Irrigation and water use
(Best practice guide for potatoes)
Growers recognise the importance of water and how valuable a resource it is. However, as demand for water increases, it is increasingly necessary to justify need and provide evidence of efficient use, both for environmental protection and to meet crop protocol requirements.

- Water requirements need to be defined and based on local climate, soil type, soil structure, crop and intended market. Include water needed for crop quality, pest and disease control, damage minimisation, etc.
- Assess adequacy of supply, distribution and application equipment and identify areas for improvement
- Keep clear records of rainfall (and evapo-transpiration if possible), water usage, scheduling, operator training and equipment maintenance across all cropping areas (six years history minimum)
- Avoid windy conditions and excess evaporation by irrigating at night, which also ensures maximum penetration of the root zone
- Set up equipment to combat high winds or provide shelterbelts to prevent drift. The Woodland Trust has published a document on shelterbelts which can be accessed at www.woodlandtrust.presscentre.com/imagelibrary/downloadMedia.ashx?MediaDetailsID=1877
- Monitor operating pressures and water application uniformity during the growing season
- Check irrigation applications match the infiltration rate of the soil to avoid unnecessary erosion
- Carry a field book to record each irrigation ‘event’ as it happens. See 6.1 Irrigation essentials – Environment Agency for more information.
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Globally, water resources are subject to extreme pressure, with urban centres competing with growers for the increasingly scarce water supply, as river basins and aquifers dry up and the climate becomes more extreme. The demand for water is expected to double in the coming decades.

The importance of water not only to agriculture but to the country as a whole was demonstrated during the extremely dry conditions of early spring 2012. Water management has been on the political agenda for some time due to the deadlines set out in the EU Water Framework Directive (http://ec.europa.eu/environment/water/water-framework) which is drawing ever nearer.

Three Government policy reviews have already taken place and many of their recommendations appear in the Flood and Water Management Act 2010. These will also be taken forward in the recent Natural Environment White Paper and Water White Paper. Changes in water policy will almost certainly have a massive impact on UK agriculture and especially on those growing potatoes.

The management and efficient use of water is a high priority within the UK Potato industry and the actions of growers will have an impact on future resources, especially as Potato Council data suggests 55% of growers have irrigation equipment and 40% of the total potato crop is grown on land with short term tenancies. However, by changing management practices and having a long term strategy for water use (use the Key principles on page 7 as a guide) the recent problems of scarcity, flooding and poor water quality could be alleviated.

This guide suggests ways of using water efficiently and helps irrigators deal with the challenges ahead. Better water management will enable growers to make the most of future opportunities and improve profits.
All growers recognise that water use and supply is an essential factor in crop production. A reliable and consistent supply of water is vital to maximise both yield and quality. With the extreme pressure on increasingly scarce water resources, it is expected that global demand for water will be expected to double over the next few decades. Worldwide irrigation uses a total of 2.7 million gigalitres to produce about 40% of the world’s food.

Climate models indicate that fresh water while abundant in places such as Canada, Russia and Brazil, in the rest of the world it will become scarce and the competition between urban, environmental and rural uses will escalate as the population increases.

The Met Office Hadley Centre, the UK’s leading climate change research facility, predicts that 40-50% of the world will be in drought by 2100 an increase of 10% from present day. Regions such as the Indian subcontinent, western states of America and South America that rely on snowmelt for irrigation, may face acute shortages. These issues, although global, are also relevant to the UK and will play out at scales of national, to river basin/catchment to local and farm levels. It is clear that more is needed to be done to recycle all water, renovate infrastructure ie new investment and more co-operation with neighbours, increase water use efficiency (on and off the farm), restore damaged river basins and end the wasteful use of water.

Over the next few years water legislation in the UK will also have a huge impact on the potato industry, even though there is still some uncertainty on the implementation of this legislation. However, these impacts can be anticipated and a pro-active approach is almost certainly the best way forward. These will be influenced by the current desire to simplify regulation by Government and key departments (Defra) and regulators (Environment Agency and Scottish Environmental Protection Agency), and by the adoption of risk-based approaches and self-monitoring.

It is important that water is applied at the correct time to achieve the right crop result. It is equally important that the application of water avoids the waste of a valuable resource with the minimum affect on the environment. Irrigation early in the growing season minimises Common scab (Streptomyces spp.), maximises tuber numbers and encourages the growth of the crop canopy. It also encourages tubers to grow at an optimum rate and, at the end of the season, it enables harvesting with minimal crop damage.

In recent years, the introduction of the Water Framework Directive into UK legislation in 2003, changes to abstraction licencing regulations and plans to place trickle irrigation under licensing control, have meant that growers need to pay even closer attention to the way in which they use water.

Evidence suggests growers need to understand how climate change could affect their water supply and inevitably, profitability. Growers must plan at least 5 to 10 years ahead to ensure their business is resilient to drought and extreme weather. Careful and effective water management planning, alongside environmental considerations, are critical to profitable cropping in the future.
Key principles
– essential ingredients for effective and efficient irrigation

2.1 Business planning

Potato enterprises need a sound business plan but the often high capital costs of irrigation, the reliance on water providers and the inflexibility of some production systems highlight its importance. There are also some opportunities that need to be considered such as water trading and the impact of government policies on the planning processes.

2.1.1 External influences

Growers need to understand how external issues affect their business. Government policies (regulations, incentives, water trading) climate change, resources (land, labour, water and energy), food and water policies, consumer demands, commodity markets and irrigation services will all have an impact.

2.1.2 Legislation and irrigation

The management of water resources has been on the political agenda for some time, due to the deadlines set out in the EU Water Framework Directive, which is drawing ever nearer. The Government’s white papers on the Natural Environment and Water aims to promote more efficient and sensitive use of water for both food production and the environment.

2.1.3 Water Framework Directive 2000/60/EC

The Water Framework Directive (WFD) came into force on 22 December 2000. The Directive sets out a timetable for both the initial transposition into laws of Members states and thereafter the implementation of requirements.
The key issues relating to the WFD are:

- It applies to all waters (domestic, industrial and agricultural)
- It aims to reduce and/or minimise diffuse source pollution from agricultural and urban run-off for the first time
- It introduces ecological water quality for the first time and includes hydromorphological aspects
- It demands cost effective measures and full cost recovery.

The key dates for the implementation of the WFD are given below:

<table>
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<td>2000</td>
<td>Directive came into force [Art. 25]</td>
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| 2003   | Transposition into national legislation [Art. 23]
         | Identification of River Basin Districts and Authorities [Art. 3]       |
| 2004   | Characterisation of river basin, pressures, impacts and economic analysis [Art. 5] |
| 2006   | Establishment of the monitoring network [Art. 8]
         | Start public consultation [Art. 14]
         | Completion of inter-calibration exercise                               |
| 2007   | Establishment of good status standards for different waters            |
| 2008   | Present draft River Basin Management Plan [Art. 13]                    |
| 2009   | Finalise River Basin Management Plans, including programme of measures |
| 2010   | Introduce pricing policies [Art. 9]                                    |
| 2012   | Make operational programmes of measures [Art. 11]                      |
| 2015   | Meet environmental objectives [Art. 4] (extended to 2027)               |
| 2021   | First management cycle ends [Art. 4/13]                                |
| 2027   | Third management cycle ends, final deadline for meeting objectives [Art. 4/13] |

The impact of the WFD on current activities is dependent on the current water quality status for each water body (rivers, lakes, streams, groundwater and coastal waters). The first requirement is to ensure no deterioration and the second is to achieve good status.

The WFD classification scheme for water quality includes five status classes: high, good, moderate, poor and bad. ‘High status’ is defined as the biological, chemical and morphological conditions associated with no or very low human pressure. This is also called the ‘reference condition’ as it is the best status achievable – the benchmark. These reference conditions are type-specific, so they are different for different types of rivers, lakes or coastal waters, so as to take into account the broad diversity of ecological regions in Europe.

