Future Phosphate Rock Production – Peak or Plateau?

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ABSTRACT: Hubbert's Peak Oil theory is more than 60 years old, yet is still to be shown conclusively to describe the real oil world. Its derivative, Peak Phosphorus was first coined just four years ago, and yet discussion has already been moved on to when the peak will occur rather than whether the model adequately describes the phosphate industry at all. This work looks at the potential flaws in the model, discussing why, if anything, it is the substitutability of oil within the energy system that is more likely to be the factor implicit in determining the peak nature of the production curve rather than the fact that oil itself is a non-renewable resource. Phosphate rock is also non-renewable, but also has no substitutes. The Hubbert model is seen to work with phosphate on a local scale, since local production can be substituted with output elsewhere, but not on a global scale. Decelerating population and other factors will determine the shape of the production curve long-term, and a rise to a plateau level of 250-280 million tonnes per year is postulated. Recent work on gathering reserve and resource information led the IFDC to increase substantially the likely tonnage available. More work is to be done on this, but already the assertion that the Peak Phosphorus curve is merely delayed by several decades by the new tonnage looks flawed. If 'Plateau Phosphorus' does describe future production, the new reserve figures could add 168 years to production availability. It is also likely that a substantial proportion of identified phosphate rock resources will also become available for mining at some point, in which case globally we may well have more than 1,000 years of phosphate rock remaining.

The 'Peak Phosphorus' concept derived from 'peak oil', a term first put forward by Hubbert[1] in 1949 to describe his hypothesis on the future path of global crude oil production. With phosphate rock prices jumping by a factor of 8 in 2008, 'Peak Phosphorus' was seized on as a means of quantifying and conceptualising what some researchers thought was a looming crisis of availability in the phosphate rock industry.

At the risk of being labelled a "sceptic", I have to say that I do not agree with the Peak Phosphorus model of the phosphate rock supply industry, although I am not necessarily a sceptic of the Hubbert curve. His concept – that oil production would rise to a peak value, after which the increasing cost of production would result in a production decline more or less mirroring the rise to form a bell-shaped curve – seems logical to me for several reasons. However, for equally logical reasons that I will discuss, I do not think his theory can be extended to describe the future production in the phosphate rock industry.

I make my assertions from a perspective of over 30 years analysing the international phosphate sector and from an academic background that includes a degree in Geology. I edited the World Survey of Phosphate Deposits in 1980[2], worked on the collection of geological data for the USBM Minerals Availability System in 1981, was a member of the United Nations Project 156 which culminated in a multi-volume report Phosphate Deposits of the World, including Volume 2, published in 1989, specifically on phosphate resources[3]. My current company is funded by 'the phosphate industry', a term that includes everything from phosphate rock mining through to delivery of phosphate-bearing fertilizers to the farmer, as well as commercial banks, non-commercial banks, other investment companies, international government and non-government agencies. As an independent analyst to all sectors of the industry, I believe my views and opinions have to be demonstrably unbiased.

I have not so far taken part in the academic or political debate on phosphate resources. Partly this was a deliberate attempt to maintain neutrality and independence and partly because, although my experience tells me that phosphate reserves and resources are much larger than the numbers being used, I felt the development of a debate on the subject was healthy. I even offered to supply data to individuals where the lack of it was cited as an obstacle to analysis, although my offers have yet to be taken up.

I would a like to state here that I am in agreement with many of the aims of the various groups who use the Peak Phosphorus concept to popularise their cause. We need to have a debate on what (if anything) we can do to use the finite resources of phosphate that exist in the most efficient way possible. This should include a debate on phosphate recovery from waste streams at all points in the chain from phosphate mining through food production to human and animal excreta.

However, the Peak Phosphorus concept, derived from Peak Oil, which after 60 years is itself still an unproven theory, has, I believe, been ushered into general acceptance with unseemly haste.

The term ‘Peak Phosphorus’ was first coined in a paper by Déry and Anderson[4] in 2007. In their paper the authors applied the Hubbert linearization analysis to phosphate reserve and production data. In the case of Nauru Island, and the USA they showed the theory worked. The results for the world as a whole were also described as ‘stunning’, but in reality the results showed that the theory did not work on a global scale. The authors’ calculations resulted in a peak in global phosphate rock production in 1989 (with the prior knowledge from their data source that a peak had already happened in 1988); it showed that the production curve at the time of writing (2007) was in terminal decline; and that the global URR (ultimately recoverable reserve of phosphate) was 8 billion tonnes. They were wrong on all three counts.

