

Statement of witness Dr Geoff Meaden

I make this statement as a witness in the case of R v Hewke and others.

1. I have lived in Canterbury, Kent, since 1974 and have worked until very recently as a Principal Lecturer in the Department of Geographical and Life Sciences at Canterbury Christ Church University. I have now retired, though I am still undertaking some research projects, consultancies and writing commitments.
2. I specialised in three areas – biogeography, which is the study of the distribution of plants and animals on the planet, local physical geography of Kent which includes coastal geography and water supply in the region and a third area, that of Geographical Information System (GIS). These are computer-based mapping and analysis programmes. Fisheries GIS is my research area and I was the Director of the Fisheries GIS Unit at the University.
3. There is presently a vast amount of evidence to suggest that the world's temperatures are rising. If we look at very long term changes in atmospheric temperatures we note that they have fluctuated periodically (but somewhat erratically) over many millions of years. The maximum range of fluctuations has been about 8C. Presently we are in a post-glacial warming phase which has been occurring for some 9,000 years, though there have been minor fluctuations during this period. Using various sorts of evidence climatologists are able to calculate the approximate rates of temperature rise or fall fairly accurately, certainly for changes that have occurred over say the last 10,000 years. From this research we can clearly establish that the present rates of temperature rise are unprecedented, even compared with rates over the past 10's of million of years. At least 99% of climatologists are convinced that this rate of rise is due to the release of so-called 'greenhouse gases' into the atmosphere. Greenhouse gases include water vapour, methane, and carbon dioxide (CO₂), and the gases are released into the atmosphere mainly by the burning of fossil fuels (coal, oil and natural gas), but also by activities such as burning forests, grazing animals, permafrost melting, etc. The amount of CO₂ (the main greenhouse gas) in the atmosphere in the pre-industrial era was 280 parts per million (ppm). It is now at 385 ppm and by the middle of this century it will be over 470 ppm. The rate of increase of CO₂ has doubled in the past 30 years. The scientists on the Intergovernmental Panel on Climate Change have all been issuing warnings that drastic actions must be taken to do something to reverse this trend, but the general public and politicians have found it difficult to adjust their life styles or to take the necessary hard and sometimes unpopular choices.
4. Climate change is currently a major cause of rising sea levels. With climate change comes increased warming which in turn leads to increasing rates of melting of the world's ice and then to sea level rise. Ice normally covers a significant proportion of the polar regions of the Earth's surface and this ice reflects much of the sun's heat. With reduced ice cover less heat is reflected and instead this heat is absorbed by sea water, causing the warmed water to expand and thus to rise (this is called thermal expansion). For the first time ever it is likely that within five years there will be no ice at all over the North

Pole during the summer. Furthermore the land in South East England is sinking by about 2mm a year. If the land is sinking it also means the sea level is rising. For these collective reasons, in the south east of England the sea level is presently rising at almost one centimetre per year.

5. It can be stated with certainty that the actual rise in sea levels is occurring exponentially. This means that rises are occurring at an accelerating rate. Even the more modest estimates suggest that sea levels will rise by nearly one metre by the end of this century, but predictions suggest that sea levels could rise by perhaps four or even five metres by the end of the next century.
6. It needs to be stated that predictions of sea level rise are extremely difficult to make with accuracy because this depends on who is doing the projection, where the base lines are set and, of course, there are so many uncertainties surrounding the predictions. For instance, we know that there will be so-called 'tipping points'. This means that if the temperatures rise above certain critical points then some new and potentially dangerous process can be triggered. A good example of this is that there has recently been a huge increase in the rate of permafrost (frozen sub-soil) melting in North America and Siberia, and this is causing greatly enhanced releases of methane into the atmosphere. Additional methane is one of the most dangerous causes of global warming. It is likely that there will be other tipping points that we are entirely unable to predict. It is also likely that the rates of glacier melt will be greatly accelerated above certain critical temperatures. Given these uncertainties, it is imperative that society acts responsibly and takes a precautionary approach to future climatic scenarios.
7. I believe that the sea level rises will be at the higher end of predictions, and indeed nearly all past estimations of the rate of rise have had to be adjusted upwards. Very recently the scientific adviser to the World Bank stated that within a short time period temperatures will be 4C above pre-industrial (1750) levels, and this fact was agreed by the British government's chief scientist. A temperature rise of this level will have catastrophic effects not only on sea level rise but it will also trigger mass extinctions of many of the planet's plants and animals who will not be able to adjust sufficiently to the enhanced temperatures and other climatic changes.
8. Climate change and increased warming means increased storm activity with more hurricanes and cyclones in tropical areas due to the warmth. But Britain will be similarly affected. Increased winds will cause higher waves and thus a greater likelihood of flooding. If storms occur in conjunction with high tides then the flooding will increasingly likely to be on a very extensive scale.
9. I shall now turn to the impacts of all of these factors on the Kent area.
10. The whole of Britain's east coast is bordered by the North Sea. This sea is relative wide in the north (about 300 miles between Scotland and Norway, but it progressively narrows until it is only some 30 miles wide near the Dover Strait. When a strong northerly wind blows down the North Sea it pushes the sea water into a narrower and narrower space causing the water to 'pile up' with a rapid consequent sea level rise. The waters have little opportunity to escape and flooding occurs. This is called a storm surge. Storm

surges push water either into the Thames estuary or through to the English Channel.