Assessment of quality is based on the extent of deviation from these reference conditions, following the definitions in the Directive. ‘Good status’ means ‘slight’ deviation ‘moderate status’ means ‘moderate’ deviation, and so on. The definition of ecological status takes into account specific aspects of the biological quality elements, for example “composition and abundance of aquatic flora” or “composition, abundance and age structure of fish fauna” (see WFD Annex V Section 1.1 for the complete list). These definitions are expanded in Annex V to the WFD.

Further details on the Directive can be obtained from:


### 2.1.4 Impact on potato growers

The impact on any individual grower will not be clear until good ecological status for each water body is decided and the necessary programmes of measures have been proposed, implemented and evaluated.

The initial characterisation indicated that many water bodies would not meet ‘good’ status. This implies that extra efforts will be required to achieve ‘good’ status, although priority must be given to ensure that there is no deterioration from current status.

The main approach being adopted by government to address some of the WFD requirements, relevant to farming, is to use the existing Catchment Sensitive Farming (see Box 1), Single Farm Payment (see Box 2) and Environmental Stewardship (see Box 3) schemes, so initial changes for farmers will be minimal.
Box 1: England Catchment Sensitive Farming Delivery Initiative

Defra’s Catchment Sensitive Farming (CSF) programme aims to tackle Diffuse Water Pollution in Agriculture (DWPA) in order to meet the objectives of the Water Framework Directive (WFD). The CSF is a joint venture between the Environment Agency and Natural England, funded by Defra working in 50 priority catchments. This is delivering practical solutions and targeted advice to enable farmers and land managers to take action to protect water bodies and the wider environment. This will achieve reductions in diffuse water pollution from agriculture by encouraging CSF.

Catchment Sensitive Farming encourages best practice in the use of:

- Fertilisers
- Manures and pesticides
- Promoting good soil structure to maximise infiltration of water
- Minimising erosion and run-off
- Protecting water courses from faecal contamination and sedimentation
- Reducing stocking density.

This is land management that keeps diffuse emissions of pollutants to levels that are consistent with the ecological sensitivity and uses of rivers, groundwaters and other aquatic habitats, both in the immediate catchment and further downstream.

For further information about the CSF, please use: https://www.gov.uk/catchment-sensitive-farming.

Box 2: Cross compliance: Single Payment Scheme

Since January 2005 the new Single Farm Payment Scheme has provided subsidies to farmers which are no longer linked totally to production. Under the scheme farmers are obliged to maintain land in Good Agricultural and Environmental Condition (GAEC) as part of Annex IV of Council Regulation EC/1782/2003. This is relevant to meeting obligations under the WFD and the proposed Soil Framework Directive (SFD). It includes soil management to minimise both on and off-site degradation. Although there are different GAEC definitions for the different UK regions, the requirements on farmers are similar.

Cross compliance requirements apply to farmers who receive direct payments under Common Agricultural Policy (CAP) support schemes and/or payments under certain Rural Development schemes.

PAYMENTS MAY BE REDUCED IF YOU DO NOT COMPLY WITH THESE REQUIREMENTS.

The two main aspects to cross compliance requirements:

- Specific European legal requirements, known as Statutory Management Requirements (SMRs)
- Domestic legal requirements requiring you to keep your land in Good Agricultural and Environmental Condition (GAEC).

Cross compliance requirements apply in addition to underlying obligations under European and UK legislation. Remember, you may face penalties if you do not carry out those obligations, as well as reductions to and loss of CAP payments.

All agricultural activities are covered by cross compliance and you must comply with the standards across the whole agricultural area of your holding, regardless of the amount of land you entered into the Single Payment Scheme (SPS). The only exception is that you do not need to produce a Soil Protection Review (SPR) for common land (unless you are the sole occupier of the common). Further information may be obtained from the Rural Payments Agency (RPA) website: www.rpa.gov.uk/rpa/index.nsf/UIDMenu/C63617FF7C4FBE2FB025767E0052995B
The Targeted element of Glastir is aimed at those areas of Wales which can deliver defined targets relating to the following objectives:

- Carbon management
- Water management
- Biodiversity
- Historic environment protection
- Improving access.

A set of targeted area maps for each of the above objectives has been drawn up by the Welsh Assembly Government. Those farms which fall into one or more of these targeted areas will be eligible to join the targeted element providing there is already a signed All-Wales Element contract.

Scotland Rural Development Programme (SRDP)

The SRDP is a programme resourced by €679m of European funding (EAFRD), match-funded by the Scottish Government, which is designed to help develop rural Scotland. The programme is spread over six years and provides help and support to individuals and groups, to help create a wealthier and fairer rural Scotland.

The scheme is designed to help meet national economic, social and environmental targets ie water quality.

Some of the SRDP schemes and initiatives include:

- Crofting Counties Agricultural Grant Scheme
- Food Processing, Marketing and Co-operation Grant Scheme
- Forestry Commission Challenge Funds
- The LEADER initiative
- Less Favoured Area Support Scheme
- Rural Development Contracts
- Skills Development Scheme.

Box 3: Agri-environment schemes

**Entry Level Stewardship (ELS)**

With well over 50% of England’s agricultural land now in Entry Level Stewardship (ELS), this is the basic underlying scheme open to all farmers and land managers in England. ELS requires a basic level of environmental management and you can choose from a wide range of more than 80 management options. These cover all farming types and include things such as hedgerow management, stone wall maintenance, low input grassland, buffer strips, maintenance of traditional farm buildings and arable options. It provides a straightforward approach to delivering simple and effective environmental management across the whole farm that complements existing farming operations and allows the farmer to create a practical environmental management programme. ELS agreements are for five years.

**Higher Level Stewardship (HLS)**

Higher Level Stewardship (HLS) aims to deliver significant environmental benefits in high priority situations and areas. It involves more complex environmental management, so you will get advice and support from Natural England. HLS is usually combined with Entry Level or Organic Entry Level Scheme options. There is a wide range of management options and these are designed to support key features of the different areas of the English countryside. HLS can contribute to a wide range of capital works such as restoration of hedgerows or traditional farm buildings. HLS agreements last 10 years.

**Glastir (Wales)**

Glastir is the new All-Wales Agri-environment Scheme introduced by the Welsh Assembly Government. It is a five year whole farm agreement and replaces Tir Mynydd, Tir Cynnal, Tir Gofal and Organic Farming Schemes. Glastir is made up of two sections – an All-Wales section and a Targeted section.

The All-Wales part of Glastir is available to all farmers across Wales who are able to accumulate sufficient points to enter the scheme. There are two additional packages available, the first is specifically for dairy farmers and the second is for farmers within certain regions of Wales.
Since the loss of set-aside there have been concerns about the management of land to efficiently produce food and its impact on the environment. Sir Don Curry’s High Level Set-Aside Group (HLSAG) commissioned a range of studies to consider the benefits of former set-aside and ultimately what our farmed environment stood to lose if no environmental solution were to take its place.

A scheme was introduced that aimed for six per cent of arable land taken to be out of production. This land would further have to be managed to benefit the environment, in addition to any other work undertaken through agri-environmental schemes. In response, the CLA and NFU, with the support of industry leaders and environmental organisations, pulled together to create a voluntary alternative – the Campaign for the Farmed Environment.

The Campaign aims to pull together the huge amount of work that farmers and land managers already do to encourage wildlife, to benefit soil and water resources and support farmland birds. It promotes existing stewardship schemes and encourages voluntary management that will benefit the environment, while ensuring efficient and profitable food production.
2.1.5 Legislation that has a direct impact on potato growers

2.1.5.1 Groundwater Directive 2006/118/EC
In 2013 the Water Framework Directive (WFD) will repeal Directive 80/68/EEC on the protection of groundwater against pollution by certain dangerous substances. The WFD states that measures would be adopted to prevent and control groundwater pollution. These measures are set out in the Groundwater Directive. This Directive is designed to protect groundwater and fill the legislative gap following the repeal of Directive 80/68/EEC.

2.1.5.2 Habitats Directive 92/43/EEC
The Habitats Directive has created a European network of protected wildlife areas consisting of Special Areas of Conservation (SAC) and Special Protection Areas (SPA). The SPAs were originally established under the Birds Directive 79/409/EEC.

