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Perigean Spring Tide

by Nicholas A. Doe

In late June and early July 1792, Captain Vancouver's ships HMS *Discovery* and HMS *Chatham* were anchored in the Teakerne Arm near West Redonda Island in Desolation Sound. From here the explorers set out in small boats to probe the maze of narrow channels and inlets that lay between them, the Johnstone Strait, and the open Pacific beyond. The last of these expeditions was led by James Johnstone and Spelman Swain, who on Tuesday, July 3rd (by Captain Vancouver's reckoning), set out in the *Chatham's* cutter and launch to explore the mainland coast. They took with them enough supplies for a week.

The two boats made their way through the Yaculta Rapids and along the Cordero Channel to the entrance of Loughborough Inlet. They entered the inlet and camped for the night. We know that this must have been on the evening of July 4th as that was the day they passed the entrance to the Nodales Channel, and they spent the whole of the next day, the 5th, examining Loughborough Inlet. Vancouver records that that night, i.e. the night of the 4th/ morning of the 5th, the crew were "incommoded" by the flood tide which they had expected to be low, as the Moon was then passing the meridian. Archibald Menzies, the expedition's naturalist, also recorded the event. In a diary entry for July 12th, the day Johnstone and Swain returned to the ships, he writes that:

"in this arm they stopped the second evening and thought themselves secure from any disturbance by pitching upon a small island for their place of rest, but in the middle of the night they were hastily roused from their repose by the flowing of the Tide, which had risen so much higher than they expected & rushed (sic) upon them so suddenly, that every person got completely drenched before they could remove to higher ground."

The tide that so "incommoded" the explorers was an interesting example of a Perigean Spring Tide. Such tides occur at irregular intervals about two or three times a year. In recent times, particularly large Perigean Spring Tides have been accompanied by dire warnings of impending earthquakes which, some seismologists suggest, may be triggered by tidal forces. Not only were the explorers "caught napping" as it were by the unusual height of the tide, they also had apparently not noticed that the Yaculta and Dent Rapids are a transition point between the tidal waters of the Strait of Georgia to the south, and those of the Johnstone Strait to the north, and that there is a marked difference in the timing of the tides on either side of the rapids.

Many factors go into determining the level of the tide – so many that each day's tidal cycle is almost never repeated in all its detail. My own interest in the tides of July 1792 stems from a kayaking trip I am planning to make some day, which will involve a circumnavigation of Vancouver Island: it would, I thought, be interesting to try to time my passage under approximately the same tidal conditions as pertained 200 years ago. I was also puzzled as to why such keen observers of the Moon and tides as our 18th century friends should have been so taken by surprise that night.

Loughborough Inlet is deep, has steep sides, and almost no islands. There are few campsites; there is therefore a good possibility that Johnstone and Swain camped near the mouth of Gray Creek (125°32'W, 50°32'N); two small islands there are marked on both British and Spanish charts. If they found this site especially welcoming because of mats of soft, green sea-grass, the author can vouch for the fact that they were not the last to make such a mistake!

The Moon, as is well known, is the main cause of the tides; but the Sun also makes a significant contribution. Theoretically, the solar tide is only 46% the strength of the lunar tide, but in coastal areas, and in narrow passage ways, this ratio is often enhanced. The Straits of Georgia and Juan de Fuca, for example, because of their length and shape, tend to swap water back and forth, see-saw fashion, in sympathy with the twice daily tides of the open ocean. In some places, near the pivot point at the southeastern tip of Vancouver Island, the principal tidal component of the Sun (P1:K1) is actually greater than that of the Moon (M2); and in my home town of White Rock beachgoers delight in the fact that the tide is always at least partially out at noon in the summer regardless of the Moon's waxings and wanings.

