

NAP benchmarks near the excavations of Wijnaldum-Tjitsma, Englum and Ezinge

An explanation of NAP heights, supplementing A. Nieuwhof & P.C. Vos: New data from terp excavations on sea-level index points and salt marsh sedimentation rates in the eastern part of the Dutch Wadden Sea.

Elevations measured in NAP cannot simply be compared, especially not when there is a large time span or distance between the measurements. That is clearly the case in this study which compares Wijnaldum in the western part of the province of Friesland and Englum and Groningen in the western part of the province of Groningen. These terps were excavated within a time span of 80 years. We therefore need to assess the history of the local NAP benchmarks and their relation with natural or man-induced subsidence. The latter is especially relevant in the northern-Netherlands, where the extraction of natural gas and salt have caused considerable subsidence in recent times.

The accompanying table shows the geographically differentiated histories of NAP benchmarks that were used during the excavations and of benchmarks in the vicinity of these locations. Although some benchmarks only have a short history, these data together provide an overview of adjustments of NAP benchmarks and of subsidence relative to NAP per region, over the last century. Salt extraction in northwest Friesland only started in 1996, after the excavation in Wijnaldum had ended. The table shows that adjustments before the start of salt extraction in Friesland amounted to 0.8-1.0 cm/10 years in both provinces, suggesting that gas extraction in Groningen hardly influenced NAP heights near Englum and Ezinge, if at all.

NWP = *Nauwkeurigheidswaterpassing* ('precision leveling'); see text.

Wijnaldum

Excavated 1991-1993.

NAP benchmark: 005D0040

Reference height: 0.5441 m +NAP (1982); 2nd NWP

Distance to excavation: 750 m.

Note: salt extraction has resulted in considerable adjustments since 1996.

Englum

Excavated 2000.

NAP benchmark: 007A0037

Reference height: 1.2871 m +NAP (1991); 2nd NWP

Distance to excavation: 250 m

Note: adjustments of this benchmark indicate gradual subsidence, of 0.8 cm/10 years since 1957.

Ezinge

Excavated 1923-1934.

NAP benchmark: 007A0035

Reference height: 0.8119 m +NAP (1921); 1st NWP

Distance to excavation: 3.8 km

Note: The brass bolt of benchmark 007A0022 was replaced by 007A0211 when the building to which it was attached was rebuilt in 1981.

Adjustments of benchmarks near Ezinge indicate gradual subsidence, of 0.9 cm/10 years since 1957.

The histories of NAP benchmarks near the excavations of Wijnaldum, Englum and Ezinge. Data provided by Rijkswaterstaat.

