IWA Sustainable Boating Group

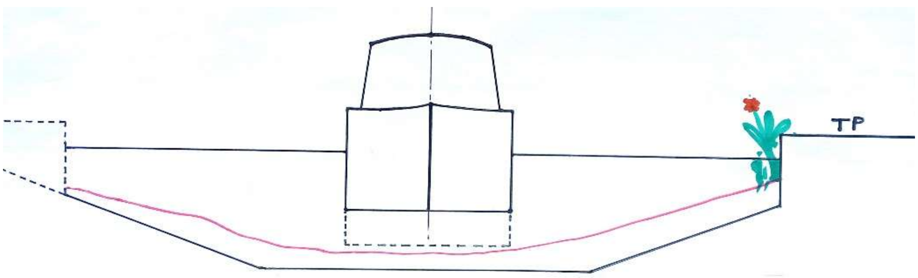
Canal Dredging and the Environment

1: Introduction

A principal responsibility of a navigation authority is to maintain the channel to size – dimensions and shape, that enables the efficient movement of all craft expected to be moving on those waters. The severe lack of maintenance and dredging over many years is now becoming apparent, to the extent that both boating and boat transport are becoming difficult and interrupted, and environmental stability is compromised with failing banks, water supply and ecology.

The largest boats on our navigable waterways vary greatly from full size narrow boats on the narrow canals of the Midlands to various barges on river navigations and particularly the waterways of the North-East, which are considerably larger and deeper drafted. Whilst there is not much freight carried on the narrow canals in modern times, there are still a number of commercial operators, carrying fuel, gas, and other supplies to boaters and canal-side businesses and dwellings. The larger freight being carried on the London Thames, the Severn and Gloucester & Sharpness canal, and in the NE the Trent, Aire & Calder and the Sheffield & S. Yorkshire navigation (i.e. adjoining the Humber) have all suffered from a lack of dredging in a similar way to the more modest and 'cruising' waterways. These larger boats may be of a traditional type of barge, or a more modern design, to which may be added maintenance boats – tugs and 'hoppers' which carry a variety of equipment and lock gates for example, and carry away dredged material. Also of a larger size are passenger boats, traditional or modern, and whilst some are operated by charities, some are operating as a business, and expect to maintain regular services or timetables.

All these examples of 'largest size', require in particular a depth of water that is well clear of the deepest level that the vessels can be loaded to. In the days of the horse this depth was usually a gauge depth of at least 4 feet (1.2m), meaning that the canal was deeper than that (about 5 feet, or 1.5m), allowing boats to carry up to about 25 tons (= tonnes) on both the narrow canals and the shorter but wider Yorkshire waterways like the Leads & Liverpool. The later, improved waterways of the NE were enlarged to a depth of 7'6" for 700 tonne barges (2.3m, 1.8m to Sheffield), and then again to 2.4m for part of the route in the 1980s, but now sadly lacking dredging maintenance.



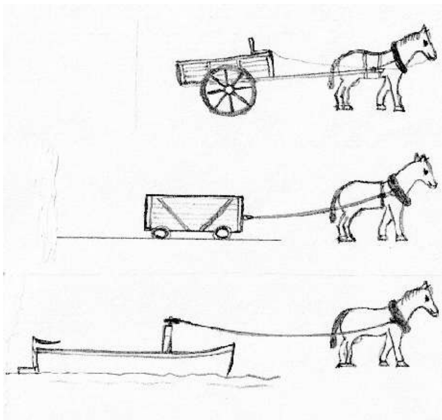
If these largest boats can be accommodated then all other craft will use less fuel and cause less wear.

2: A moving boat in a channel

As a vessel moves along a channel, the water has to pass back in the other direction, to fill the space left by the vessel, so the 'cross-section area' of the channel should be many times greater than the cross-section of the part of the vessel which is in the water. If the channel is restricted because of siltation or other reduction in area, the water must pass faster relative to the speed of the vessel. Boaters sometimes notice that they move slower in tunnels, for example. It can thus be seen that the energy required to move the vessel is inversely proportional to the cross-sectional area of *water* compared to that of the immersed part of the *vessel*. There are documented cases of silted canals causing twice as much or more fuel to be used to move a given distance because of lack of dredging, and whilst some of these cases are simply a lack of depth, in fact any reduction in cross-sectional area will increase fuel consumption from the nominal expected in canal transport, by all vessels. See Appendix 1 for more detail on the disturbed water, and Appendix 2 for propellers.

3: The environmental case for canal transport

In the days of horse power when many canals were dug in the late 18^{th} century, a single horse could maintain a steady 3miles/hour towing a barge loaded with between 25 and 30 tons along the level canal (i.e. between locks). The same horse attached to a cart on the roads and tracks of those days would only be expected to be loaded to 1 ton; and if the horse was used to pull a truck on rails (e.g. from mines and quarries etc), could be loaded to about 5 tons. This gave rise to the sometimes-quoted ratio of 1:5:25 for road, rail and water, and illustrates the relative efficiencies of such transport systems – and the superiority of water transport in terms of energy use.



1 ton - Horse and cart

5 tons - truck on rails

25 tons – horse towing barge

This of course was at approximately 3 miles/hour and relatively slow speed compared with what is available today – but with economies of scale magnifying these ratios rather than reducing them, it can be seen that the larger craft of the NE, and on river and coastal navigations elsewhere, there is a very convincing case for water transport – *where* appropriate freight may occur. This demonstrates the environmental advantages of water transport – reduced fuel costs, reduction in road transport (for those cargoes), and therefore reduced fuel, emissions and costs, on such routes.

