9	5.1	8.1	6.8	
Olsen P	A1	10	23	5	6	2	5
	A2	8	17	6		9	
	B	20	19	9	8	3	
SO4	A1	6.0	1.5	2.5	2.0	3.0	4.0
	A2	2.5	2.5	2.5		1.5	
	B	35.0	1.0	62.0	<1.0	33.5	
Exch K	A1	0.02	0.10	0.38	0.14	0.04	0.04
	A2	0.01	0.09	0.33		0.05	
	B	0.03	0.06	0.07	0.05	0.03	
Exch Ca	A1	1.0	0.9	1.2	13.3	3.4	3.2
	A2	0.6	1.2	0.5		1.8	
	B	0.2	0.9	0.5	8.1	5.3	
Exch Mg	A1	0.15	0.24	0.28	0.14	0.74	1.18
	A2	0.21	0.14	0.22		0.35	
	B	0.06	0.64	0.03	0.09	1.12	
Exch Na	A1	0.6	0.3	0.2	0.2	0.2	0.3
	A2	0.2	0.2	>0.1		0.1	
	B	0.3	0.3	>0.1	<0.1	0.1	
C E C	A1	10	9	13	16	10	16
	A2	8	10	7		7	
	B	10	9	7	10	11	
P retn.	A1	12	22	36	27	25	35
	A2	6	35	29		13	
	B	22	19	30	16	67	
Org matter	A1	1.8	2.9	3.7	3.9	4.2	5.3
	A2	0.5	3.4	3.1		3.2	
	B	2.4	2.4	2.4	1.9	3.2	

*Data provided by the Soil Science Department, Massey University, Palmerston North. Phosphate and sulphate values are expressed as micrograms per gram (air dry). Exchangeable cations and CEC values are expressed as meq/100g (air dry). Organic matter was determined as the percentage loss from an oven dry sample after ignition at 500°C. Phosphate retention is expressed as a percentage.

Appendix 4

POLLEN IDENTIFICATIONS AND COMMENTS PROVIDED BY DR W.L. McLEA FOR A POLLEN SAMPLE FROM PEAT BENEATH A PARABOLIC DUNE

The pollen sample is from peat beneath parabolic dune ridge c (Pig. 23 inset, main text).

Identifications:

Species	**No.**
Orchid ?	1
Poaceae	2
Gleichenia	3
Cyathea dealbata type	9
Cyathea smithii type	12
Monolete fern	2
Pteridium	5
Trilete fern	2
Nothofagus fusca type	1
Dacrydium cupressinum	27
Prumnopitys ferruginea	1
Prumnopitys taxifolia	4
unidentified podocarp pollen	10
Phyllocladus	2
Agathis	7
Laurelia ?	2

Comments:

The sample is from peat and identifications are from a slide measuring 22 x 32 mm. Preservation of some grains is poor, which probably means that they were present when the peat formed. Later pollen, deposited in anaerobic conditions, are better preserved. *Cyperaceae* belonging to several taxa were present. They were very abundant and were not counted. There was abundant charcoal which probably came from burning of the peat. No obvious wood fragments were seen.

An absence of *Pinus* pollen indicates that the deposit is probably pre-European.

Rimu and matai pollen can travel many kilometres from source and could have come from the mainland. Broadleaf pollen such as rata and kamahi are not usually dispersed very far by wind. The absence of rata and kamahi pollen from the sample suggests that these species were not growing near the site.

Appendix 5

POLLEN DIAGRAM FROM MATAKANA CORE

A swamp adjacent to a tidal creek on Matakana Core was sampled for pollen (NZMS 260 U14 80,'973). The swamp occupies a late Pleistocene-early Holocene fluvial course, drowned by the Postglacial Marine Transgression. A sediment core was taken from the swamp *c.* 200 m upstream of an active salt marsh (Betts 1996). Radiocarbon ages from the core (NZA4654 and NZA4833) are reversed and appear to be too old as the swamp would have formed near the end of the Postglacial Marine Transgression. Being an estuarine site some of the pollen and charcoal may have been transported to the site by water. No tephra deposits have been identified in the sediment core.

Results

The pollen diagram (Fig. A5.1, see end of report) is divided into three zones. The lower boundary, between Zone 1 and Zone 2, represents a change from scrubland to forest vegetation. The upper boundary, between Zone 2 and Zone 3, represents a change from predominantly forest vegetation to small trees, shrubs and bracken.

