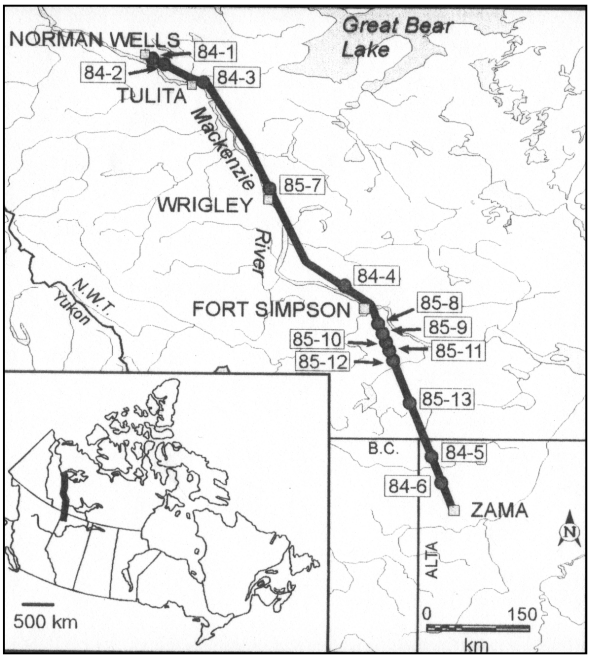
The Norman Wells Pipeline Thermal Monitoring Program

Margo Burgess
Geological Survey of Canada

Many people presenting at this workshop have referred to data that has been collected as part of the Norman Wells Pipeline Thermal Monitoring Program. The way that people have presented that data emphasizes the point that the original purpose for which data is collected is not necessarily the way that the data will be used. Data may be collected for a quick geotechnical study or engineering geothermal design, but even if no monitoring is undertaken afterwards, the data collected has value for many other purposes. For example, Fred Wright made use of the borehole logs collected along the pipeline to validate his permafrost temperature model.



The pipeline-monitoring program was set up to allow us to assess the effect of the right-of-way clearing, pipeline installation and pipeline operation on permafrost conditions (temperature and thaw depth, and thaw settlement) along the right-of-way. A series of boreholes were drilled at sites (called thermal fences) along the right-of-way (ROW), and at each site a borehole was also drilled in natural undisturbed conditions off ROW. Temperature cables were installed in these boreholes and on the pipe itself. Cables are set up at thirteen locations along the pipeline, at which there are often two or three thermal fences of arrays of cables. The program began with boreholes installed over the winters of 1984 and 1985 with funding from Indian and Northern Affairs, NOGAP and PERD. The program today is funded almost entirely by PERD, and logistical and in-kind support from Enbridge Pipelines (the owner and operator).

We have proposed that several of the off ROW boreholes be included in the Canadian and International permafrost monitoring network..

The original objective was to monitor thaw and thaw settlement along the ROW (Fig 1). This involved monitoring changes in the ground surface and changes to the depth of cover over the pipe in the ground. The boreholes off ROW were set up to monitor natural