Spring Tides occur whenever there is a full or new moon. They are larger than usual because, for a few days, the lunar and solar tides are synchronised. Perigean Spring Tides occur when, simultaneously, the Sun, Moon and Earth are aligned, and the Moon is at its closest point to the Earth in its orbit around the Earth. Because the Moon is closer, its contribution to the tide is larger than usual. There is a similar effect for the Sun, but because the Earth's orbit is very nearly circular, the effect is less pronounced.

Perigean Spring Tides are often associated with major flooding, particularly when accompanied by strong onshore winds. The rise of the tide is accelerated because when the Moon is aligned with the Sun, the Sun's gravitational field distorts the Moon's orbit, making it more elliptical, so that the Moon swings by the Earth closer than is normal at perigee. As it does so, its orbital velocity increases, and because the Moon's orbital rotation is in the same direction as the Earth's axial rotation, the Moon appears to "dwell" in the sky and the lunar tidal forces, enhanced by the close passage of the Moon, are given extra time to do their work.

Whilst Captain Vancouver was surveying the coasts of British Columbia and Alaska in the 1790s, he reckoned his time as being 16 hours ahead of Greenwich, not as we do today eight hours behind. Consequently we can identify the night of the flood as actually being the night of the 3rd / morning of the 4th, July 1792 (Julian Day 2375759.8).

Figures 1,2, and 3 show the astronomical conditions for these two days.

Figure 1, records the angular distance between Sun and Moon. An angular distance of 0° corresponds to an eclipse of the Sun, and an angular distance of 180°, to an eclipse of the Moon. The Figure shows that there was a full moon on the night of the flood, (July 3rd 2300 PST), but an eclipse was missed, as it often is, by a few degrees.

Figure 2 plots the distance between the Earth and the Moon. Distance is significant because the closer the Moon is to the Earth, the stronger is the lunar tidal force, so much so that each 1% decrease in distance results in a 3% increase in force. Most of the variation of distance is a consequence of the Moon's approximately elliptical orbit around the Earth, and I say approximately, because the smooth predictable curve beloved of mathematicians is constantly perturbed in a very complicated manner by the Sun, by the gravitational anomalies of the Earth, and by the other planets of the solar system. The average time between close approaches to the Earth, perigee, is 27.5 days in contrast to the 29.5 days between new or full moons. Consequently perigee seldom coincides with a new or full moon, but as Figure 2 shows, on the night of the flood it did. In fact perigee came just 1 hour before full moon, a very unusually close coincidence.

