IRRIGATION
A GUIDE FOR NEW GROWERS

Photo: Iain Tolhurst

This publication was written by Pete Dollimore. It was produced as an outcome of the partnership between The CSA Network UK, The Gaia Foundation's Seed Sovereignty Programme and The Organic Growers Alliance. Funded by Farming the Future.

INTRODUCTION

Irrigation is one of those subjects that seems so straightforward at first glance, but as soon as you begin to investigate the options, it can become a bit daunting.

The recent boom in regenerative agriculture has paralleled a renaissance in small-scale local food growing. Those of us that have been growing for some time have been inundated with requests for advice. Following the driest summer since 1976 and the hottest on record[1], many people have been seriously revising their plot irrigation tactics. I hope this guide will help new growers get their heads around the subject and avoid some of the expensive pitfalls that lead to an ill-conceived and badly-designed system.

I also want to share what I have learned over the last 25 years rather than repeat the same information in emails and conversations. I am not an expert on the subject but do have a range of hands-on experience and really hope I can draw together some of the technical and design elements in a useful way for people who are simply trying to produce some food for their community.

Whether you have 20 hectares of field veg or a 10m^2 Polytunnel, there are four elements that all systems will have in common:

- Source - where does the water come from?
- Storage - how, if necessary, is it stored?
- Transfer - how is it moved?
- Application - how is it provided to the crop/soil?

Photo: Phil Sumption

The variety of options can be challenging for growers as you work towards increased efficiency, reliability and self-sufficiency while reducing workload, risk and cost. Typical things to bear in mind at the research stage are:

- Scale of your operation
- Soil and crop type
- Local resources
- Financial resources
- On-site working hours
- On/off grid and available power
- Site gradient, elevation and aspect
- Cultivation methods
- Owned or rented land

What's in the guide?

This guide gives an overview of the commonly-used installations with details of concepts, terminology, equipment, design, regulations and related aspects. It will also describe some techniques to help growers estimate how much and when to water their crops.

Although relevant to field scale systems it will focus on the smaller, market garden scale where perhaps tractor use is optional rather than essential. These might range from 0.25 to 2 hectares and include perennial, annual and greenhouse crops. It doesn't really matter what scale you're operating at as the available materials, the science and practice and the decision making process are much the same. Hopefully this guide will help folk work out what might be best for them.

1. www.metoffice.gov.uk/about-us/press-office/news/weather-and-climate/2022/joint-hottest-summer-on-record-for-england

Photo: Phil Sumption

CONTENTS

What's not in the guide?

The guide won't cover the use of low voltage and renewable energy pumps or the design of gravity flow or surface flood systems. These are presently uncommon in the UK and it is difficult to outline widely tried and tested methods (although worldwide, surface flood is the most commonly used). I will leave it to others with practical experience to illustrate the potential of these techniques.

Ways of reducing the need for supplementary irrigation, such as deep mulching and certain soil and crop management practices, are effective and prudent. Again these won't be explored but I encourage you to research and apply as best you can. It may not remove the need for irrigation but will certainly reduce it, as well as stress, on both crops and growers.

The main types of **sprinkler**, **dripper** and spray equipment will be covered but there are many different types, models and variations in an innovative market. I want to avoid brand recommendations, so I'll concentrate on giving you universal information.

I will focus on tried and tested techniques, systems and designs rather than specific products which can come and go. However some may be used as examples of what is available and potentially fit for purpose.

I suggest you have an internet browser or catalogue on hand to bring up images of hardware. It would have been a nightmare to provide photos of all equipment and materials mentioned in this guide, so please go find them for yourselves!

I do hope you find this helpful.

Pete Dollimore, Organic Growers Alliance, April 2023.

PART 1 - SOURCING AND STORING WATER

This part deals with the six main elements that allow us to get and store water on site. These are:

1. Mains public water supply
2. Water tanks
3. Rainwater harvesting
4. Open reservoir
5. Local watercourse
6. Boreholes

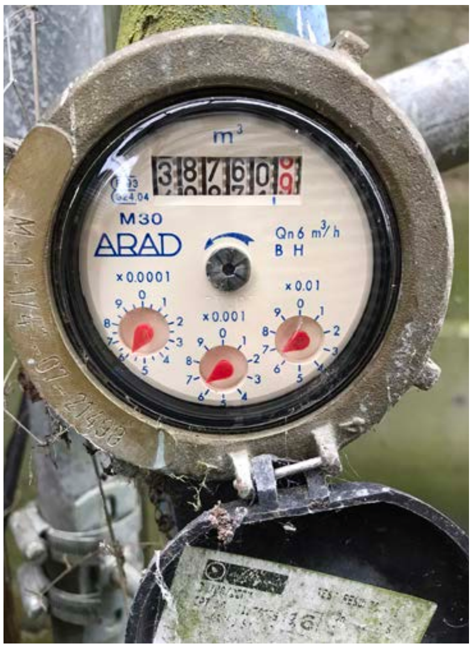
1. Mains public water supply

We are fortunate in the UK to have an extensive and reliable supply of clean mains water. For smaller growers this can be the best option as it removes the need for a heap of infrastructure. Most growers will use mains water, where available, to get new set-ups started off and even well-developed systems will utilise the mains supply ongoing as a back-up. Where the quality of abstracted or stored water may be an issue, mains should be used for overhead watering fresh salad crops.

So why not just use mains?

Cost:

This has to be compared to the capital and maintenance costs of the alternatives but, depending on where you are located, the cost per m^3 (1000L) in 2022 was between £1.30 - £2. This is still a cost-effective way to maintain high-value crop quality in propagation, salads and protected units. It can become prohibitively expensive when watering field-scale and staple crops.



Mains water meter

Regulations:

The use of mains water in England and Wales is regulated by the Water Supply (Water Fittings) Regulations 1999. The type of fittings and system design for a mains supply are covered by WRAS (Water Regulatory Advisory Scheme) Regulations and apply to 'any water fitting which, when installed, will carry or receive water from the public mains water supply'.

They exist to prevent waste, inaccurate measurement and, most importantly, the contamination of public drinking water. Some materials can affect the flavour, odour or colouration of water. Others can impart toxic chemicals or create conditions that allow bacteria and microbes to flourish. Failure to comply with the regulations is a criminal offence and may result in prosecution.

Incoming mains supply ***stop cock*** *in a* ***ground access box****, Hankham Organics*

If you are considering a direct mains-fed system you should contact your water provider to arrange a free visit and they will tell you what your obligations are. These will be mainly to use WRAS certified pipes and fittings, prevent contamination and back flow and ensure work is to a standard that will minimise the risk of waste through leaks or damage to the installation.

Chlorine and carbonate levels:

Chlorine is used to control biological pathogens in the water supply and as such will have a low-level effect on your soil biology. Most of the chlorine will off-gas if the water is tank-stored for several hours, especially during summer when temperatures are higher.

Carbonates and bicarbonates occur naturally and increase the pH of water, this may be helpful on acidic soils but generally they are undesirable due to the deposits that can form on equipment. Natural rainwater is slightly acidic so continuous use of hard water in protected cropping systems may increase soil alkalinity over time causing changes in mineral availability and biological activity.

High pressure/low flow:

As water needs to be pumped over vast distances mains will often be supplied at high pressures, particularly when close to the pumping station or at lower altitudes. Despite this, flow can be low so essentially the worst of both. High pressure puts fittings and application equipment under stress and low flow will limit the volume available (see the relevant section in Part 4 - glossary).

Too far from the supply:

Essentially your site may need to be off-grid, or incur an expensive extension.

Risk of outages:

Mains is reliable but not infallible. If it's your only source of water you'll be in all sorts of trouble when it's down.

Sustainability and resilience considerations:

Although our national water supply system is a brilliant achievement of modern civilisation, a lot of energy, technology, materials and infrastructure go into keeping the taps on and making the water potable. Building your own system avoids buying into an unnecessarily purified product pumped across miles of countryside.

On the positive side, mains water is guaranteed potable so it's great for washing produce and people as well as keeping everyone hydrated. If you are overhead watering fresh produce, particularly when close to harvest time, you need to be confident that your water supply is clean. Adequate filtration and/or UV treatment can be complicated and expensive so drinking water may be the best option.

www.lws.uk.com/Resources/Technical-Documents/water-regulations

https://www.waterregsuk.co.uk/

2. Water tanks

These could range from a 1,000 litre intermediate bulk container (IBC) to a 500,000 litre purpose-built, rubber-lined, **galvanised steel** storage tank. If the water is separated from the natural environment in a purpose-made container, we will define it as a tank. Your minimum tank capacity should be enough for about one day's maximum usage – 15-20m^3 per 4000m^2 growing area.

A tank is obviously useful for storing harvested rainwater but is also handy for filtered borehole or abstracted water, particularly where the direct pressure or flow is insufficient to run the irrigation. In such cases tanks can gradually fill over time so sufficient water is available on demand.

Where mains supply is high-pressure but low-flow (a common issue), a tank is used in a similar way. In such an instance, a **non-return valve** must be fitted to the incoming main and the outlet should not be in contact with the maximum level of the full tank. By physically separating mains supply water from the irrigation tank contents, risk of contaminated back flow is avoided. Mains water stored in a tank should not be considered potable unless the tank and ensuing pipework has been specified for potable water.