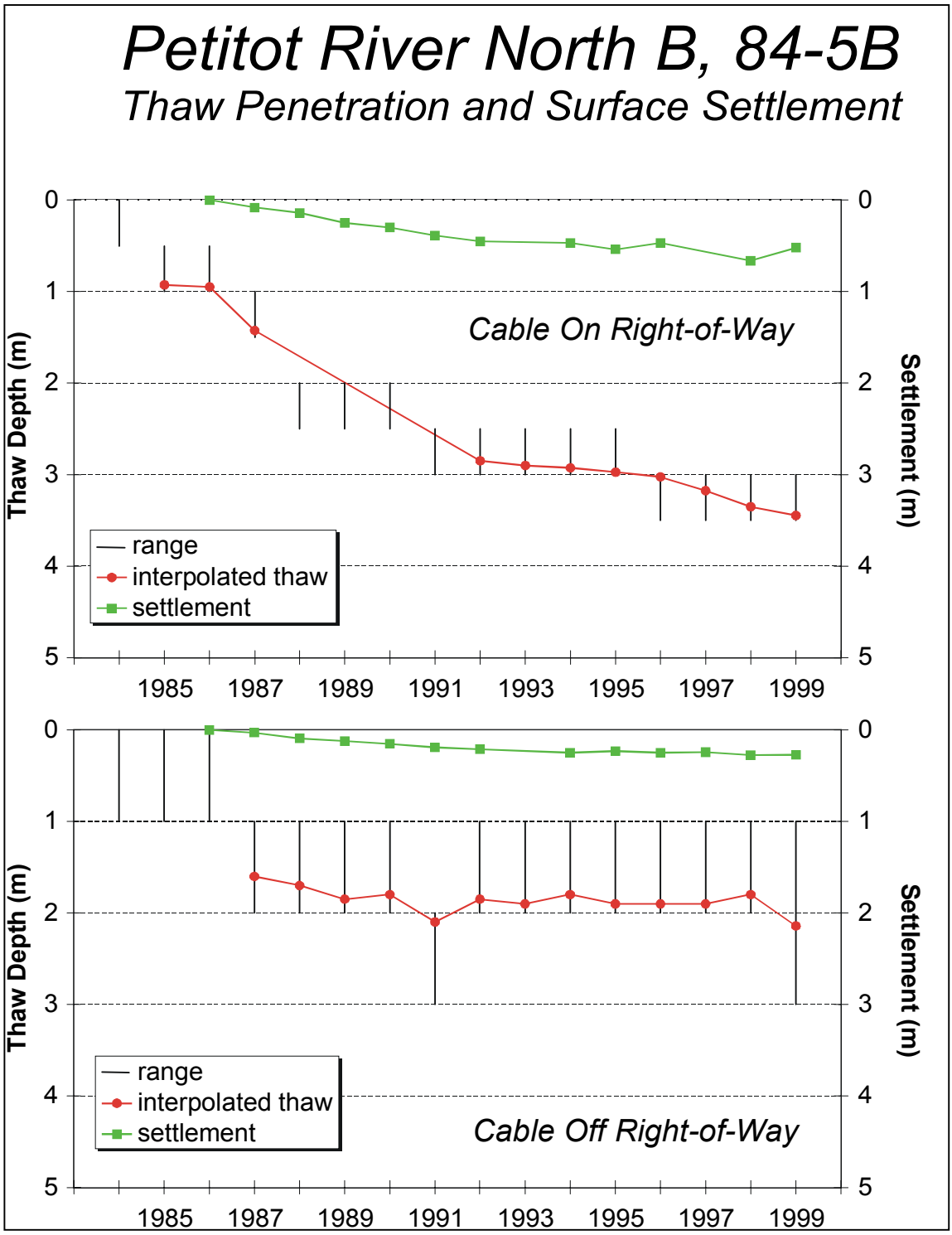


Figure 1

variations in permafrost conditions, and the utility of these for longer term permafrost temperature monitoring was recognized from the outset. These holes are not as far from the edge the right-of-way as we would like in all cases, such that the influence of conditions on the ROW can be seen in some of the deeper sensors.

In the early years, measurements were taken manually during frequent visits to the sites, up to nine times per year. Over time the number of visits per year has declined, and currently a visit to all sites takes place once per year (Fig 2) . As the number of visits declined, temperature dataloggers have been installed on select ground temperature cables at select sites (Fig 3). Air temperature sensors and miniloggers have also been installed, particularly at those CALM sites set up in collaboration with Charles Tarnocai.

The cables that were constructed for the original measurement program were not designed to connect to automatic dataloggers, so a number of technical problems developed. The cable connectors were not environmental and moisture could seep into the connection, introducing capacitance effects which would increase the sensor response/stabilization time. When taking manual measurements this could be accommodated by the operator, whereas the automatic readings with the data logger were recorded too quickly to allow for the dissipation of the capacitance effect, resulting in noisy measurements. This can be compensated for to some extent by carefully positioning connectors during field installation to avoid moisture infiltration, although this can be difficult to ensure when different observers may visit the site on each occasion.