But it all depends on maintaining this dredged profile, in order to ensure efficiency and reliability.

If the needs of navigation are met – then all other uses for the canal water such as water transport and supply, maintaining heritage and ecological stability and of course the safe access and use by a wide range of activities may be assured.

We must also, when considering this aspect of maintenance, consider the causes of any siltation. Whilst long-term siltation will tend to happen anyway along the length of any slow-water waterway, some exaggerated deposits occur from un-protected outfalls or feeders, sometimes from unprotected banks where there has been some erosion, sometimes in cuttings from excessive leaf and branch-fall, or a combination of these. The worst (and most expensive to dispose of) siltation is where it occurs in cuttings, by remote locks and weirs, and in urban or industrial areas where the deposits may be contaminated – and require special treatment on disposal.

Disposal is also subject to monitoring by the Environment Agency, which requires permissions or license conditions – all adding to costs, especially when the dredged material has to be transported some distance for safe disposal. To quote just CRT's recent estimates (2025), at least half of the 6.5 million pounds dredging budget is spent on disposal costs rather than the actual dredging operation.

4: Safety considerations

Manoeuvring, steering, accident rate, visibility and usefulness are all improved with cleaner water and defined channel. To Summarise:

- Manoeuvring of boats greatly eased by having sufficient depth of water. If the water is shallow: reversing, turning, mooring up, or avoiding other craft can be difficult especially for the inexperienced, as the boat will tend to remain in a straight line if shallow.
- Several unfortunate accidents can be quoted of steerers falling into the water by leaning over the side when in difficulty (one quite recent, in Birmingham).
- Clearer water is also safer, as boat movement, and the bottom for fallen objects (or persons!) may be seen or located more easily, as well as being a healthier water-space.
- Flood relief: any excess water entering any canal must be assured of the largest channel possible for movement to downstream weirs.

5: Water supply levels

During periods of high use, or drought conditions, some variation in level is inevitable between locks, particularly on summit levels, where a greater depth is usually designed in; levels may go down considerably after high usage, making passage more difficult. Overflow weirs also should of course be maintained to pass any excess or floodwater, from whatever cause.

6: Other uses for canal water

In many cases of short distances and in some for longer distances, canals are used to convey the water being used for navigation to a reservoir for use as a water supply. For example the Llangollen branch of the Shropshire Union system conveys water from the River Dee above Llangollen to a reservoir at Hurleston, for eventual use in the Cheshire area water supply. Also, the Gloucester & Sharpness Ship Canal passes water from the River Severn towards Bristol for water supply. There are others, and shorter sections for such use – but all should require a maintained canal profile in order to ensure cleanest water and minimum disturbance for other uses (e.g. to minimise velocity and ensure cleanliness of water flow). A new long-distance scheme for the Grand Union Canal is presently under consideration – and if pursued will require reliable maintenance for this reason, and to ensure minimum level-drop along any long pound.

In urban or industrial areas, canal water is sometimes used for cooling or other industrial applications where water can be returned (clean!) to the canal. A more recent development is to use the canal water as a heat-source in heat-pump systems, with both domestic and commercial applications to heating (and sometimes cooling, or 'air conditioning') being considered. This is most appropriate where there is a nearby canal, to reduce capital costs over ground-sourced systems, and could be of an increased capacity compared to air-sourced systems. An example in Liverpool is being discussed at this time (Nov. 2025). Either way, heat-pump systems use less energy to produce heating than any other system other than geothermal. Unlike cleaning uses, heating or cooling applications take water through pipes and heat-exchangers and return it to the canal in a clean condition – thus there are no losses of water, unlike 'open use' applications like cleaning where losses due to evaporation and other disposal (wet refuse, ground) uses some of the water supplied, and cleaning the water before return has to be incorporated.

To summarise the requirements for other uses:

- ensure cleanest water,
- minimise disturbance for other uses e.g. maximising cross-section minimises velocity.
- to minimise level drop along a pound. The new scheme for the Grand Union Canal presently under consideration will therefore require maximum section.
- To maximise water volume to reduce any temperature-change due to heating/cooling uses.

7: The need for cleaner water

As a result of these considerations, it can be seen that relatively 'clean' water is preferred in each canal pound – in spite of there being in some areas natural 'staining' present from iron or other geological influences, such as in the Stoke on Trent Potteries area. Sources of canal water are principally from reservoirs situated to collect water from headwaters – normally expected to require little treatment other than control weirs and perhaps 'sump and screen' debris catchment, to feed a 'summit level', or sometimes a 'long pound'. Other sources include groundwater entering tunnels, and convenient streams feeding directly into a canal – which *do* require monitoring, as sometimes sediment concentrates after periods of excessive run-off or flooding. These are sometimes addressed by 'spot-dredging', rather than awaiting a longer dredging programme for the whole canal. There are also some groundwater sources from disused mines (e.g. Bradley).