11. It was just such an event that occurred in 1953. A particular set of weather conditions occurred on January 31st of that year whereby there was an intense low pressure system that moved south eastwards from northern Scotland towards Denmark. With this direction of movement very strong northerly winds during the night blew down the North Sea. Extensive flooding occurred along the low areas of eastern England in Yorkshire, Lincolnshire and East Anglia. However, the worst flooding occurred on both sides of the southern North Sea, i.e. around the Thames estuary and in the low lying areas of Holland and Belgium. In the latter areas more than 2,000 people perished. Though casualties were much less in Britain, the costs of flood damage were exceedingly high, and it prompted the need for massive flood protection schemes. Indeed, this 1953 flood event was a major reason for building the Thames flood barrier near Woolwich, i.e. to stop London from future marine flooding. Last year a similar storm surge was reported and threatened eastern England, and the fact that it caused little damage was fortuitously, i.e. because the surge did not coincide with a high tide.
12. Due to rapidly rising sea levels and the enhanced need to protect London from flooding, there are plans to replace the existing Thames flood barrier within the next twenty years. It is likely to be situated much further downstream, probably somewhere between Gravesend and the Hoo Peninsular, thus giving enhanced protection to London and its eastern suburbs.
13. However, in times of high water levels, this flood barrier will act like a dam and halt a tremendous amount of water that would naturally 'escape' up the Thames. Instead of being able to escape upstream the water will rise up behind the barrier, enhancing the likelihood of flooding along both the south Essex coast and the low lying parts of the north Kent coast. Places like Kingsnorth in Kent are downstream so they will be extremely vulnerable to a future tidal surge.
14. But it is not only the immediate areas downstream of the flood barrier that will be at enhanced risk. Much of the north Kent coast is extremely low lying. This includes all of the outer Medway estuary, the area between the Isle of Sheppey and mainland Kent (known as the Swale), the Graveney and Seasalter marshes to the East of Faversham, and the former Wantsum Channel area which was until Medieval times a narrow sea channel separating the Isle of Thanet from mainland Kent. Of course there are also large areas of south Kent that will be at increased risk, including mainly the whole of Romney Marsh. Much of the land in all of these areas is barely up to two metres above sea level, a height to which storm surges would easily reach.
15. It should be mentioned that there are existing newly developed Shoreline Management Plans for both the Medway and Swale estuary areas and for the north Kent coast between the Isle of Grain and the South Foreland. These Environment Agency plans clearly state the unsustainability of longer term (up to 100 years) sea defences in much of these areas. This is from both a practical and economic viewpoint. Much of the lower lying land will therefore

be abandoned to the sea under so-called 'managed realignment' and this includes substantial physical structures including roads, houses, business premises, etc, for which no compensation is presently foreseen. It is clear that the cost of raising flood defences along just the vulnerable coastline of Kent would be prohibitive, and already the authorities are not prepared to pay to defend a large number of Kent properties and their associated infrastructure.

16. To accompany this Witness Statement, marked GM/1, are four series of maps have been prepared and which should be made available. Each of these are now described:

The first six maps show the detailed topography of Kent. The first of these six shows the present coastline and I have included a few main towns for location purposes plus the location of the Kingsnorth Power Station. Subsequent maps in this first series give the likely location of the coastline following a 1 metre, 2m, 3m, 4m and 5m sea level rise. I use the term 'likely location' because we do not know the level of coastal defences that might be built during the next two centuries, i.e. the likely time period over which this degree of sea-level rise could occur. Given the intentions of the authorities both to not hold the line on all sea defences in the future (see para. 3 above), and not to be able to afford the massive costs associated with building future defences of perhaps up to 3 metres higher than at present (a minimum of £10 million per km), then it is quite possible that all of these areas may be liable to future flooding, and that a good proportion of the areas shown will be abandoned to the sea. It is clear from these maps that the really significant changes will occur at perhaps a two or three metre rise, and this is likely to occur around the middle of the next century.

The second series of maps show the human features associated with a small sub-section of the Kentish area, i.e. the coastline between Faversham and Whitstable. This area was chosen both because I had the requisite data for the mapping and because it illustrates an area where the Environment Agency has already noted that it will not defend. The maps show all the human features in this area, the present coastline, and the coastline with 1m, 2m, 3m, 4m and 5m sea level rises. In this smaller area the results of sea level rise are quite catastrophic and by some 200 years time more than one third of the present land area might be under water.