By 2007, the time the paper was written, not only was phosphate rock production far from being in terminal decline, it had surpassed the 1988 peak in each of the previous three years. The authors could have easily discovered this by asking the IFA[5] or me[6].

From today’s perspective it has been a demonstrable fact for more than 6 years that phosphate rock production did **not** peak irrevocably in the late 1980’s. In my opinion, publications such as that published by the UK Soil Association in 2010[7] that still maintain that phosphate rock production might have peaked in the late 1980’s, damage only their own credibility.

In addition to not correctly predicting the timing of a peak, Déry and Anderson’s calculations also produced an estimate of global phosphate rock reserves (URR) of 8 billion, which was significantly at odds with the level quoted in their USGS data source at just under 18 billion tonnes remaining reserves (equivalent to a URR of around 24 billion).

So did Déry and Anderson’s paper receive the criticism it deserved?

Not a bit of it. In fact the 'Peak Phosphorus' concept was seized upon by the academic community and in 2009 Cordell, Drangert and White published "The Story of Phosphorus: Global food security and food for thought"[8]. In this report we are told, "The concept of the 'peak' production of non-renewable resources such as oil or phosphorus ***is the subject of limited dispute today***, but the exact timeline for the peak in production is debated" (my emphasis). The authors go on to say, "While it is understood that phosphate rock, like oil and other key non renewable resources ***will follow a Hubbert production curve***…" (my emphasis)[8]. And so, the Peak Phosphorus ***hypothesis*** skips a few steps and becomes a ***law***.

Actually, although the authors do not recognise its significance, the second half of the above sentence gives a clue as to why the Hubbert hypothesis is unlikely to work for phosphate rock whereas it might with oil. The sentence continues, "…a key difference between peak oil and peak phosphorus, is that oil can be replaced with other forms of energy once it becomes too scarce."[8]

In other words, although oil is a non-renewable resource, it is part of a larger group (energy) which is, to all intents and purposes, renewable. I believe that it is the substitutability of a commodity that is key to obtaining a bell-shaped Hubbert curve, not the fact that it is non-renewable.

This would explain why, on a national scale, the Peak Phosphorus theory appears to work. Production of phosphate rock from Nauru reached a peak and then declined as reserves were depleted, but in the process, consumers of Nauru rock just substituted rock from another supplier. In the case of the USA, rock production in the USA was substituted by rock production in other countries which then supplied either phosphate rock to the USA or phosphate products to either the USA or to its former markets. On a global scale this substitutability through trade is not possible and the theory breaks down.

In the case of oil, it is logical to believe that as oil becomes scarcer and more costly to produce, so its market price will inevitably rise. Eventually (as indeed is happening now) other sources of energy, and eventually sun energy, will become more cost effective than oil. Oil production could doubtless peak at this point and begin to decline. However, global energy production as a whole could still continue to increase, even if oil production declines.

With phosphates we are in a different situation entirely. Yes, phosphate rock is a non-renewable resource, but it is also not possible to find a substitute (unless recent reports of arsenic-based bacteria are to be believed). As a result, what happens when the price begins to rise as production costs increase? No substitute product is available, so it is left to the phosphate market alone to balance supply and demand. The mechanism through which it does this is price. If phosphate rock demand exceeds supply, prices rise to encourage more production (or capacity addition) and to discourage demand. Phosphate rock prices will continue to rise until a balance is reached between supply and demand. Likewise in an over-supplied market, prices fall to discourage production and encourage consumption.

In a section headed "Sceptics of the 'Hubbert' Curve"[9] this idea of market control through price is dismissed by Cordell and White as "neoclassical economic theory - which does not acknowledge the finite nature of non-renewable resources like phosphate rock (or oil)"[9]. I prefer to call it the real world.

So if not a Peak, what will the phosphate rock production curve look like?

Phosphate mining on a large scale is relatively new. Phosphate rock production reached 10 million tonnes per year for the first time around 1930[12]. Phosphate resources globally are unknown in quantity, but have been relatively well known in individual deposits since the acceleration in geological exploration work after the last phosphate price hike in the mid 1970's. My experience is that early work on delineating reserves and resources tends, if anything, to underestimate the final total, sometimes significantly.