Since April 2005 there are 634 designated SACs in England. All affected land owners/occupiers were notified and management agreements established. The agreements specify Potentially Damaging Operations (PDOs) which are not allowed without the expressed consent of Natural England. Special Nature Conservation Orders can be invoked which provide a permanent ban on PDOs.

All permitted activities occurring prior to designation have to be reviewed to assess impact on a SAC and if having an adverse effect then the permit /consent must be revised or revoked.

A list of all SACs (UK) is available at www.jncc.gov.uk/protected/sites/sacselection/SAC_list.asp

2.1.5.3 Nitrates Directive 91/676/EEC
The Nitrates Directive, adopted by the European Union in 1991, aims to reduce water pollution caused by nitrogen from agricultural sources and to prevent such pollution in the future. The Directive requires Member States to:

- Designate as Nitrate Vulnerable Zones (NVZs) all land draining to waters that are affected by nitrate pollution
- Establish a voluntary code of good agricultural practice to be followed by all farmers throughout the country
- Establish a mandatory Action Programme of measures for the purposes of tackling nitrate loss from agriculture. The Action Programme should be applied either within NVZs or throughout the whole country
- Review the extent of their NVZs and the effectiveness of their Action Programmes at least every four years and to make amendments if necessary.

2.1.5.4 Key requirements of the NVZ rules in England
The key measures included in the new NVZ rules in England include:

- **Manure N farm limit:** Farmers must ensure that the total loading of nitrogen from livestock manures to the farm does not exceed a loading limit of 170kg of nitrogen per hectare per year
- **Closed periods:** These are times during the year when the spreading of organic manure with high available nitrogen content (e.g. slurry, poultry manure) is prohibited. Closed periods apply for both organic manures and manufactured nitrogen fertilisers and typically range from 3-5 months depending on the soil type and land use
- **Crop requirement:** Farmers must plan all applications of nitrogen to a crop (whether the nitrogen is present within manufactured nitrogen fertiliser, organic manure,
or any other nitrogen-containing material) so that they are compliant with an upper cap on nitrogen applications (termed an N Max limit)

- **Spreading locations:** Farmers are required to undertake a written assessment to identify areas of land at risk of runoff and causing water pollution. Applications of nitrogen fertiliser and organic manures to areas of land identified as posing a high risk runoff are prohibited

- **Spreading techniques:** Farmers must spread organic manures and manufactured nitrogen fertilisers in as accurate a manner as possible. High trajectory spreading techniques for spreading slurry are strictly prohibited, unless the equipment used can achieve an average slurry application rate of not more than 2mm per hour when operating continuously. Additionally, applications of organic manure to bare soil or stubble will require incorporation into the soil in certain situations

- **Record-keeping:** Farmers are required to keep a record of all nitrate applications they make to their land. All records must be made available for inspection and kept for at least five years.

Full details of the requirements on farms in the NVZ are available via the following web link: https://www.gov.uk/nitrate-vulnerable-zones

### 2.1.5.5 Checking compliance with the NVZ rules

The NVZ rules under the Nitrates Directive are also a Statutory Management Requirement (SMR) for cross compliance under the Single Payment Scheme. This means that farmers will have to comply with the new NVZ rules to be entitled to their full subsidy payment; failure to comply could lead to deductions.

The EA has taken a risk-based approach to enforcement, prioritising farms that have the greatest potential for nitrate loss rather than visiting all farms. In Wales the regulations are the same as in England. Around 2.3% of Wales is currently within a NVZ. In Scotland only four areas have been designated as being in NVZ. These are Lower Nithsdale, Lothian and borders, Strathmore and Fife and Moray Aberdeenshire/Banff and Buchan.

The EA has published a set of Q&A which provide practical advice on detailed aspects of the NVZ rules and can be accessed: http://www.environment-agency.gov.uk/static/documents/Business/NVZ_QA_Version9_Sept2011.pdf

### 2.1.5.6 Environmental Liability Directive 2004/35/EEC

Directive 2004/35/EEC (The Environmental Liability Directive) seeks to achieve the prevention and remedying of environmental damage – specifically, damage to habitats and species protected by EC law, damage to species or habitats or a SSSI for which the site has been notified, damage to water resources and land contamination which presents a threat to human health. It reinforces the ‘polluter pays’ principle – making operators financially liable for threats of or actual damage.

The Environmental Damage Regulations, which transpose the requirements of the Environmental Liability Directive into national law in England, came into force on 1 March 2009.

For damage to water or biodiversity, remediation may involve:

- **Primary** remediation (to return the site to baseline condition)
- **Complementary** remediation (equivalent off-site measures where primary remediation does not return the site to baseline condition),
- **Compensatory** remediation (to compensate for the ‘interim loss’ of natural resources and services pending recovery).

### 2.1.5.7 Agricultural Wastes Regulations

These refer to the Waste Management (England and Wales) Regulations 2006. These Regulations implement (in part) the Waste Framework and the Landfill Directives and amend the Environmental Protection Act 1990 (in particular the s.75(7)(c) exemption for “waste from premises used for agriculture”) and the Environment Act 1995.

It is important to recognise that the Directive definition of waste is strict – “Any substance or object which the holder discards or intends or is required to discard.” Agricultural waste is taken as waste from premises used for agriculture within the meaning of the Agricultural Act 1947. Since May 2006 agricultural waste, previously exempt from control, now comes under the Waste Regulations, although there are provisions for quite a wide range of exemptions.

### 2.1.5.8 Water Resources Act 2003 and Abstraction licensing

Many of the current and future changes in water resource management in England and Wales stem from the Water Act 2003 published on 28 November 2003, and the consequent measures being implemented by the
EA through their Catchment Abstraction Management Strategies (CAMS). The implementation of the Water Act is ongoing, via a series of Commencement Orders, with the different provisions of the Act being brought into force at different times.

The key issues with respect to potato growers are:

- All small abstractions, currently set at 20m$^3$/day, do not need a licence. This is unlikely to be relevant to most potato growers but does offer opportunities for growers of other high value produce on small areas (~1ha) to abstract without the need for a licence.

- The use of water for trickle irrigation will need an abstraction licence in the near future. In this context, potato growers using trickle irrigation should be aware of the CAMS process and the implications of using trickle. The CAMS process requires the EA to develop a ledger of all abstractions in each catchment. However, because trickle irrigation was not licensed, the EA have limited records of abstraction quantities and cannot therefore accurately incorporate this uncontrolled but legitimate use into the CAMS ledger. The formulation of the ledger takes place before formal public consultation on CAMS and therefore potato growers using trickle irrigation are advised to be pro-active in supplying the necessary information on trickle irrigation water use to their local EA CAMS officer.

- The status of licences has changed significantly. All abstractors now have a responsibility not to let their abstraction cause damage to others. From 2012, the EA will be able to amend or remove someone’s permanent licence without compensation if they are deemed to be causing serious damage to the environment.

- All new licences are time-limited. All licenses issued since the Water Act (2003) came into force and many issued previously, are now time-limited. Government policy is to encourage all other licence holders to move to time-limited status. Normally these licences will have to be renewed at 12 yearly intervals, although some licences may have shorter or longer durations and there are transitional arrangements to bring all the licences in each catchment to a Common End Date (CED). There will be a presumption of licence renewal so long as three tests are satisfied. The EA considers these tests to be an ‘Environmental MOT’. The three tests are:

  Test 1: Continued environmental sustainability: To assess whether the continued abstraction can be sustained without significant impact on water resources, other water users or the environment.

  Test 2: Continued justification of need: To assess whether the abstraction is still required, based on the ‘reasonable’ requirements of the licence holder and to check that the maximum levels of abstraction are still reasonable.

  Test 3: Efficient use of water: To assess whether the right amount of water is being used in the right place at the right time.