Figure 1: Phase of the Moon

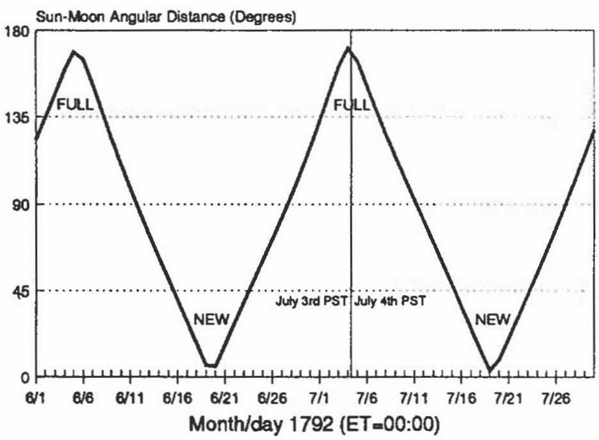


Figure 2: Earth-Moon Distance

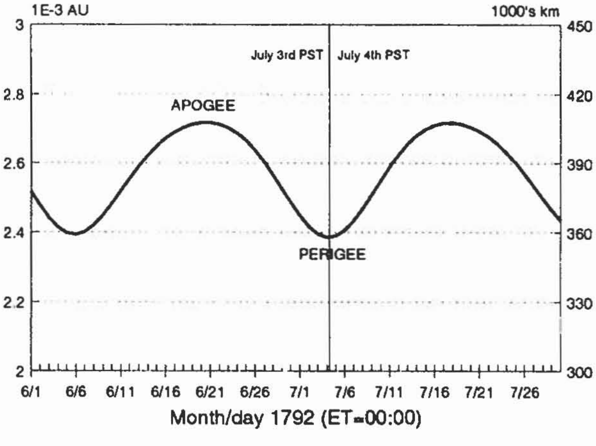
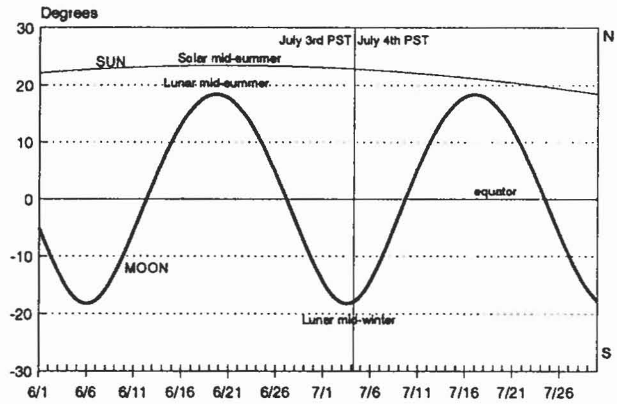


Figure 3 shows plots of the Sun's and Moon's declinations. The declination of a heavenly body is one of those intimidating terms that is actually fairly simple. It is the latitude on the surface of the Earth at which the body appears directly overhead. Thus, if the declination of the Sun is zero, it appears directly overhead at noon on the Earth's equator.

This is the time of the equinoxes. In the (northern) springtime, the declination of the Sun slowly increases until it reaches a positive maximum on mid-summer's day. The Sun is then directly overhead at noon on the Tropic of Cancer at latitude 23°27'N, and because the northern half of the Earth is tilted towards the Sun, it gets warmer there.

The Moon goes through exactly the same cycle as the Sun, except that it does so once a month instead of once a year, and the angles are a little different and not so constant. Probably everyone has noticed that sometimes, particularly during the winter, the Moon appears very high in the sky, rising in the north-east and setting in the north-west. This is

Figure 3: Sun & Moon Declinations



the time of month when the Moon's declination is at its most northerly (positive) value and it is lunar mid-summer. At other times, the Moon appears very low on the horizon, even at midnight. This is lunar mid-winter.

Figure 3 shows that at the time of the flood, it was lunar mid-winter. This is no surprise as the path of the Moon is never more than five degrees from that of the Sun (the ecliptic) and consequently, the lunar season is always the opposite of that of the Sun at full Moon, and the same as that of the Sun at new moon. However, the high positive and negative declinations of the Sun and Moon had two effects on the tide on the night of the flood. Firstly, because the line joining the Moon through the centre of the Earth to the Sun, was strongly tilted with respect to the equatorial plane, the levels of the two daily tides were appreciably different. This may have contributed to the element of "surprise". The other effect was that because at the peaks of the declinations, the rate of change of declination is zero, all of the orbital motion was directed in exactly the same direction as the Earth's axial rotation, thereby maximizing the effect of the increased velocity due to the approach of perigee. The increased velocity prolonged the length of the tidal day by 12 minutes at the time of the flood, three minutes of which was, by my calculations, attributable to the fact that the Moon had reached its most southerly declination. Twelve minutes may sound insignificant, but when the tide on a gently sloping beach is rising at a rate of several vertical feet per hour towards one's campsite, it does not seem

