Appendix H: Broulee Island Connectivity

Broulee Island and tombolo are located at the southern end of Broulee Beach.

A tombolo is a salient (foreshore widening) which extends sufficiently to connect dry sand (i.e. above mean sea level) to an offshore feature (such as an island). Where a feature is located sufficiently close to shore, sand will accumulate in the lee to form a tombolo during periods of low wave energy. During high wave energy, tombolos may be severed from the feature, resulting in a salient. Once connected, a tombolo will starve downdrift beaches of normal longshore sediment supply. The effect of periodic tombolos is the temporary storage and release of a "slug" of sediment to the downdrift region (Chasten et al., 1993).

The periodic or ephemeral tombolo at Broulee Island has been historically breached during large swells, separating the island from the mainland temporarily, although the most recently recorded breach occurred sometime between May 1984 and May 1987.

Ballard (1982) provides an extensive history of the salient/tombolo at Broulee Island between 1828 and 1981. A variety of data sources were used including maps, photographs, illustrations, documented observations and NSW legislative assembly proceedings. Ballard found that the tombolo was severed rapidly from waves originating on its southern side (Bengello Beach) but then took a longer period of time to re-connect to the island. Analysis of a series of aerial photographs between 1961 and 1981 clearly showed the transport of sediment from the tombolo to the north into Broulee Bay when it was breached.

The status of the Broulee Island tombolo between 1828 and 1901 has been tabulated by WRL in Table H-1, based on findings by Ballard (1982). In 1873, shortly before it was severed, vegetation (including root systems) on the tombolo was removed to widen a track which existed between Broulee Island and the mainland. From 1920 to 1930, shell-grit was mined from within Broulee Bay which may have resulted in a depleted supply of sediment to maintain the tombolo (Ballard, 1982). Unfortunately there are large gaps in the record when the tombolo may have been severed which have gone unrecorded, particularly between 1901 and the first aerial photograph in 1961.

Table H-1: History of Broulee Island Salient/Tombolo Condition (1828-1901)

Date	Salient/Tombolo Condition	Reference
1828	Connected	Ballard (1982)
1837	Connected	Ballard (1982)
1839	Connected	Ballard (1982)
1841	Disconnected (Possible)	Ballard (1982)
1843	Disconnected	Ballard (1982)
1845	Connected	Ballard (1982)
1869	Disconnected	Ballard (1982)
1873	Disconnected	Ballard (1982)
1891	Connected	Ballard (1982)
1892	Connected	Ballard (1982)
1901	Disconnected (Possible)	Ballard (1982)

Ballard's aerial photography analysis has been extended by WRL through examination of historical aerial images provided by the Office of Environment and Heritage (OEH) between 1961 and 2011 (reproduced at the end of this appendix as Figure H-2 to Figure H-19). Additional photographs from other sources were also collected and included in the analysis with the status of the Broulee Island tombolo between 1961 and 2017 tabulated in Table H-2.

Table H-2: History of Broulee Island Salient/Tombolo Condition (1961-2017)