Zone 1 shows relatively low frequencies of podocarp pollen and high levels of *Cyathea* and monolete fern spores. After allowance is made for the high pollen production of *Dacrydium cupressinum*, the pollen of Zone 1 suggests that the vegetation was dominated by ferns and scrub. *Metrosideros* pollen appears at the top of this zone, possibly indicating the early stages of forest development. *Kunzea/Leptospermum* pollen, however, which are also indicators of forest regeneration, are absent. Aquatic pollen counts are very low.

Zone 2 shows considerable increase in the pollen of trees and shrubs, particularly podocarps. Small trees and shrubs exhibit a sharp peak, in particular, *Leguminosae*, *Metrosideros* robusta type and *Muehlenbeckia*, followed by a decline. *Cyathea* and monolete fern spores also increase. This increase may be an early successional change as a result of continuing development or recovery of the local vegetation. A small increase in *Nothofagus* possibly reflects an increase in *Nothofagus* populations in upland areas in the region, such as the Kaimai Ranges (*cf.* Newnham *et al.* 1995). No particular significance is attached to the increase because *Nothofagus* is a cooler climate species and its rise coincides with an increase in *Ascarina*, an indicator of warm, moist climates.

Charcoal counts rise sharply in this zone. High charcoal counts coinciding with dominant podocarp pollen suggests that the charcoal and pollen were derived from different sources. Alternatively, *Dacrydium cupressinum* can withstand most ground fires and can persist over long periods (Bray 1989), which may explain its occurrence with the high charcoal counts. The coincidence of other tree pollen and charcoal is probably due to natural fires caused by lightning strike or volcanic activity elsewhere in the Bay of Plenty.

The decline of *Ascarina* pollen at the top of zone 2 suggests that a cooler, drier climate then became established (cf. McGlone 1983; McGlone *et al.* 1977; 1984, McGlone 1988; Newnham *et al.* 1989).

Zone 3 contrasts sharply with Zone 2. The podocarp and *Nothofagus fusca* pollen drop substantially and *Pteridium* increases sharply. In the upper part of the zone, pollen of the modern adventive *Pinus radiates* first appears and Podocarp pollen declines, which reflects the clearance of native forest and the planting of exotic forest following European settlement. The first appearance of gorse pollen (Ulex) coincides with the first occurrence of exotic pine pollen.

Small trees and shrubs increase in this zone, especially *Kunzea/Leptospermum* and to a lesser extent *Metrosideros.* These are colonisers which follow vegetation disturbance and their failure to increase following the major charcoal peak in Zone 2 reinforces the suggestion made above that initial disturbance by burning occurred elsewhere in the Tauranga district.

The aquatics *Cyperaceae*, *Haloragaceae* and *Restionaceae* increase strongly to dominate the pollen spectrum in Zone 3. Herb species show a marked increase in this zone, including the adventive *Taraxacum*.

Interpretation of vegetation changes

Prior to the development of Matakana Barrier, the swamp site would have been adjacent to the open sea with exposure to considerably higher wave energy and salt-laden onshore winds than at present. Such environments do not favour well-developed forest vegetation, and scrubland would probably have been more dominant. Zone 1 and the lower part of Zone 2 appears to be consistent *with* this situation.

Formation of the barrier would have decreased exposure to wind-borne salt and reduced the overall strength of onshore winds. A change to a more sheltered, less saline environment would have allowed a transition from scrubland vegetation to lowland forest similar to the successional change described from Zone 2 above. The brief peak in *Leguminosae* possibly represents an early successional stage.

The lowered energy regime of the site following barrier development may have provided the conditions for the spread of local aquatic vegetation, indicated by the rise in *Restionaceae* in Zone 2. A further spread of aquatics is apparent in Zone 1 and possibly represents the transition from an active salt marsh to a freshwater swamp.

The virtual disappearance of indigenous trees, appearance of modern adventive pollen such as *Pinus*, *Ulex*, *Taraxacum* and increases in disturbance indicators such as *Pteridium* and *Kunzea/Leptospermum* all mark the destruction of natural vegetation and the introduction of exotic species by humans. *Pinus*, *Ulex* and *Taraxacum* were introduced by Europeans within the last 225 years. The initial increase in *Pteridium* and *Kunzea/Leptospermum* are probably a result of forest clearance following Maori settlement within the last 600-700 years.

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