Two breached dams (V24/55) lie in a former streambed at the western foot of the ridge with the pā V24/54 and 56 (Fig. 4 detail). The present-day stream flows across the flat to the west. The upstream dam has a distinct race or overflow channel from the pond across a small point, exiting below the dam. The dams had been cut through to drain the ponds sometime after 1944 since they appear full of water in aerial photographs at that time. From ground observation it is clear that, more recently, the old cuts in the dams had been further lowered by bulldozing. In these recent cuts, the fill of the upstream dam shows a lower and original soil horizon about 1.4 m above the streambed, on which there is a deposit of undisturbed midden. This is overlain by disturbed midden and clay fill (the body of the dam), the latter up to 2.4 m above the old streambed. There is some quarrying at the foot of the adjacent ridge. Overall, the sequence of the site is best interpreted as follows:

- In the nineteenth century (possibly earlier) a Māori settlement is built on and around the points in the stream bend (similar to V24/7 and 76 at Herbertville). There are a number of pits in the area around the streambed which may belong to this settlement.
- At some time in the course of the settlement midden was deposited on the points.
- Later, possibly in the course of the settlement, the opposing points in the stream were filled over and the points joined to form the dams.

The dams may have been for a mill that was part of the old Māori settlement. The fall from the dammed water level to that of the stream bed below the dam might have run an undershot wheel. It is equally possible that the dams were built by a farmer for stock water, perhaps in the 1930s.

4.3 RANGITOTO

Figures 17 and 18 show the previously recorded Rangitoto (pā V23/4) which was re-mapped from purpose-flown aerial photographs RAN (16 June 1998). The general environs of the site is the northern end of the belt of dunes running north from Porangahau. There is an old coastline composed of mudstone which runs through the area and is more or less continuous with the coastline west of Blackhead. The site is located on a small hill, a remnant of the former coastline, amongst sand dunes 900 m inland from the modern coast and not far south of a small river. The hill is 110 m in length; terraces cover most of the hill, running for some 87 m along its length. A series of long terraces

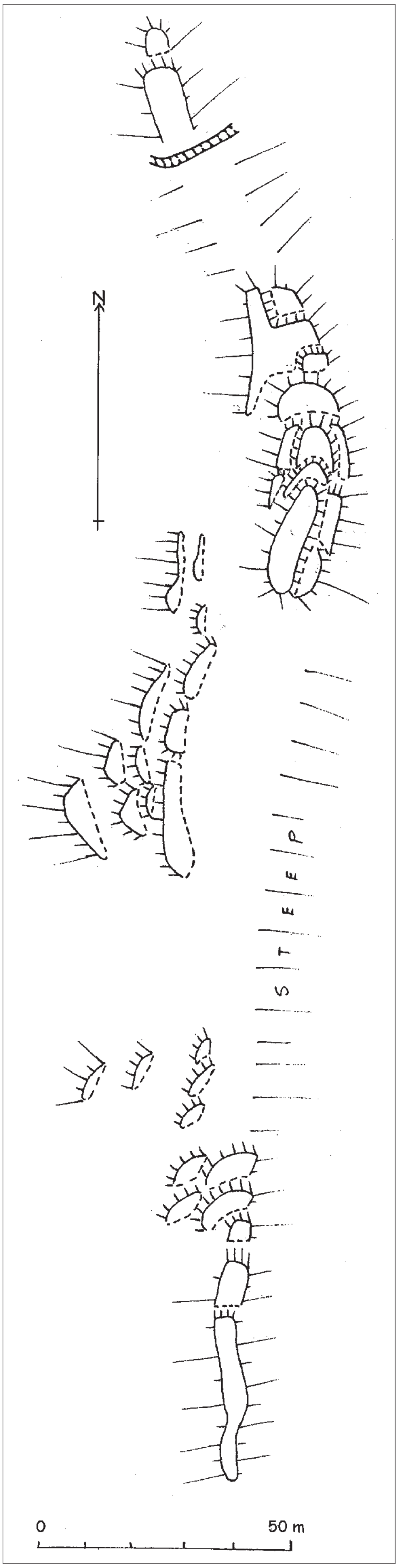


Figure 19. Previously unrecorded pā V23/55 at Aramoana. Mapped from purpose-flown aerial photographs ARA 16 June 1998.

Figure 20. Aerial oblique of Kairākau vicinity showing the Ponui Stream (right) and Mangakuri River (at bottom). At the top, pā V22/271 is just visible. Pā V22/268 and V22/267 lie on the ridges just above the limestone gorge of the Mangakuri River. On the south side of the same river is site V22/284. The view is to the north-east.

run down the north-facing slope over a distance of 23 m, the longest of which is 30 m long. Two shallow pits are located 45 m from the top of the hill on the east-facing aspect. A hoanga (grinding stone) or tūāhu (ceremonial stone) is located on the northern side of the hill, 10 m north of the base of the hill. Pits have been recorded on the hill to the west of the site (Bain n.d.). These are not visible on the purpose-flown aerial photographs.

4.4 ARAMOANA VICINITY

Figure 19 shows pā V23/55 at Aramoana, mapped from purpose-flown aerial photograph run ARA (16 June 1998). It is located 400 m up a steep-sided ridge that runs north-east to south-west and parallel to the coastline. The pā runs along the top of the ridgeline and consists of three groups of terraces. A group of terraces at the southern end of the site are distributed over some 80 m, running south-west to north-east down the top of the ridgeline. At the northern end of this series, too, there are five terraces running down the north-west-facing slope of the ridge. Thirty metres north of this group there is another series of terraces on the north-west-facing aspect of the ridge. They are distributed over an area that measures 66 m south-west to north-east and run