Test 1 will be largely undertaken by the EA through CAMS and other water regulation processes, although licence applicants may be required to provide additional information. Test 2 will require the licence holder to submit a structured case for licence renewal, addressing and quantifying a range of factors that impact on the requirement for irrigation (justifying ‘reasonable’ need). The methodologies are already in place for justifying reasonable need for a new abstraction licence, though the use the applicant has made of the licence in previous years can also provide useful supporting information. Test 3 requires the licence holder to demonstrate that ‘efficient use’ will be made of the water in future but largely based on evidence on the use of the water in previous years.

The EA has a duty to promote efficient use of water by abstractors, as enshrined in Test 3. It is suggested that the best way to achieve this is to help potato irrigators use their water more efficiently, by for example ensuring that the requirements in assurance schemes match those in any water auditing procedure. Non-renewal remains as an ultimate sanction.

2.1.5.9 Flood and Water Management Act 2010

The Flood and Water Management Act gained Royal Assent on the 8 April 2010. The Act will implement several key recommendations of Sir Michael Pitt’s Review of the Summer 2007 floods, protect water supplies to consumers and protect community groups from excessive charges for surface water drainage.

The Act’s provisions include:

- New statutory responsibilities for managing flood risk: There will be national strategies and guidance on managing flood risk in England and Wales. Unitary and county councils will bring together the relevant bodies,
which will have a duty to cooperate to develop local strategies for managing local flood risk

- Protection of assets which help manage flood risk: The Environment Agency, local authorities and internal drainage boards will be able to ensure that private assets which help manage the risks of floods cannot be altered without consent. For example, putting a gate in a wall that is helping protect an area could increase the risk of flooding.

- Powers to carry out environmental works: The Environment Agency, local authorities and internal drainage boards will be able to manage water levels to deliver leisure, habitat and other environmental benefits.

- Sustainable drainage: Drainage systems for all new developments will need to be in line with new National Standards to help manage and reduce the flow of surface water into the sewerage system.

- New sewer standards: All sewers will be built to agreed standards in future so that they are adopted and maintained by the relevant sewerage company.

- Reservoir safety: The public will be protected by a new risk-based regime for reservoir safety. It will reduce the burden on regulated reservoirs where people are not at risk, but introduce regulation for some potentially risky reservoirs currently outside of the system.

- Protection of water supplies: there will be wider powers for water companies to control non-essential domestic uses of water in times of drought.

- Other protection for water company customers: there will be new powers to reduce the level of bad debt, new arrangements for managing very risky infrastructure projects which could be a threat to the ability of the water company to provide its services, and updated arrangements for administration of water companies should they get into difficulties.

2.2 Business fundamentals

Growers need to be on top of the internal factors affecting their business: such as finance (equity, capital, succession plans), personal traits for example attitude to risk, and embracing new technologies, health and safety, farming systems (are they flexible enough?), water delivery infrastructure and business and market options.

The level of operating surpluses, debt and the cost of servicing it as well as the value of assets will dictate the ability of the farm enterprise to access finance and...
Section 2

invest in any capital upgrades to irrigation systems. The business structure and its succession plans will also affect the growers’ willingness to take risks and use new technologies or practices. Business improvement/benchmarking software is available on the Potato Council’s website: www.potato.org.uk/publications/potato-council-guide-business-improvement

Any existing irrigation infrastructure and production system will influence the capacity of the business to change. By being flexible, small changes can be introduced and tested before implementing more significant changes but where capital works are more expensive, the risks are also higher.

How the water is accessed will further influence the range of options available. It is essential that growers must allow for the reliability of supply, water pressure (eg to drive sprinklers or for trickle/drip irrigation systems) and any need for on farm storage.

Another factor that is essential to consider is labour. The availability of labour will influence the degree of technology that is introduced to the system and decisions on the type of crop grown. As new technologies emerge in irrigation, management often becomes more complex. Increased automation will often result in an increase in the level of sophistication required in technical understanding in order to get the best results. Health and Safety issues may mean a workforce with different skills, such as computing, are required. A skills audit of staff and the expertise available to the grower is a good exercise to see if there are any gaps.

2.2.1 Cost/benefit analysis of irrigation

An important tool to the potato grower is to weigh up the costs and the associated benefits of the irrigation system and see if what is being used is actually cost effective or not. A main driver for irrigation of potatoes is the need to meet quality standards for Common scab, particularly for the pre-packed market. Even minor scab lesions can drastically reduce the value of crops. The Potato Council report Changes to water policy and their effect on the potato industry (Tompkins and Clayton, 2003) summarises the impact of increasing restrictions on water abstraction and the effect on the costs of irrigation that has resulted from changes in legislation and policy on environmental protection.

Farmers are generally most interested in maximising economic returns so where water is scarce (limiting), these should be maximised per unit of water applied (£/m³). In a study conducted by Cranfield University in 2007, an irrigation cost-benefit analysis was undertaken.

A comparison of irrigation benefits less costs (expressed as £/m³ of irrigation water applied) provides the farmer with an indicative value of water for that field and hence best economic use. In order to assess the additional value that irrigation provides, it was necessary to estimate crop yield for an equivalent un-irrigated potato crop. This was derived by crop modelling using local soils and climate data.

2.2.2 Costs

The costs of irrigation will vary considerably according to local circumstances. This variation is due to:

- The crop requirements for irrigation
- Source of irrigation water (surface or groundwater)
- The need for water storage
- Type of application system and
- The size, configuration and topography of the irrigated area, its distance from and height above the water source.

A study by Cranfield University found that most irrigation in England is applied through hosereel-gun systems. For a typical hosereel system without winter storage, capital costs are approximately £2800-£3200 per hectare irrigated, the total annual cost is estimated at £500-£800 per hectare irrigated and the average cost per unit of water applied is around £0.40-£0.45 per m³ applied net of losses (£4.00-£4.50 per ha/mm).

Winter storage will typically increase the annual costs per hectare and the costs per unit of water by 50% and 130% for unlined and artificially lined reservoirs respectively. Average costs for unlined reservoirs are approximately £0.63 per m³ net of losses. Artificial lining would increase this to about £0.92 per m³. For larger reservoirs there may be economies of scale.

Fixed costs account for over 60% of total costs even for direct abstraction to hosereel-gun systems, and over 70% with storage. The more efficient systems including boom, centre pivots and trickle systems, have an even higher proportion of fixed costs to variable costs. If fixed costs are already ‘sunk’, water conservation measures can only hope to recoup some of the running or variable costs. Total running costs for hosereel systems are typically about £0.15 per m³ net of losses, or £0.12 per m³ including losses, and not all of these are directly related to the volume of water applied.

Irrigators using hosereel-gun systems with an ample water supply and sunk capital costs might therefore
typically hope to save around £0.10 per m³ of water conserved by reducing losses. Savings would be less with more automated systems.

Water charges in EA Anglian Region 2012/2013 were only £0.0252 per m³ for direct summer abstraction and £0.00234 per m³ for winter abstraction and half these are fixed costs under the present two part tariff system. Measures to increase supply, such as water harvesting or re-use, will save only the variable part of the abstraction charges, ie around £0.01 and £0.001 per m³, of extra water produced in summer and winter respectively.

### 2.2.3 Benefits

Irrigation serves mainly to increase crop yield and crop quality over and above that obtained through rain fed crop production. The size of the benefit depends on crop type and variety, the stages in the crop cycle when water is applied, the standard of crop husbandry and environmental factors, especially soil and climate.

For potatoes, the quality assurance benefits of irrigation are substantial. They relate to the whole crop, not just to the extra yield due to irrigation. Quality criteria are increasingly specified as a condition of contract and sale. Failure to meet quality standards can lead to large price deductions and possibly to rejection.

### 2.2.4 Climate change and drought

Climate change predictions include likely changes to water resource availability across much of the globe. In many areas water resources are expected to decrease, particularly in semi-arid areas. Increases in extreme weather events, including flash flooding, are predicted, even in areas where overall average rainfall is predicted to decrease.