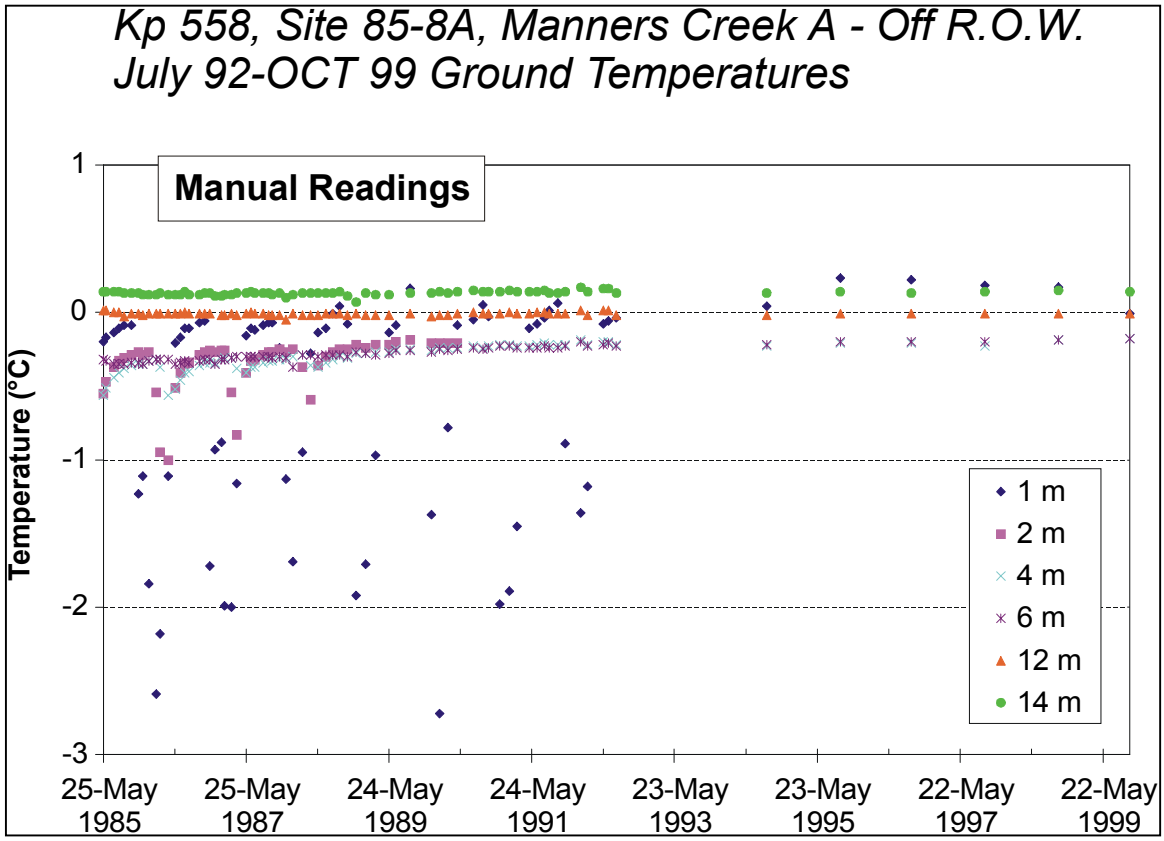


Figure 2

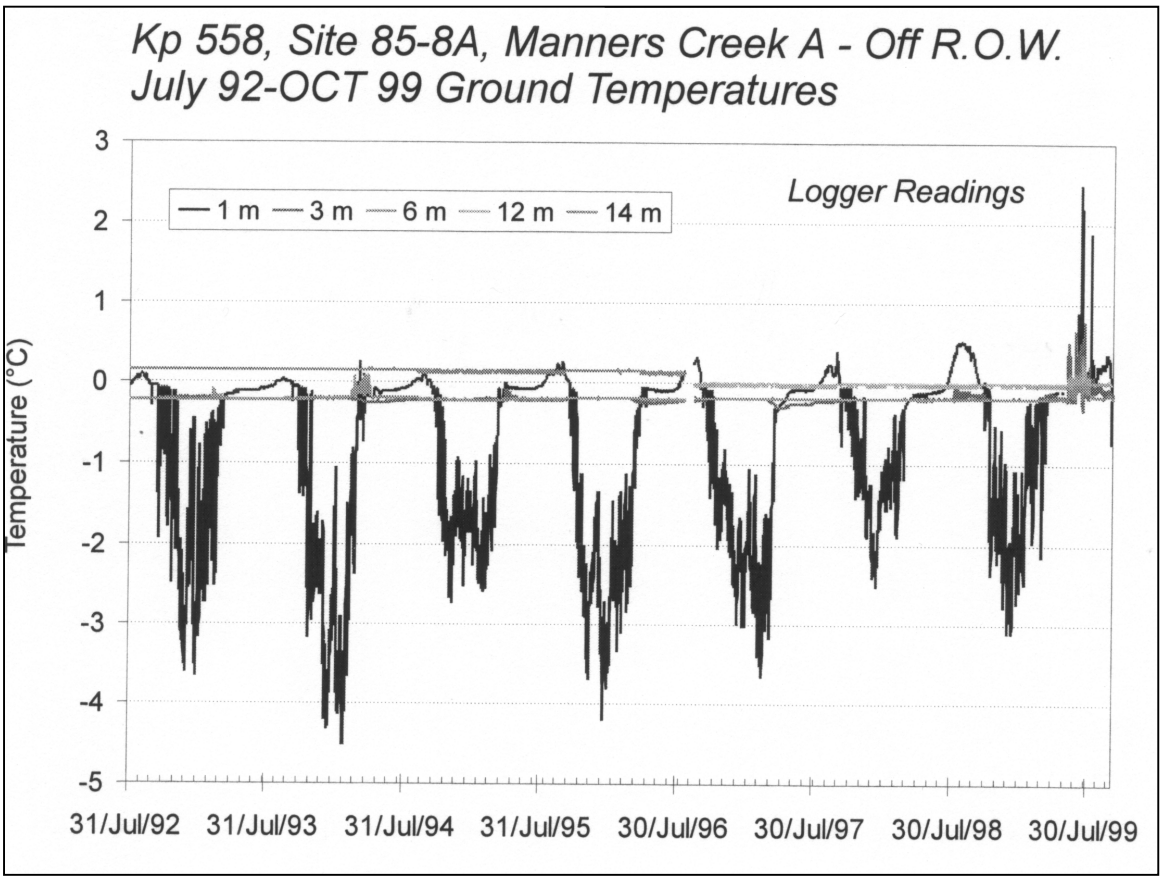


Figure 3

When monitoring permafrost temperatures in the discontinuous permafrost zone, the climate signal can be almost completely filtered out by latent heat effects when permafrost temperature is near 0 degrees (which is the case for many of the pipeline off-ROW monitoring sites). When monitoring, it may appear that there is no change occurring in permafrost, while in nearby unfrozen ground a pronounced temperature signal may able observed (compare off ROW to on-ROW trends at kp583 and kp 588 in Fig 4). Once permafrost thaws and mean annual temperature rises above above freezing, the ground temperature signal begins to track the trend that had been apparent at the unfrozen sites.