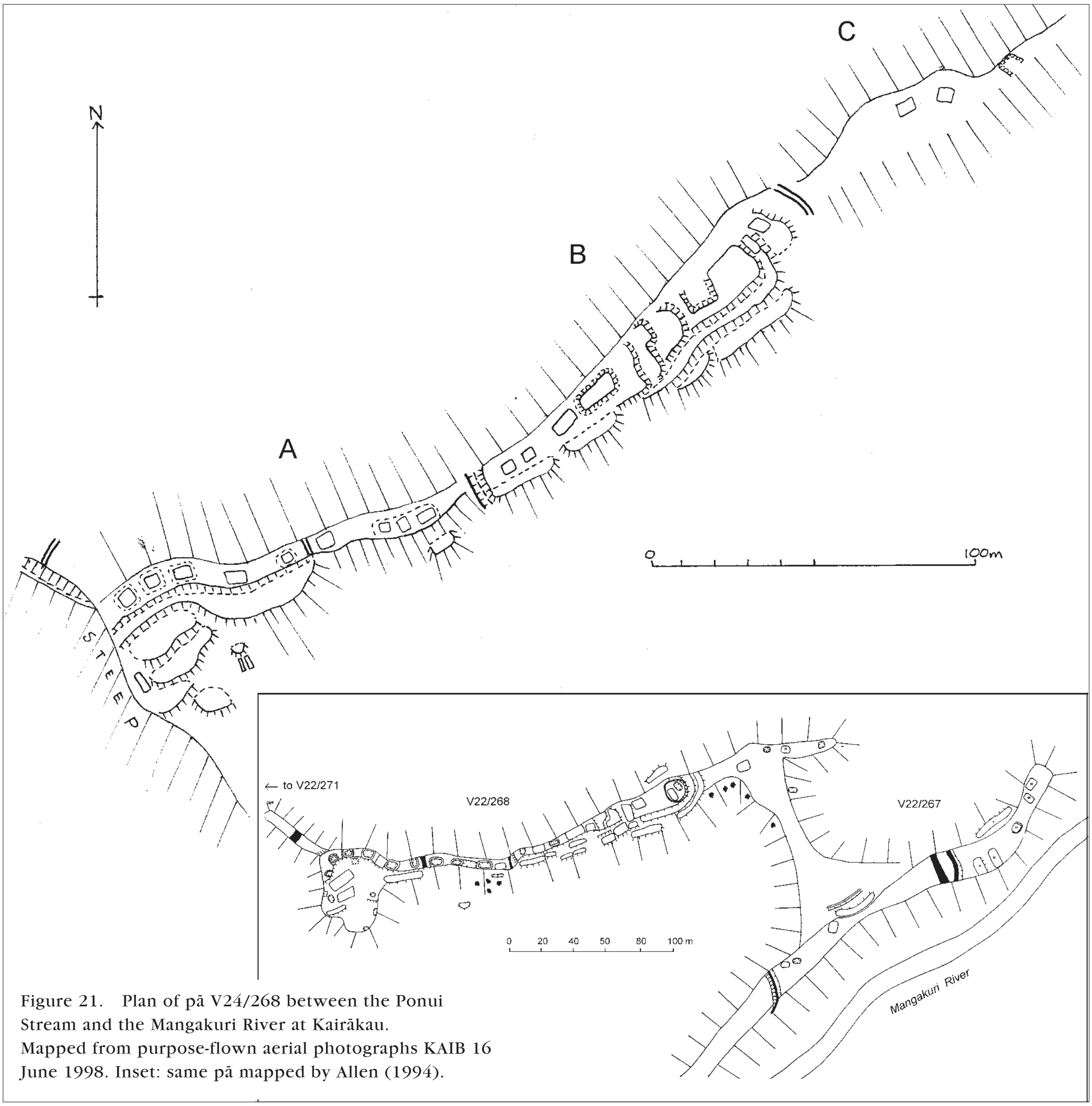


Figure 21. Plan of pā V24/268 between the Ponui Stream and the Mangakuri River at Kairākau. Mapped from purpose-flown aerial photographs KAIB 16 June 1998. Inset: same pā mapped by Allen (1994).

down the slope for 30 m. The third group of terraces is at the northern end of the site. These terraces run down the top of the ridgeline over a 73-m long area. A possible defensive ditch is evident at the northern end of the site. There are a further two terraces immediately beyond the ditch. A very steep slip is clearly evident on the north-east-facing end of the ridge. A fence line runs through the site and may have destroyed some of the features.

4.5 KAIRĀKAU VICINITY

At this northern end of the survey region, three aerial photographic runs were taken on 16 June 1998, indexed as KAIA, KAIB and KAIC (only the first two are reported in the present analysis). Many of the sites in this area had been

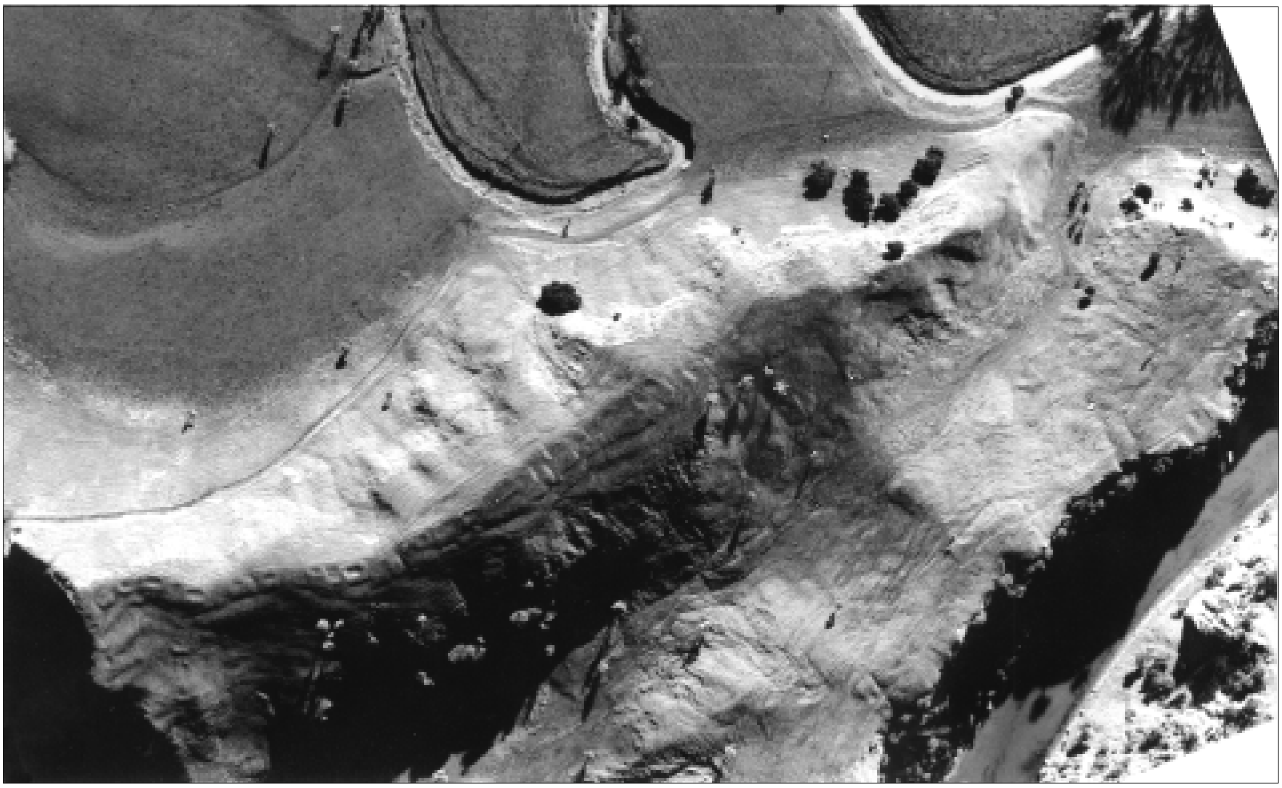


Figure 22. Purpose-flown aerial photograph from the series KAIB 16 June 1998 at Kairākau. The photograph shows the Ponui Stream at the top and the Mangakuri River at the bottom. Pā V22/268 (centre) and V22/267 (bottom, above gorge) are clearly visible.

previously recorded and mapped by Allen (1994: 428–429) in his Manawarākau polity (population 300–400 people) and this enables a comparison to be made between the two survey methods. Figure 20 shows the landscape setting of the main pā at Kairākau.

Figures 21 and 22 show pā V22/268, situated on a long, narrow, steep-sided ridge that runs north-east to south-west overlooking the Mangakuri River to the south and the Ponui Stream to the north. It is part of the site that Allen (1994) named Mangarākau. The site was mapped from aerial photographs KAIB (16 June 1998). It is distributed over an area of ridge 330 m in length, with 270 m within the defended area. There is a defensive ditch at the western end of the site. A path (possibly of ancient usage) runs below the crest of the ridge between this ditch and area A (Fig. 21) which covers the south-western end of the site. Along the top of the narrow ridge there is a minimum of nine pits, seven of which are of raised-rim form. A defensive ditch recorded by Allen is located between two pits 65 m from the western end of the ridge. This feature was difficult to interpret from purpose-flown aerial photographs. At the western end of area A, several large terraces run 37 m down the south-east-facing slope. These are poorly interpreted and planned by Allen. There is another defensive ditch at the easternmost end of area A. Area B is located east of this feature. There is another transverse defensive ditch 138 m east of the ditch in area A; this feature is unrecorded by Allen, who records the defensive feature at the eastern end of the site as a scarp only. The scarp, however, is hard to determine on the aerial photograph run KAIB (16 June 1998) (Fig. 22), and Allen may have been unable to recognise the infilled ditch in a ground view.