Figure 4: Tides
Loughborough Inlet & Desolation Sound

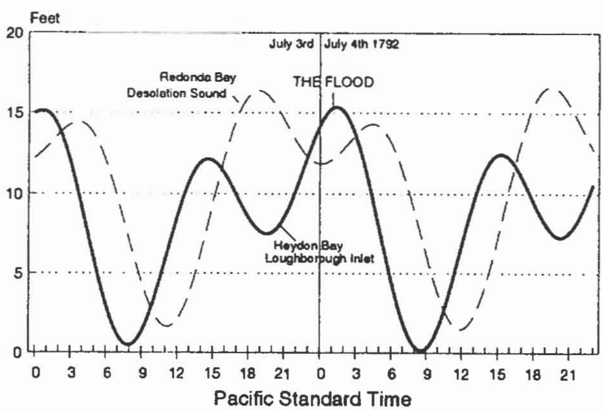
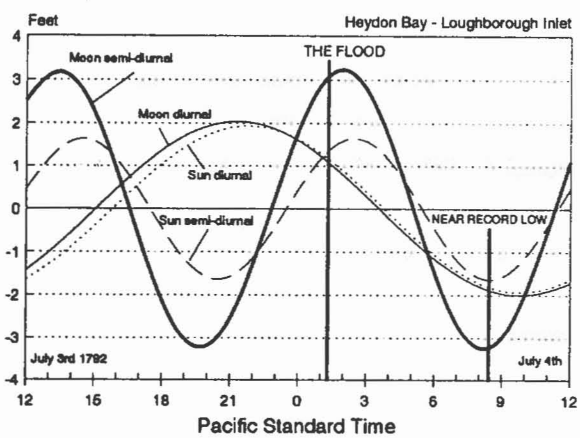


Figure 5: Components of the Tide



that way at all!

Figure 4 shows the tide that resulted from these particular alignments, and sure enough, shortly after midnight at 0054 Local Apparent Time (0121 PST), there was a tide exceeding 15 feet in Loughborough Inlet when the Moon was 13° past the meridian (i.e. past due south). The next morning at eight, the tide sank to the lower low water level for large tides.

At Redonda Bay, near where the ships were anchored, the evening tide on the 3rd peaked between six and seven o'clock, which would be a good time to make camp. Unfortunately, in Loughborough Inlet the tide at this time had already been ebbing for several hours and it began to flood again a little more than an hour later. The evening ebb may not have been obvious because the evening low tide in the inlet was much higher than the morning low tide. It is also interesting to observe in Figure 4 that, because of differences in topography, the highest tide of the day at Redonda Bay immediately followed the lowest, whilst at Heydon Bay in the inlet, the reverse was true.

For those interested in the relative contributions of various components of the tide that night, I have plotted in Figure 5 the semi-diurnal (i.e. twice daily) and diurnal (i.e. once daily components) of both the solar and lunar tides. The Moon's diurnal and the Sun's diurnal and semi-diurnal components contributed equally to the "incommodity", while the Moon's semi-diurnal component contributed as much as these three components together. The next morning, all four components were close to their minima, and the tide was within inches of being as low as it ever gets.

During their passage through the rapids, Johnstone and Swain had moved from the waters of the Strait of Georgia to those more akin to the open coast. They had obviously observed the tides of the Strait quite closely, for it is a general rule there that Spring Tides are low when the Sun or Moon are due south. However, on the open coast it is very different.

The author first became aware of this after planning a very unsuccessful trip to see the tidepools on Botanical Beach near Port Renfrew based on the timing of the tide at Ambleside Beach in West Vancouver! It was a long way to go to see surf sweeping up to the salal at the top of the beach.

Calculating the delay between the tides at different places is not quite as straightforward as it may seem. Because the pattern of the rise and fall varies from day to day, and from location to location, any comparison based on the timings of a particular point in the cycle, high high water (HHW) for example, is likely to give a different answer from a comparison based on the timings of say low low water (LLW). What we need is a comparison method that includes all of many cycles, not just one particular point.