Benefits over a reservoir:

- Water is easier to keep clean; a lid/cover will keep out light (which encourages algae) and debris
- All the water is available to use (most reservoirs need an amount left if the ecology or clay liner is to be maintained)
- Leaks and damage are easier to identify and repair
- Known capacity is easier to estimate (how much has been collected/is available)
- More space efficient (vertical sides)
- Clarity on who owns the water
- Reduced evaporation/soakaway losses
- Can be used to store water from a variety of sources
- Capacities up to about 100m^3 are relatively easy to self-install

Rainwater storage inside glasshouse at Hankham Organics

Photo: New Leaf Urban Farmers

Pallet-mounted IBC's for rainwater storage, collected from a polytunnel

Drawbacks:

- Compared to a reservoir the potential capacity is limited
- The sides can be damaged when empty, especially by snow if a fabric cover is fitted
- Larger tanks with diameters over about 14m need a steel lid as the sides stop being self supporting
- They have a finite lifetime so panels, liners, outlet and covers may need replacing, especially if exposed to the elements
- Larger tanks (>10m^3) will require a thick, reinforced concrete base
- The contents can get warm during summer if not being used and replaced, this encourages algae and compromises water quality. Unless light is excluded and the contents are well filtered before entering, this is not the best way to store water long term although cycling the water to filter it and keep it aerated, as in a swimming pool or fish tank, is an option

Generally speaking a water tank is probably the one 'no brainer' in an installation. They are relatively cheap, easy to install and can be used as the hub into which any water source can be delivered and from which the main pump draws. If you are setting up a new market garden, I recommend that you get a tank and build the rest of the system around it. Things are definitely more complicated without one.

3. Rainwater harvesting

Fresh rainwater is the best for your plants and will offer a very low risk of contamination, assuming the collection surface is reasonably clean. Storage is clearly important as (with the exception of protected/ greenhouse spaces) the need to irrigate is coupled with lack of rain. If there is inadequate storage, rainwater collection can be a fairly pointless exercise for larger growing areas.

Photo: New Leaf Urban Farmers

Retro-fitted water harvesting from polytunnel

This is one aspect where doing the maths is really important. Try to estimate the cost and effort of harvesting rainwater in light of your roof area, potential storage capacity and expected rainfall then compare this to other options. The best scenario is a) significant storage potential and/or b) significant collection area.

Any non-porous, roof-like area can be used to harvest rainwater, the larger and the higher the better. The guttering and pipework should be of an appropriate capacity to ensure maximum collection from high rainfall events and be checked regularly for debris and blockages that could negate all your brilliant design work when there's a lovely summer deluge.

Estimating the volume you'll collect is pretty straightforward, calculate the roof area as if it was flat (not the surface area of the sloped sides). Refer to data from your nearest local weather station to estimate how much you would expect over an average summer. The Met Office provides data from as far back as the 1850s (though mostly from the 1950s) to the present day for a range of stations across the country.

www.metoffice.gov.uk/research/climate/maps-and-data/historic-station-data

Float switch used to automate tank filling from rainwater storage, Hankham Organics

Sand filter installation for stored collected rainwater filtration, green filters are in paralel followed by the red filter which contains sand and ground biochar.

Specify your storage tank to maximise capture of summer rainfall events rather than attempting to store winter rains into the summer. Storing large quantities of stagnant water in tanks during the summer risks encouraging algae so a naturalised reservoir is better for long-term storage (see above 'Water Tanks').

Once rainwater hits the ground or a natural drainage channel you no longer have the automatic right to use it. It will come under the same regulations as that in a waterway (see **abstraction** below). If you can keep it in your own pipework until it reaches the storage it clarifies your right over it.

www.gov.uk/government/publications/rainwater-harvesting-regulatory-position-statement/rainwater-harvesting-regulatory-position-statement

4. Open reservoir

Photo: Phil Sumption

Reservoir at Gosberton Bank Nursery (Seed Co-operative)

If there's one thing that gets people excited about water storage it's the idea of a lovely big reservoir complete with weeping willow, lily pads, croaking frogs and a dilapidated rowing boat tethered to a creaky wooden pontoon. Well, this may be possible but if you plan to use the water it had better be kept topped up or a mosquito-ridden mud hole is the more likely scenario.

If you employ people or invite the public onto your land, it should be well fenced and a life-ring and 'Deep Water' signs placed adjacent to avoid any issues with health and safety.

The sad reality is that unless you already have an established spring-fed lake or are prepared to go fairly big (>2000m^3), a reservoir may just become an expensive, open-topped tank. This will increase challenges regarding public safety, water quality and surface evaporation.

If you do decide to create one you should give prior notification to the local authority on a template plan and if well located it should fall within PDR (permitted development rights). You can receive 15 hours of free advice from the Environment Agency.

For small to medium-scale growers the scale of a useful reservoir isn't going to be more than the 25,000m^3 above ground level (that is the amount of water held above the original ground level held behind raised banks) classifying it as a large raised reservoir covered by RA75 regulations. It's even unlikely to be 10,000 to 25,000m^3 which is classed as small and presently unregulated beyond the initial planning and construction stage. These sizes relate to the 'above ground' capacity relevant to the damage that would occur should a bank collapse.

For water stored at and below ground level, regulations are just a local planning issue so make sure you get people on side and site it respectfully.

Unless you are on heavy clay or wetland the reservoir will need either a plastic or clay lining and construction should be done by an experienced professional. Plastic costs around 40% more than clay lining[2], plastic can be punctured more easily but clay may crack if it dries out and tree roots can grow through it.

Dug out spoils should be kept near to the reservoir. If used to raise the bank height the angle of the banks must not exceed 45 degrees or the slippage of the material, whichever is less. The capacity needs to be about 50% larger than the maximum volume you plan to use.

Building a reservoir is a serious project so get good advice, go as big as you can afford and find a contractor who has experience and testimonials to back it up. Find out if anyone locally has recently created one, go and visit and ask as many questions as they are prepared to answer.

Pumping water out requires a permanent installation and a floating suction inlet or floating **foot valve** is an option. This is covered in the next section.

The 20m^3 daily abstraction limit applies to reservoirs, even if you own it and have captured all of the water from your own land. If your cropping area is larger than 0.6ha you may need to exceed this in a dry season so consider applying for an abstraction licence.

www.gov.uk/guidance/reservoirs-owner-and-operator-requirements

2. *Thinking about an irrigation reservoir? https://tinyurl.com/EA-Reservoir*

5. Local watercourse

If a water course runs through your land, you own it. If it forms part of your boundary you own it up to half-way across. Technically the water is not yours, it's just passing through, but you are permitted to abstract up to 20m^3 /day without a licence. If you require more than this, yes you guessed it, you'll need to apply for an abstraction licence from the Environment Agency.

Local water can be used to fill a tank, reservoir or used directly via an appropriate type of **sprinkler**. Sprinklers and spray line will require some filtration, this will depend on the quality of water being abstracted.

Water quality is an issue, particularly with rivers, so pumping it to a storage point via filtration is recommended. This type of water source should be limited to irrigating fallow land, newly sown or freshly planted crops unless the quality can be guaranteed suitable for mature crops through effective anti bacterial filtration such as UV or reverse osmosis. There is a risk you are importing not only human pathogens but also plant and soil diseases.

The best use of this source is to top up a storage installation at a time when water quality is good and the quantity plentiful, though realistically few people will have the capacity to store all their year's water needs.

If there is a public path or highway between your water source and delivery point it can complicate things but generally there are three options:

1. A submersible pump sending water through a temporary, above-ground poly-pipe or 'lay flat' hose to the delivery point.
2. A Power Take-Off (tractor) or mobile petrol-powered pump with a suction hose and **foot valve** in the watercourse, delivering as above.
3. A semi-permanent pumping station in secure housing with a buried poly pipe delivering the water. The pump may be submersible, petrol or electric powered but should be suitable for some particulate matter and able to supply the volume and pressure required.

Submersible pumps and **foot valves** can be kept clear of the mud or debris by caging them in a large submerged mesh housing. You can build one from plastic or wire mesh and check it regularly to keep it clear of blockages. As this type of set-up is more prone to becoming blocked, ensure any electricity supply runs via an overcurrent device which will turn off the pump if it is struggling.

Photo: Phil Sumption

4. Boreholes

Photo: Adam Payne

Sinking a borehole at Southern Roots Organics, Pembrokeshire

Growers, out of necessity usually, tend to undertake most work 'in-house' and soon become Jacks and Jills of all trades. If there's one place to draw the line it's drilling a hole deep into the ground. This really is a job for the professionals and even in the investigative and research stages there are serious limits to what you can usefully achieve.

There are a variety of things you can do to work out whether this is a serious proposal. Consider all the other options based on availability, cost, resources, time and energy. If they seem unrealistic a borehole may be for you. Certainly, once you have a successful well it is the most reliable option year round and if properly treated can be used as drinking water and for general domestic use.

Next you need to go to the British Geological Survey (BGS) website and have a look at their 'GeoIndex' maps (navigate to 'onshore map viewer' then 'boreholes') to see how many boreholes are already in your area. This will give some clue to the local popularity and viability and you may even find a friendly neighbour who you can go for a chat with. BGS can prepare an initial prognosis report and you can also order a geological map of your area for £30 which every self-respecting grower should own, even if you have no idea what all the pretty colours mean. You should also check if you are in a protected zone. This is more relevant to waste water and contamination than abstraction but worth knowing.

Before you contact a drilling company think about access for large machinery as this may dictate the siting of a borehole. It may need to be a Summer job if you want to locate away from a hard track. Under Section 32 of the Water Resources Act, The Environment Agency needs a groundwater investigation consent (GIC) form notifying them that you intend to investigate and you need to notify the BGS if you intend to drill deeper than 15 metres.