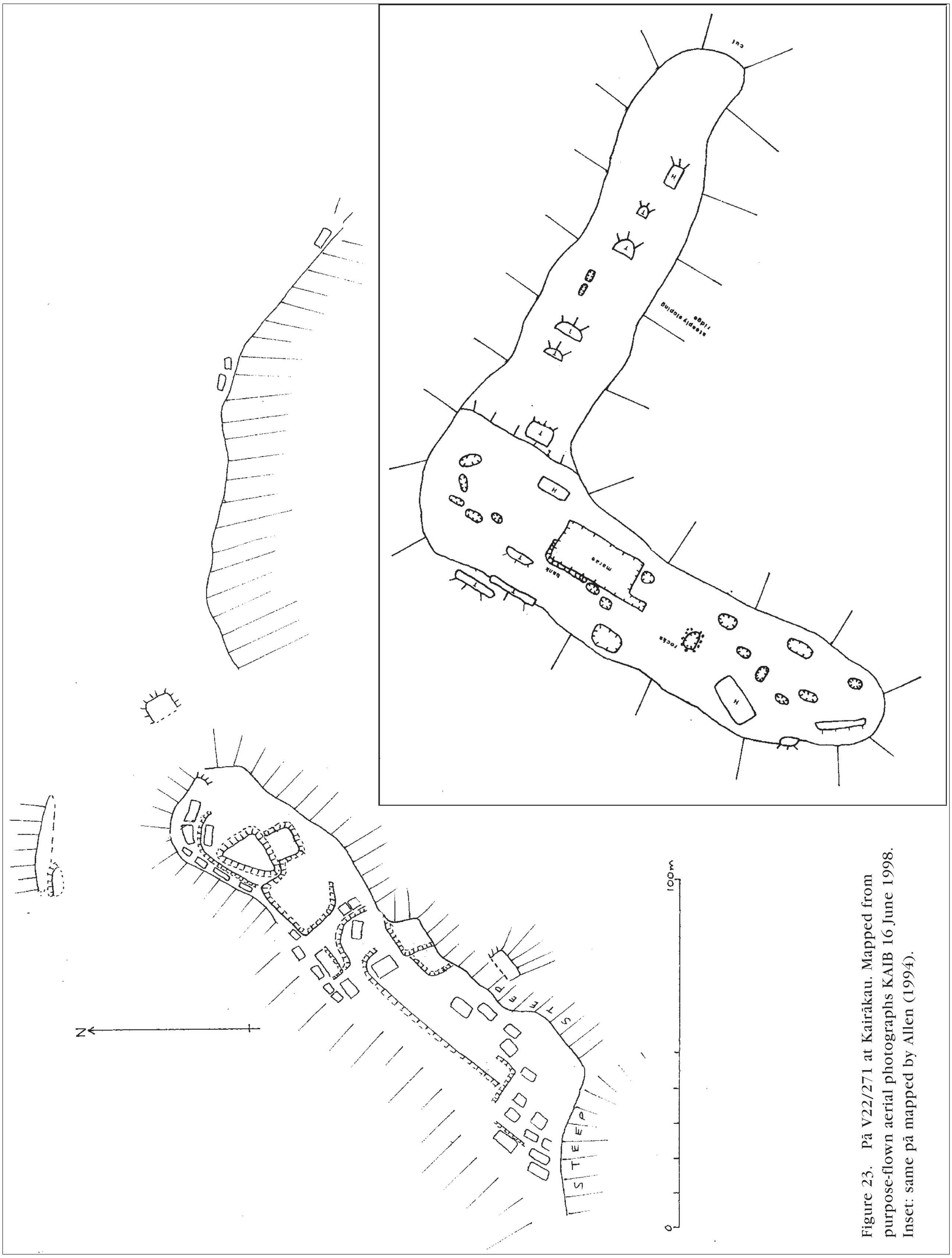


Figure 23. Pā V22/271 at Kairākau. Mapped from purpose-flown aerial photographs KAIB 16 June 1998. Inset: same pā mapped by Allen (1994).

Figure 24. Purpose-flown aerial photograph KAIB 16 June 1998 of pā V22/271 above the Mangakuri River at Kairākau.

Area B consists of a series of terraces and house sites that run along the top of the ridge and down the south-east-facing slopes. Area C is located 40 m beyond the defended areas of the site on the north-eastern end of the ridge. Area C is made up of three possible house platforms or pits that have been eroded so that the features can no longer be distinguished. To the south, this area links via a low saddle to V22/267 which is not shown here.

Figures 23 and 24 show pā V22/271, also mapped from photographic run KAIB (16 June 1998). The site is located on the same ridgeline as V22/268, overlooking the Mangakuri River, but is south-west of the road. The main area of the pā is 145 m long and approximately 27 m wide running north-east to south-west along the top of the hill. No artificial defensive features are evident on the aerial photographs; this is also reported by Allen. At its north-eastern end, above the scarped edge of the site, there are a number of pits that run in a semicircle beneath a linear terrace and a tihi (the central or highest platform of the pā). A steep ridge with a few terraces runs down to the road. The most obvious feature of the north-eastern end of the site is a large level-bottomed rectangular depression, 28 m long by approximately 17 m wide, reported to be a marae or large wharepuni floor by Allen (1994). A bank is evident for a distance of 17 m on the north-western side of the 'marae' and for 7 m on the north-eastern end. This feature may outline a house floor of traditional wharepuni form. Allowing for drains under the eaves and a space in front of the porch, this suggests a house about 12 by 5 m in plan—a very large house. Between the 'marae' area and the south-western end of the site, there is a large flat area approximately 50 m in length from north-east to south-west. The features at the south-western end of the pā are difficult to interpret from the aerial photograph run KAIB (16 June 1998). There appears to be a number of pits and terraces that cover an area approximately 30 m (north-west to south-east) by 25 m (north-east to south-west). Allen depicts these features schematically. Beyond the main area of the pā, there are three visible pits on the ridgeline that runs down to the east from the crest of the hill, and also some terracing on the north-facing slopes of the hill.

Figure 25 shows pā V22/274, also previously recorded and mapped by Allen (1994). This site was remapped from run KAIA (16 June 1998). The site is situated on the northern end of a steep-sided ridge above the western bank of the Mangakuri River. The site consists of four visible terraces and two groups of pits. At the northern end, above a steep slope to the river (A), there is a cluster of five (possibly six) raised-rim pits. Approximately 3 × 5 m in plan, they are distributed over an area 45 m long. Allen recorded a transverse ditch at the southern end of the site; this was a difficult feature to interpret correctly from the aerial photographs. A further three raised-rim pits (B) are located on the western side of a small stream gully separating them from area A. These pits are distributed over an area 20 m long. Area (C) is a series of four visible terraces running north-east down the ridgeline, visible in the aerial photographs KAIA (16 June 1998). They are located on the eastern side of the stream gully. Allen also failed to record the well-formed pits west of the gully at B, depicted the pits at A schematically and missed out the terraces at C, all of which are easily determined on run KAIB.