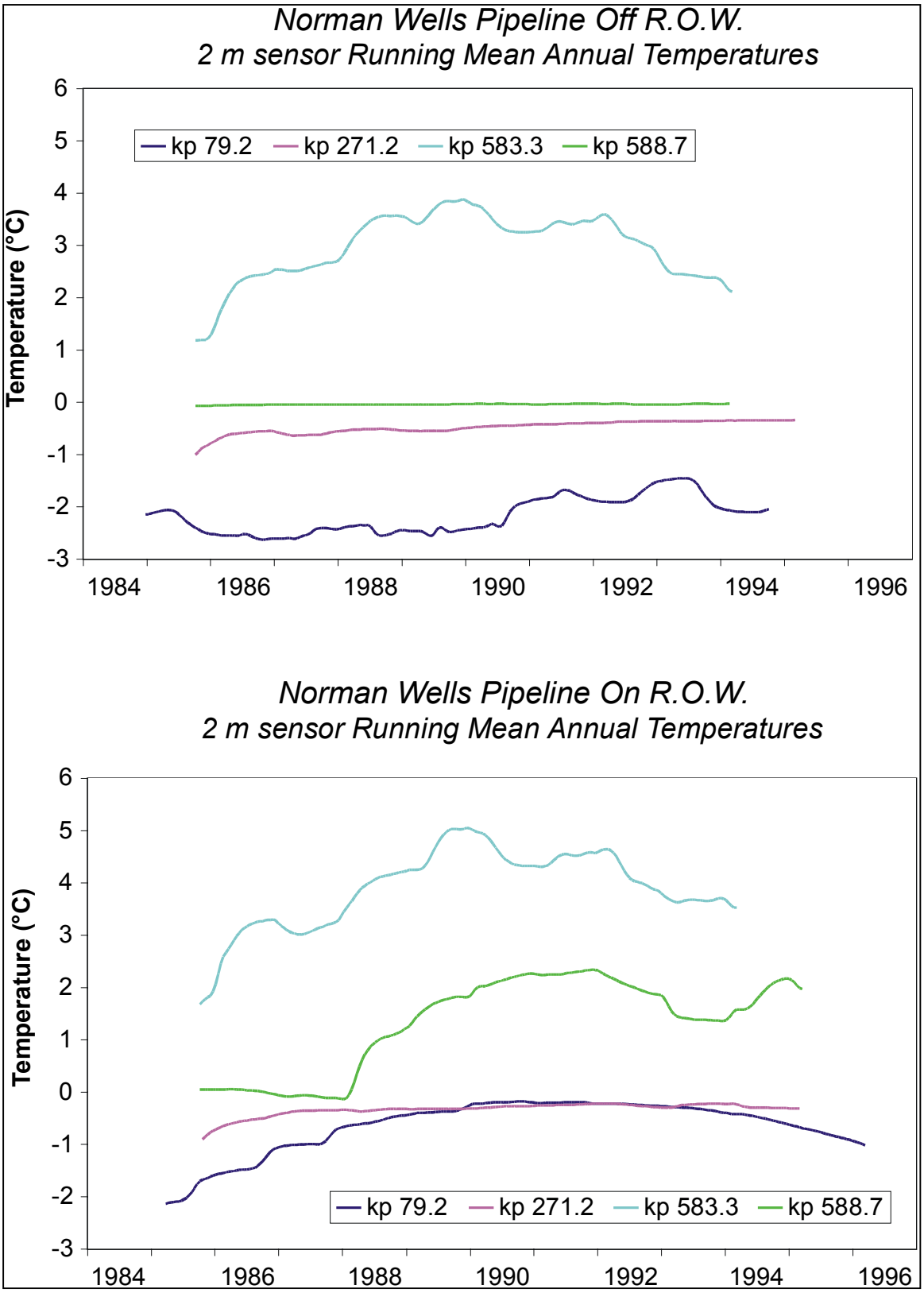

Norman Wells Pipeline Off R.O.W.
2 m sensor Running Mean Annual Temperatures
Temperature (°C)
kp 79.2
kp 271.2
kp 583.3
kp 588.7
6
5
4
3
2
1
0
-1
-2
-3
1984
1986
1988
1990
1992
1994
1996
Norman Wells Pipeline On R.O.W.
2 m sensor Running Mean Annual Temperatures
Temperature (°C)
kp 79.2
kp 271.2
kp 583.3
kp 588.7

Figure 4