Potatoes are much more sensitive to soil water deficits compared to other crops such as wheat and need frequent irrigation, especially while tubers are growing. Reduced rainfall in many areas is predicted to increase the need for irrigation of potato crops. For example in the UK the amount of arable land suitable for rain fed potato production is expected to decrease by at least 75%. As well as reductions in overall rainfall, potato crops also face challenges from changing seasonal rainfall patterns.

Due to the changing rainfall patterns over the last couple of years, there has been a shortage of irrigation water in some regions of the UK. If water supply is restricted, the question then arises as to whether irrigation should continue on part of the crop or to be applied to the whole crop using limited amounts. A lot will depend on which market the crop is intended for. Irrigation increases crop yield but quality is often of greater importance, because a crop that does not meet the necessary quality criteria will either fetch a lower price or be unsalable to the target market.

<table>
<thead>
<tr>
<th></th>
<th>Irrigated</th>
<th>Not irrigated</th>
<th>Difference due to irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Averaged over 20 years</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield t/ha</td>
<td>50</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>Price (£/t)</td>
<td>90</td>
<td>66.50</td>
<td>28.50</td>
</tr>
<tr>
<td>Revenue (£/ha)</td>
<td>4500</td>
<td>2660</td>
<td>2090</td>
</tr>
<tr>
<td><strong>Design dry year</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield t/ha</td>
<td>50</td>
<td>36</td>
<td>14</td>
</tr>
<tr>
<td>Price (£/t)</td>
<td>175</td>
<td>96</td>
<td>79</td>
</tr>
<tr>
<td>Revenue (£/ha)</td>
<td>8750</td>
<td>3456</td>
<td>5294</td>
</tr>
</tbody>
</table>


Example of yield and quality benefits associated with irrigation on a potato crop, on a medium AWC soil in the Fens. 2005.
Drought early in the growing season restricts the canopy expansion which then has a knock on effect on light interception and yield. During canopy expansion the crop hasn’t reached its maximum rooting depth so the Soil Moisture Deficit (SMD) at which there is a yield penalty will be lower. It is often stated that dry soils encourage root activity to search for water. However, the opposite is the case and in fact moist soils encourage root growth. Thus, it is essential that irrigation takes place at lower SMDs and earlier in the season to encourage root growth (in dry conditions).

In dry years, growers have had to irrigate the soil to minimise bruising and aid lifting during the harvest. To be able to do this, the grower must apply for an extension to their abstraction licence. The Environment Agency’s position on this is to ‘vary your licence now’, ie apply for the extension before the season starts. More information on how to do this can be found at: http://publications. environment-agency.gov.uk/pdf/GEHO1111BUIU-E-E.pdf

**2.3 Irrigation planning**

Investigation and planning is essential prior to establishment. The right site must be matched to the production system, crop choice and irrigation design, with soil type, landscape and the security and supply of water. As drought and the shifts in the markets change, then the grower must revisit and revise their plans and the varieties grown.

**SITE SUITABILITY.** Understand the site. Assess, understand and update information about soil type and the variability, topography, climate, water supply, salinity and depth to groundwater and any site preparation needed.

The basic site characteristics will dictate the suitability of the location for irrigation. Factors include:

- Soil type: A soil survey is recommended to aid planting decisions and the design of the irrigation system
Constraints such as salinity and acidity should be noted for remediation, special management or designated as ‘not suitable’. The water holding capacity of the soil should be determined as a guide to irrigation

- Slope: Surface irrigation requires gently sloping and consistent gradients whereas trickle/drip can be used on steeper ground
- Underlying Geology: Sites with poor drainage and shallow water tables are more susceptible to salinity and rising groundwater
- Climate: Rainfall, temperature and wind will be a guide on how much irrigation is needed. The incidence of frosts, hail, heat waves and storms should also be considered.

PRODUCTION SYSTEM AND CROP CHOICE. Select crops that are suitable for the location. The history of previous irrigated potato crops should be noted. Decide if you are aiming for high yield, high quality or both.

2.3.1 Water characteristics
The quality, quantity and reliability of water supply has to be factored into decisions about the crop choice and irrigation system.

- Quality: Salinity will limit the amount of potatoes that can be grown if at all. Contaminants such as sediment (especially after flooding) and dissolved salts may necessitate filtration or chemical treatment
- Quantity and availability: The amount of water available at different times of year will impact on the area of crop and variety grown to be irrigated
- Security and variability: The reliability of water supplies is essential. If the supply is variable then it’s important to plan a system that is flexible to cover the dryer seasons
- Supply: Growers need to know how quickly the water can be delivered and the consistency of supply to allow easier management
- Regulations: Growers need to apply for the appropriate abstraction licence to fulfil their needs.

Planning for improvement also means trying to find some time to assess performance and to record areas where adjustments or improved practice can make savings or lead to more efficient performance. Optimising water use to benefit crops, other water users and the environment mean that growers have to increasingly justify their need for water to demonstrate that it is being used efficiently. Matching the potential crop requirements with a suitable source of water at the right time is at the core of any plan for water use.

2.3.2 Water requirements and reservoirs
As has already been mentioned, water requirement will vary with soil type, climate, crop and the growing system. Storing water on-farm in reservoirs has become increasingly important for businesses that depend on irrigation to supply high quality produce. Recent drought such as the recent 2011-2012 growing season and the long term threat of climate change have only increased concerns about the reliability of future supplies for irrigation.

The benefits of a reservoir include:

- Security and a degree of flexibility, by balancing supply and demand and taking advantage of groundwater and high river flows when water is plentiful
- Reduced environmental impact of direct abstraction during low flows
- Reduced risk associated with potential water conflicts in the catchment
- Taking advantage of groundwater and high river flows when water is more plentiful and reliable and storing it for summer use. However Hands off flow i.e. abstraction prohibited or Section 57 restrictions when abstracting can still apply if water is extremely scarce. Under section 57 of the Water Resources Act 1991, the Environment Agency can reduce or stop spray irrigation to protect the environment. This is a last resort restriction. More information can be found at: http://publications.environment-agency.gov.uk/pdf/GEHO0412BUNH-E-E.pdf

- Charges for abstraction during the winter months (November to March) are a tenth of the cost of summer abstractions.

Most reservoirs are clay lined and constructed where the need for costly provision for peak flood flows that require large overflow arrangements can be avoided. Where no suitable clay is available a geotextile underlay needs to be used to protect the artificial liner from stone damage.

Reservoirs that have a capacity of 10,000m³ of water stored above the lowest surrounding ground level now come under the Flood and Water Management Act 2010...
and the Reservoirs Act 1975. More information can be found on the Environment Agency website: (www.environment-agency.gov.uk/business/sectors/118421.aspx) this means:

- Only those reservoirs assessed as a higher risk are subject to regulation
- All undertakers with reservoirs over 10,000m³ must register their reservoirs with the Environment Agency
- Inspecting engineers must provide a report on their inspection within 6 months
- All undertakers must prepare a reservoir flood plan
- All incidents at reservoirs must be reported.

The reservoir sections of the Flood Management Act 2010 are, however, dependent upon the development of secondary legislation (regulations and orders) before the law can be fully implemented, so it is likely that many of the provisions in the Act will not come into force for some time yet. Depending on scale, site considerations and the need for lining (which can account for 60% of the total cost) costs can vary from £2-£4m³.

Cranfield University is currently doing some R&D into collaborative approaches and reservoirs for Defra with the results due in 2013. Further information can be found on the process of concept through to building reservoirs in the Environment Agency/Cranfield University publication Thinking about an Irrigation Reservoir? A guide to planning, designing, constructing, and commissioning a water storage reservoir.

2.3.3 The need for water and how much to supply

Three main factors affect crop water supply:

- The level of water demand, expressed as evapo-transpiration (ET)
- The amount of water in the soil
- The ability of the root system to extract water from the soil.

2.3.4 Evapo-transpiration (ET)

The demand for water by a plant is referred to as evapo-transpiration (ET) and consists of transpiration from plants (crop ET) and evaporation from the soil surface and air (ET0).

ET is usually calculated from meteorological data and is expressed as the daily rate of water used in mm. ET data is available from sources such as the Meteorological Office, the internet, and by using in-field or on-farm ET gauges and computerised irrigation scheduling programs.