Date	Salient/Tombolo Condition	Vegetation Status	Reference
1/08/1961	Connected	No vegetation	OEH Aerial Photograph
??/03/1963	Connected	No vegetation	Oblique Photograph
??/02/1694	Connected	No vegetation	OEH Aerial Photograph
3/02/1965	Connected	?	Ballard (1982)
15/05/1966	Disconnected	N/A	Ballard (1982)
??/??/1967	Disconnected	N/A	Moruya & District Historical Society Observation
7/01/1969	Disconnected	N/A	OEH Aerial Photograph
9/05/1971	*Connecting*	?	Ballard (1982)
4/06/1972	Connected	No vegetation	OEH Aerial Photograph
??/06/1974	Disconnected	N/A	Ballard (1982)
10/09/1975	Disconnected	N/A	OEH Aerial Photograph
11/03/1977	Disconnected	N/A	OEH Aerial Photograph
28/07/1977	Disconnected	N/A	Ballard (1982)
26/11/1977	Disconnected	N/A	OEH Aerial Photograph
28/11/1977	Disconnected	N/A	OEH Aerial Photograph
??/12/1979	Disconnected	N/A	WRL Site Inspection
21/12/1980	*Connecting*	No vegetation	OEH Aerial Photograph
27/06/1981	Connected	No vegetation	OEH Aerial Photograph
11/04/1984	Connected	Thinly vegetated	OEH Aerial Photograph
29/05/1984	Connected	Thinly vegetated	WRL Site Inspection
22/05/1987	Disconnected	N/A	Landsat Satellite Image
25/10/1988	Disconnected	N/A	OEH Aerial Photograph
19/01/1989	Connected	No vegetation	Landsat Satellite Image
22/11/1991	Connected	No vegetation	OEH Aerial Photograph
15/04/1993	Connected	Thinly vegetated	OEH Aerial Photograph
6/03/1996	Connected	Vegetated	DLWC Oblique Aerial Photograph
6/02/1999	Connected	Vegetated	OEH Aerial Photograph
7/03/2005	Connected	Vegetated	OEH Aerial Photograph
28/03/2007	Connected	Vegetated	OEH Aerial Photograph
15/05/2011	Connected	Vegetated	OEH Aerial Photograph
8/12/2012	Connected	Vegetated	WRL Site Inspection
24/02/2017	Connected	Vegetated	WRL Site Inspection

Based on the histories presented in Table H-1 and Table H-2, Broulee Island has been disconnected three to five (3-5) times between 1828 and 1901 (73 years) and three (3) times between 1961 and 2017 (56 years). While significant gaps in the dataset are acknowledged, on average, the tombolo has been severed approximately every 15-25 years. At the time of writing, the island has remained connected for at least 28 years. There is not enough evidence

to confidently comment on the varying length of time that the island may be disconnected for, following a breach, but it is noted that, following the breach in May/June 1974, a tombolo did not reform until late 1980/ mid 1981; a six to seven (6-7) year duration. Note that WRL has made no attempt to estimate the varying volume of sand released into Broulee Bay when severing of the tombolo has occurred in the past.

On 24 February 2017, WRL undertook a cross-sectional survey at the approximate narrowest point of the tombolo. Ground surface elevations were measured using a Trimble R10 RTK-GPS and offset using the NSW CorsNET network. The transect had a volume of 159 m^3/m above 0 m AHD and is shown in Figure H-1.