In general, when comparing Allen's plans with our own, which were derived from aerial photographs with ground controls, it is evident that the aerial view makes it easier to:

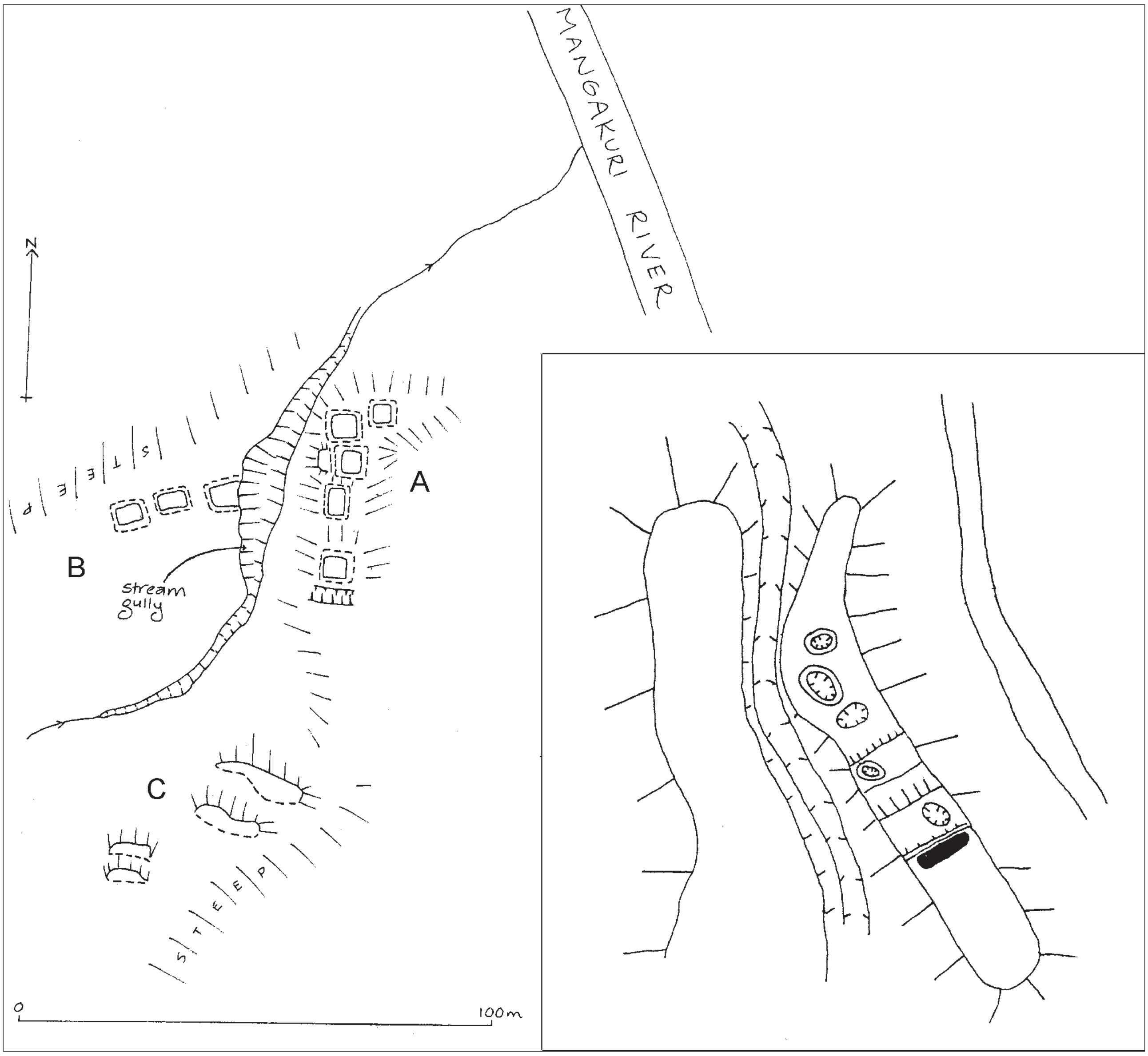


Figure 25. Pā V22/274 at Kairākau. Mapped from purpose-flown aerial photographs KAIA 16 June 1998. Inset: same pā mapped by Allen (1994).

- Detect all relevant features
- Depict the detailed plan configuration of terraces
- Detect the impression of eroded and largely infilled pits, and
- Interpret the overall pattern of the site and its setting.

Allen's records were made on foot with tape and compass and it could be expected that there would be deficiencies in recognition of features and also the overall pattern. His particular interests were in broad measures of site size (for an analysis of polities), and compared with our controls his scales are reliable.

5. Conclusions and recommendations

5.1 AREA COVERAGE AND SETTLEMENT PATTERN

The reconnaissance flights gave a good picture of the extent of surface sites within the survey area. The present survey has recorded, as far as possible, all sites with surface earthwork features within the coastal catchment of southern Hawke's Bay. The aerial survey method covers only larger and more readily visible field monuments. Using the aerial photographic method, significant improvements in the accuracy and details of site plans have been possible. A process should also be developed for protection of wāhi tapu areas in the District Plan. Sub-surface sites, notably middens, have not been included in the search. Also, some earthwork sites such as heavily eroded or ploughed pits will not show. Even with ground survey, sub-surface sites are difficult to record comprehensively. In the course of reconnaissance survey, exposed middens lying in eroding sand were observed in the dune lands north of Porangahau and these warrant ground recording.

The two major concentrations of settlement were at Porangahau and at Kairākau. Both had clusters of pā with good outlooks to seaward and downriver—examples are V24/95 and V22/268. The defensive perimeter of the pā are well adapted to the landforms on which they were built. Transverse ditches and banks, rarely compound, cut off segments of ridge or the points forming river bends. Some pā had many (up to 60) raised-rim pits within the defences. The smallest defended areas, with only two or three pits and as many terraces, such as V22/274, may have been refuges for small numbers of people. There were small pā or pā complexes at all the small embayments along the coast.

At Porangahau, in addition to the pā built by the river, there were others on the low hills and terraces adjacent to fans emerging from the hill country. Pā V24/57 had easy access to the Porangahau River over the intervening flat land. These pā appear to have been built in response to the availability of good soils on the stream fans (probably as good as alluvial soils) and possibly because of a perception of lack of available settlement space on the main river. A notable site complex consisting of pā and open settlement areas has been recorded in a meander belt adjoining the river at Herbertville (V24/7, 76).

Complexes of up to 10 pits are found in some areas and there are many isolated pits or pits in small groups. The inland limit of settlement tends to be the crest of the coastal range, no more than 2 km from the coast in most cases but up to 6 km from the mouth of a river.

Late pre-European Māori settlements, especially near rivers, can be demonstrated to have persisted through to the mid or late nineteenth century. Some of these sites, such as V24/121, were adapted to nineteenth-century conditions by the use of ditch and bank fences.

Traces of the early pastoralism of the region have also been recorded in the form of ditch and bank fences (V24/81, 82), building foundations (V24/77) and coastal roads and tracks.

5.2 ARCHAEOLOGICAL SITE PROTECTION

The present aerial survey has provided much new data to assist with the protection of historic heritage through the provisions of the district plan. A range of resource management approaches is recommended. Sections 5, 6 (e), 7 (e) and 8 of the Resource Management Act require councils to manage archaeological sites sustainably. In the Gisborne District, listing archaeological sites in the district plan, and attaching rules for protection, has reduced regulatory and land owner issues and assisted with the empowerment of iwi in the processes of the district plan. This process provides a clear and transparent record for all regulatory and land managers.

As a result of the aerial survey, 109 new sites have been identified. These, as well as those already recorded in the NZAA site record file, provide a reasonable basis for historic heritage protection in southern Hawke's Bay. Further discussion and consultation with tangata whenua and landowners regarding listing is recommended.

The information used here is based on aerial photographic analysis that mostly detects the large monument sites, or cropmarks, but not other site types. These larger monuments all warrant protection. Field inspection of these sites is warranted. Further detailed work on unsurveyed site types such as middens or gardened soils is warranted to broaden the picture.