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IRRIGATION AND WATER USE (BEST PRACTICE GUIDE FOR POTATOES)

2.3.5 The water held in the soil

The amount of water that soil is capable of retaining depends on its texture and structure. In a saturated soil, all spaces between particles are filled with water but drainage progressively removes water from the larger pores between particles first. After a few days drainage, the only water left is that contained in pores sufficiently narrow that the forces holding it around the soil particles are in equilibrium with gravity.

This is known as ‘field capacity’ (FC) and represents the upper limit of available water in the soil. As drainage and crop extraction proceed, a point is reached when the plant cannot extract any more water (the permanent wilting point or PWP). The soil water available for the crop is the amount held between FC and PWP and is described as the available water capacity (AWC): thus AWC = FC – PWP.

Sandy soils hold relatively little water as their texture allows water to drain freely down the soil profile and these soils have a small AWC, however, by the addition of organic matter, the AWC can be improved. Heavier loam and clay soils are equally porous by volume but because this pore space is composed of much narrower pores, they are able to retain more water against gravity. These soils have a larger AWC.

Readily available water (RAW) is the water that a plant can easily extract from the soil. RAW is the soil moisture held between field capacity and a nominated refill point for unrestricted growth. In this range of soil moisture, plants are neither waterlogged nor water-stressed.

2.3.6 Typical soil Available Water Capacity (AWC)

An estimate of AWC for a crop rooting to 700mm, with 330mm of topsoil and 370mm subsoil (soil type sandy silt loam) would be calculated as shown in the table above.

Depletion of the AWC below 50% would result in a large yield penalty. If conditions are hot and dry the evapo-transpiration rates will be high and a significant yield penalty would occur at lower soil moisture deficits. This needs to be taken into account when scheduling irrigation.

<table>
<thead>
<tr>
<th>Soil horizon</th>
<th>Depth</th>
<th>AWC%</th>
<th>Available water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil</td>
<td>330mm</td>
<td>19%</td>
<td>63mm</td>
</tr>
<tr>
<td>Subsoil</td>
<td>370mm</td>
<td>17%</td>
<td>63mm</td>
</tr>
</tbody>
</table>

Source: Irrigation Best Practice: Water Management for Potatoes: A Guide for Growers (basford et al., 2005)

<table>
<thead>
<tr>
<th>Topsoil AWC % (readily available %)</th>
<th>Subsoil AWC % (readily available %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silt loam</td>
<td>23 (15)</td>
</tr>
<tr>
<td>Medium sandy silt loam</td>
<td>19 (11)</td>
</tr>
<tr>
<td>Clay loam</td>
<td>18 (11)</td>
</tr>
<tr>
<td>Medium sandy loam</td>
<td>17 (11)</td>
</tr>
<tr>
<td>Loamy medium sand</td>
<td>13 (9)</td>
</tr>
<tr>
<td>Loamy coarse sand</td>
<td>11 (7)</td>
</tr>
<tr>
<td></td>
<td>22 (14)</td>
</tr>
<tr>
<td></td>
<td>17 (11)</td>
</tr>
<tr>
<td></td>
<td>16 (10)</td>
</tr>
<tr>
<td></td>
<td>15 (11)</td>
</tr>
<tr>
<td></td>
<td>9 (6)</td>
</tr>
<tr>
<td></td>
<td>8 (6)</td>
</tr>
</tbody>
</table>

Source: Irrigation Best Practice: Water Management for Potatoes: A Guide for Growers (basford et al., 2005)
2.3.7 Soil Moisture Deficit (SMD)

Soil Moisture Deficit (SMD) is an indicator of the moisture status of the soil and is the key measurement used in irrigation scheduling.

When water is lost from the soil by evaporation and transpiration, water content is reduced and a SMD develops (below FC). Water from the larger pores tends to be extracted first, because it is held less tightly by the soil. As this process continues only tightly retained water remains and eventually the plant closes its stomata to reduce water loss. The point at which this occurs is known as the ‘critical SMD’. Closed stomata results in lower rates of photosynthesis and potentially lower yields. If the soil is allowed to dry beyond the ‘critical SMD’, the rate of water uptake decreases and plant growth is compromised.

The SMD should be monitored and irrigation triggered before it reaches a critical level. The amount of irrigation that should be applied at any one time is limited by the current SMD as well as the infiltration rate of the soil, ie irrigation should not be applied at a faster rate than can be accepted by the soil. For example, there is no benefit from applying more than 20mm of water at an SMD of 20mm.

However by applying less, ie 15 or 18mm, this allows spare capacity in the soil should rainfall occur after irrigation has been applied (though amounts below 18mm are considered impractical for rain guns). Irrigating with more water than the soil can accept is not only a waste of resource but likely to cause run off and erosion.

IRRIGATION AND DRAINAGE SYSTEM. Match the irrigation methods, crop choice and site characteristics to design a system for optimal water use efficiency. Reuse water where feasible.

2.3.8 Irrigation system options

Irrigation systems include surface flow, sprinklers and various forms of trickle/drip irrigation. Each has its own special applications, merits and limitations.

Surface flow (flood or furrow) irrigation is very rarely used in the UK and tends to be used in countries where the general infrastructure is low. This type of irrigation is best suited to heavy soils with limited drainage and the application of large volumes of water to large areas. Energy costs are low as this option relies on gravity to move the water.

Sprinkler type irrigation systems range from rain guns, linear and centre pivots. Large areas can be watered and they are reasonably precise in how they deliver water. They require water under pressure to operate and consequently energy costs are relatively high, as are the infrastructure costs.

Drip or trickle irrigation allows very precise water delivery to plants and their roots. They can to be used in a variety of situations. This option requires a pressurised water supply which can be expensive to install but they are very efficient on water use.

2.3.9 Design of system

The irrigation system chosen must match:

• The water supply and delivery system
• The soil type and topography
• The crop requirements.

Automation, maintenance and fitting in with other farming operations (eg planting and harvesting, etc.), along with price and operating costs are other factors that need to be considered when designing a system.

The irrigation system needs to suit the management skills and the goals of the irrigator. For example, a poorly managed trickle irrigation system can be less efficient than well-managed flood irrigation on the appropriate soils.

Most well designed systems aim to achieve high levels of uniformity in delivering water and typically 85-95% consistency over a field is realised. This means that the potato plants are watered evenly, eliminating any gaps that would lower the water use efficiency.

It is important to match pumps and motors to the size of the job and to maintain the system regularly as energy consumption (ie cost of diesel) has a major impact on the running cost and greenhouse emissions.

2.3.10 Uniformity of application across the crop area

Irrigation should be applied as evenly as possible to ensure a uniform crop response. Variable applications often lead to over-watering of some areas while other parts receive an adequate amount. This can also lead to lower crop yield and poorer quality, as well as creating ponding on the surface and possible run-off problems.

Uniformity is very difficult to visually measure, so is often overlooked. Application uniformity must be checked periodically to identify any spatial variability that may have arisen since the last check. Then the set up (eg lane...
spacing, etc.) and operation (eg water pressure) of the system can be checked and improvements made as necessary.

Uniformity is influenced by three main factors:

- Correct operation of equipment (pressure, trajectory and sector angle)
- Lane spacing – the area of wetted overlap (how far the water is being ‘thrown’)
- Local weather conditions, including wind speed and direction during irrigation.

2.3.11 Applying irrigation water efficiently

Most growers (approximately 70%) still use rain guns fitted with hose reels because they are flexible, robust and fit in well with the rotational pattern of cropping in the UK.

2.3.12 Getting the best from rain guns

It is vital that rain guns are operated at their design pressure, providing a good distribution of many small droplets that will land gently which percolate through the soil. If pressures are too low, larger droplets are formed, and can cause soil capping or erosion.

All rain gun nozzles have a design pressure that is linked to a water throw radius. This can be found in instructions provided with the machine. However, as a general guide, the pressure needed at the rain gun (not the hose-reel) will be approximately 4.5-5 bar. A spigot is usually fitted on the riser of the rain gun trolley so that a pressure gauge may be attached.