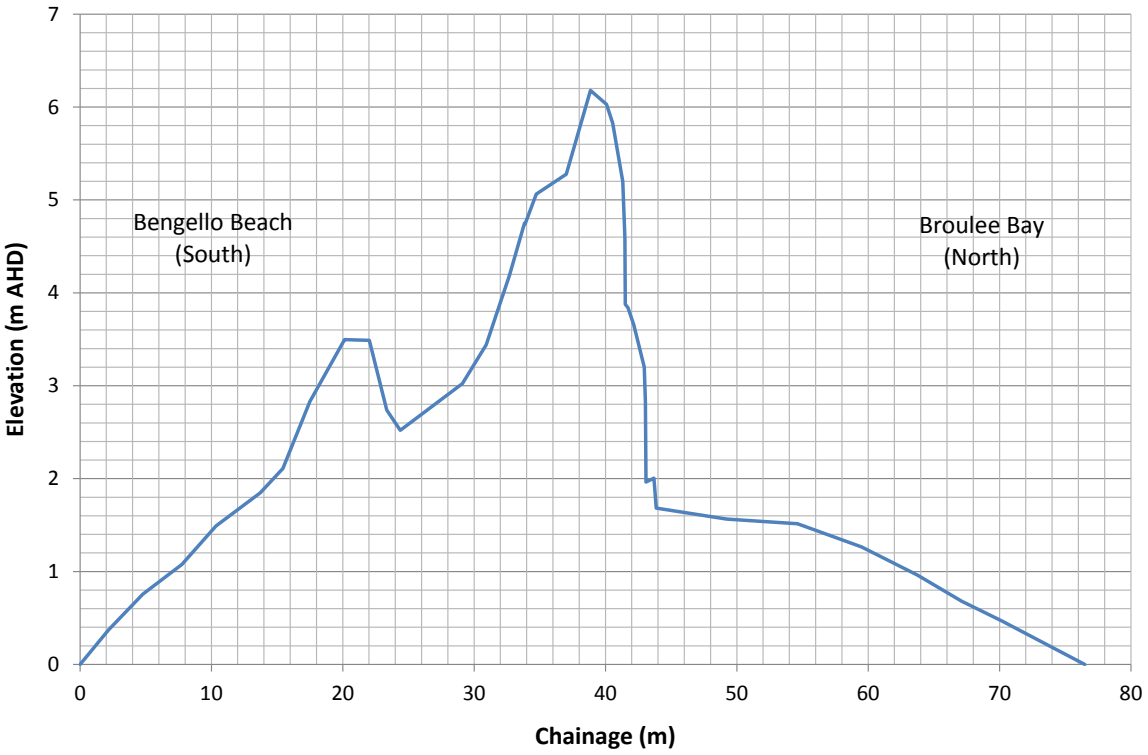

Figure H-1: WRL Survey of Broulee Island Tombolo (Facing West)- 28/02/2017

In addition to the present connected state, WRL has also considered the scenario of erosion/recession of Broulee Beach with Broulee Island disconnected in this report. Such a breach would almost certainly be initiated from the southern side (Bengello Beach). WRL has not undertaken an assessment of the potential for a breach to occur on the present profile. Detailed modelling of the potential for a breach would be complex as it involves interactions between wave runup, wave overtopping, cross shore erosion, longshore processes and vegetation. It is noted that the nominal design storm demand for the centre of Bengello Beach (170 m^3/m above 0 m AHD, based on erosion measured during May/June 1974) is slightly larger than the volume currently in the tombolo transect. However, the present profile appears to have more volume and is heavily vegetated in contrast to the un-vegetated state of the tombolo prior to the May/June 1974 storm sequence (Figure H-5). Indeed, the tombolo is now in its most heavily vegetated state since aerial photograph records began in 1961, which may contribute to the lack of breaches in the last 28 years. However, WRL considers that it is likely that the tombolo will be severed again at some stage in the future.