In order to minimise sediment arising from the canal water itself, several aspects of the dredging work must be addressed:

a. Sufficient cross-sectional area: for example, the normally achievable canal dimensions provide a ratio of at least five times that of a boat loaded to a draught of 3ft 4" (1m).
b. Sufficient depth – it is important to achieve at a width of two boats (for passing) a minimum depth – ideally 1.5m on the narrow canals, but often only 1.2m or less is achieved.
c. Sufficient maintenance of the bank – there should of course be an awareness that any *reduction* in maintenance of both the bank and appropriate depths results in increased *rates* of erosion – and therefore non-clear water and more frequent dredging being required.
d. Tree-cover maintenance in cuttings and off-side. Whilst healthy looking trees offering shade can be left for a while, continuous or regular monitoring of all arboreal encroachment over the water surface is important, and removal of branches and trees where appropriate, to reduce accumulation of debris', and therefore dredging frequency.

8: Ecology of the canal corridor

Whilst obvious in many rural lengths, the canal corridor through urban and even industrial areas is often found to be a conduit for flora and fauna, connecting adjacent parks and green land by trees, hedges and waste or currently unused land as well as the water and its margins: valuable habitat for a range of wildlife. It is also important to remember that much of canal routes follows closely that of a river, stream or other water-course, which of course will have its established ecology influencing that of the canal (as evidenced by the continual re-spreading of Himalayan Balsam). Whilst the main 'design' of a navigable canal includes a 'tow-path', and space for each lock operation, it is important to maintain a 'green' dimension to the surroundings throughout the canal's length. Thus hedges, trees, grass, rather than brick walls & concrete (even fences); and planning precautions to limit encroachment into this space are all important. Whilst trees are important – they should not be allowed to grow too close to either side of a canal, because of increased leaf-fall, eventual branch-fall into the water, *and* encroachment, and associated costs. The forestry and shrub-cover in cuttings and embankments respectively are particularly likely to cause problems if not monitored and managed appropriately (e.g. problems on the Shropshire Union Canal). This aspect is quite separate from routine towpath maintenance and grass-cutting, which has to be carried out on a seasonal programme anyway.

9: Species of interest

Of course, all wildlife appreciates relatively clean water – but the presence of fish generally helps with this aspect. Species found in neighbouring watercourses are probably the most appropriate to encourage, although where the angling interest is present there may be good reason to transfer popular fish from other places, if compatible. Aquatic plants found in the region can also be encouraged, as well as ferns, grasses and small ground covering plants, which would form good habitat for fauna. In any restoration programme there will be some disturbance to recently established ecological migration from adjacent habitats – this has sometimes been addressed by building further adjacent 'wild-life refuges', or conservation areas specifically for endangered habitats. Examples on the Montgomery Canal and Droitwich Barge Canal have shown some successes in this respect – but have also experienced some problems (mainly maintenance issues).

It has to be said however, that it is a sad reflection on our national agricultural policies over the years that have led to the decimation of many sensitive species. It is also unfortunate that the nature of various 'protection' schemes such as SSSIs might only include areas seen to be under threat, rather than the wider corridor which would include the total habitat and thus more readily allow restoration of previously stable ecologies existing with the built heritage structures restored.

10. Change

Perhaps the most pertinent observation regarding the ecology of the canal corridor is the significance of any change. Either 'restoration' – e.g. from a derelict or unused state, or 'development' – e.g. building of houses or factories, should be seen as an *opportunity* to restore *or improve* this channel and natural corridor, rather than allowing it to be harmed. Unfortunately, resistance to any proposed 'changes' for such improvement results in 'development' or financial aspects taking priority. Generally speaking, the opportunity for a regularly maintained navigation is certainly preferable to dereliction or abandonment – but it must include the whole ecology or 'green' element, in order to ensure both local and tourism support, as well as to justify built heritage and canal use.

10: Measurement and planning for dredging

There have been several improvements in recent years in surveying techniques to establish profile in a watercourse – radar or ultrasonics can be used to scan the canal bottom from a moving boat, thus avoiding the need for a lot of manual measuring with sticks, measuring tapes etc. This can be useful when planning a long length for efficient use of the dredging equipment. It is observed however, that current expenditure appears to be more often spent on dredging where 'problem-spots' are identified by boaters – and not planned maintenance dredging to avoid such scenarios. This is due almost entirely to lack of funding to catch up with the back-log identified several times over the years. CRT for example, have only one such craft suitably equipped – surely, they need one in each Region?   Perhaps also, there is a case for volunteer groups to use the simpler measuring system to survey a length of canal in their area? (i.e. small boat, measuring staff with pad, detailed map and notebook. Measurement need only be taken in the middle of the canal for a useful monitoring of condition for the canal authority).

11: Contractors

In recent years the navigation authorities have tended to abandon out-dated equipment in favour of contracting out such tasks as dredging – a sad situation when each Region requires immediate action from time to time as well as a continuous programme of 'catch-up' with de-silting. The very recent change to commissioning new work-boats to enable the authority's own staff to dredge and dispose is welcome – this needs urgent expansion to cover all canals. (this is not to denigrate the usual contractors – Land & Water, and Rothen – both excellent companies – but they have a wide area of range and application and do not *rely* on CRT or other navigation authorities' contracts).

A new work-boat commissioned by CRT with its own power supply for hydraulic feet and a platform for a tracked dredging machine was shown off at the Crick Boat Show this year...

The return to navigation authority staff being able to manage dredging operations is vital to reducing the costs of contractors, not to mention the improvements to programming sensible long-term dredging within the organisation.

12: Conclusions

In terms of current climatic emphasis, it is 'energy efficiency' of canal transport – which includes all craft of a motorised nature such as cruising or working narrow boats and motor yachts, and their fuel consumption, which is to gain from any improvement in dredging. Reducing the use and consumption of all fossil fuels is the objective, and all waterway users therefore benefit from thorough dredging operations when they occur. Even electric drive boats (potentially more efficient anyway) benefit as the energy stored in their batteries has to be generated from somewhere ….