I agree with Cordell, Drangert and White [8] that phosphate rock production is likely to rise through a decelerating growth trend to a maximum level sometime within the next 50 years. The actual maximum (in tonnage and timing) will depend on a number of variables, but I think that it will most likely be in the range 250-280 million tonnes per year around mid-century. This is somewhat higher than the 29 million tonnes per year P peak level obtained by Cordell et al [8] (equivalent to around 230 million tonnes rock equivalent[*]), but closer to the 70 million tonnes P2O5 (30.5 million tonnes P or 245 million tonnes of rock product) calculated as the 'most likely' consumption level in 2050 by Ingrid Steen, Agronomist to Kemira Agro in 1998[10].

Despite the general agreement on a slowing of production growth, I do not agree with Cordell et al[8] that there will then be a peak in production followed by an equally precipitous decline. I believe that production levels will most likely plateau and then remain more or less level into the 22nd century and beyond.

This plateau-effect will happen because of the conflicting impact of several demand-side factors. By 2050, population growth will have slowed to 0.3% p.a.[11] growth in per capita meat consumption in the developing world will also have slowed, but is likely to still keep demand for cereals higher than growth in population; the bulk of the developing world will already have a fairly high level of calorie consumption by 2030[17] (unfortunately this is not the same thing as reducing the incidence of poor nutrition). These factors will tend to increase the growth in grain consumption and possibly phosphate demand beyond any residual growth in population. Acting in the opposite direction will be the degree to which efficiency of phosphate production and use in agriculture is increased (that is the amount of food we can produce per unit of phosphate), together with the degree to which phosphate recovery is implemented. In other words, the 'plateau' might turn out to be a slowly rising (or falling) trend going forward, but growth or decline is likely to be very low and outweighed by annual variations in output.

Implicit in the demand forecast is the assumption that we can maintain the impetus in keeping food output per person at a relatively high level. In terms of cereal production per head of population, gains in the green revolution in the 1960's and 70's seem to have been lost in the 1985-2000 period, only to be recouped in recent years. Our base-case forecast here assumes a value of 0.36 going forward.

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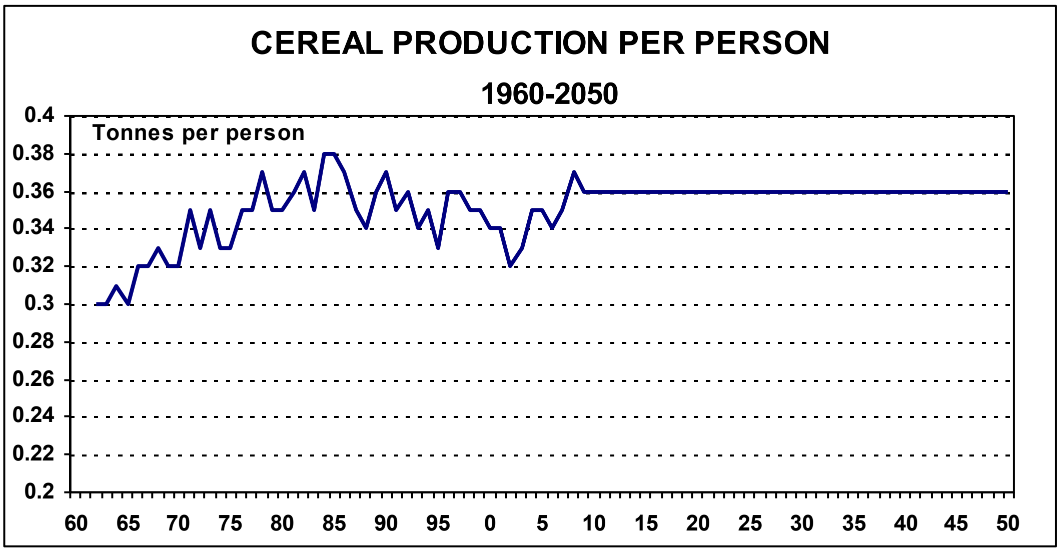
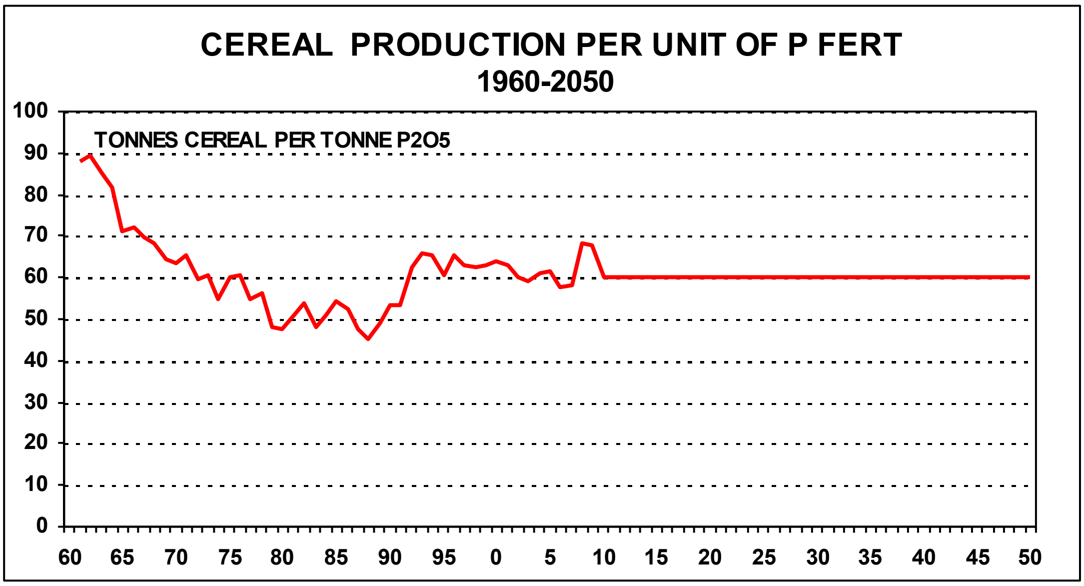
[*] All figures in this report, unless otherwise specified are in product tonnes, a conversion factor of 8 is used here from tonnes P to phosphate rock product tonnes