Figure H-2:OEH Photogrammetry - Broulee Island 1/8/1961

Figure H-3: OEH Photogrammetry - Broulee Island February 1964

Figure H-4: OEH Photogrammetry - Broulee Island 7/1/1969

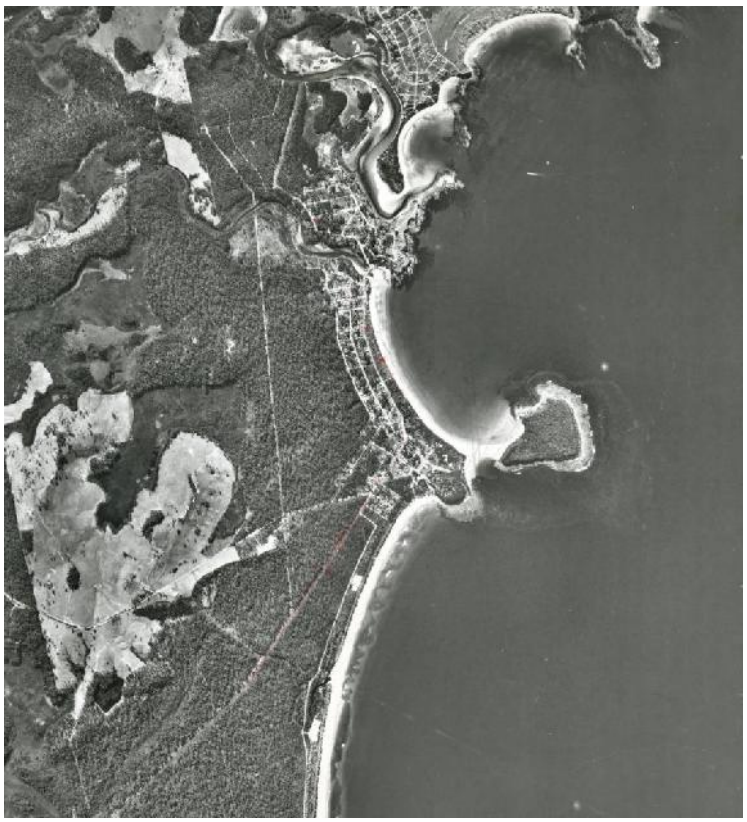

Figure H-5: OEH Photogrammetry - Broulee Island 6/4/1972

Figure H-6: OEH Photogrammetry - Broulee Island 10/9/1975

Figure H-7:OEH Photogrammetry - Broulee Island 11/3/1977

Figure H-8: OEH Photogrammetry - Broulee Island 28/7/1977