Engineers have long since had the solution to problems of this sort – what they do is to look for the peak in the cross-correlation function of the two patterns. This sounds terribly technical, but in fact is quite simple. Imagine you had two rolls of film each of which had been exposed to a light whose intensity varied with the height of the tide at the two separate locations. The clear patches on the films would correspond to low tide. The pattern of light and dark would be different on the two films, but to find a best match, you could lay the films together, hold them up to the light, and then slide one strip of film

Figure 6: Tidal Stations - Vancouver Island (see Figure 7)

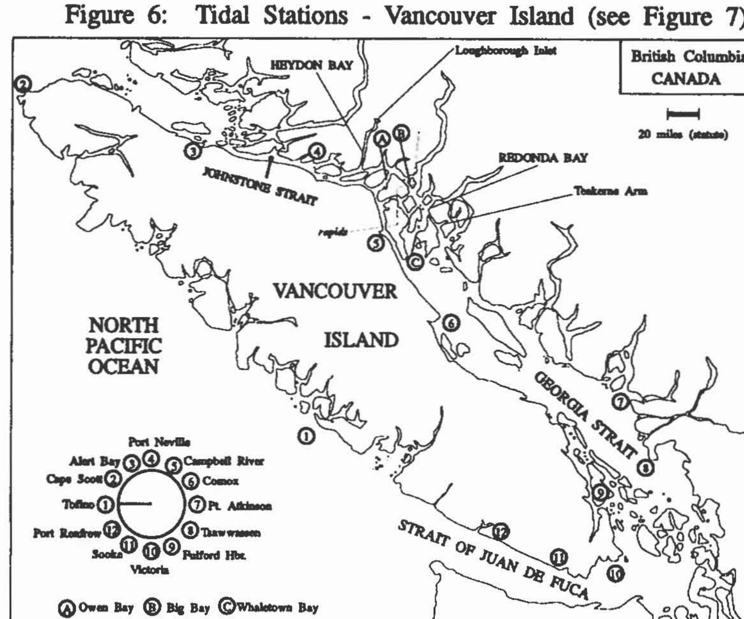
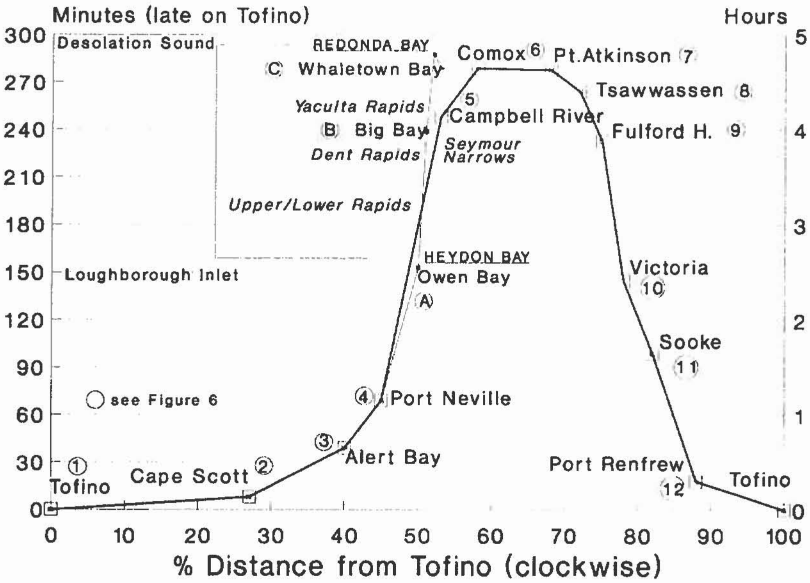


Figure 7: Tidal Delay - Vancouver Island



over the other until the maximum amount of light could be seen through the two films. The offset of the two films is then a measure of the time delay between the two patterns.

Using a computationally equivalent technique, I have plotted in Figure 7 the relative time delay between the tides at Tofino and the various points around Vancouver Island shown in Figure 6. The picture that these calculations paint is as follows. Envisage the Strait of Georgia as an inland sea whose level rises and falls with little variation in the timing of the tides around its shores. The rise and fall of this inland sea is close to being in antiphase with the rise and fall of the open ocean; when it is high tide at Tofino, it is within an hour and a half of being low tide in the Strait.