Chart 1



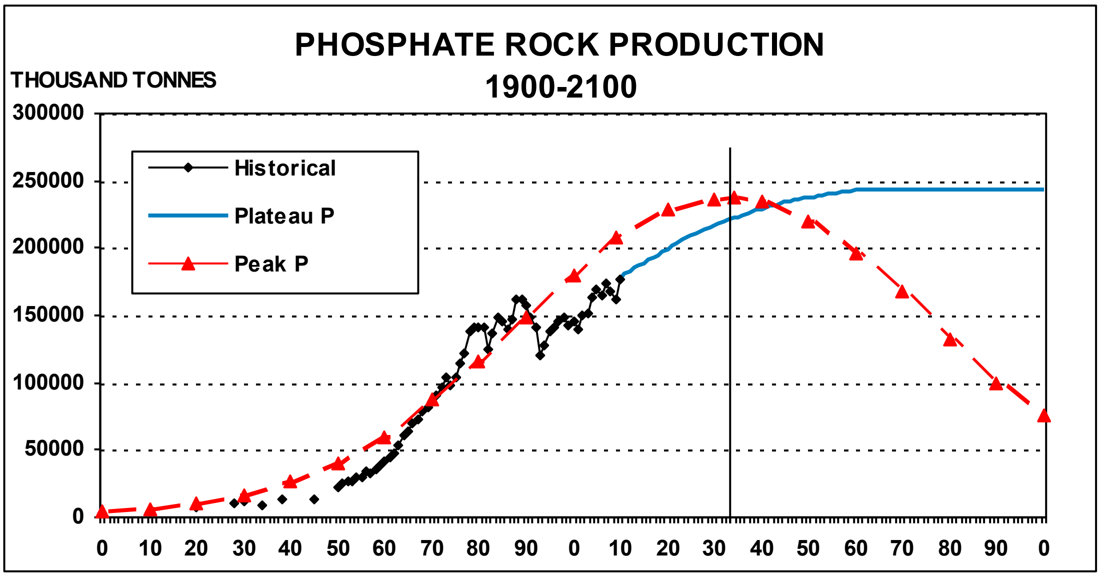
In terms of cereal production per unit of phosphate fertilizer, the period 1960-1985 was one of decline, which was then partially reversed at the end of the 1980's (this can partly be explained in terms of the build-up of inefficient phosphate use in the USSR and dramatic decline in use during the political break-up at the end of the 1980's). Since the early 1990's, we have produced an average of 60 tonnes of cereal per tonne of P_2O_5 consumed and this is the value assumed in our long-term base-case 'Plateau Phosphate' forecast[13,17].