Whilst dealing with dredging of canals it is important to also consider the dredging of all reservoirs and feeders which supply the water. Depending on local conditions, these too will silt over time, and need this aspect of maintenance to reduce unexpected short-fall, failure of supply, or passing their debris into the canal.

Unfortunately, the demise in recent years of the concept of 'maintenance', in practice only carried out as 'emergency work' or 'special catch-up operations' under various names, means that a great deal of the 'backlog of maintenance' (a term in this subject dating back to the 1970's) will take a lot of special effort to recover the whole of our navigable waterway network. It is doubly unfortunate that because there is so much to do, that some environmental disadvantages will also occur, albeit temporarily. Hopefully any improved rate of dredging will all be planned to minimise any disturbance and identified problems in each particular area of operation.

The requirements of clean and sufficient water are similar for all applications for waterways: water supply, industrial and domestic heating, cooling, etc, environmental stability including provision for excess or limited supplies such as flood or low-flow, safety considerations, and navigation, all re-enforce the need for a thorough and sufficiently funded dredging regime, distinct from other maintenance responsibilities.

References:

1. 'Hydraulic aspects of the Montgomery Canal Restoration', British Waterways, 2006
2. 'Review of UK inland waterways transportation from a hydrodynamics point of view'; Momchil Terziev[1,*], Jonathan Mosse[2], Rosemary Norman[3], Richard Lord[4], Tahsin Tezdogan[5], Atilla Incecik[1] 2024
3. www.canalrivertrust.org.uk/specialist-teams/engineering/dredging (a web-page describing and illustrating CRT's dredging programme, with some good video).

Appendix 1.
Disturbance of Water by a Moving Boat

Introduction: As a boat moves forward in a channel, an equal quantity of water has to move back down the channel past the boat. When the channel is many times the size of the boat (in 'cross-section' – that is, area at 90 degrees to the line of movement) this movement of water will be relatively slow. However, as the canal silts up, the smaller c/s area available causes an increased velocity of water relative to the boat and therefore will either require more power to achieve the same speed or result in a slower speed for the same 'throttle' setting. Either way (or anywhere in between) more energy (fuel) will be used for a given distance.

The *volume* of water displaced (i.e. moved back down the canal) is of course the same as the displacement of the boat (water displacement, as in Archimedes).

The *length* of boat is irrelevant – only the ratio of *area* determines the ratio of *speed.*

Therefore: Speed of boat/speed of water = area of water/area of boat

That is: relative speed of water and boat is inversely proportional to *area* of water and boat.

This of course assumes the cross-sectional area of the canal being relatively consistent, and the area of the boat under water being consistent along the length of hull and proceeding at a steady speed.

1: Speed of returning water:
The actual area available for the 'returning' water then, is the cross-sectional area of the channel *minus* the part of the boat's cross-sectional area that is below the water-line.
So, the formula would look like this:

$$S_b/S_w = (A_c - A_b)/A_b$$

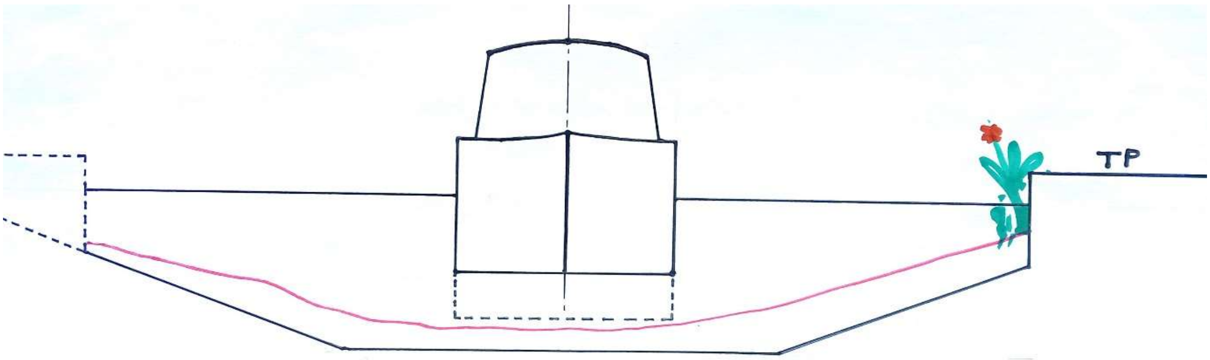
Where: S = speed, A = area, b = boat, c = channel, w = water

e.g. if the channel area is $12m^2$ and the boat is $1.1m^2$, the ratio will be (12 – 1.1) ÷ 1.1 = 9.9 ….. which is very good. But if Ac is reduced to $8m^2$ (very silted) and boat is heavy with $2.2m^2$ (loaded, or heavily built), then the ratio will be only 2.6! (not good = very inefficient!).

2: Speed of boat through water:
The speed of the water passing the *hull of the boat* is the sum of the two velocities (at least in theory, we must assume *average* velocities of water, see later), because they are in opposite directions:

$$S_t = S_b + S_w \qquad \text{where t = total}$$

Which illustrates why the motor cannot maintain (land) speed with the same input with a silted canal, as the boat only experiences *water* speed.



the red line = siltation

3. Variations
It is interesting to consider the distribution of water around the moving hull, as more can be deduced from established testing than just the calculated 'average' velocity.