Be aware that drilling companies are unlikely to say 'it's not worth it', more likely they'll say 'we'll keep drilling till we find it' so be very clear about your financial limits and the risk you are taking. Once the drilling goes deeper than about 5m you will start to get wash-out building up which needs disposing of. They usually use an additive to assist in drawing up the substrate (E.g., polyacrylamide) which you may or may not be happy with being dumped on site so check this out with the company beforehand.

Of course there is water once you get below the **water table** but there isn't any guarantee that the available quantity and quality will be what you need and the cost of investigation will be the same. Some areas have much higher success than others so if you are in the unknown bracket you are taking a higher risk and even if your friendly neighbour has a successful well you may still encounter issues.

Quantity: There will be a 'recharge rate' meaning that once a source of water is found it will have a maximum amount that can be drawn. This can change over time but if your needs are modest it shouldn't be an issue if the investigation has been done properly. Anyone intending to abstract more than 20 cubic metres per day from a groundwater source needs an abstraction licence.

Quality: Some filtration will be required and perhaps pH adjustment (acidity can be high). If there are metals present or bacteria this could be an added expense with a reverse osmosis system and/or UV treatment.

The pump and headworks can be installed by the drilling company and will need a source of power. Basically, once you've decided you want to try for a borehole it's a job for the professionals and you are in their hands. So find a reputable company and agree on all cost scenarios beforehand.

www.gov.uk/government/publications/water-supply-borehole-construction-and-headworks-guice-to-good-practice

www.gov.uk/guidance/groundwater-source-protection-zones-spzs#find-groundwater-spzs

www.gov.uk/government/publications/apply-for-consent-to-investigate-a-groundwater-source

PART 2: TRANSFERRING AND APPLYING WATER

Having considered various sources and storage installations in the last section, we will move on to the parts required to connect these and get the water where it is needed. Looking through the website or catalogue of a supplier will reveal a baffling range of pipes, pumps, fittings and other gizmos. There are a few key things to consider which will narrow down your choices as follows:

Overhead and drip irrigation both have their uses in the greenhouse. Hankham Organics

Are you extending a mains (public water) supply or building a completely separate system? If extending the mains you should involve a professional plumber who can at least advise on the correct fittings and backflow protection. This was discussed in the previous section and will affect the type of fittings you purchase and the importance of correctly installing them.

What is the maximum volume of water (flow) and pressure requirement your system will demand? This will be based on the area to be irrigated, distance/height water needs to travel and the type of application equipment.

You can do a quick flow calculation based on your whole cropping area receiving 20mm of water in 20 hours. This may not be very accurate but is close enough as a starting point as it assumes four hours of watering per day for five days (more details in the next section). For 0.4 hectares (1 acre) this would be 80m^3 so your system should be capable of moving at least (80/20=4m^2) 4000L per hour.

Most small, local systems with appropriate diameter pipework can operate well at 2-3 bar. If you have further to pump, larger **sprinklers**, narrower pipework or a gradient to work against this will need to be higher. These considerations will influence decisions such as tank size, type and capacity of pump, pipework and fittings you select and perhaps even the number of valves and sets of application kit.

Are you creating a permanent system or a temporary (seasonal) set-up? This will determine the level of **freeze protection** and type of fittings and pipes you may choose.

Who will be using the system and will it be easy for them to operate?

How many outlets and what type of valves and connectors will you use?

What sort of working hours are you putting in and will you be able to water everything on top of your other work?

Also think about how you want to prioritise aspects like time, energy, money, crop health, space and resource use. Your informed choices in the design stage will allow you to focus on what's important to you and your system.

Modern irrigation is generally plastic but **galvanised steel**, brass and aluminium fittings are also available. These are generally used where structural strength is required but are becoming less common due to the higher cost. **Galvanised steel** pipes are recommended for entry and exit from larger pumps and tanks and also downpipes/standpipes where mechanical damage is a risk. Brass is mainly used for valves and quick-fit connectors where a combination of strength, moving parts and rust resistance is required. For the main part I will be concentrating on the range of plastic materials available.

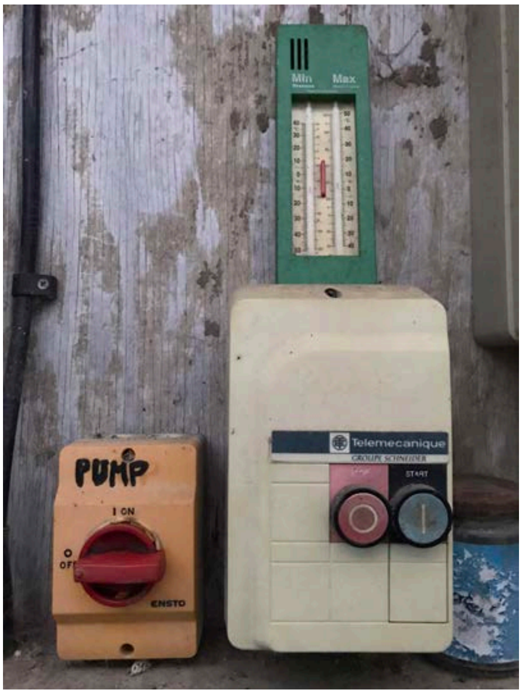
Design

Whether looking at how an existing system has been designed or thinking about designing one yourself, there are several key factors to consider:

- **Freeze protection** - water expands when it freezes. This can cause serious damage to pumps, pipework and other components so systems should be designed to be frost proof, either insulated (E.g., underground) or fully drainable. Drainable systems should have a drainage valve at their lowest point.
- **Air bleeding** - the ability to vent air pockets from the highest point of the system as well as avoiding areas where air can become trapped. A pressurised airlock can stress the whole system, damaging weaker parts. This occurs as a jolt (water hammer) when air rapidly expands/contracts as taps are opened and closed. Water cannot be compressed so if all air is removed from the system the whole thing will operate much more smoothly.
- **Pressure** - the fixtures and fittings need to be suitable for the water pressure and pressure should be maintained through the system when in use. Pressure will be determined by the pump and **head** (height of supply over delivery point) or mains supply. Some equipment is designed for low-pressure applications, useful if you are relying on gravity but if you're not it may need protection via a pressure regulator. See the Glossary for more details.
- **Flow** - This is again dictated by the pump or mains specifications but is reduced over distance due to the **friction and turbulence** within the pipework. Use a wider diameter pipe for long distances, see the Glossary for more details.
- **Coverage** - delivering water to a bed of crops evenly and effectively requires the correct spacing of **sprinklers/ drippers** and awareness of the volume being delivered.
- **Access** - at some point part of the system will need a repair or alteration. The easier you can access it the better so burying pipe-work under concrete, behind tanks and buildings or within hedges is best avoided. Pipework should not hinder daily activities so a balance needs to be found.
- **Compatibility** - fittings may be in metric or imperial measurements, there are also specific brand types and standard parts so if adding to an existing system check which you need.
- **Isolation** - ensure plenty of isolation points, i.e. valves that can be turned off. If a pipe bursts or you need to make alterations you may be able to avoid taking the entire system out of action.

Pressure guage


In-Line pressure reducing/restricting valve



Pump DOL (Direct On-Line) starter and overcurrent device

The next section looks at various components including:

- Pipework and connectors
- Pumps
- Filters
- Application kit
- Other fittings and relevant information.

PVC** 50mm **union

Pipework and connectors

In terms of placement there is a choice between underground, overground, or a bit of both. If coming directly off a mains supply or pumping for any distance outdoors, it is best to go underground. Outlets and valves can be at ground level, buried in access boxes or as rising stand pipes. Protected crops may require overhead-watering systems which have to be permanently overground. As long as an overground system has been correctly designed (i.e. isolating the installation and opening up all taps and valves drains it out), damage can be avoided. It also ensures full access for maintenance and saves a heap of digging.

*Brass quick connector threaded to poly **compression fitting** on 32mm **LDPE** pipe.*

The supply pipework can be designed as a radial or ring system. Radial has a starting point (pump) and an endpoint (furthest outlet). A ring has the advantage of maintaining even pressure around the whole system, perhaps requiring more pipe length (there and back) but of potentially smaller diameter. The decision will likely be determined by your site layout. If you can easily create a ring main it is desirable.

The commonest pipes in use are **MDPE** (Medium density polyethylene). You may also find **HDPE** (high density) and **LDPE** (low density) which are respectively stiffer or more flexible. Blue HD and **MDPE** are used for mains, potable public water. Black is for non-mains 'internal' supply and both use screw-on **compression fittings**. **LDPE** is used for smaller pipes and micro irrigation setups and uses barbed connectors.

*Quick fit connector into 32mm **MDPE**.*

For protected areas **PVC** is usually used (polyvinyl chloride). It's not the most environmentally benign material, but certainly widely available, reasonably affordable and easy to use. **PVC** pipework and fittings are rigid but brittle, so require adequate support. **PVC** fittings are glued together to form a permanent fixture above ground, thus the design stage is very important.

PVC pipes

Tubing is usually 32, 40 or 50mm. Fittings can be purchased in imperial measurements if repairing an older system; but use metric for all new set-ups. Full lengths can be run end to end as they have an incorporated socket. Otherwise connectors will need to be fitted with sockets, **elbows** and **tees** used to route the pipes. **Unions** (which join at a sealed flat surface rather than insert) can be used either side of equipment to allow easy removal, such as for filters. They are also useful when adding or repairing sections if the pipework cannot be easily moved.