Chart 2



The result of this long-range phosphate fertilizer demand scenario is a build-up in phosphate rock requirements in the next few decades as illustrated in the following chart. The 'Peak P' line shows schematically the path expected by that theory. The 'Plateau P' line forecast is derived from the above relationships between population, cereal production and fertilizer use.

Chart 3



Historical data sources: 1900-1980, Le Marché Mondial des Phosphates et des Engrais Phosphatés[12]; 1981 to date Fertecon Research Centre[6] and IFA[5]

Implications of 'Plateau Phosphorus'

If rock production reaches a plateau of 250 million tonnes per year, we will be consuming around 2.5 billion tonnes of reserves per decade. The Peak Phosphorus theory was based on a remaining reserve estimate produced by the USGS[16] (Jasinski 2007, 2008) of 18 billion product tonnes, equivalent to a total reserve including that already mined (URR) of 25 billion tonnes.

I agree with Cordell, Drangert and White[8] that we are likely to have consumed somewhere in the region of 7 billion tonnes of reserves in going from the low level of production in 1900 to the 2007 level. I also agree that we will have consumed a further 6 billion in getting to the Peak Phosphorus peak level in 2034. If you believe in the symmetrical bell-shaped curve, it would consume roughly another 13 billion tonnes of reserves to bring production back down from the peak to zero. So a scope estimate of total rock produced (URR) in the Peak Phosphorus case would be around 26 billion tonnes.

It now becomes clear that the size of the remaining reserve base at 18 billion tonnes is very important to the Peak Phosphorus theory. If the URR is around the 25 billion tonne level (6 already consumed plus 18 remaining), the production curve barely has time to reach the peak level before reserve availability begins to be an issue. The peak theory states that this issue with remaining reserves will be enough to constrain production, indeed strong enough to make production fall off fairly rapidly.

However, let us consider now what happens if we add a further 42 billion tonnes to the remaining reserve figure (making 60 billion in total). In 2010, reviewing material in the public domain, Van Kauwenbergh[14] at the IFDC estimated the most likely level for phosphate rock reserves to be 60 billion tonnes and resources to be 290 billion tonnes.

The new IFDC reserve estimate adds 42 billion tonnes to the USGS figure for remaining reserves as used by the Peak Phosphorus model. In the 'Plateau Phosphorus' model, this 42 billion tonnes is equivalent to an additional 168 years of production at the plateau rate of 250 million tonnes per year. If we are able to mine the bulk of the identified resources, the new IFDC study adds over 1,000 years to production life.

What impact would this additional 42 billion tonnes of reserves have on the Peak Phosphorus curve?

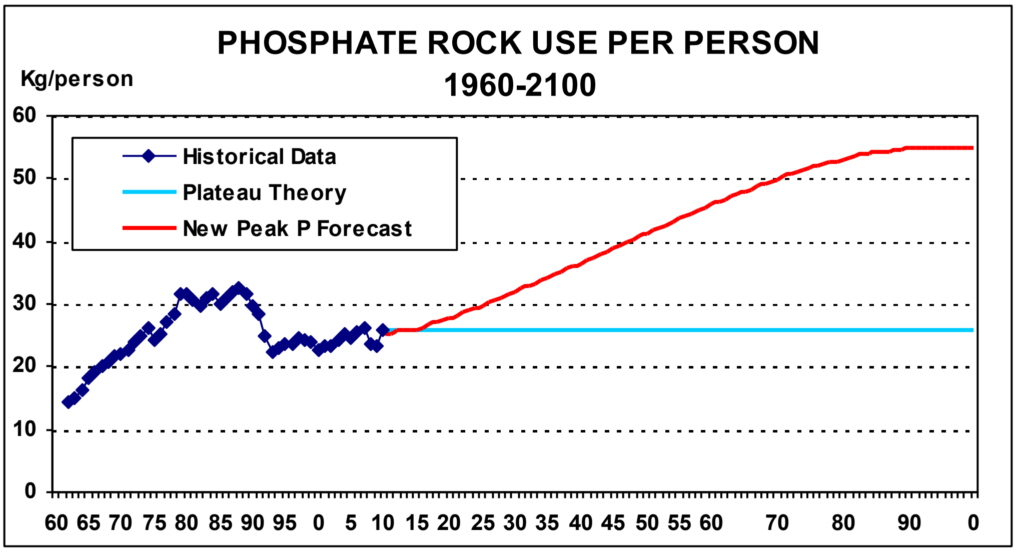
The Global Phosphorus Research Initiative (GPRI) published a statement in response to the new IFDC study which, amongst other things, states that the new numbers do not invalidate the Peak Phosphorus theory. In its statement, the GPRI states that "if the 60 000 Mt reserves figure was accurate, the peak phosphorus timeline would be pushed forward by several decades. That is, there would still be a peak in the production of phosphorus this century". [15]