In addition, tangata whenua have strong views on sites which are significant to them. After tangata whenua and land-owner approval, all recorded sites in the New Zealand Archaeological Association file should be listed in the district plan with rules setting out the protection measures. With tangata whenua consultation and participation, a process should be developed for identifying and protecting wahi tapu, wahi tapu areas and other sites of interest. Consideration should also be given to the protection of historic buildings as part of the overall procedure.

The New Zealand Archaeological Association is currently undertaking a major upgrade project of its database which involves revisiting archaeological sites, checking whether they still exist, updating location details, reporting on their present condition and upgrading the site record form. This project is proceeding nationally, with financial support from the New Zealand Lottery Grants Board and local authorities. It offers district councils and tangata whenua throughout New Zealand an opportunity to include accurate updated information in district plans.

When land owners are informed of sites on their property and the associated legal requirements, some raise concerns about both aspects. A process is required to manage these issues. As an example of such a process, the Gisborne District Council logged all concerns and then provided archaeological expertise to land owners to discuss and clarify them. Consequently, all the issues of concern were resolved.

Caring for archaeological sites by the land owners concerned is also a complicated matter that cannot be dealt with in detail here (Jones et al. 2002). However, with the exception of the Kairākau gorge sites and pā V24/95 on the abandoned Porangahau River loop, it is noticeable that almost all sites have suffered from heavy stocking. Particularly important sites based on assessment of their earthworks should be fenced off from stock and grazing allowed only at light rates. Such fenced-off areas should not be grazed in winter, and should be spelled from grazing at an early stage in drought periods so that some grass cover survives. In general, cattle grazing should be avoided (Jones et al. 2002).

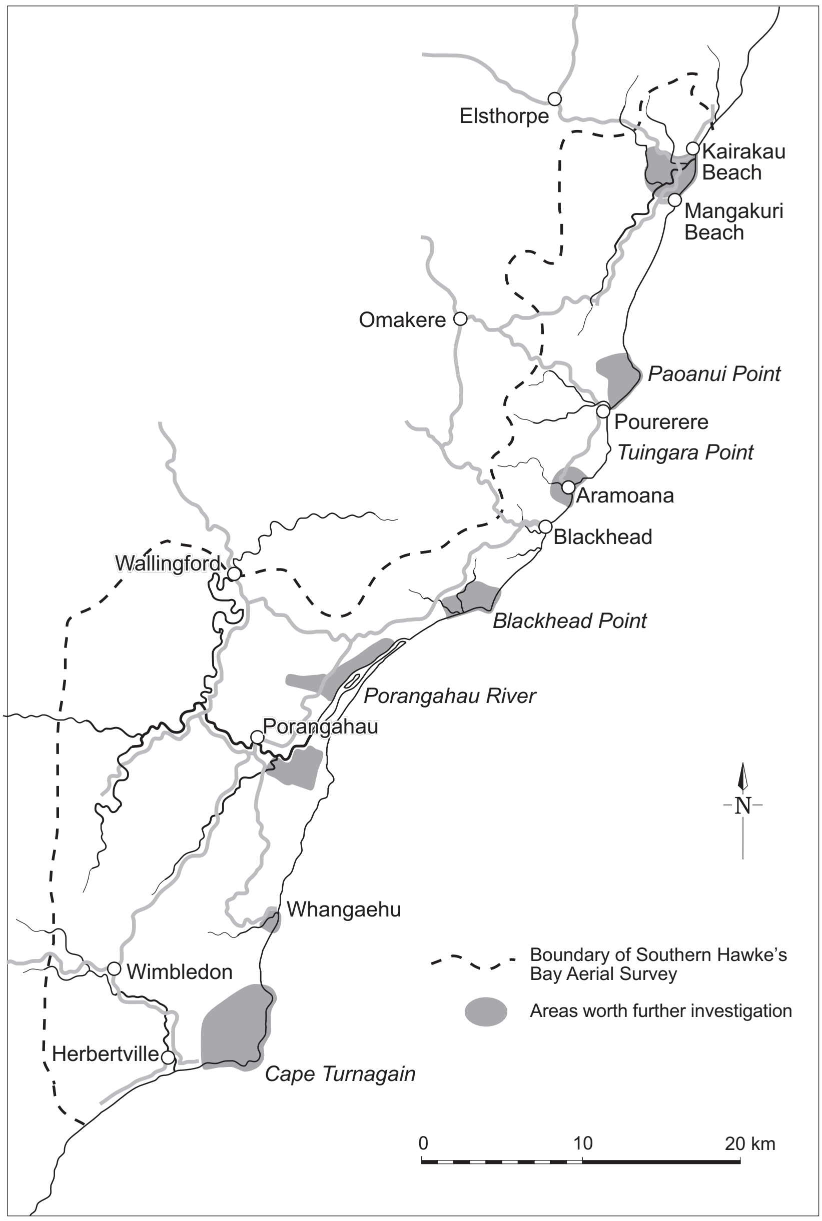
5.3 POSSIBLE HISTORIC AREAS

In addition to listing sites in the NZAA file, a number of historic areas are suggested. Historic areas under sections 23 and 31 of the Historic Places Act 1993 are potentially similar to historic landscape areas, a concept which is in wide use throughout the world. However, a full analysis of this subject is beyond the scope of this report. Figure 26 shows eight areas which are worthy of investigation and proper establishment using a methodologically rigorous historical landscape approach. Figure 4 (detail) shows the possible Porangahau north and lower Porangahau historic areas. From north to south these are:

- Kairākau gorge and surrounding hillscapes, roughly the area shown in the oblique aerial photograph (Fig. 20)
- Paoanui
- Aramoana
- Rangitoto and its surrounding dunelands near Blackhead Point
- Porangahau north: the pā V24/57, 58 and pit complexes shown in Figs 8 and 9, as well as the old coach road and unrecorded middens in the dunes to the north
- Lower Porangahau: the ridges and surrounding flatlands from pā V24/95 east to the pā complex V24/54 and V24/80 including the river flats. Note that there are buildings in the village that could contribute to a wider area than that depicted
- Whangaehu
- Cape Turnagain (Cook associations)

Of these, the ones with the most visible sites from the point of view of aerial archaeology are Kairākau, Rangitoto, Porangahau north and lower Porangahau. The last two could be linked by including the dunelands north and east of the Beach Road bridge (see Fig. 4 detail).

Figure 26. Suggested historic areas worthy of further investigation. See also Fig. 4.



5.4 AERIAL PHOTOGRAPHIC AND MAPPING TECHNIQUES

Aerial photographs enable rapid discovery and interpretation of the pattern of surface features. However, the scale of conventional aerial photographs is too small (they cover too large an area) and the sunlight angle is too close to the vertical to reveal archaeological features effectively. In addition, the poorer resolution of older aerial photographs means that many surface archaeological sites cannot be seen.

In the present project it has been possible to locate and photograph archaeological sites so that all relevant surface details are revealed. To achieve this in future, it is recommended that heights of about 2800 feet be adhered to with the standard 80-mm lens for the 6 × 6 cm format. At such a height this format covers an area of about 600 m^2 on the ground (the original scale is about 1:10 000). This should enable most archaeological sites to be covered in one frame. Very large sites, which need to be photographed in more than one frame, will need an adequate system to create photographic mosaics. Initially, this can be done by principal point/coordinate point alignment. In future, however, scanning the photograph and adjusting by computer 'rubber-sheeting', transformation or ortho-correction using relative (tape and compass) or absolute (GPS) control points will be desirable.