3a. Variation 1. *across the section available*:
In open water the fastest 'returning water' might be assumed to be that adjacent to the hull in motion. However, with the freely moving medium of the surrounding water, there may well be a slightly slower layer touching the hull due to friction, depending on surface finish. There is then the maximum velocity of water *very close* to the hull – and then gradually reducing velocities as measurements are taken further and further away from the hull, until at some distance, there is no longer any 'returning water', only perhaps some resultant turbulence and waves. This variation in velocities is known as 'laminar flow' and is studied in fluid dynamics to improve performance in both shipping and aircraft design and their propellers.

However, in the enclosed channel of the typical canal or lock cut this 'some distance' is not reached, and the space available between hull and canal bed is *all* used by the returning water – which may well be slightly slower at the banks of the canal due to friction there, and will show signs of turbulence as well as it's velocity back down the canal. Any flotsam present in the water near the bank will allow some observation of this.

Observing from the bank, as the bow passes a given point, the disturbed water quickly responds to the bow wave and starts moving back along the canal, maintaining fairly constant velocity depending on the shape and length of the boat and conditions remaining in the channel (i.e. distribution of returning water due to position of boat in the channel). Then as the wave from the stern passes, a more turbulent phase is again seen as the water settles into a 'non-moving' but still disturbed patch of water. As the boat disappears from view the water eventually regains its 'quiet' status once again. If the boat is motor (propeller) driven there will also be some disturbance following the vessel due to the turning of the propeller, mainly in the centre of the channel or wake of the boat. This also dies down gradually after a boat has passed the viewing point. (see Appendix 2).

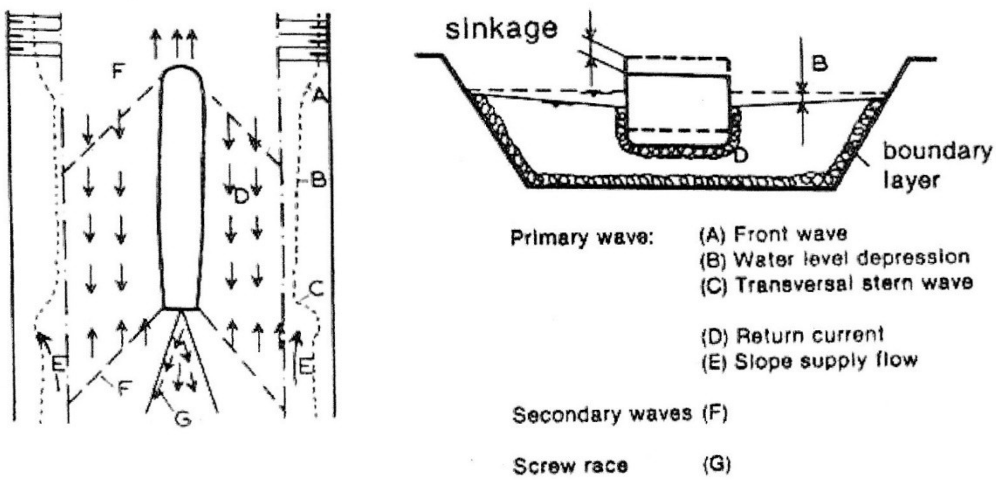
3b. Variation 2. ***along the vessel*:**

The initial disturbance of the bow of a vessel gives way to a relatively smooth movement of water along the length of a barge or other vessel with a lengthy section of constant shape. At the stern there is similar disturbance (as at the bow) in the water as it returns to quiet canal conditions. This is evidenced by seeing any aerial view of a barge or narrow boat in motion – with two vee-shaped waves emanating from bow and stern.

However, if the vessel is not floating level in the water, e.g. 'stern-heavy' as with an empty motorised freight boat, the greater depth at the heavy end will cause an increase in returning water velocity along its length. Depending on how close this end is to the bottom, the extra pressure on the hull progressively along the length will cause water to flow from under the vessel around the bilges to the sides. This is one reason why traditional barges and some narrow boats have a 'rounded chine', rather than a sharp corner which causes extra turbulence. An idea exploited by builders of some steel boats is to 'chamfer' the chine corner with a smaller plate at about 45 degrees, which also eases this movement around the hull. The fact that such boats rock more easily than a more 'square' hull bottom is evidence that the water moves around the hull more easily with a less sharp corner!

3c. Variation 3. ***depression***

As the returning water is being directed 'past' the moving vessel, it exhibits a slope similar to any open channel passing water. Thus the water level by the stern of the moving boat will be lower than at the bow – depending on the speed of the boat in the water. So in spite of being a 'displacement' hull, the *appearance* of the boat will indeed 'tip' up at the bow, if only slightly when going faster than a very nominal speed. So, the stern at least, will be even nearer the bottom. This also implies that in spite of the note about assuming constant displacement along the length above; there may well be an acceleration of water velocity along the length due to slope, as well as any inclination of the boat. This is sometimes referred to as 'sinkage'.



3d. Variation 4. ***around or under the hull?*:**

Considering the space around the vessel's hull that returning water is expected to move through, the space 'under' the hull if level will vary according to (a) the loading or draught of the boat, and (b) the dredged condition of the canal. The sides, width of canal and boat, are of course the same (for a given waterway), unless we are dealing with restricting the width of a length of canal for some reason – e.g. 'soft-banks', 'narrow sections', tunnels, or other special sites.