*19mm **LDPE** Manifold to barbed **Tee** with 1/2" threaded branch to a director for drip line connection*

All joins must be glued with proper **PVC** adhesive which forms a weld partially melting the bonded surface. I would recommend completely building a section at a time, cutting and pushing fittings together before glueing to ensure it all fits. Insert pipes into sockets as far as they will go, this will ensure a good surface for adhesion. Use a recommended cleaner before glueing, wear rubber gloves when using these substances as most others melt and the solvents are pretty nasty. The glue does not work well in low temperatures (under about 4°C), which is annoying because a frozen day when the system is drained is otherwise an ideal time to do this.

Cut tubing carefully with a large hacksaw and remove any rough edges, quickly clean both surfaces to be attached using a lint-free cloth and always replace the lid on the cleaner as it is highly volatile. It is good to prepare several fittings and clean them at the same time.

When ready, begin sticking pieces together by applying adhesive to both surfaces, completely covering the areas that meet. It is better to go on the liberal side but avoid pushing excess glue into valves. The bond sets very fast, especially in warm weather. Once committed to pushing the fittings together do it quickly and firmly, ensuring any angles are positioned correctly before it sets.

Standard sprayline comes in 4.5m or 5m lengths, pre-drilled for **sprinkler** heads with either an M11 or 1/8 ww thread (which tapers so that the insert tightens up, be careful not to over-tighten).

There are a range of **sprinklers** available to use with **PVC** overheads. It is important to keep it simple and consistent so find out what other growers are using and get free advice from sales reps and the Internet. Inverted bridged rotor **sprinkler**s are pretty standard.

PVC pipe must be well supported and a tensioned wire is suitable for directly tying onto or hanging from (wire hooks can be made or purchased). Support it well to ensure it does not sag when carrying water. Warped pipes, once exposed to sunlight for a season, are very difficult to re-straighten.

HDPE/MDPE

Use blue pipe for all mains/public water supply. Connectors should be WRAS approved if using for potable water. If only for irrigation the black pipe and non-approved fittings are much cheaper but refer to the previous section on mains water supply as separating irrigation systems from public potable water is a legal requirement and water companies are becoming more strict on this (despite the fact they can't keep raw sewage out of our rivers and seas). Useful diameters available are 20mm, 25mm, 32mm, 40mm and 50mm.

Various designs of compression connectors are available and they all involve placing the screw-on cap and grip washer over the cut end of pipe first, then inserting this into the connector and ensuring it pushes past the sealing washer to butt up. Reinforcing inserts are sometimes recommended to strengthen/ seal the cut ends, especially for higher operating pressures. Push the grip washer up to the connector, then screw the cap on tight. Some models advise using a wrench to tighten, while others require only hand-tightening and may be damaged by over-doing it. For overground installations ensure the pipe and connector materials are sold as UV-stabilised.

Saddle clamps can be used to create a branch without having to cut and dig up a large section of pipework. Ensure the hole size drilled is correct and neat and it's worth using a little squidge of silicon to create a good seal, especially with old or scratched pipework.

LDPE

This is usually used for micro irrigation and to connect supply pipes to **sprinkler** heads. It is not recommended for use with mains or high pressure systems. It is robust but flexible and 19mm is useful for creating manifolds to supply drip lines and mobile micro **sprinkler** sets. These require simple barbed insert connectors.

I have found that the prices of similar fittings range enormously. This seems to depend on popularity, so the commonest fittings are very cheap. Often, money can be saved, for instance by using a **tee** and stop-end rather than an **elbow**. On cold days a thermos of hot water is useful for softening the ends to insert connectors. If your supply pressure is much over 1 bar, **hose clips** can be used to secure pipework to the fitting or a pressure regulator can be used to prevent connections from popping apart.

With the range of micro irrigation systems on offer there is some discrepancy in sizing which is less of an issue with the other pipe sorts. As 13mm may be internal or external diameter, don't assume other fittings will be a perfect match. Trial and error is the only real way to find out as this smaller pipework has no standard parts and even reputable brands can use questionable sizing.

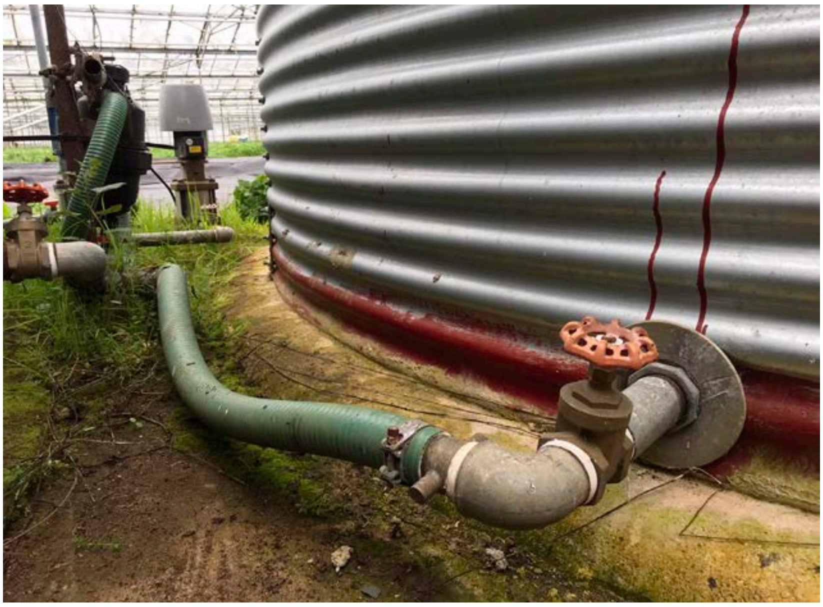
Hoses

A hose is any reasonably flexible pipe but usually refers to a highly flexible and durable type designed to be regularly moved, coiled and trampled on, such as Tricoflex which is constructed from three layers of material. Diameter 12-15mm or 19mm is normally used. For longer runs and/or low pressure systems, use the larger diameter.

Manifold hose used to connect drip tape

Flexible hose is used to connect from your permanent supply outlets to temporary mobile application equipment or hand-held lances. It can also be used to connect to **PVC** overhead, saving the need to allow for freeze drainage of a permanent system.

It is essential to have a quick and easy way of connecting these to outlets and various models of plastic and brass quick connectors are available. For market gardens a robust and durable brass fitting works best, Genuine Geka fittings are great. Once you have decided on a type of quick connector, try and stick to the same make as seemingly similar fittings from different manufacturers tend not to fit together well. It's worth pointing out that these fittings won't come apart easily under pressure.



Green suction hose from tank outlet via disc filter to pump

For those who manage it the reward is a good soaking, so turn off taps and release any pressure before disconnecting. A **hose clip** will be required to hold a hose end connection onto the hose.

Other types of hose include 'lay-flat' and suction. Lay-flat hose fills out when used but can be rolled up into an amazingly small reel compared to the same diameter poly pipe. It is not suitable for permanent or buried pipework but great as temporary transfer hose.

Suction hose is a type that will not close up or kink and inhibit flow when under negative pressure. Used on the suction side of pumps the fittings need to be particularly well sealed to prevent air being drawn in.

Pumps

Working out the pump type and capacity requirements may be the most important decision of the whole design. You'll need to know the pressure of the water source. Is it lower than the pump, so needs suction, or higher providing sufficient pressure to stay primed? You also need to estimate the flow required in the system and the pressure required to run the application kit. Most modern pumps are centrifugal, meaning they contain a spinning impeller to move fluid from either the centre to the periphery or up through a vortex-like chamber.

There are five main types of pump used in horticultural irrigation. They offer a range of powers and an infographic showing how flow reduces, depending on head, will be available in the technical info.

Pump	Power source	Flow	Pressure	Water quality	Typical use
Vertical	Electric (1 and 3)	Med - high	Med - high	Clean	Medium to large horticultural/agricultural irrigation. Fixed position.
Horizontal	Electric (1 and 3)	Low - high	Low - high	Clean	Small to large horticultural/agricultural irrigation. Fixed or semi-mobile position
Submersible	Electric (1)	Low - med	Med - high	Dirty	Bringing water up from a borehole, well, tank, river, reservoir
PTO-mounted	Tractor (Diesel)	Med - high	Med - high	Dirty	Mobile transfer for abstraction, tank filling, direct irrigation
4-stroke	Petrol	Med-high	Low-high	Clean/dirty	Mobile transfer for abstraction, tank filling, direct irrigation

Horizontal pumps are ideal for smaller systems and are good value, particularly the units incorporating a pressure switch and **expansion vessel**. This allows the pump to be left active so it will run on demand when a valve is opened and the pressure drops. The expansion vessel prevents stress on the system, buffering the changes in pressure as it switches on and off.

Pressure is maintained in the system within a selected range. A wide range will mean the system cycles between a max and min pressure and can be annoying when using application kit. A narrow range keeps the pressure more consistent but also means the pump is switching on and off more frequently. It's worth soundproofing the pump shed if it is positioned near working areas, this also doubles as **freeze protection**.

*Horizontal pump with **expansion vessel**, intake filter and automatic pressure switch set-up in a plastic garden storage box. The Montessori Place.*

Horizontal pumps are commonly self priming so can cope with modest suction requirements and a few bubbles in the system, depending on the spec. The range of this type of pump has increased over the years as they seem to have become more popular than vertical pumps.