With appropriate controls and correction methods, high-angle (near-vertical) obliques will yield adequate mapping bases. This may be relevant where aircraft with bottom apertures are not available. However, taking high-angle obliques can be time-consuming. Provided the location of sites are known, a large number can be covered by vertical aerial photographs more quickly than by high-angle oblique photographs.

Care should be taken in choosing sun angle, even when taking overlapping (stereo) photographs. The minimum surface-relief difference distinguishable in stereo view at a scale of about 1:2500 on a standard enlargement appears to be as great as 60 cm. Smaller relief differences will not be detected unless some other cue such as a cropmark or shadow is visible on the photograph. Many archaeological features have relief differences of less than 60 cm (e.g. the difference between the surrounds and the base of an infilled pit, or the top of a worn stone row). Hence, although relief changes may not be visible in the stereo view, a shadow mark will give the mapper a cue from which to delineate the archaeological feature. Wide-angle lenses (as opposed to the standard 80-mm lens) would increase the relief effect, but would also increase distortion further away from the centre of the photograph. If a program to correct for distortion were available and operable, it would make the use of wide-angle lenses more feasible. However, for simple mapping from uncorrected photographs, the use of the 80-mm lens (or even longer focal lengths) is recommended.

Accceptable plans (accurate to ± 3% in position of points on the plan) can be made by means of small-format aerial photography. In future, we recommend that at least one photograph in an overlapping run (i.e. allowing for stereoscopic viewing) should cover the whole site area.

It is not economically feasible to map at conventional archaeological scales using aerial photographic prints at scales larger than about 1:2500. Most New Zealand sites will be less than 600 m long, and will fit on a 25-cm print at this scale. Larger scales will require correspondingly larger prints and are not as cost-effective.

The degree of site detail which can be depicted on a drawing depends on scale. With negatives at a scale of 1:10 000, the overall pattern of sites can be viewed and interpreted with ease. However, it is difficult to depict fine site detail—certainly not at 1:10 000 or even at a scale as large as 1:2000—for features such as a narrow drain encircling a raised-rim pit, or the detail of a ditch and bank. At scales smaller than 1:2000 clear conventions need to be developed early in the mapping process on the abstract depiction of features such as raised-rim pits. At 1:10 000 they may be black rectangles about 0.8 mm long. At 1:2000 an open rectangle 4 mm long is possible, and scales larger than 1:1000 are necessary to depict the rim and drain will require. The last is not practicable to make off a photographic print. Conventions for depicting sites at various scales are not as rigorously established in New Zealand as they are in the United Kingdom (Bowden 1999: 168–174; Wilson 2000: 232–235).

Grid references at levels of precision appropriate to the current NZAA site recording scheme do not require differential GPS methods. Differential GPS methodology will be appropriate if and when the extent of sites is recorded in cadastral or other GIS data bases which require zooming to scales larger than 1:10 000. This will apply to most local body GIS systems in the near future. However, such systems are not widespread in archaeological practice and do not need to be.

Overall, this aerial survey shows how useful aerial survey can be for mapping large monuments and gaining an overview of the field monuments of an area. For a more complete picture, aerial photography needs to be supported by ground survey during which the essential ground controls for the photographs can be observed efficiently. The two techniques must work together.

6. Acknowledgements

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7. References

Allen, M. 1994: Warfare and economic power in simple chiefdoms: the development of fortified villages and polities in mid-Hawke's Bay, New Zealand. Unpublished PhD thesis, University of California, Los Angeles.

Allen, M. 1996: Pathways to economic power in Maori chiefdoms: ecology and warfare in prehistoric Hawke's Bay. *Research in Economic Anthropology 17*: 171–225.

Bain, P. n.d.: Rangitoto Pa: A preliminary report on a conservation proposal for Rangitoto pa and surrounding midden sites. Unpublished report, Department of Conservation, Napier, New Zealand.

Ballara, A. 1995: Porangahau: the formation of an eighteenth-century community in southern Hawke's Bay. *New Zealand Journal of History 29(1)*: 3–19.

Battersby, J. 2000: The one day war: the battle of Omarunui 1866. Reed, Auckland.

Bowden, M. (Ed.) 1999: Unravelling the landscape: an inquisitive approach to archaeology. Tempus, Stroud, UK.

Buchanan, J.D.H. 1973: Maori history and place names of Hawke's Bay. Simmons, D.R. (Ed.). Reed, Wellington.

Cowan, J. 1983: The New Zealand Wars: A history of the Maori campaigns and the pioneering period. Vol. II: The Hauhau Wars. Government Printer, Wellington.

Hunter, R. 1993: Te Apiti and southern Waimarama: archaeological sites survey December 1992–May 1993. Unpublished, filed with NZAA central file, Wellington.

Jones, K. L. 1990: Age of pa in relation to river terrace soils and landforms, East Coast, North Island, New Zealand. *Geoarchaeology: An International Journal 5(3)*: 255–273.

Jones, K.L. 1994: Ngā Tohuwhenua mai Te Rangi: A New Zealand Archaeology in Aerial Photographs. Victoria University Press, Wellington.

Jones, K.L. 1996-97: The development of aerial photography in New Zealand archaeology. Part 1 and 2. *AARGnews* [Aerial Archaeology Research Group, Cambridge] *13*: 7–13, 13–22.

Jones, K.L. 1999: Small format aerial photography for mapping standing earthworks. *AARGnews* [Aerial Archaeology Research Group, Cambridge] *18*: 8–14.

Jones, K.L.; Harlow, D.; Gosling, D. 2002: Caring for archaeological sites: New Zealand guidelines. Draft for discussion, March 2002. Department of Conservation, Wellington. 104 p.

Lillie, A.R. 1953: Geology of the Dannevirke Subdivision. (*New Zealand Geological Survey Bulletin n.s. 46.*) Wellington, New Zealand Department of Scientific and Industrial Research/ Government Printer.

New Zealand Geological Survey 1972: Geological map of New Zealand: North Island. First ed. New Zealand Department of Scientific and Industrial Research, Wellington.

New Zealand Soil Bureau 1954: General survey of the soils of North Island, New Zealand. (*New Zealand Soil Bureau Bulletin (n.s.) 5.*) New Zealand Department of Scientific and Industrial Research, Wellington.

Prickett, N.J. 1990: Hawke's Bay coast archaeological survey, summer 1989–90. Unpublished report to New Zealand Historic Places Trust, filed with the NZAA central file.

Prickett, N.J. 2002: The archaeology of New Zealand shore whaling. Department of Conservation, Wellington.

Smart, C.D. 1966: The ditch-and-bank fence. *New Zealand Archaeological Association Newsletter 9(1)*: 19–28.

Warner, W.S.; Graham, R.W.; Read, R.E. 1996: Small format aerial photography. Whittles, Caithness.

Wilson, D.R. 2000: Air photo interpretation for archaeologists. Tempus, Stroud.

Glossary

AGL Height or Altitude above Ground Level.

DCDB Digital Cadastral Data Base, the computerised form of the New Zealand legal land boundaries, formerly published as maps at 1:50 000 in the NZMS 260 series (now no longer published).

Differential GPS A GPS system which achieves greater precision by having available recorded data on the apparent position (determined from satellite at the exact time of the ground survey observations) of precisely known ground stations.

GPS Global Positioning System.

Iwi Tribe, people.

LINZ Land Information New Zealand.

NZAA New Zealand Archaeological Association.

NZAM New Zealand Aerial Mapping Ltd.

Original scale Scale on the negative or contact print or on postive film (e.g. slide film).

Pā Site, usually a settlement, defended by ditches and banks.