| | Wijnaldum (Excavation 1991-1993) | | | | | Englum (Excavation 2000) | | Ezinge (Excavation 1923-1934) | | | | | | | | |
|--|--------------------------------------|--------------|--------------------|--------|--------------------|--------------------------|--------|-------------------------------|----------|--------|-------------------------|--------------------|-------------------------------|--------------------|-----------------------|--------|
| Benchmark no. | 005D0015 | 005D0040 | 05G0266 | | | 007A0037 | | 007A0022 >>>>>>>>>> | 007A0211 | | 007A0035 | | 007A0028 | | | |
| Address | Hauleweg 9 | Alde Leane 2 | Buurren 5 | | | Englumerweg 11 | | Garnwerd, Oostumerweg 8 | | | Garnwerd, Oostumerweg 8 | | Garnwerd, '125 m S. of ferry' | | Ezinge, Torenstraat 2 | |
| Year | NWP 2 | NWP 5 | NWP 2 | NWP 5 | NWP 5 | NWP 2 | NWP 5 | NWP 1 | NWP 2 | NWP 5 | NWP 2 | NWP 5 | NWP 1 | NWP 2 | NWP 2 | NWP 5 |
| 1921 | | | | | | | | 1.3508 | | | | | 0.8119 | 0.7650 | | |
| 1933/1 | 0.9419 | | | | | | | | | | | | | | | |
| 1933/2 | 0.9432 | | | | | | | | | | | | | | | |
| 1942 | | | | | | | | | 1.2438 | | | | | 0.6820 | | |
| 1954 | | | | | | | | | | | | | | | 1.2055 | |
| 1957 | 0.9235 | | | | | | 1.3095 | | 1.2656 | | | | | 0.7250 | | 1.2481 |
| 1959 | | | | | | | | | | | | | | 0.7250 | | |
| 1969 | | | | | | | | | | | | | | | | |
| 1972 | | | | | | | | | 1.2440 | | 1.0564 | | | 0.7169 | | |
| 1975 | | | | | | | 1.3129 | | 1.2469 | | | | | | | 1.2471 |
| 1976 | 0.9047 | | | | | | 1.2998 | | 1.2377 | | | | | | | 1.2365 |
| 1978/1 | | | 0.5253 | | | | | | 1.2380 | | | | | | | 1.2377 |
| 1978/2 | | | | | | | | | 1.2375 | | | | | | | 1.2377 |
| 1980 | | | | | | | | | | | | | | | | 1.2377 |
| 1981 | | | | | | | 1.2968 | 1.2862 | | 1.2307 | 1.2202 | 1.0452 | 1.0347 | | 1.2354 | 1.2248 |
| 1982 | | | 0.5441 | | | | | | | | | | | | | |
| 1987 | 0.8921 | 0.8863 | | | | | 1.2876 | 1.2782 | | 1.2129 | 1.0364 | 1.0274 | | | 1.2282 | 1.2190 |
| 1989 | | | | | | | 1.2904 | 1.2809 | | 1.2116 | 1.0353 | 1.0261 | | | 1.2299 | 1.2205 |
| 1990 | | | | | | | 1.2863 | 1.2774 | | 1.2221 | 1.0301 | 1.0215 | | | 1.2260 | 1.2172 |
| 1991 | | | | | | | 1.2871 | 1.2778 | | | | | | | | |
| 1992 | | | | | | | 1.2864 | 1.2771 | | | | | | | | |
| 1993 | 0.885 | 0.8816 | | | | | 1.2864 | 1.2771 | | 1.2040 | 1.0271 | 1.0185 | | | 1.2262 | 1.2171 |
| 1994/1 | | | | | | | 1.2868 | 1.2776 | | | | | | | | |
| 1994/2 | start salt extraction Friesland 1996 | | | | | | 1.2868 | | | | | | | | | |
| 1996 | | | | | | | 1.2843 | 1.2737 | | | | | | | | |
| 1997/1 | 0.8838 | 0.8777 | | | | | 1.2831 | 1.2736 | | | | | | | | |
| 1997/2 | 0.8781 | 0.8761 | 0.5164 | 0.5144 | | | 1.2845 | 1.2738 | | | | | | | | |
| 1998 | 0.8791 | 0.8736 | | | | | 1.2825 | 1.2727 | | 1.1834 | 1.0071 | 0.9979 | | | 1.2210 | 1.2113 |
| 1999 | | | | | | | 1.2849 | 1.2739 | | | | | | | | |
| 2000 | 0.8628 | 0.8570 | 0.4787 | 0.4731 | | | | | | | | | | | | |
| 2001 | 0.8542 | 0.8481 | 0.4653 | 0.4594 | | | | | | | | | | | | |
| 2002 | 0.8481 | 0.8420 | 0.4505 | 0.4447 | | | | | | | | | | | | |
| 2003/1 | 0.8355 | 0.8297 | | 0.4247 | 0.8887 | | 1.2697 | 1.2567 | | 1.1584 | 0.9852 | 0.9729 | | | | 1.1924 |
| 2003/2 | | 0.8319 | | | | | | | | | | | | | | |
| 2004 | | 0.8266 | | 0.4143 | 0.8720 | | | | | | | | | | | |
| 2005 | | 0.8206 | | 0.4039 | 0.8610 | | | | | | | | | | | |
| 2006 | | 0.8218 | | 0.4055 | 0.8592 | | | | | | | | | | | |
| 2007 | | 0.8210 | | 0.4022 | 0.8586 | | | | | | | | | | | |
| 2008 | | 0.8195 | | 0.4000 | 0.8553 | | | 1.2620 | | 1.1593 | | 0.9738 | | | | 1.2016 |
| 2009 | | 0.8184 | | 0.3994 | 0.8546 | | | | | | | | | | | |
| 2010 | | 0.8170 | | 0.3960 | 0.8511 | | | | | | | | | | | |
| 2011 | | 0.8162 | | 0.3962 | 0.8523 | | | | | | | | | | | |
| 2012 | | 0.8152 | | 0.3935 | 0.8495 | | | | | | | | | | | |
| 2013/1 | | 0.8089 | | 0.3867 | 0.8433 | | | 1.2541 | | 1.1603 | | 0.9748 | | | | 1.1968 |
| 2013/2 | | 0.8111 | | | | | | | | | | | | | | |
| 2014 | | 0.8092 | | 0.3883 | 0.8431 | | | | | | | | | | | |
| Adjustments in published benchmark heights | | | | | | | | | | | | | | | | |
| Start-1997 | from 1933: -0.06 m | | from 1978: -0.01 m | | | from 1957: -0.03 m | | from 1942: -0.05 m | | | | from 1957: -0.03 m | | | | |
| 1997-2013 | -0.07 m | | -0.13 m | | | -0.02 m | | -0.02 m | | | | | | -0.01 m | | |
| Total, including difference NWP 2 and 5, earliest-2013 | from 1933: -0.13 m | | from 1978: -0.14 m | | from 2003: -0.05 m | from 1957: -0.05 m | | from 1942: -0.07 m | | | | (period too short) | | from 1957: -0.04 m | | |
| Average subsidence/10 years until 1997 | 1 cm | | 0.5 cm | | | 0.8 cm | | 0.9 cm | | | | | | 0.9 cm | | |

- Level of excavation NAP reference point
- Computed heights if 007A0022 had been continuous: height of bolt 007A0211 +0.1855 m for relocation.
- Rijkswaterstaat: probably not correct
- Rise instead of subsidence; 1942 data not reliable.
- Assumed height, allowing for 4 cm subsidence between 1957/1959 and 1921.