Vertical pumps can be set up in the same way but the components need to be sourced separately and assembled, which requires some electrical know-how. More commonly these pumps are set up to run continuously when switched on with excess pressure being shed via a PRV (**pressure release valve**) back into the tank. These tend to be used where more power is required and as such are fixed down to a base plate with sturdy steel pipes at the entry and exit points before converting to **PVC** or **poly** pipe.

They are used for higher flow applications as they are so efficient, especially if run off **3-phase**, but need to have minimal restriction to flow on the suction side. They don't operate well when significant suction is required or any air enters the pipework and have a small bleed screw halfway up to release any trapped air from the impeller.

Submersible pump

Submersible pumps are used for abstraction in boreholes, wells and from rivers, reservoirs and tanks where water needs to be pushed against a gradient. Centrifugal pumps work by pushing and have poor suction power, so if you need to draw water up any distance the pump is best placed at the lowest point. Submersible pumps are designed to be completely waterproof and will deal with some suspended solids (quite a bit if you spec for it, though who really wants to have to deal with sludge?).

Most, with the exception of borehole pumps, have a float switch attached to ensure they don't run dry. This is a simple device which inverts when the water level drops, cutting off the power supply. These devices can also be procured separately to use in tanks, in this case the switch will stop a submersible pump from filling the tank when the tank is full (e.g., when pumping up to a holding tank from a borehole). As the tank empties the float switch inverts and starts the pump again.

*Vintage Vertical Pump with galvanised steel pipework, **gate valves** and brass NRV. **Expansion vessel** in the background.*

PTO and 4-stroke pumps are both used in a similar way, they are usually robust and able to cope with some dirt in the water but always check this. On-farm use is usually for pumping from a local water source, either direct to crops or to fill a tank/reservoir. They generally have good suction and self-**priming** characteristics and some control of power using the motor throttle.

Gravity isn't exactly a pump but it will do the same job. For every 10m of elevation you will get 1 bar of pressure (see glossary).

Filters

Disc filter overdue for a clean

Simple filtration units for removing particles can be placed in-line with pipework. These vary in size and capacity depending on the pipe diameter and water flow but come in two types, mesh and disk. Disc filters last longer, cope with high pressure and are easier to get clean but are less accurate where a particular screening size is required.

For the filtration of larger quantities of dirty water a suitably sized sand filter set-up can be used. These can be a simple container which water filters through under gravity. More generally it is a rounded metal tank with water moving through sand under pressure. As the sand collects filtrate and the flow starts to reduce, the filter is backflushed to remove the filtrate. Sand filters will remove most of the suspended solids highly effectively. Secondary filtration will be required if salts, heavy metals, bacteria or very fine particles need removing completely. Where water needs to be guaranteed free of bacteria, reverse osmosis or UV filtration will be needed.

Application kit

This can be divided into two types, those that mimic rainfall (**sprinklers** and sprayers) and those that trickle at the soil surface (drippers and soaker hose) .

A further division into Macro and Micro irrigation is usually made. For market gardeners, either may be deployed for different reasons and as long as they are used at the appropriate pressure they will do the job.

Sprinklers and sprayers:

The types commonly deployed in market gardens need to be robust, easy to move about and provide an even coverage and adequate quantity without exceeding the soil's absorption capacity. They should also ensure accurate watering so different crops are not adversely affected and there's minimum spread to to non-cropping areas.

Field sprinklers – 9m radius, 350Lph – with 180° deflector, used to water-in newly planted leeks

As most growers use a row cropping bed system a supply pipe is run down the row with micro tubes coming off to **sprinkler** heads on a rod or stake. These will provide an even application to several beds all the way down the row and the **sprinkler** head specification can be selected depending on the normal cropped area or rotation block. The smallest heads apply at a diameter of around four metres with larger units going up to 25m. Above this **sprinklers** tend not to be used in a line as the power knocks the stakes over so they are operated individually from a hose reel traveller or a stable tripod or skid base.

*Field **sprinkler** unit with road deflector (180 degree spray)*

Generally larger diameter **sprinklers** are less suitable for small scale growers but the impact type can be really useful as they can be adjusted to a 90 degree angle and set up on corners facing into the plot. They are less ideal for bare soil watering as the droplet size is large and can cause structural damage to the soil surface. Once there is good leaf cover they work well.

The smaller units tend to be sprayers in that they disperse via a deflected **jet**. They have rudimentary or no moving parts but as the **nozzle** size is quite small are easily blocked and require adequately filtered water. They do however create a fine droplet size, this is great for watering bare soil but can be affected by wind blowing the spray about. This is known as '**spray drift**' and can be partially offset by reducing the flow or pressure.

Rotor **sprinkler**s have better wind resistance while still creating a droplet size suitable for retaining bare soil surface structure. They have a larger **nozzle** size which is directed into a jet that spins around.

Most systems have a type of quick-fit connector which joins the **sprinkler** unit and tube to the supply pipe. They may be push fit, twist in or a sliding lock type and tend to vary a lot between brands and over time. They do allow for quick dismantling, moving and reassembly but make sure you keep these fittings clean as you move kit around. This is quite tricky so it's worth carrying a cloth to wipe muddy connectors before fitting them back together.

*Micro **sprinkler** and stake statement (60L/ hr). The Montessori Place*

Have a proper look at the range of sprayers and **sprinklers** available from your supplier, bearing in mind operating pressure, radius or diameter of coverage, application rate and how easy they are to assemble and move about. For small plots where an area of similar crops may be only 100m^2 a micro **sprinkler** set run from **LDPE** supply pipe will be suitable. As the crop area increases the pipe diameter and **sprinkler** size will also need to increase if you want to avoid multiplying small irrigation sets and the painstaking work moving them. It is a balance between working out the optimum area you want to receive the same treatment and the amount of kit and/or work you give yourself. As the crop area scales up, so does the equipment.

Supply pipes up to 32mm are ok to coil up and move around providing you are getting perhaps 15m width from the irrigated band. Above that pipe diameter they become quite awkward and alternative systems should be considered.

The two main options are solid set pipe and **sprinkler** units and reel and boom sprayers.

Solid set systems incorporate a riser and rigid supply pipe which clip together end to end, they are a great investment for larger growing areas.

Reel and boom sprayers are moved about and positioned by a tractor (smaller versions are available). The reel is set up on the headland facing the beds and connected to a water supply (these systems need a decent pressure and flow). The boom is connected to the reel hose and pulled to the opposite end of the beds using the tractor where it is unhitched. The boom is then slowly pulled over the crop area by the reel winding it in. The power to turn the reel can be a small electric motor or combustion engine but more commonly is provided by a turbine running off the irrigation water flow, thus transferring the power requirement back to the pump. For obvious reasons these systems can have their limitations in mature crops.

For protected cropping, as already mentioned, PVC overhead lines are commonly used, but mobile micro **sprinkler** sets can be just as good if you don't mind the work and don't want the extra infrastructure and dodgy plastic.

Lastly on the subject of spray lines, there is a type of hose called spray or **sprinkler** hose that has small holes on the upward facing side. It is possibly the simplest method but leaves can block the upward spray jets.

Photos: Iain Tolhurst

Reel and boom sprayer in action at Tolhurst Organic

Drip Irrigation

The benefits of using drip irrigation for water efficiency cannot be overstated. Claims of 70% reduction in water use compared to sprinklers seem dramatic but they're not unrealistic when you consider that the water goes directly to crop roots and never sits on the surface, subject to evaporation. On the down side, the pipes can interfere with weeding and cultivation operations and once set up, aren't usually moved until the crop is pulled out. This means it's not so practical for short term crops but worth considering for perennials and crops grown through mulches or ground cover, or for protected crops that need constant watering.

Drip line set-up to water under sheet mulch

There are four types:

Soaker hose or leaky pipe is made from a perforated, flexible, rubber material that is great for smaller areas and around perennial crops. It has a reputation for uneven watering which is probably due to the lack of **pressure compensation** along long lengths or on slopes. If set up correctly with a pressure regulator (0.5 bar) and short (<25m) lengths following contours, it should work fine.

Drip tape to squash, not normally required but this was an exceptionally dry season.

Drip tape comes as a flat-reeled and thin-skinned pipe and doesn't cope well at pressures over 1 bar so needs a regulator. If looked after it can do a few seasons but is generally a disposable type (it's difficult to know whether the total plastic use compared to thicker-walled pipes is any greater as they are so thin - more research needed). Each tape system has its own type of connectors with a range of brands, sizes and qualities which makes it difficult to keep track over the years. If you are happy with one, make sure you have enough to last a while.

Bursts or rodent/hoe damage can be fixed by cleanly cutting the tape and inserting a correctly-sized connector. If you find your connectors leaking due to ordering the wrong type, a little wrap of **PTFE** tape around the barbed end can do wonders until you source the correct ones. The ends of drip tape can be tied off.

Drip line is a smooth and robust hose with inbuilt emitters that can operate at higher pressures. It costs quite a bit more than tape but I am still using sets that were built 20 years ago. If the water is clean and they are occasionally flushed out there's no reason they shouldn't last even longer. It is easy to set-up and roll away and the emitters are pressure compensated so it will work on slopes and over long lengths.

Compared to the previous types the emitters are at a wider spacing along the pipe so coverage is less even.

Sealed drip line emitter

This makes it fine for established crops or those with extensive root systems but I have seen visible differences in quality along rows of young peas and beans depending on being near or in-between the emitters. Drip line can be folded and tied off at the ends or use a **stop end/end cap** if you're posh.