Pdop Position dilution of precision. In GPS work, a measure of expected positional accuracy determined by the satellite configuration.

Photogrammetry See stereo photogrammetry.

Post-processing In differential GPS survey, the correction of the primary survey data using known distortions recorded by precisely located ground stations.

Proofs Also known as contact prints, a sheet of positives printed by exposing them in direct contact with the photographic paper; hence, the proofs are at the same scale as the negatives.

Raised-rim pit A semi-subterranean pit, rectangular in plan, with a rim around the outside of the depression and sometimes a drain around the rim.

RN Run Number. The number of a particular run in an aerial survey.

'Rubber sheeting' or transformation A process in which an oblique or otherwise distorted photograph is corrected to an approximate horizontal plan view. Control points on the scanned photograph are entered into a file and checked against the known coordinates of those points, and the photograph corrected accordingly.

Scale, small/large Small and large refers to the fraction expressed in the scale, so that 1:10 or 1/10 is a larger scale than 1:250 000 or 1/250 000. The distinction can be remembered thus: a small-scale plan covers a large area, and a large-scale plan a small area.

Stereo photogrammetry Use of the stereo effect in overlapping, and known lens chararacteristics to calculate and allow for photo distortion in order to produce an accurate plan.

SN Survey Number.

Transformation See 'Rubber-sheeting'.

Appendix 1

CONTROL METHODOLOGY AND GPS SURVEY

Control methodology

The distance and bearing between points on the ground can be measured and used to give a scale for and to determine orientation (north direction) of the aerial photographs. The scale of the image on a negative may also be determined using the formula: scale = lens focal length/AGL (height above the ground). In this survey, we attempted to achieve negatives at a scale of 1:10 000. In this case, the necessary AGL (height) was:

Height = lens focal length/desired scale

= 0.08 m × 10 000

= 800 m (or 2625 feet)

When the photograph is enlarged from the 58 × 58 mm negative (the actual image dimension of a 6 × 6 cm negative) to a 20 × 20 cm print, the enlargement ratio is calculated and applied to determine the scale of the photograph. The typical enlarged print for mapping site detail used in this project was 20 × 20 cm, so the enlargement factor was 3.45, giving an enlarged photograph a scale of about 1:2900. Occasionally, this was enlarged by laser copying to mapping scales of 1:1800. Although unusual, this scale was satisfactory for determining and drawing (with pencil or ink) most archaeological surface details.

In practice, such a calculated scale cannot be relied on to an accuracy of within ± 15% (Jones 1999). Control points were observed by GPS (and presented as grid references accurate to 1 m) for nine of the 13 sites. Ground controls were generally the tops of fence posts recognisable in the aerial photos; water troughs were also readily recognised, and one corner was observed as a control. The survey results were successfully 'post-processed' and provide a basis for the following:

- Scale and orientation of the sites (a **relative** control, it does not fix the position of the site in the map grid)
- Fixing the position of the sites on the map grid (an **absolute** control)
- Checking possible lens and elevation-difference distortions; however, we believe that these distortion sources will be slight where controls are in or near the horizontal plane passing through the site, and/or towards the centre of the negative image

A number of software programs are available which can take in a scanned aerial photograph, allow a comparison of grid points measured on the photograph with absolute grid control points measured by GPS or other survey, and correct the photograph to minimise any distortion. An enhancement of such programs allows contour information (a digital terrain or elevation model) to be used for correction. However, there is no such detailed contour information available for any of the sites in the present study. To prepare it for the study would cost more than the primary objective or archaeological mapping permits. At the time our survey was being written up, computer capability in DOC did not allow this type of work to be carried out readily. It is intended that this be undertaken in the near future.

On some sites, we had difficulty in locating control points that were visible in the aerial photographs. An alternative to observing existing controls, after the photographs have been taken, is to install clearly recognisable markers before the flight and to record their position (or spacing and orientation) accurately. This process requires a good understanding of the site extent, something which may not be recognisable until in the air. It would have the advantage that low-resolution scans, for correction, will still show the control points. On a trial desktop exercise with unmarked controls, it was often difficult to detect the observed control point in the scanned photograph as shown on the computer's VDU screen. This problem could be overcome by inking fine crosshairs over the position of the controls before the photographs are scanned. Another method would be to measure the x, y coordinates of the control points on the photograph in pixels and enter them into the program, or to position the cursor at that point and transfer to the correction program accordingly.

For some sites, we also observed relative controls while in the field—usually a recognisable straight length of fence (its ends marked by changes in direction, a large post or a gate) measured by tape, and its orientation observed by prismatic compass. This was done to check for an inexpensive method of establishing control of scale and orientation of the aerial photograph. Compass bearings were taken at least 3 m away from the steel wire. On more or less level ground, these relative controls exactly matched the corresponding length and orientation calculated from the differential GPS readings. Thus, tape and compass measurements from control points observable in aerial photograph produce results for scale and orientation similar in accuracy to those from differential GPS. Tape and compass techniques, because they are cheap, are preferable for deriving scale and orientation where:

- Changes in ground level over the area to be mapped are less than the equivalent of slopes of 1:5
- There is no need for grid references more precise than the standard 100 × 100 m.

However, in specialist mapping applications, precise grid points may be needed for a 'rubber sheeting' or orthophotograph correction or to link many photographs into a plan, i.e. where the site is covered by one or two photographs.

In place of differential GPS survey, it should be possible to observe and measure control points off a baseline with tape and compass if the site is on slopes of less than 1:5. For steeper slopes, measurements with an Abney, a self-reducing plane table and alidade, or with a total station should be possible. Differential GPS is an advantage only where precise measurement of some points and the true extent of a site perimeter is needed to position the plan of the site in a GIS system or the DCDB and designed to be viewed at a large scale.

Field GPS survey for photocontrol, 16–18 December 1998

The following notes are by John Craven.

Equipment: Rover Unit used was the Trimble ProXL GPS Receiver with 2.4 m pole.

Application: Differential GPS with results post-processed against a base station in Napier.

Method: Suitable control points were located by Kevin Jones and me by visiting the sites involved. Points were identified on the laser copy of the photograph (at scales of about 1:1800) before selection. Each point is given a unique code, relating to the applicable photograph, with this code marked by a pinprick through the control on the photograph and annotated on the back. Although not always possible, an attempt was made to select locations within a horizontal plane similar to that of the archaeological site.

GPS fixes of each proposed control point were collected continuously for 1 minute or more (i.e. with a collecting epoch of 1 second) using the rover unit. Hence, a minimum of 60 fixes are obtained for each point and averaged for each feature. GPS fixes were also collected for several known survey marks.

Settings on the rover unit screened out using any satellite configurations over a PDop value of 6, but 95% of readings are observed with a PDop under 4 with a large proportion under 3. For a brief time (approximately 0.75 hour each day in the late afternoon), this requirement stalled observations.

Files of GPS readings from the base station at Napier were retrieved on completion of the job. These files represent the same time frame as that from the rover unit, enabling the rover files to be post-processed differentially to improve the accuracy. Post-processing was performed using Pfinder software V3.00 with the Mcorr400 file.

Since GPS results deliver on the WGS84 datum, derived coordinates have been converted to NZMG and to NZGD1949. An Excel spreadsheet has been compiled showing all control points with both NZMG (m) and NZGD49 (Lat/Long) coordinates and filed with Science & Research Unit, DOC. The deduced antenna height is also shown and can be used for relative purposes. Note that a constant of 2.4 will need to be subtracted from this to show the ground height (2.4 being the pole length).