It is worthwhile fitting a gauge here to ensure that the correct pressure is being achieved at the rain gun.

There is always a pressure gauge provided on the intake to a hose-reel and this should also be checked to ensure that water pressure at the machine matches...
the manufacturers’ recommendations. This value varies depending on the machine and may be between 8-10 bar, though some machines may have hose-reel connection pressures of as low as 5.5 bar.

2.3.13 Problems that may occur with rain guns

2.3.13.1 Low Pressure

The main reasons for low pressure are:

- **Rain gun/nozzle size**: incorrect selection: too large will allow too much water outflow and not permit adequate system pressure rise to achieve the desired trajectory. Applying water through rain guns at amounts greater than 25mm per pass may aggravate the overall pressure/flow balance within the system, causing instability of the machine, which may in turn cause problems during reel wind-in.

- **Pipe size**: in narrow bore pipes, frictional pressure from the pipe wall reduces flow rate in the pipe for any given pump pressure. To maintain flow rates, therefore, pump pressures have to be increased.

- **Pipe lengths**: as length increases, more pipe is in contact with water and thus more energy is needed to offset the increased friction. This is often a problem with ‘new’ fields further away from the pumping source.

- **Land contours**: every 10m rise in the land is equal to 1 bar pressure within the pipe. This must be considered when laying out pipes for seasonal use or when planning the routing of any system. Pressure is, of course, increased within the pipe for a downhill slope in the land surface (an extra 1 bar for a 10m fall).

- **Pump**: incorrect speed: poor pump selection or worn components can all result in reduced water pressure. Excessive suction lift at the water source can also limit pump performance.

2.3.13.2 Pipe sizes and lengths

Energy is lost within distribution pipework due to the friction of water passing through it but a good design should allow for no more than 10% of the pump energy to be lost in this way (in addition to the equipment connection pressure and any lifts involved).

- Select the largest internal diameter pipe (that is consistent with cost and other practical factors) to minimise friction losses and reduce energy consumption.

- Examples of the amount of energy used (expressed as head losses) at two flow rates and for three internal pipe diameters are shown in the Table below. It can be seen that the energy does not relate linearly to pipe diameters, which means that for a relatively modest increase in diameter, the pressure loss drops considerably. There is only 15-20% reduction in

<table>
<thead>
<tr>
<th>Pipe internal diameter (mm)</th>
<th>Water flow 15 litre per second</th>
<th>Water flow 30 litre per second</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>2.8</td>
<td>10</td>
</tr>
<tr>
<td>150</td>
<td>0.5</td>
<td>1.5</td>
</tr>
<tr>
<td>200</td>
<td>0.12</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Note: 10 metre pressure = 1 bar (1 atmosphere).
All pipes sizes should be checked to make sure it is the internal diameter which is used for calculations.
pressure loss for a 50% increase in diameter (from 100 to 150mm), but a 95-97% reduction for a doubling of diameter (from 100 to 200mm).

• Most growers have to accept some constraint on where crops are grown and how water is delivered to the field. Good planning should ensure that the furthest locations will be served by the largest affordable diameter pipe

• Block cropping will concentrate the demand on the distribution system, so operators need to consider whether pipe size is large enough for the demands of such a layout. A ring system design allows water to flow within the ring circuit in either direction at lower flow rates within the pipe. This reduces energy consumption due to friction and provides more pump energy for the irrigation equipment.

2.3.13.3 Pumps
All pumps have an operating ‘window’ in their original specification to optimise flow rate, pressure, operating efficiency and power input, this is designed around a fixed operating pump speed.

• Check the pump isn’t operating outside this window, trying to supply a volume of water in excess of its capacity, to meet the needs of too many hose-reels or nozzles.

2.3.13.4 Lane spacing
All hose-reel/rain gun combinations will work at varying lane spacings. This is listed within the equipment instructions. In the UK a lane width of 72m is commonly selected, which allows the rain gun trolley or sledge to follow pairs of potato rows or one bed. Little damage to crops is normally caused, though increased attention is being paid to this potential problem, especially for high value crops (eg with offset equipment).

Other growers now leave these rows unplanted, accepting the production loss is balanced by the reduced amount of grading out required.

• It is critical that the lane spacing remains unaltered during irrigation and all adjustments to the equipment permit correct overlap of water from lane to lane at 72m. Generally this means that the water should have a throw of approximately 43m.

2.3.14 Checking water distribution
• Check in the field using 5 litre catch cans, spaced at 3m intervals across the full wetted area, and covering the overlap of adjacent pulls. Measurements of the volume of water collected at each point can then be plotted to show the areas of non-uniformity on a graphical image

• A value called the Coefficient of Uniformity (CU) is calculated from these measurements. The larger the figure, the more even the application – though much higher than 90% would not be expected in the field

• If gun pressure is poor then the pattern shown in the chart above, taken from a field study, may result (see the charts above). This poor distribution will result in a greater cumulative disparity in the SMD if repeated over time

• A correctly set up rain gun with correct operating pressure at the gun to match the chosen lane spacing, produces a much better performance

A suitable CU target for rain guns is 80-85%. Simple checks to uniformity – and the amount actually applied – may be found by using a number of simple rain gauges, or ‘catch cans’. Results greater than 75% are acceptable but lower figures show scope for improvement.
Section 2

2.3.15 Calculating the Coefficient of Uniformity (CU)

The CU can be calculated by carrying out a simple field interception of water across an irrigator’s wetted area. This is done out by putting out ‘catch cans’ – normally 5 litre paint pots at 3m intervals to ensure that the whole distribution is intercepted.

The volume of the ‘can’ must be known, so that the ‘depth’ of water collected can be calculated. For example, a can with an opening of 20cm diameter (radius of \( r = 10\text{cm} \)) will have an area of \( 314\text{cm}^2 \) (area = \( \pi r^2 \)) and so 10mm of rain will give a volume of 314ml in the can. Therefore the volume of ‘rain’ in the can (measured as ml or cc) should be divided by 1/10 of the area (cm\(^2\)) to obtain the depth of rain in mm.

For a 72m rain gun lane width, the wetted area (assuming no side wind effect) will probably be around 85-90m in width. Thus around 30 cans will be required, placed at right angles to the irrigator travel direction as it is drawn across the field. Once the irrigator has passed over the line of cans, the volume of water in each can is measured using a graduated measuring cylinder and the volume recorded for each can. The volume per can must then be calculated into a depth per can by dividing by the known collecting area (opening size).

The Coefficient of Uniformity (CU) as a percentage can be calculated using the formula:

\[
CU = (1 - \left( \frac{\sum (x - xm)}{y} \right)) \times 100
\]

where, \( \Sigma \) means the sum of the following eg

\[
\Sigma x = x_1 + x_2 + x_3 \ldots x_n
\]

\( n \) = number of cans

\( x \) = depth of ‘rain’ found in each can (mm)

\( xm \) = mean depth (mm) for all cans (\( xm = \Sigma x / n \))

\( y \) = total of depth (mm) from all cans (\( y = \Sigma x \))

and \( x-xm \) is always expressed as a positive value (eg if \( x=5 \) and \( xm=6 \) then \( 5-6=1 \) not –1)

Fewer cans can be used but the result will be less accurate.

2.3.16 Mitigating for wind effects

The irrigation season in the UK will most certainly include many days of windy weather, when waiting for still conditions may not be feasible. To reduce the effect of wind on uniformity, farmers should aim to:

- Set the rain gun sector angle at 210° or more (rather than the normal 180°). This allows the rain gun to cover the ends of the cycle for longer, depositing more water at the edges of the lane width. Any risk of possible overwatering is more than outweighed by better distribution in windy weather.
- Make the most of the opportunity to irrigate at night, when the mean UK wind speed is about half of that found during the day.
- Plan to include most of the longer ‘pulls’ at night, where possible, so that a greater area receives water more uniformly.
- Where newer ‘variable angle’ rain guns are used, lower the angle (to around 15° from the horizontal, compared with the normal angle of around 22°) when the weather is windy. In calm conditions these guns may be increased to a 25° angle to maximize throw, thus achieving good overlap.
- On exposed sites, better uniformity can often be achieved by adopting a lane spacing narrower than 72m. This may, in turn, affect other farm operations such as spraying and fertilising but often 60 or 66m spacing can offer improved application uniformity.