As the available clearance between the bottom and the *underside* of the hull decreases with siltation (or heavily loaded cargo!), more returning water will have to move around the *SIDES* of the boat than under. The velocity of returning water *under* the hull may well increase with smaller clearance conditions, but as the bottom gets *very* close the velocity here will *decrease* – simply because there is not enough room for any quantity of water to pass *under* the hull, together with water friction with the hull and bottom controlling what water there is there. This emphasises the even greater amount of returning water passing the *sides* – and a consequent increase in speed of returning water at the banks relative to boat speed.

3e. Variation 5: *Shape of hull, efficiencies and appropriate speed of vessel:*

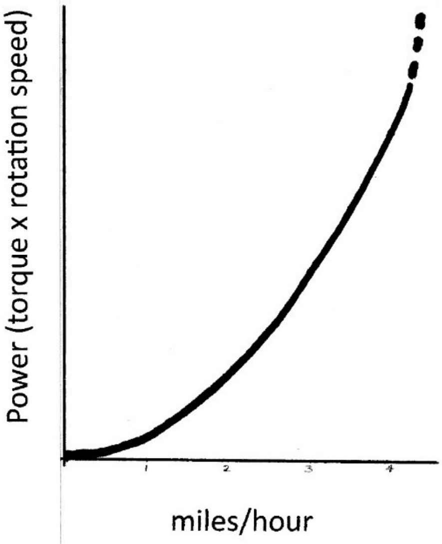
With the vast majority of canal boats of all descriptions likely to last a long time, it is only of passing reference that we mention that some boat hulls are more efficient than others. Narrow boat building since the industrial age of the 17th C. is only a 10:1 length/breadth ratio application of the barges around the lower rivers and coast, which have evolved over millennia to take advantage of natural sources of both materials and design concepts (e.g. wood, 'knees', 'ribs', etc). The style of hull shapes have tended to incorporate curves and pointed ends instinctively to reduce drag, and on canals to ease hauling and manoeuvrability.

It goes without saying that ALL the variations mentioned above ALSO vary with speed of the vessel. Thus any measurements taken of velocities across the section, along the vessel, amount of depression or whether the water passes around or under, etc, these conditions are assumed in some way to be relative, or 'normal', and any increase or decrease in speed of a boat will result in similar changes in water velocities.

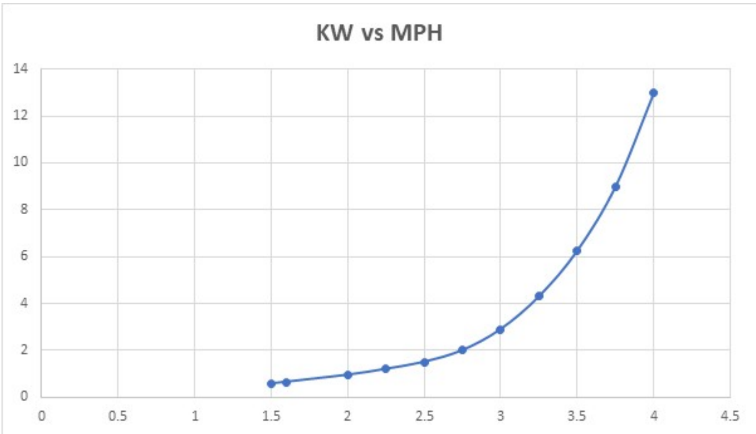
4. Variation of Power and Speed

A moving boat requires ever greater power input in order to increase speed, which in tests follows a square or cubic law type of curve. Depending on type of boat from submarines to multi-hull etc - we are concerned here only with displacement craft such as barges and narrow boats, and in a relatively narrow channel.

The power required to produce a required forward movement increases exponentially from zero, the gathering increase in power for each increment of raised speed being specific to each boat. The following graph illustrates the square law, and how the gradient increases with attained boat speed, which is similar to the cube law (which is steeper) found by boats on relatively open water. In practice, the curve will be modified at each end – from zero may be uncertain according to type of control system used, and will in any case be relatively linear in the very low-speed range. The upper end will certainly be steeper on inland waters (hence cube law approximation), and reach a limit beyond which no more power will enable any higher speed.



An electric-drive boat is a very convenient system in which to take measurements of power and speed, to illustrate some of the relationships mentioned above. Power to the motor is measured electrically, and land speed can be observed using GPS and mobile phone. An example of measurements on such a boat are given next (thanks to Dave Jesse).

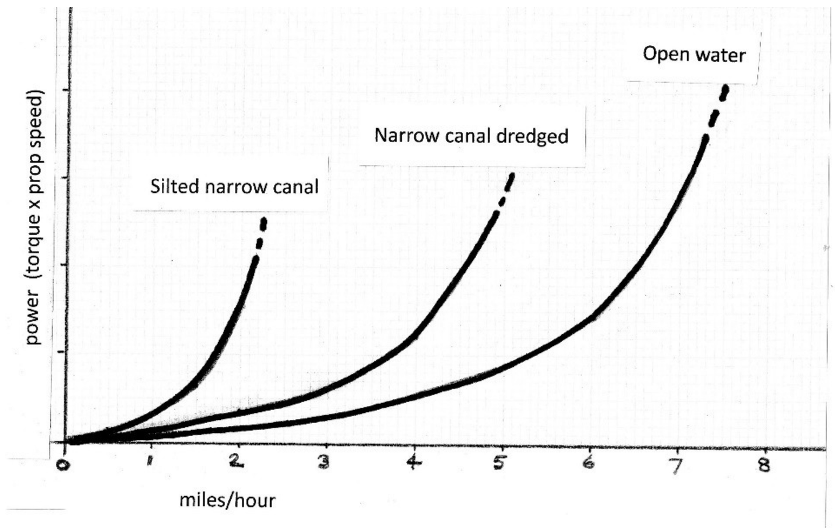


To give an example, 2.0 kW gives NB *Firecrest* a speed of 2.7 mph in open water. In a channel with a 5% blockage factor the water will flow back at 0.1 mph, giving an actual forward speed of 2.6 mph. In still water this would require 1.7 kW so the 5% blockage has increased power usage by 0.3 kW/17%.