Comparisons using the observed survey stations with recorded meridional circuit coordinates for the same stations show a consistent shift of 1.5–2.0 m in the NE direction (i.e. the observed coordinates appear to be NE of the recorded coordinates by the said amount). This shift is constant and will be caused by the conversion parameters from WGS84. Stations visited repeatedly show good reliability and a range of under 1.5 m relative accuracy is expected between observed control points.

Appendix 2

LIST OF SITES RECORDED

SR NUMBER	PROJECT NUMBER	SITE DESCRIPTION	EASTING	NORTHING
Newly recorded sites				
V24/67	VT22	Pits/terraces	2821100	6097700
V24/68	VT23	Pits	2820800	6098200
V24/69	VT24	Pits	2820600	6098100
V24/70	VT25	Pits	2820500	6098200
V24/71	VT26	Pits	2820600	6098200
V24/72	VT27	Pits	2820400	6098200
V24/73	VT28	Pits	2820500	6098000
V24/74	VT30	Pits	2820700	6097500
V24/75	VT31	Pits	2821000	6097900
V24/76	VT34	Swamp pā/midden	2811000	6073800
V24/77	VT35	Wool shed cropmark	2811700	6073200
V24/78	VT36	Ditch and bank fence	2811500	6073500
V24/79	VT33	Coach Road	2820400	6096000
V24/80	VT29	Housefloor/ditch and bank fence	2820700	6094400
V24/81	VT06	Ditch and bank fence	2819700	6093700
V24/82	VT05	Ditch and bank fence	2819500	6093500
V24/83	VT04	Pits/terraces	2819400	6093400
V24/84	VT03	Pits	2819400	6093300
V24/85	VT32	Pits	2820000	6093100
V24/86	VT01	Pits	2820200	6093600
V24/87	VT02	Pits	2820200	6093700
V24/88	VT54	Pits	2818700	6097100
V24/89	VT55	Pits	2818900	6097200
V24/90	VT56	Pits/terraces	2819400	6097000
V24/91	VT57	Pits/terraces	2819500	6096800
V24/92	VT58	Pits	2819600	6096800
V24/93	VT16	Pits	2817200	6094800
V24/94	VT17	Pits	2817400	6094700
V24/95	VT18	Pits	2817200	6093200
V24/96	VT19	Pits	2818300	6094700
V24/97	VT20	Pits	2817800	6094500
V24/98	VT21	Pits	2817700	6094900
V24/99	VT37	Ovens	2818900	6094700
V24/100	VT38	Ditch and bank fence	2818000	6094700
V24/101	VT39	Pā	2816700	6094500
V24/102	VT40	Ditches	2816500	6094300
V24/103	VT41	Pits	2816300	6094400
V24/104	VT42	Pits	2816300	6094800
V24/105	VT43	Pits	2818100	6096200
V24/106	VT44	Pits/terraces	2818200	6096100
V24/107	VT45	Pits	2818300	6095900
V24/108	VT46	Pits	2818600	6096100
V24/109	VT47	Pits	2818800	6096000
V24/110	VT48	Pits	2818300	6095600
V24/111	VT49	Pits	2818600	6095200
V24/112	VT50	Pits	2819300	6096100

SR NUMBER	PROJECT NUMBER	SITE DESCRIPTION	EASTING	NORTHING
V24/113	VT51	Pits/terraces	2819300	6096000
V24/114	VT52	Pits/terraces	2818300	6096500
V24/115	VT53	Pits/terraces	2818600	6096200
V24/116	VT07	Pits/terraces	2817100	6093100
V24/117	VT08	Pits	2817800	6093100
V24/118	VT09	Pits	2818200	6092600
V24/119	VT10	Pits	2818100	6092200
V24/120	VT11	Pits	2817900	6092000
V24/121	VT12	Pā	2818800	6093100
V24/122	VT13	Ditch and bank fence	2817400	6094800
V24/123	VT14	Pit	2819300	6094900
V24/124	VT15	Pits	2817000	6094900
V23/50	VT59	Pits/terraces	2840300	6118400
V23/51	VT60	Pits	2840400	6118600
V23/52	VT61	Pits	2840300	6118700
V23/53	VT62	Pits	2840700	6118400
V23/54	VT67	Pits/terraces	2835600	6107800
V23/55	VT63	Pā/terraces	2837211	6109827
V23/56	VT64	Pits/terraces	2837000	6109600
V23/57	VT65	Raised-rim pits	2836900	6110100
V23/58	VT66	Terraces	2836800	6110200
V23/59		Pits	2839000	6115800
V23/60		Pits/terraces/stone rows	2841200	6117000
V23/61		Raised-rim pits	2836400	6110600
V23/62		Pits/terraces	2836500	6110600
V23/63		Raised-rim pits	2836700	6110200
V23/64		Pits	2836400	6110200
V23/65	VT76	Pā	2842900	6128000
V23/66	VT77	Pits	2842300	6128300
V23/67	VT78	Pits	2843000	6128200
V23/68	VT79	Pits	2841500	6128800
V23/69	VT80	Pit	2841200	6128900
V23/70	VT81	Pits	2841200	6129300
V23/71	VT82	Pits	2843700	6129400
V23/72	VT83	Pits	2843900	6129400
V23/73	VT84	Pits	2843900	6129900
V22/455	VT103	Pits/terraces	2844900	6132800
V22/552	VT75	Raised-rim pits	2843900	6131600
V22/553	VT68	Pā	2843455	6131258
V22/554	VT69	Pits/terraces	2843642	6131118
V22/555	VT70	Terraces	2843823	6131013
V22/556	VT71	Raised-rim pits	2843700	6131300
V22/557	VT72	Pits	2844100	6131200
V22/558	VT85	Pits	2843600	6130200
V22/559	VT86	Pits	2843600	6130400
V22/560	VT87	Pits	2842200	6130400
V22/561	VT88	Pits	2841200	6130200
V22/562	VT89	Pits	2841500	6130600
V22/563	VT90	Pits	2842000	6130700
V22/564	VT91	Pits	2842300	6130600
V22/565	VT92	Pits	2844500	6130800
V22/566	VT93	Raised-rim pit	2844400	6131300
V22/567	VT94	Terraces	2844500	6131100
V22/568	VT95	Pits	2845000	6130800

SR NUMBER	PROJECT NUMBER	SITE DESCRIPTION	EASTING	NORTHING
V22/569	VT96	Pits	2845400	6131400
V22/570	VT97	Pits	2845400	6131600
V22/571	VT98	Pits	2845300	6131600
V22/572	VT99	Pits	2845300	6131700
V22/573	VT100	Pits	2843400	6130200
V22/574	VT101	Pits	2845600	6132200
V22/575	VT102	Pits	2845300	6132000
V22/576	VT104	Pits	2844700	6132900
V22/577	VT105	Pits	2843400	6132100
V22/578	VT106	Pits	2843400	6132900
Sites recorded again				
V24/7		Pā	2811200	6073800
V24/14		Pā	2818100	6082500
V24/54		Pā	2820300	6094100
V24/55		Dam/pits/midden	2820000	6093700
V24/56		Pā	2820200	6093400
V24/57		Pā	2820700	6097700
V24/58		Pā/pits	2820900	6098000
V23/4		Pā	2829900	6103400
V23/43		Pa/monument	2837000	6110200
V22/267		Pā	2844800	6132000
V22/268		Pā	2844500	6131900
V22/271		Pā	2844100	6131900
V22/274	VT74	Pā	2843900	6131200
V22/276		Pā	2819400	6132300
V22/277	VT73	Pits/house site	2844200	6131400

‘Project number’ is a working reference number used before submitting to the NZAA site recording scheme. Archived documents can be traced by the use of this number.