Dripper nozzles/feeders are pierced into a plain 13mm **LDPE** pipe at the required spacing. The **nozzles** emit directly out of the pipe to the soil and adjustable types are available. Feeders can be set up further from the pipe via a microtubule and stake. This allows for a more bespoke set-up including feeding direct to the roots of larger crop plants such as fruit bushes or even pots. They are more difficult to roll up and store though and not usually suited to vegetable growing.

*Micro-**sprinkler** establishing protected crops before drip line is set up*

Drip irrigation can be built into manifolded sets to cover beds or supply a series of rows. There are various ways of doing this. Some systems have their own header pipe designs but using ½" threaded connectors to join the drip pipe end connector to a series of T connectors along a 19mm **LDPE** pipe can create a decent reusable manifold, sized to your bed system. Lastly all pipes can move around with the expansion and contraction caused by hot sun then cold water. This is more of an issue with dripper pipe so it is worth making some hoops out of wire to pin them down. They can be kept slightly taut by securing the manifold then tying back the opposite end to a stake with expandable elastic or a rubber tie.

Other fittings and relevant info

Most types of irrigation systems can be made compatible, Threaded BSP (British Standard Part) fittings enable all different types of systems to be joined with a common connection. The trouble with threads is they need to be twisted on (not much good for long hoses/pipework) which tends to limit their use to permanent installations.

However nearly all systems have **BSP threaded** options, so with a bit of imagination just about anything can be united including **galvanised steel** pipework to both PVC and Geka fittings, PVC to **MDPE** compression connections, to branch off 19mm **LDPE** manifolds to dripper lines and join different sizes of all sorts of pipes. It is important to make a good seal using plumber's **PTFE** tape. This should be wound flat around the thread in the same direction as the thread would undo (i.e. clockwise looking at the end). Use at least six layers, more for metal to plastic joins.

If you're thinking about using second hand equipment check what condition it is in - whether spares are still available, it's compatible with **BSP threads**, suits your way of working/system/crops, and hasn't had any nasties put through it. It is good to reuse and recycle whenever possible but fixing old crappy gear can be a real pain when you are trying to water, harvest, sow, plant, weed, pack, and deliver all in the same day.

Automation systems are beyond the scope of this guide but outlet tap timers are available and an easy way to ensure the correct quantity is applied or set up for weekend watering.

Always test for leaks before burying, clamping or tying in your new or repaired installation. An easily-visible pressure gauge is useful as it will show you if the system remains pressurised, so you know if you are losing water somewhere.

Finally, a word about suppliers. eBay and Amazon are very useful in emergencies but it's best to find an established reputable company, ask a rep. to visit and create a working relationship with someone you can talk to in person and will stand by the quality of their products. They should be able to supply what you need at short notice if you are a regular customer.

PART 3: WHEN TO WATER AND HOW MUCH?

Photo: Adam Beer, Pitney Farm Market Garden

It is really important to know how much to water your crops. It's not just a matter of being efficient. Over or under watering crops can have profound effects on crop and soil health and an opportunity to optimise growth can become quite the opposite.

Overwatering will wash available nutrients to deeper zones making them less available. It can also, particularly in warm soil, create anaerobic conditions which directly damage root growth and desirable soil micro-organism communities. As such it can make the difference between success and failure. Remember, roots need air as well as water and should be encouraged to grow away from the plant in the search for water and nutrients.

Under-watering often results in wasted water as not only will the potential benefit not be fully realised but much can be rapidly lost in evaporation. Another issue can arise where insufficient water is applied but at regular intervals. This can result in shallow rooting due to the surface zone remaining wet while the underlying substrate remains dry.

In warm dry conditions moisture evaporates from the surface and can draw moisture upwards. When underlying layers remain dry and the wetted zone hasn't linked into the deeper soil reserve, moisture may be drawn upwards faster than gravity can draw it down.

Depending on your soil and the prevailing weather, creating a cycle of sufficient wetting and drying will maintain soil aeration, produce deep rooting and resilient crops and efficient use of a valuable summer resource.

Once you have the capacity to irrigate don't forget that natural rainfall is the best for your crops and we need to be aware of how much has fallen and been absorbed before dashing out with the sprinklers. We should also have a good understanding of our soil characteristics which influence its ability to absorb, hold and provide water to crops as well as how it responds to different methods of irrigation.

This part is divided into four subjects:

- Weather and climate
- Application rates
- Soil characteristics
- Estimating soil moisture

Weather and climate:

Farmers and growers are renowned for bemoaning the variety of climatic events we experience in the UK and for good reason. Our maritime climate is predominantly mild, wet and windy with few extremes, which is generally good news for growing stuff, but it can be extremely unpredictable. Recent years have seen the effects of climate change adding fuel to the fluctuations resulting in more extreme events and even less predictability.

www.ipcc.ch/report/ar6/wg1/resources/spm-headline-statements/

Despite this we do have some amazing resources available to both predict and measure the conditions we experience.

Online forecasts are useful and easy but it is best to use them with some broader background knowledge of both regional and local weather patterns. In the South-East UK we experience some quite predictable patterns in autumn and winter as Atlantic low pressure systems move across the country bringing SW winds and rain, often followed by dryer and cooler W and NW winds. During summer we can experience a 'blocking' high pressure with warm light S and E breezes and blue skies. Learning how to read an isobar chart and recognise patterns relating to your local climate can really improve your ability to read real-time signs as well as backing up the reliability or otherwise of online forecasts.

www.metoffice.gov.uk/weather/maps-and-charts/surface-pressure

www.metoffice.gov.uk/weather/maps-and-charts/rainfall-radar-forecast-map

You may find that your particular spot is usually a bit colder or wetter than the forecast predicts or that certain wind directions cause more problems. Clouds, bird activity, atmospheric pressure and shepherd's sunsets are all helpful indicators. Get tuned in to the weather and it may not take too long for your intuition to start surprising you!

On-farm measurements should include temperature (showing Max and Min over 24 hr periods), rainfall, wind direction (and ideally speed), barometric pressure and humidity (hygrometer). It isn't easy or cheap to keep all these active and recording constantly and you need to enjoy geeking out at the weather. Once the growing season begins at least some way of knowing how much rain has fallen is particularly important. A rain gauge is ideal but if you are collecting water from a roof into a tank this can also be a useful measure.

10mm rainfall = 10L/m^2, on 0.4 ha (1 Acre) = 40m^3

After rainfall, wind is arguably the next most relevant factor. Dry weather and a good breeze will dry your soils out very quickly, which is wonderful in March and April but a real pain in July. After wind, temperature has the next biggest influence. More heat means faster evaporation and particularly with direct sun on bare soil, surface moisture is rapidly lost.

The best strategy to avoid water loss by evaporation is to water early in the day when the soil is at its coolest. Certainly avoid the heat of the day and although evenings are cooler, regularly leaving crops wet into the night can encourage mildew, blight and other fungal diseases.

I can't stress enough the importance of constantly observing how the weather affects your soils and crops. In this age of on-line, abstract and ephemeral information we seem to have stopped paying close attention to what's happening in front of our eyes. Nothing I write here or that you watch on YouTube will be as useful as going out every day and experiencing what's actually happening.

Application rates

V/a/t = Volume (L or m³)/Area (m²)/Time (minutes or hours)

Photo: Pam Bowers, Strawberry Fields

Knowing the volume of water per minute that your application kit provides when running at the correct pressure will give you the cornerstone for several calculations. Add to this an estimate of the area watered and you have a proper measurement of the equivalent in mm of rainfall, based on the time the irrigation has been running.

Relating this back to the whole transfer system; V/t is used to determine how many sprinklers or lines of dripper can be run before reaching the maximum **flow** capacity. An easy way to keep track of this in practice is a pressure gauge measuring the system pressure. When it drops to a critical level (eg 1.5 bar) you know you are running at the maximum effective flow. It is essential to work out a calculation based on the desired pump and pipe capacity if you want to design a system from scratch (See Part 2).

Application kit will be accompanied by technical specifications which will give you V/t and, in the case of sprinklers, a diameter or radius coverage. This is the limit of the coverage, not necessarily the effective wetted circle as a stand-alone unit. When sets of sprinklers are combined at the recommended spacing you can confidently divide the total area by the number of sprinkler heads to calculate V/a if you know the output per head.

Dripper application rate will be either per metre of length (tape and soaker types) or per emitter with the emitter spacing giving the 'per metre' clue (e.g., 2Lph/emitter @ 25cm = 8Lph/m). The spread or width watered will again be given in the technical specifications. (Lph = Litres per hour = V/t)

Application rate example:

Micro-sprinkler system, NaanDanJain - Hadar 7110.
Medium range rotor with red nozzle.

Available technical specifications:

Working pressure 1.5 - 3 bar,
Flow rate 61L/h @ 2 bar
Wetted Diameter 7m @ 2 bar

Line of 7 rotors on an 18m long bed system at 2.7m spacing running at 2 bar.

So, 7m diameter wetted. 18.9m x 7m = 132.3 m²

At a flow rate of 61L/h/rotor = 427L/h

So 427L/132.3m² = 3.227L/m²/h = 3.2mm rainfall equivalent per hour.

To work out V/t where the technical spec is unknown or you want to double check, you can coil a known length of dripper pipe into a large bucket and run it for 10 minutes then measure the volume collected. A similar method can be used for sprinklers where one head is placed in a bucket and it will need to be covered by a sheet of plastic or old compost bag to capture all the spray.

The point of all this is to work out how long you need to run any particular set of irrigation to achieve the desired volume per m² of veg bed.