The third series of maps show the same area as the above series, but this time we deliberately only show the actual features that are lost with each incremental rise in sea level. About 5% of the land area here is lost with each one metre rise in sea level, and this land contains a number of roads, electricity pylons, a railway line, farming land, and parts of the urban areas of Faversham, Seasalter and Whitstable. It is likely that certain individual structures such as the railway embankment will be given protection.

The last three maps are included to show the affect of sea level rise even on an inland city such as Canterbury. Given a 5 metre rise here a significant wedge along the River Stour's flood plain becomes vulnerable to permanent flooding, and with a 10 metre rise much of city centre is entirely inundated. 10 metres might seem like a high level for marine

flooding to reach, but given a storm surge then water would 'pile up' down the Stour estuary as it was forced into an ever decreasing channel. As fresh water from the River Stour continued to flow down towards this water then it would not be able to escape to the sea. Huge areas of land would be flooded with the water remaining around for days. This is precisely what happened in the lower Stour valley after heavy rains in 2001 and it is what happened around Hull in 2007.

17. It is difficult to be precise about the impact that sea level rise will have on property in Kent. The amount and extent of flooding is totally unpredictable. Any flood event is dependent on a number of factors - tide, winds, waves - which I cannot be specific on. It is also dependent on the strength of the flood defences at every point along the coast, and as we saw in the New Orleans flood two years ago, there will always be a weakest point that eventually gives way, but we do not know where that point will be. However, we do know that seaside areas do attract a large population and Kent has many areas where many hundreds of people live at little above sea level. A single flood event in any of these properties has an average cost valued at 10% of the value of the property, though it is very much higher than this for people who are obliged to evacuate their properties. And increasingly we are going to find that insurance for any low lying properties is going to be harder to obtain or very much more expensive. Once the new London flood barrier has been built these negative consequences are likely to be exacerbated.
18. A further very important factor to consider is that much of the Kent coast is already protected from flooding or coastal erosion by various sea defences, e.g. sea walls, promenades, revetments, etc. Whilst these defences obviously work to prevent attacks from the sea, they do have a long term negative effect. Because of the wall, waves cannot naturally run up and down the beach, and instead they crash against this sea wall. As they continue to do this the beach level gradually drops, i.e. by perhaps several centimetres per year. Lower beach levels naturally mean deeper water and an increasing wave strength and height. This is because when waves travel across deeper beaches their energy is not absorbed; shallow beaches exert lots of friction on the waves so they quickly lose their energy. So, when future storm surges occur they will almost certainly be accompanied by much higher waves, especially in those vulnerable areas that are presently defended by sea walls. Unless very substantial extra funding is spent on wider, deeper and stronger sea defences, then breaching of the defences is much more likely and the potential for flooding is enhanced.
19. Recently, in the UK we have not had a large, catastrophic marine flood event. We have had severe flooding on inland rivers such as around Tewkesbury or Hull in 2007, but there are not many examples of sea flooding. With increasing time gaps between flood events complacency sets in, and it is a proven fact that people begin to think that "it won't happen to us". Yet, on a world scale, every year we see increasing natural disasters, one of the foremost of which is flooding. You can be very certain that the authorities in places such as New Orleans would have been confident that they had sufficient flood protection in place. But this was not the case. The point is that we in Britain will certainly have a major marine flood event to come, and

given sea level rise, then the longer we wait the more catastrophic it will be when it does occur.

20. Indeed, all the time that global warming continues the likelihood of catastrophic events grows incrementally. I predict that by the end of the next century, when we have a severe storm surge event, then all the land that is presently at 5 metres or lower in the Kent area will be flooded. This possibly means that some 20% of Kent will be under the sea. It is impossible to be precise on this because we do not know what individual places or areas may be offered enhanced flood protection. But the Isle of Thanet will again become an island with about three miles of sea between North Thanet and the mainland. Similarly the isle of Sheppey will be some three miles out to sea.
21. The situation is so urgent that unless we act immediately to rapidly reduce greenhouse gases emissions, by the end of the next century we may have to abandon up to 20% of Kent to the sea. The physical, social and economic consequences of this can only be negative and potentially catastrophic. If we don't want this scenario then it behoves us to act with urgency and with a recognition that reducing the emission of CO₂ and other greenhouse gases is by far the best and cheapest method of arriving at a sustainable solution.

Please note that this written Witness Statement is being produced because I am unable to attend the court in person. From August 23rd to September 8th I am on a lecture tour in Brazil. This tour includes giving the keynote speech at the most important conference in my research area. My tour has been planned for many months and cannot reasonably be cancelled.