Consequently at either end of the Strait, water pours in and out continuously through the narrow confines of the Gulf and San Juan Islands to the south, and the Discovery Passage and Desolation Sound Islands to the north. The back and forth flow along the Strait of Juan de Fuca is fairly evenly distributed, but through the narrow channels of the north the flow becomes, almost literally, precipitous, with no let up in the powerful and turbulent currents that result from the differing heights of the tide at the ends of the rapids.

As shown in Figure 7, Johnstone and Swain in a short journey, had moved from a tidal region where the presence of the Moon due south, signalled low tide to one where, the tides being a substantial fraction of a 13 hour semi-diurnal tidal day earlier, it signified almost exactly the opposite.

Could the flood have been foreseen? Most certainly yes. The movement of the Moon was closely observed by Captain Vancouver, which he used almost exclusively for fixing his longitude. The unusual alignment of Sun and Moon at perigee was not only tabulated in his Nautical Almanac, but exaggerated, as noted in Figure 8. The series of tidal rapids obviously marked connecting points between substantial bodies of water. Possibly everyone was too busy to notice: the expedition lacked the presence of a professional astronomer, and as Vancouver remarks in his Journal on hearing the news of the death of the astronomer William Gooch, who was to have joined the expedition in August 1792:

". . .we had little leisure for making such miscellaneous observations as would be very acceptable to the curious, or tend to the improvement of astronomy"

Perhaps we should add *". . .or keep the crew's bedrolls dry".*

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The author is an engineer living in White Rock. His interests include sea-kayaking, and 18th century navigational techniques.

VII. JULY 1792. [79]

Days of the Month.	Days of the Week.	Semidr. ☽ at Noon.	Semidr. ☽ at Midnight.	Hor. Par. ☽ at Noon.	Hor. Par. ☽ at Midnight.	Propor. Logar. Noon.	Propor. Logar. at Midn.
		M. S.	M. S.	M. S.	M. S.		
1	Su.	16. 28	16. 34	60. 25	60. 46	4741	4716
2	M.	16. 38	16. 42	61. 4	61. 18	4694	4678
3	Tu.	16. 45	16. 46	61. 28	61. 32	4666	4661
4	W.	16. 46	16. 45	61. 32	61. 27	4661	4668
5	Th.	16. 42	16. 38	61. 17	61. 3	4679	4696

FIGURE 8: Captain Vancouver's Nautical Almanac shows the Moon's parallax peaking at 61'32" on the night of the 3rd July 1792 (Greenwich time). Parallax is a measure of the closeness of the Moon to the Earth and was an important figure in 18th century navigational calculations. The tabulated parallax is the maximum value that can ever be achieved, a very rare event. The Moon comes this close to us only once or twice a century, the last time being in 1912. However, on this particular occasion, the Nautical Almanac is in error: the correct figure was 61'26".

The average value of lunar parallax is 57'03". At the July 1792 perigee the Moon was 8% closer than average, and the lunar tidal forces 25% stronger than average.

Also tabulated in the Almanac is the apparent size (semi-diametre) of the Moon's disc.

ACKNOWLEDGEMENTS

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SELECTED BIBLIOGRAPHY

Doodson, A.T. & Warburg, H.D., **Admiralty Manual of Tides**, HMSO London 1941.

Forrester, W.D., **Canadian Tidal Manual**, Dept. of Fisheries & Oceans, Ottawa 1983.

Lamb, W. Kaye Ed., **A Voyage of Discovery to the North Pacific Ocean 1791 - 1795**, George Vancouver, Hakluyt Society, London 1984.

Newcombe, C.F. Ed., **Menzies' Journal of Vancouver's Voyage April to October 1792**, Victoria BC 1923.

Wood, J.F., **The Strategic Role of Perigean Spring Tides in Nautical History and North American Coastal Flooding**, 1635 - 1976, US Dept. of Commerce, 1976.