Appendix 3: Time and Space Analysis - Cook's Voyage on Waihou River, 21st November 1769

(Note: some interpretations of Cook's journal imply that this trip took place over two nights and that the crew overnighted somewhere up the Waihou, as well as after return to the Firth of Thames. This is probably confusion brought about by the fact that the 'ship's day' was deemed to start at midday, rather than midnight.)

Speed of rivers and tidal currents

e.g. https://hypertextbook.com/facts/2006/NervanaGaballa.shtml:

> 'The speed of a river varies from close to 0 m/s to 3.1 m/s (7 mph - about 6 knots [kts]). Factors that affect the speed of a river include the slope gradient, the roughness of the channel, and tides. Rivers tend to flow from a higher elevation to a lower elevation. The gradient is the drop of the elevation of a river. Therefore, the river's speed is at its maximum at the headwaters (high gradient, high energy) and at its minimum at the base level (no gradient, lowest energy). An incoming tide can reverse a river and cause it to flow against the gradient -- uphill!'

Bill Vant, Senior Water Scientist for Waikato Regional Council (Pers. Comm. - email, September 2018) noted:

> ' ... a couple of times I've seen the [Waihou] river flowing strongly "upstream" at the Paeroa bridge (on SH2: "Puke Bridge"). Velocity about 1 m/s [1.9 kts] ... High spring tide at a time of low river flow. The "null point" was a couple of km further upstream.'

(Reiterated in (Vant 2011 p. 10).)

In the lower reaches of the Waihou, the valley is nearly flat, so river current is likely to be <= 2 kts under normal flow conditions (i.e. not in flood).

Current due to tides (ref: Chesapeake Bay, Potomac River mouth): approx -1.5 kts (flood, i.e. incoming) and +1.5 knots (ebb)
(https://tidesandcurrents.noaa.gov/currents15/tab2ac5.html)

The conditions reported by Vant (2018) above would be fairly rare (high spring tide combined with low river flow). There is no indication in the Cook Journals that these sort of conditions prevailed on 20th November 1769, so it will be assumed that the net flow (river current less incoming tidal flow) would have been roughly zero on the trip upriver, and for the return trip, the net flow would have been approx 2 + 1.5 = 3.5 kts downstream.

Tides and Meteorological Data

Average wind speed Onetangi (Waiheke Island) in Nov = 5 kts, west-north-westerly.
(https://www.windfinder.com/windstatistics/onetangi_waiheke_island)

High & low tides are about 6.25 hrs apart. Note, however, Vant's comment:

> 'The time of local high water at any point in the river channel is progressively delayed as the incoming tide moves upstream.' (Vant 2011 p. 9)

The high tide is delayed by up to about two hours at the Puke bridge near Paeroa. It is likely that the delay would be of the order of one hour downstream, around Hikutaia, the

maximum distance upriver that Cook's party went. If the high tide was 3 pm near Hikutaia, as noted in Cook's Journal, the preceding low tide, at the river mouth (exact time not given in the Journal) would have been c. 8 am.

Met data for Auckland, 20th November 2018 (non-daylight saving) (https://www.timeanddate.com/sun/new-zealand/auckland)			
Sunrise	Sunset	Nautical twilight begins	Nautical twilight ends
5.00 am	7.13 pm	3.55 am	8.18 pm

Navigation Analysis

Banks: We had yesterday resolvd to employ this day in examining the bay so at day break we set out in the boats. A fresh breeze of wind soon carried us to the bottom of the bay ...

Cook: At day-break, therefore, I set out in the pinnace and long-boat, accompanied by Mr. Banks, Dr. Solander, and Tupia; and we found the inlet end in a river, about nine miles above the ship: into this river we entered with the first of the flood ...

According to various Internet referencess, speed of a small ship's boat under sail could be as high as 5-6 kts; under oars, probably only 1-2 kts.

Sunrise at that time of the year is 5 am (non- daylight saving). So, assume Endeavour's boats left the ship c. 5 am with good following wind (say, 5-10 knots). Assume boat speed under sail = 3 kts.

From Endeavour to river entrance: 9 nm at 3 kts = 3 hrs. Arrived river mouth c. 8am. Tide started rising at that time (Cook's Journal: ' ... into this river we entered with the first of the flood ...')

Assume tidal current up-river roughly balances river current, and they were still under sail up-river.

13 nm upstream from mouth at 3 kts = 4.3 hrs

Total sailing time up-river: 4.3 + 3 = 7.3 hrs + 1 hr (estimated) at Oruarangi = 8.3 hrs. So, they would have arrived at the measured tree c. 1.20 pm.

Cook: We proceeded up the river till near noon ...

High tide upriver was approx 3.00 pm, as noted previously.

Cook: About three o'clock, we reimbarked, in order to return with the first of the ebb ...

Banks: It was now time for us to return, the tide turning downwards gave us warning so away we went and got out of it into the bay before it was dark [approx 8.15 pm at that time of year]. We rowd for the ship as fast as we could but nigh[t] overtook us before we

could get w[i]th[i]n some miles of it. It blew fresh with showers of rain, in this situation we rowd till near 12 and then gave over and running under the land came to a grapling and all went to sleep as well as we could. ...

Departed downstream 3.00 pm (Cook's Journal). 13 nm downstream with river current and ebbing tide: speed = 2 + 1.5 = c.3.5 kts = approx 3.7 hrs to get to the Firth, ie arrived about 6.45 pm. Sunset was c. 7.15 pm, last light c. 8.15 pm, low tide c. 8.15 pm. They couldn't get back to Endeavour, rowing against the tide, and into a head wind, before dark, so they headed towards the shore, anchored & sheltered till next morning, when they returned to the ship.

(So, 12-14 nm upriver was feasible, and fits with Journal entries!)

References:

Vant, B. (2011). *Technical Report 2011/06: Water Quality of the Hauraki Rivers and Southern Firth of Thames, 2000-2006*, Waikato Regional Council, Hamilton.