Figure H-9: OEH Photogrammetry - Broulee Island 26/11/1977

Figure H-10: OEH Photogrammetry - Broulee Island 21/12/1980

Figure H-11: OEH Photogrammetry - Broulee Island 27/8/1981

Figure H-12: OEH Photogrammetry - Broulee Island 12/4/1984

Figure H-13: OEH Photogrammetry - Broulee Island 25/10/1988

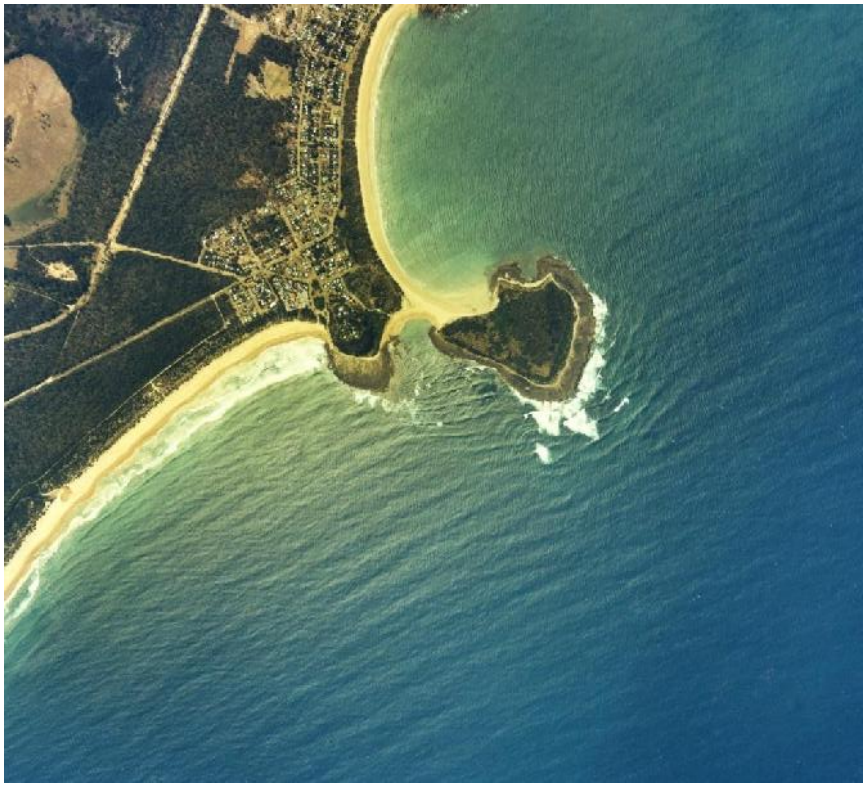

Figure H-14: OEH Photogrammetry - Broulee Island 22/11/1991

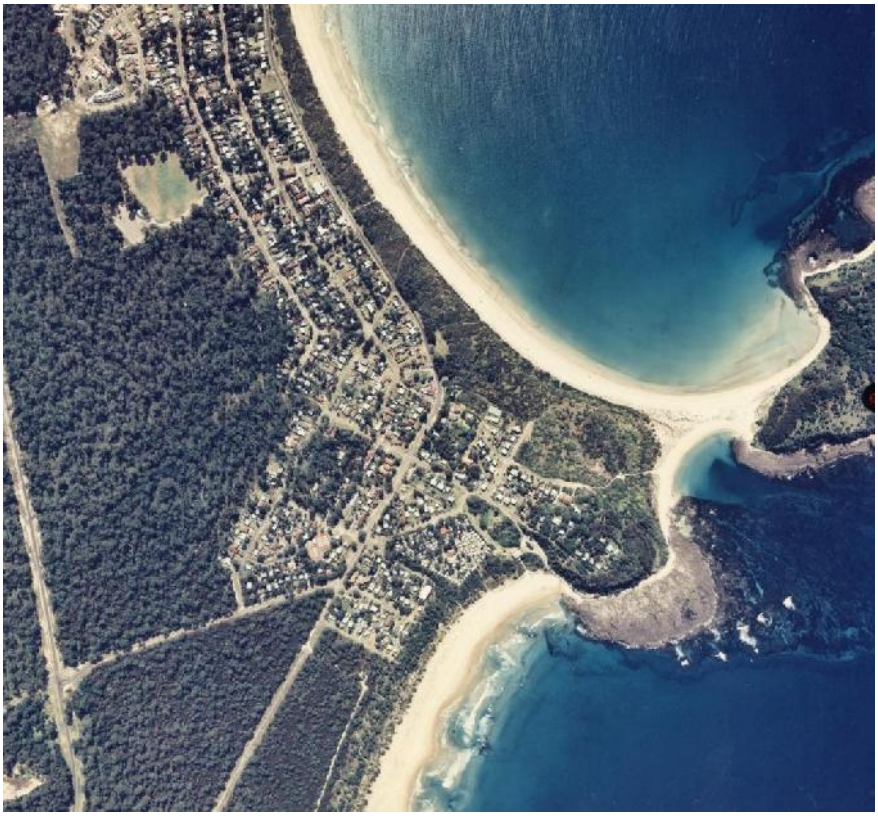