At 10% blockage the equivalent figures are 0.3 mph, 2.4 mph, 1.4 kW/43%, while at 15% they are 0.5 mph, 2.2 mph, 1.2 kW/67%.

The graph above illustrates the significance of the control of speed – because the increase in gradient represents the ever-increasing fuel consumption due to greater turbulence and returning water velocity. The individual graphs below illustrate that ever-increasing energy is used as speed is increased, although at low speeds a near linear increase prevails. So as each increment of speed is progressively greater, there is obviously a limit both to maximum speed (in any given conditions) and to a 'sensible' speed regarding energy input – i.e. fuel consumption, where the *gradient* of the graph has not increased by a significant amount.

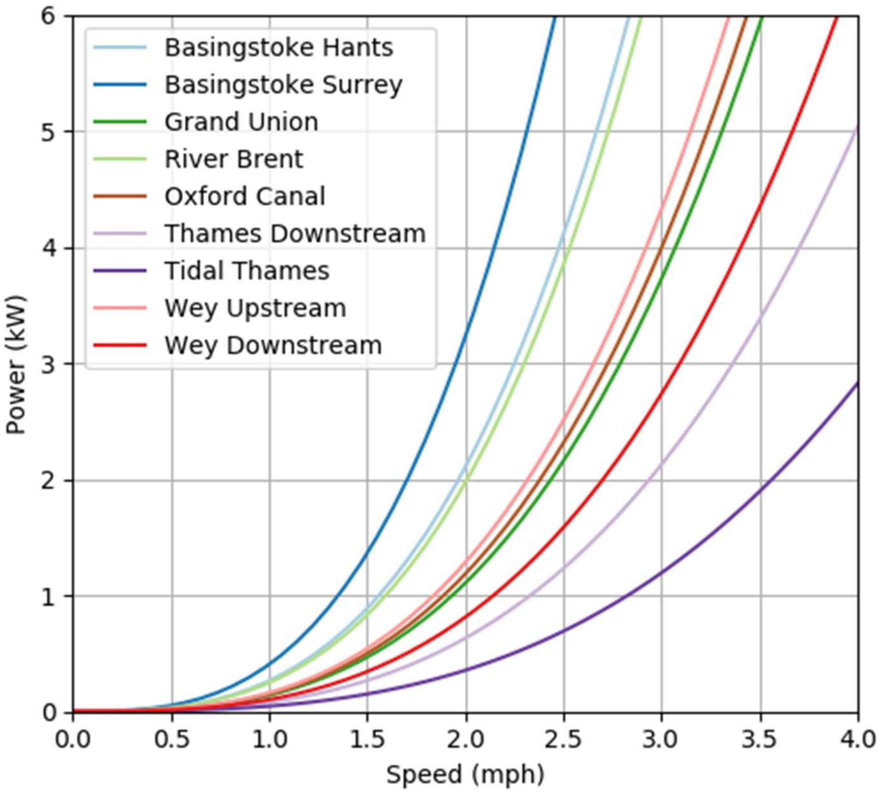
Conditions for different blockage scenarios:



A boat in different waters

The several conditions shown here illustrate how important sufficient depth of water is to fuel consumption, rather than the faster ends of performance. Likewise, each boat will exhibit a similar curve of power requirement – though where it lies on the graph (i.e. *actual* measurements) will depend entirely on the boat's individual design, and of course on the size of waterway.

Now for actual results on several waterways. The graphs shown next are from the electric drive NB Perseverance, cruising various southern waterways, which shows how useful electric drive is for taking measurements:



(DJ)

Conclusions:

In practice, while handling canal boats of any sort, the steerer should become aware of the effect on the water of the speed that is set, by throttle or motor control. Typically, boaters are told to avoid a 'breaking wave' at the banks as this is clearly too fast. This condition is too fast because of potential damage to the banks (i.e. causing unnecessary erosion) and will be using more energy than necessary (fuel), because the boat will not be moving any faster along the canal, even though the throttle setting is higher, when causing excessive turbulence and waves. In fact, it can be shown that a more sensitive approach can save on fuel – where a boat steerer 'feels' the prevailing condition of the canal bed by being aware of the 'returning water', turbulence and sinkage, and altering speed more slowly (i.e. thinking ahead) to suit. This means reducing power input as more turbulent conditions are encountered – rather than increase power in order to maintain boat speed.

1. The benefits of a more reliable maintenance regime include less fuel consumption for all craft, less erosion and damage to the bank, and less frequent dredging and repairs in the future, added of course to cleaner and safer water.
2. An education programme illustrating that greater awareness of water disturbance will reduce fuel (or battery) consumption, under any condition of canal, but particularly when the canal requires dredging is we feel, desirable.
3. Ballasting a boat to be level, rather than being deeper in the water at the stern, can improve both manoeuvrability and fuel consumption (with other parameters unchanged).