One way to envisage this is to imagine splitting the Peak P curve shown in Chart 3 above into two halves by the vertical line, both the left and right hand pieces have a total cumulative production of 13 billion tonnes. We now have to pull the right-hand side away (into the future) in order to fit our additional 42 billion tonnes of production in between.

The distance you have to go into the future with the right-hand half of the curve depends on the shape of the curve joining the two halves. If it is flat (as in Plateau Phosphorus) you have to take it 168 years into the future. However, in order to obtain a peak this century, along the lines described by the GPRI, one has to allow the production of, and demand for phosphate rock to continue to grow at around current levels way past the 250 million mark in 2030 (even though population growth has by then slowed to below 0.6% p.a.), [11] continue growth in phosphate use past 2050 (when population growth has slowed to just 0.3%)[11] and finally slow to zero growth at around 2080 as you approach the peak. By doing this, can you both create a peak this century and consume the additional reserve tonnage proposed by the IFDC study (21 billion before the peak and 21 billion after). The only problem with this model is that by 2080 it predicts the world will be consuming a vast amount of phosphate – around 700 million tonnes each year.

Population forecasts beyond 2050 show the most likely scenario is that growth will slow to near zero[13]. To preserve a notion of a peak in phosphate rock production in the current century, the authors seem to be proposing that rock consumption per person will rise continuously from today’s level of around 25kg, reaching a peak of around 70kg of phosphate rock per year if the peak is to be in 2080, more than double the maximum of 32kg at any point in history so far. Even allowing the peak to be at the end of the century results in an annual phosphate rock use at that time of 55kg per person as shown in Chart 4..

Chart 4



Thus a consumption level of 55kg per person or more is required to obtain a peak in the current century. This seems to me to be very unlikely. To assume this outcome also seems counter to the very idea of gains in efficiency and reserve conservation that the phosphate debate should be all about trying to bring about.

Does the shape of the curve matter?

Well, yes and no. It does not matter in as much as I believe we should, in any case, be thinking about how we conserve non-renewable resources and developing techniques and processes for recycling nutrients. However, this is already happening to some degree.

On the mining side, producers now tend to mine much more of the phosphate section than in the past, thus increasing the overall reserve base. Techniques for upgrading lower quality parts of reserves are also improving, as is the ability of phosphate fertilizer plants to accept lower grade phosphate raw materials. As the industry becomes ever more vertically integrated, use of low grade ores is made easier because transportation is minimised. This also tends to lower the energy consumption of the industry. Whereas 30 years ago we used to ship over 50 million tonnes of phosphate rock around the world, we now ship less than 30 million tonnes. New investments in Morocco and elsewhere are directed not just at expansion, but also at conserving power and water resources as well as reducing dust and other potential pollutants.

Efficiency in the use of fertilizers has also been improving thanks to efforts by the IFA, IFDC, and other bodies. This move to more sustainable use of fertilizer in nutrients farming should be supported as it not only reduces reserve depletion, it also lowers the levels of nutrients escaping into waterways, where they can cause environmental damage.

We should also be looking further down the chain, through food production, consumption, wastage and recovery of nutrients from human and animal excreta. These developments also have the two-fold benefit of reducing nutrient loss and improving the environment.

However, one of the possible dangers in the Peak Phosphorus concept is that it seems to create a one-way bet for investors. If you believe in the Peak Phosphorus curve, prices will have to jump to very high levels for a long time in order to drive demand to ever lower levels after the peak. This belief could validate a flood of investments in an industry that has already been through a long period of low returns after the last price peak in the mid-1970's.   Yes, over-investment now will probably lead to a period of low fertilizer prices, but that in itself could result in the debate about nutrient recovery being shelved once more, just as it was through the last 3 decades following the price peak in the mid 1970's.

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