Figure H-15: OEH Photogrammetry - Broulee Island 15/4/1993

Figure H-16:OEH Photogrammetry - Broulee Island 6/2/1999

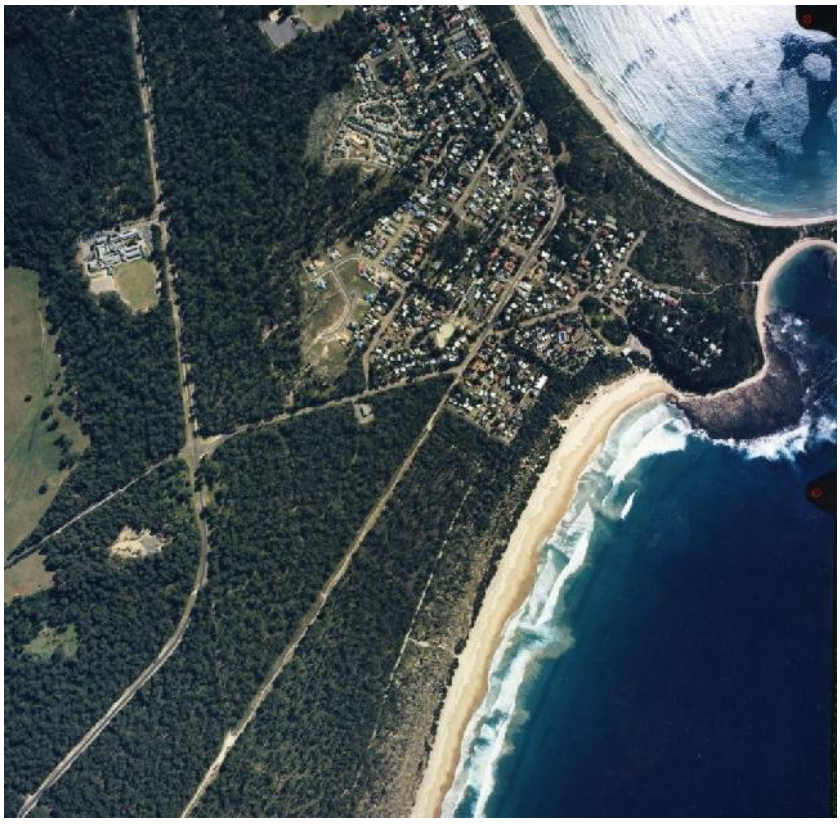

Figure H-17: OEH Photogrammetry - Broulee Island 7/3/2005

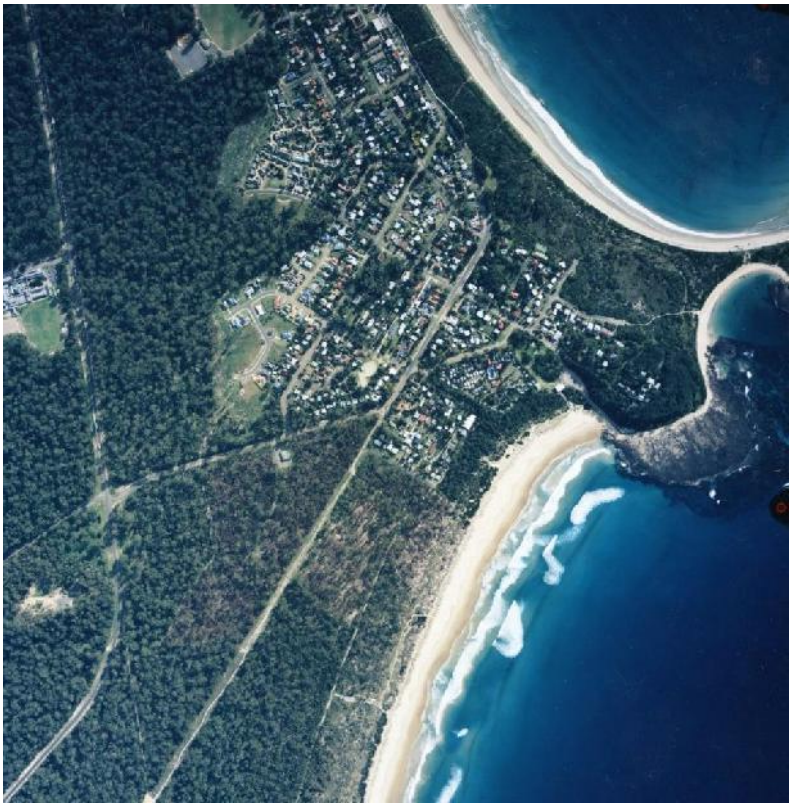

Figure H-18: OEH Photogrammetry - Broulee Island 28/3/2007

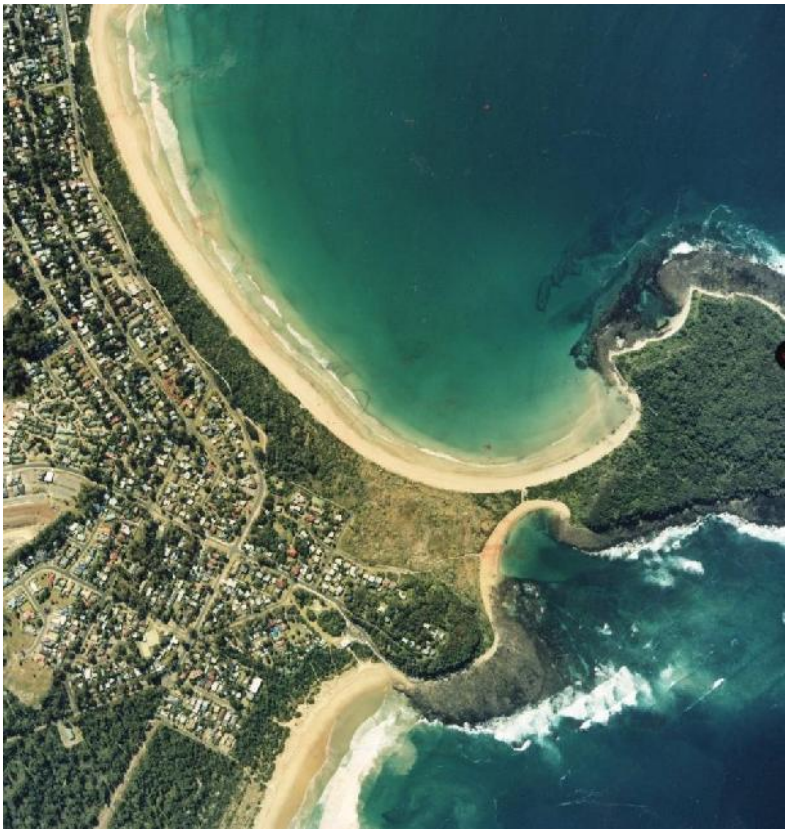

Figure H-19:OEH Photogrammetry - Broulee Island 15/5/2011