Appendix 2:
Propeller

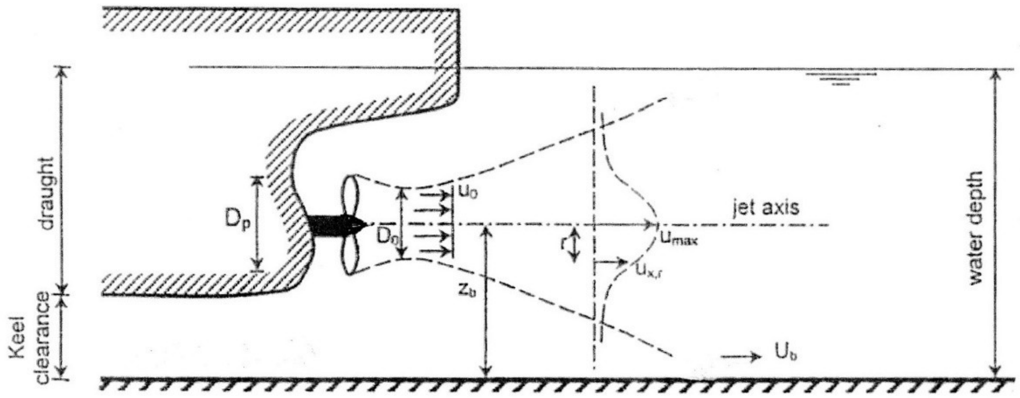
The vast majority of canal boats in the British Isles used for leisure, passenger or transport purposes are motor driven using a propeller. Other propulsion methods exist of course – the 'butty' boat or hopper (unpowered) boat to be towed, and horse-drawn – where the tow is from the towpath and therefore angled to the line of movement; and there's also the 'stern-wheeler' paddle, which is rare. Tugs are also used – sometimes also for pushing (usually work-boats), so are powered suitably higher than for their own size.

A propeller works by rotating a set of angled blades in order to obtain thrust – and in a canal setting we are dealing with displacement craft – where a boat does not change its attitude (angle) with increase in speed (unlike some faster cruisers etc). The condition of the water is generally still, and the resultant thrust results in a movement of the boat through the water according to the space available (see Appendix 1).

As the propeller revolves from a stationary start, the blades impart a pressure on the water at an angle – which results in some movement outwards – or a radial expansion of disturbance, as well as movement backwards resulting from axial thrust. As the boat speed picks up and settles to the set speed, this radial movement of the water will be minimised, as the boat is moving through the water approaching the speed the propeller is rotating. So, any *change* in speed of the propeller, either up or down, will cause extra pressure on the blades (on one side or the other) – AND an increase in radial disturbance, during that phase.

The water directed back from the propeller moves through stationary water – and therefore becomes affected – and affects – that water. The resultant 'jet' of water emitted gets larger with distance from the boat. The jet also still has a 'turning' motion resulting from the turning of the propeller, although reduced by the presence of a rudder, and gradually dissipates as it settles into canal conditions again.

A small reduction in jet diameter is theoretically present aft of the propeller due to the moving water closing into the jet axis after passing the blades. This is only for a very short length – but emphasises the importance of a smooth 'cone' over the propeller nut, to reduce local turbulence.



One environmental *benefit* of the use of propellers (or paddles even!) is that the disturbance of the water particularly at the surface, together with the pressure exerted by the blades, helps to 'aerate' the water – increasing oxygen absorption and improving water health, for both fish and aquatic plants. (in a similar way to rapids, waterfalls and weirs on rivers).

The actual design and application of propellers to each craft is another subject altogether – e.g. size and pitch, number and shape of blades, etc., as there are many variables which a boat designer or owner may wish to exploit. However, there is one aspect which concerns us in terms of effect on the environment of the channel (canal). Under given conditions, a larger prop will rotate more slowly than a smaller one to achieve the same thrust, because of the larger area of water being 'pushed'. For a simple example, the higher-speed typical outboard motor uses a relatively small prop, rotating fast in order to produce thrust – whereas a typical canal boat with a diesel engine rotates relatively slowly in order to propel e.g. the same boat. The range is even more interesting when comparing older style canal boat engines, seldom rated at more than 10 HP or so, with a large propeller (up to 30 inches diameter on the old working boats). Modern engines need to be rated at 30 HP or so to deliver the same performance using smaller propellers (typically 16 - 18 inches). This is partly because of the smaller draught of modern cruising boats limiting size, but also because of adaptation of engines from the motor industry, rather than using what were 'industrial' or marine engines, in the past. With the advent of greater interest in electric drive, which has a linear relationship from the stationary of torque, rotation speed and power *in a propeller application*, a fresh look at propeller size can be taken. (diesel engines generally require a clutch incorporated in a gearbox, because of the limited ‘useful’ range of speed available from an i/c engine).

Conclusion:
Generally speaking, the *largest propeller suitable for the hull of the boat* is the best to choose – other parameters following - such as number of blades and pitch, which must be matched to whatever drive is provided and use of the boat. This will ensure slowest rotating speed in *normal cruising conditions* and will ensure minimal disturbance to canal water, and therefore bed and banks of the canal – of interest in the context of canal dredging and the environment – and therefore fuel consumption as well as navigation authority maintenance costs.