Soil characteristics

There will be a maximum volume of water any soil can absorb in a given period of time. This is known as the **infiltration rate** and is affected by the porosity and existing moisture content of the soil surface. Porosity is mainly determined by particle size, organic matter content and plant cover (roots). The prevailing moisture content has a profound effect as dry soil needs to hydrate before water can start to move down under the influence of gravity. Such soil has a lower infiltration rate as the **surface tension** of water limits the re-wetting process. Infiltration will reach a steady state once the soil approaches saturation and a completely saturated **soil profile** and the presence of a **water table** will then limit infiltration.

The relevance of this is that your application equipment should not irrigate at a rate greater than the soil can absorb. You can either choose the optimum **infiltration rate** and run the equipment sporadically on dry soil until the soil moisture is at a level where water is well absorbed. Or spec your equipment to apply only what a dry soil can absorb, and then accept that it will have to be left on for longer to achieve an adequate level than the previous option.

Another related point is that of surface capping. When a bare soil surface is flooded, particularly by heavy rain or watering on loose, dry soil, the top few millimetres can become consolidated. When this dries out it forms a hard crust that inhibits seed emergence. Some soils, particularly over-cultivated silt and clay soils with low organic matter and/or poor structure are particularly prone. Direct sown crops should be carefully irrigated to avoid exceeding the infiltration rate but in transplanted crops it is not such an issue. Although surface capping is bad for soil structure, it can be used to limit early weed emergence.

Timing watering to top up rainfall or pre-empt it can help avoid issues around re-wetting, especially if there's a risk of loss by run-off. When heavy summer showers are forecast, dry soils can be lightly watered to open them up. If the showers miss your land, do another top-up application before the soil dries out too much. Conversely, light rain that wets the surface can provide an opportunity for a top up with irrigation before it is lost through evaporation. This all depends on reading the weather, measuring rainfall and understanding your soil characteristics and crop needs.

Field Capacity

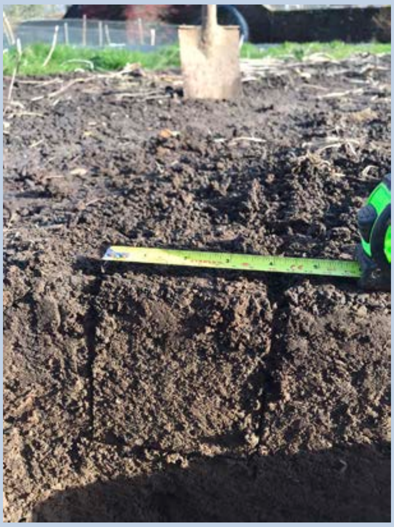
Field Capacity is the maximum amount of water, as a percentage of its volume, that the soil can hold once any excess has been lost to gravity. The absorbency and **capillary action** between soil particles will hold moisture, so sandy soils tend to have a low field capacity and clay soils quite high.

There are many factors affecting this and it is extremely difficult to get a scientifically accurate measurement but for the purposes of decision making when irrigating crops you can run this simple test. It will allow you to estimate the volume of water you can apply to an area of soil (assuming it is all absorbed) before excess starts to drain down to be lost through the profile.

Cornell University NRCCA Study Resources. Competency Area 2: Soil hydrology AEM
https://nrcca.cals.cornell.edu/soil/CA2/CA0212.1-3.php

Field Capacity test

1. Wet an area of bare soil (within your normal cropping land) to saturation or continue to Step 2 if the soil is already saturated by rainfall
2. Cover the wet soil with a plastic cover and wait for excess water to drain away. For sandy soils this will be no more than one day, for loam two days and clay soils should be given three to four days
3. Collect a soil sample of one litre. This can be done by digging a hole with one defined vertical wall then cutting a 10cm x 10cm x 10cm block out of this from the surface
4. Record the weight of the 1 litre moist soil sample as WET WEIGHT
5. Spread the soil on a metal tray and dry in an oven at 105°C overnight
6. Record the weight of the dried sample as DRY WEIGHT



Calculate Field Capacity

The first calculation will determine the mass of water in one litre of soil at field capacity

Wet weight (g) – Dry weight (g) = Mass of water (g)

We now need to determine field capacity as % volume (as opposed to mass)

As 1g water = 1ml, the mass of water (g) is the same as the water volume (ml)

The volume of each weighed soil sample was 1L (1000ml), so use the following equation:

100 x (water volume (ml)/soil volume (ml)) = Field capacity (% volume)

Using the results

We now know how much water is needed to saturate one litre of soil if it was completely dry. From this we can draw some useful conclusions. With some extra techniques to estimate soil moisture along with an idea of what rate our equipment will be applying water, we can get an informed estimate of the correct amount to irrigate our crops.

Example

Field Capacity = 40% of Soil Volume
= 40L of water/100L of soil

If we estimated that the top 10 cm of our soil had dried out to an average of 50% of it's field capacity, we would need 20L of water per m^2 to bring it back up to 100%.

This would be equivalent to 20mm of rainfall. If the soil was dry at deeper levels or estimated to be drier than 50%, more would be needed to bring it close to field capacity.

Estimating soil moisture

Soil ball (clay) pressed in the palm to estimate moisture

The squeeze or feel test for soil moisture determination is a great test as it will help you get to know your soil up close and personal and once you get a feel for it you can check anywhere, anytime, with no more than a trowel required.

Make an estimate of soil moisture status by firmly squeezing a handful of soil and comparing results with the table, then check soil moisture at various depths to get an idea of the profile.

Moisture meters are also available and range from £10 to upwards of £300. Detailed discussion of these is beyond this guide but the cheap analogue versions can be of use for determining moisture levels at various depths and give a rough idea of the soil state to inexperienced growers. However the scale is normally arbitrary so you need to calibrate it to your own soil by using the meter to measure the two extremes we identified when determining field capacity (do this when running the test?). Then you can assume that the quartiles between these correspond to 25%, 50% and 75% of field capacity.

There is a point between 5% and 25% soil moisture known as the wilting point; this will vary between different soils and if you know your soil type, it can be estimated. The amount of water between the wilting point and field capacity is known as the 'available water' and this is the bit we need to keep happy.

Field Capacity	Moderately coarse texture (fine sandy loam, sandy loam)	Medium texture (silt loam, sandy clay loam, loam, very fine sandy loam)	Fine and very fine texture (clay, silty clay, sandy clay, silty clay loam, clay loam)
100%	Upon squeezing, no free water appears on soil but a wet outline of the ball is left on the hand.		
75-100%	Forms weak ball, breaks easily when bounced in hand.	Forms ball, very pliable, slicks readily.	Easily ribbons out between thumb and forefinger.
50-75%	Will form a ball, but falls apart when bounced in hand.	Forms a ball, slicks under pressure.	Forms a ball, will ribbon out between thumb and forefinger.
25-50%	Appears dry, will not form a ball with pressure.	Crumbly, holds together from pressure.	Somewhat pliable, will ball under pressure.
0-25%	Dry, loose, flows through fingers.	Powdery, crumbles easily.	Hard, difficult to break into powder.

The point at which a plant actually begins to wilt depends on the crop; its maturity and root health as well as the transpiration rate and climatic conditions. E.g., over-wintered mizuna may be seen to wilt on a sunny spring day despite having been well watered whereas summer purslane may look perfectly sprightly in bone dry soil and full midday sun.

Average soil water content figures for three soil types

	Sandy soils	Loam soils	Clay soils
Field capacity (volume)	15 - 25%	35 - 45%	45 - 55%
Wilt point (volume)	5 - 10%	10 - 15%	15 - 20%
Total available water (volume)	10 - 20%	20 - 30%	15 - 25%
Infiltration rate (Steady)	>10mm/hr	5-10mm/hr	<5mm/hr

The point at which a plant actually begins to wilt depends on the crop; its maturity and root health as well as the transpiration rate and climatic conditions. Over-wintered mizuna may be seen to wilt on a sunny spring day despite having been well watered whereas summer purslane may look perfectly sprightly in bone dry soil and full midday sun. Different crops vary in their tolerance levels to both drought and over-watering. If you wish to specialise do more research and find out what they like. Watercress is an extreme example of a crop requiring a lot of water and very little soil. Asparagus can grow in extremely sandy soils with barely any rainfall.

In summary; get to know your soil, understand the needs of your crops, keep a close eye on rainfall during the warm season and learn how your irrigation kit works.

PART 4: GLOSSARY OF TERMS

Concepts and processes

Abstraction: The process of removing water from a natural source.

Capillary action: Water, due to its surface tension, can hold itself in small pores against the force of gravity. The smaller the pore diameter the greater its resistance to gravity, to the point where it can draw itself up several metres

Field Capacity: The maximum percentage moisture in soil once excess has drained away by gravity.

Flow: The volume of water being moved per unit of time (V/t), E.g., litres per minute.Sometimes called 'flow velocity' or 'volumetric flow rate' it can also be measured to include the cross-sectional area of the pipe.

Freeze protection: Outdoor systems will need to be either well-insulated or drainable. The ground is the best insulator and buried pipe-work is generally safe. Ideally over-ground pipe work will need drainage taps at the lowest points. These can be part of the delivery system or purpose made. Depressurising and opening up your system and ensuring water is not sitting in fittings can be sufficient. Freezing water may safely expand along short sections of straight plastic pipe as long as there is space for it to do so. Expanding ice can comfortably crack most pipes and fittings at -6°C.

Friction and turbulence: These slow the flow of water and can be reduced by increasing pipe size (reducing flow speed). This is particularly relevant over long distances and at low pressures. Higher pressures can overcome this resistance but will also cause higher stress on the components and use more energy.

Head: A way of describing pressure (see above) but as a measurement of one specific part of the system compared to another. It usually describes the height of the water source compared to where it is being pumped or used and may be measured in elevation (metres).

('Head' may also be used to describe the top-most part of a system or equipment such as a 'sprinkler head' or 'well/borehole head').

Infiltration rate: The speed water can be absorbed into soil and is drawn downwards under the effects of gravity.

Pressure: The force exerted by water or its ability to overcome resistance, such as gravity (measured in psi or bar). 1 bar is the pressure required to push piped water up to a height of 10 metres and also the pressure experienced 10 metres below a piped water source. 1 bar is 1Kg per cm^2. 1L of water weighs 1Kg.

Pressure compensation: Application systems are designed to work at an optimal pressure and flow. Pressure compensation means that at, or above this threshold, each outlet will deliver the same pressure and flow of water. E.g., dripper pipes will provide even amounts from each dripper rather than more being delivered where the pressure is higher, such as nearer the pump or lower down the hill.

Water cannot be compressed so it cannot absorb pressure. Pressure can however be absorbed or lost in pipework, air pockets and the turbulence of flow. Anything which creates resistance will reduce pressure in flowing water. Pressurised water that is not flowing will reach equilibrium so the pressure will be measured as the same from all equal height parts of the system. Once it starts flowing then resistance factors as well as the loss of pressure at delivery points change the pressure characteristics.

Priming/Air locks: Priming is the process of filling a pump with fluid and expelling the air from it.

An air lock is trapped air in the system. Water cannot be compressed which means water systems generally flow smoothly unless air is trapped. Air is compressible so it will cause jolts known as 'water hammer' and unpredictable changes in pressure as it expands and contracts in the system. Systems should be designed so that any air will rise to, and can be expelled from, the highest point.

Run: The length of pipe from the water source or pump to its furthest point.

Single phase/Three phase: Types of electricity supply. Single phase is one phase of the three used to commonly provide power on the national grid. Three phase motors are more efficient but run at a higher voltage with more wires.

Soil profile: The vertical cross section of soil revealing features not normally in view. When referring to water we are concerned with the soil moisture content and water movement characteristics within the soil profile.

Spray drift: The effect of wind on fine spray, blowing it away from the intended watering area.

Surface tension: A characteristic of the surface of water due to hydrogen bonds (attraction) between the molecules. It is why water is able to form droplets, cling to smooth surfaces and allow pond skaters to walk on it.

Water hammer: A jolt through the water system caused by an air lock/sudden change in pressure. It will cause damage to components if left unmanaged.

Water table: The underground level below which the ground is saturated. If you have a well, the water table is the height of water in the well.

Parts and materials

Ball valve: A type of plastic or metal valve commonly installed in irrigation systems, the handle operates within a 90 degree turn so is quick to use and easy to see if it is on or off. Metal versions with the longer handle are called lever ball valves. In higher pressure systems they can cause 'water hammer' due to the speed of shut-off.

BSP thread: British Standard Part. There are many types of standard thread types with acronyms such as BSF, BSW, UNF UNC, NPT NPS, SAE. As long as you use a matching type, they will screw together. BSP tends to be the commonest in irrigation fittings and will be listed in the part name.

Compression fitting: A common fitting for joining poly pipes which uses a screw-on ring to tighten a grip washer which holds the pipe ends into the sealed connector.

Drain valve and air release valve: Both work in a similar way, allowing air to be expelled but shutting off once pressurised water hits a sprung valve. Drain valves allow water to drain out once the pressure drops again and are commonly used at the end of PVC overhead spray-lines. Air release valves are positioned at high points to automatically purge air from the system.

Dripper: A type of nozzle or outlet that allows small amounts of water to seep out of a pipe directly on to soil or into pot substrate.

Elbow: An 'L' shaped fitting allowing a sharp 90 degree turn in pipework.

Expansion vessel/Pressure vessel: A component designed to buffer changes in pressure and prevent water hammer. It comprises a small tank where the system's water is separated in one half from compressed air in the other half by a diaphragm.

Foot valve: The combination of a strainer (filter) and non-return valve (see below).

Galvanised Steel: Ferrous steel externally coated in a rust resistant metal. Used where strength is required but it will rust, particularly internally, over time.

Gate valve: A brass valve with a simple sliding shut-off, operated by turning a screw handle. Especially good for larger diameter pipework, commonly installed at tank outlets and to isolate the supply near pumps where the slower shut-off action prevents 'water hammer'.

Ground access box: An accessible chamber in the ground, used to house valves (valve box), flow meters, take-off connectors (watering point) and any other features that might otherwise be buried.

HDPE: High Density Polyethylene.

Hose clip, jubilee clip: A metal or plastic ring which secures the end of a hose or pipe to a fitting, essential in systems running at higher pressures.

Jet: Water directed in a concentrated aim from a nozzle, usually at high pressure

LDPE: Low Density Polyethylene.

MDPE: Medium Density Polyethylene.

Non-return valve (NRV) or check valve: Prevents back-flow ensuring water can only travel in one direction through pipework. Essential to prevent back-flow in mains water systems when mains water is used for irrigation, both in pipework and integrated into outlet taps. Used in foot valves to prevent drawn-up water draining back out and thus keeping the pump primed. Also used to maintain direction of flow where separate sources (e.g., reservoir and borehole or mains tank and rainwater tank) share pipework.

Nozzle: A tubelike spout used to direct water flow from the end of a pipe.

Poly: Polypropylene/polyethylene fittings and pipe

Pressure relief valve (PRV): Can be set to release water out of the system when it reaches a critical pressure. Used to prevent pump strain and damage to fittings where either a pressure control switch isn't used, or as a safety back-up. Excess water is returned back to the tank.

PTFE tape: Polytetrafluoroethylene tape is used to seal threads against leaks. Apply by wrapping it flat around the male thread in a direction which stretches rather than creases it up as it turns into the female thread.

PVC: Poly Vinyl Chloride, an as yet unrecyclable plastic.

Saddle clamp: Allows a junction to be made in a pipe without cutting it. The saddle clamp fits over the existing pipe, a hole is drilled in the pipe then the junction is made. This is cost effective, quick and avoids measurement errors. However they are not suitable where movement may occur such as mobile systems.

Spray head: A type of nozzle creating multiple small jets or a fine mist

Sprinkler: A type of nozzle arrangement where the water is deflected or spun to cover a wide area in a rain-like fashion. They may have adjustments to allow for portions of the full 360 degrees to be watered.

Stop cock: Essentially a tap but in line, so without an outlet. Used on incoming mains to isolate the consumer's own system.

Stop end: A plug or bung to stop off pipework. These can be a solid plug or have a sealable cap to allow for washing through and purging air. Often, flexible pipework can be stopped off as effectively by clamping, folding or tying it off. Figure 8 clips, bands or cable ties can be used to secure folded pipework.

Tap: A type of valve using a screw and washer system, commonly used in domestic and garden settings. It is associated with its own outlet or faucet.

Tee: A 'T' shaped fitting which allows a 90 degree branch to be made off a straight line. The branch may be a different size to the line.

Union: A fitting which allows pipework to be split without having to move it along the length. Useful for installation parts that may need to be removable, e.g., pumps, filters and dosers. Also used in repairing or modifying buried or fixed installations.

Recommended reading

Adams CR, Bamford KM, Early MP (2008). *Principles of Horticulture*, Fifth Edition. Butterworth Heinemann

Price D (2022) 'A new pond on your farm'. *The Organic Grower* (No 60, Autumn 2022, p26)

Rain Bird (2018) *Landscape Irrigation Design Manual*
www.rainbird.com/sites/default/files/media/documents/2018-02/IrrigationDesignManual.pdf

van den Berge (2020). Good agricultural practice in irrigation management. FiBL, Switzerland
www.fibl.org/en/shop-en/2522-irrigation

Wallace K (2022) 'Water saving from polytunnels'. *The Organic Grower* (No.60, Autumn 2022, p30)

Ward RC, Robinson M (2000). Principles of hydrology. McGraw-Hill, London.

Weil RR, Brady NC (2016). *The Nature and Properties of Soil*, Global Edition. Pearson Education Limited.

Suppliers list

The following companies sell a range of irrigation equipment. All have received at least one recommendation from practicing growers, none have financially contributed to the creation of this guide.

Access Irrigation, Northamptonshire	*www.access-irrigation.co.uk*
BHGS, Evesham	*www.bhgsltd.co.uk*
City Irrigation, Kent	*https://cityirrigation.co.uk*
Easy Irrigation, Berkshire	*www.easy-irrigation.co.uk*
Fargro, West Sussex	*www.fargro.co.uk*
Hortech, Lincolnshire	*www.irrigationonline.co.uk*
Hortisystems UK, West Sussex	*www.hortisystems.co.uk/irrigation*
HydroSure	*www.waterirrigation.co.uk*
LBS, Lancashire	*www.lbsbuyersguide.co.uk/irrigation*
New Leaf Irrigation, Lancashire	*www.newleafirrigation.co.uk*
XL Horticulture, Devon	*www.smithnjones.co.uk*

Thanks to Farming the Future for funding this publication.
Author: Pete Dollimore. All photos by the author except where stated.
Design: Phil Sumption, Bio Communications.
www.organicgrowersalliance.co.uk
www.communitysupportedagriculture.org.uk
www.seedsovereignty.info

Farming the Future
COMMUNITY SUPPORTED AGRICULTURE
Seed Sovereignty
Organic Growers Alliance