2.4 Alternatives to rain guns

2.4.1 Booms

Boom equipment can offer more even water distribution than a rain gun and regularly operates at a CU of 90% when set up correctly. This is because a boom carries a large number of small nozzles or sprinklers. The trajectory for droplets to the soil is shorter and a good overlap along the boom profile is achieved. Booms will generally produce a larger number of small droplets that create less damage to soil and plants, mainly due to the droplets having less energy. When compared to rain gun use, booms are generally more efficient and tend to result in more uniform and higher quality crops with cleaner foliage. However, booms do not ‘throw’ water from the unit as far as a rain gun and this reduction in the wetted front as the boom moves means that the soil must accept the water over a shorter period if operated at the same forward speed and application rate. On a few soil types this can be a problem, such as soil with a high silt content or where slopes are significant, ie over 5%.

Obstructions such as poles or trees are challenges to boom usage, as are fields that are oddly shaped. However, it is worth checking just how much of the field area is affected, as often the proportion can be quite small. In addition, booms can be supplied with a central...
rain gun so that where obstructions are found the booms may be folded and the rain gun used.

The cost of boom equipment tends to be more than for a rain gun but over a 10 year life (including extra labour costs) the extra cost per hectare can be recouped in crop quality and yield improvements. In addition, booms tend to operate at a lower pressure than rain guns (around 3 bar), which results in energy savings and more efficient water use.

2.4.2 Sprinkler and drip irrigation

Mobile sprinkler systems requiring hand movement between applications are not very common. They can be used on small areas ie awkward field extremities, vegetables or hardy ornamental stock. ‘Solid set’ or fixed sprinkler systems are more common, as they almost eliminate seasonal damage to the soil or crop and provide good uniformity. The recent availability of single moving part sprinklers with laterals typically spaced at 18m and with good uniformity characteristics, may herald a renewed interest in sprinklers.

Drip or trickle irrigation systems normally place the water directly into the soil or onto the soil surface, giving minimal risk of run-off. All drip systems can accommodate growing techniques with little or no modification and field lengths are not normally a problem due to the availability of pressure compensating systems. Drip irrigation involving soil surface or buried pipes is unaffected by wind and, in addition, places water close to the rooting zone (limiting evaporative loss). A correctly designed and installed system should easily achieve a CU above 90%. However, these systems are often more susceptible to poor management due to the complexity and the potential blockages of individual drippers, with consequent impacts on uniformity and the cost and practical issues of pipe installation and retrieval currently challenge its more widespread adoption.

2.5 Irrigation techniques

Irrigation systems that allow each nozzle to apply variable rates of water according to soil type and moisture deficit are helping growers use limited water more efficiently. Irrigation is central to the success of most potato cropping systems. With low rainfall during the growing season and the potential of winds removing 5-8mm of moisture a day, by applying water farmers have been able to take unreliable low moisture-holding soils into useful production. However, water use is restricted, which means farmers need to be efficient in using it.
That requirement, plus the realisation that soil types could be extremely variable under large irrigation systems, suggested that variable rate irrigation could help. Using electromagnetic mapping to analyse soil type under irrigation systems, creating zones in which soil moisture probes are placed that wirelessly transmit moisture deficit information from two depths back to a central base station. It gives real-time moisture monitoring accessible through a website and the information can then be used to produce irrigation maps for the amount of water needed to be applied in each zone. The water required is then applied using a variable rate irrigation system which individually controls each sprinkler head to apply the correct amount of water.

In studies, farms using this system have saved up to 20% water, with no loss in yield. With a water saving and the same yield, there is an increase in water use efficiency. Measurements on two booms using water meters suggested a saving of around 12 litres/second. Potentially the whole system could be automated to apply water at a designated soil moisture deficit. Further information can be found in the waterwise document published by the Environment Agency: http://publications.environment-agency.gov.uk/PDF/GEHO0307BLVH-E-E.pdf

2.6 Drainage

Excess irrigation water will drain away below the crop, flow off as surface water and potentially wash away ridges and beds causing greening of the potato tuber. If drainage is impeded below the root zone then there may be a possibility of waterlogging, salinisation and the eventual installation of a sub-surface drainage system. The design of drainage systems is much easier if you have an understanding of the site’s soil and geology.

If drainage water is of suitable quality it can be harvested and re-used for irrigation. By re-using the water, the overall water use efficiency is improved, saves nutrients that would otherwise be lost and reduces the contaminants reaching water courses. More information on drainage can be found at: www.ofwat.gov.uk/future/sustainable/drainage and www.environment-agency.gov.uk/business/sectors/136252.aspx

Source: www.wdfupdate.blogspot.com
Section 3

Irrigation management

Irrigation requires regular decisions about when to irrigate and how much. These decisions must balance the availability of water with the needs of the crop, the capacity of the system to deliver the water, how, where and when required.

3.1 Water benchmarking

The first step in irrigation is to develop a water budget. The budget compares the crop requirement for water with the water that is expected to be available. In times of drought this is a crucial tool and can be modified if the circumstances change. Budgets can be used on an annual basis or broken down into monthly intervals.

It is essential that the budget allows for all the components, including all potential water sources (rainfall, irrigation and re-use), the initial store of water in the soil and losses such as evaporation from reservoirs. As well as the plant requirement, drainage also should be factored in.

3.2 When to start irrigating

Start dates for irrigation have become earlier in the life of the crop. The main driver for this has been quality and the control of common scab in both the pre-pack and processing sectors where tolerance levels have markedly declined.

Irrigation should be targeted to begin shortly after emergence and no more than 15% crop cover, to ensure that topsoil is close to field capacity by the time tuber initiation occurs. However, there is a risk of nitrogen leaching from the soil, particularly if the weather turns wet. With little ground cover, evapo-transpiration rates are low and the risk of leaching will be high, with soils at or nearly at field capacity. If irrigation needs to start earlier than the abstraction licence allows then it is essential that the Environment Agency is contacted as early as possible (0370 8506506) so that changes to the licence can be made.

3.3 How much water and when?

Around 40% of growers that irrigate still do not use any form of scheduling, which should form the basis of planning water use during the irrigation season. It would be unwise to rely solely on scheduling without examining soil in the field but equally basing irrigation decisions subjectively on gut feeling, what the neighbours do, experience or walking the crop, will not ensure optimum water application or crop response.

The aim of scheduling is to apply the ‘right amount of water at the right time’ and three basic approaches are used either on their own or in combination:

- Calculating crop water requirements based on climate and evapotranspiration
- Monitoring soil moisture levels in the root zone
- Monitoring the plants themselves.

The key is to use a range of tools and indicators, while still keeping an eye on the basics such as weather forecasts and visually inspecting the crop.

3.4 Soil moisture monitoring techniques

Optimising the use of water for both crops and the environment often depends on someone recording rainfall, checking equipment and scheduling the irrigation equipment. A range of sophisticated techniques and tools are available to measure soil water content and schedule irrigation to assist in optimising water, crop yield and quality and environmental care.

There are several soil moisture monitoring methods, that can be used based on different technologies. The two broad categories are direct methods which use techniques for measuring the soil water content or tension and indirect methods which rely on environmental measurements to estimate crop water loss.
3.4.1 Direct methods
This equipment measures soil moisture directly and depends on the siting of equipment at points that are typical to the soil type and irrigation applied. Variations in the soil texture or the amount of water applied across the field often causes difficulties in interpreting data, though it is normal to have a number of measuring points to overcome this.

3.4.1.1 Neutron probes
This technique is based on fast moving neutrons colliding with hydrogen atoms in water and slowing down. The neutron probe has both an emitter and detector which is used to count the neutrons slowed following collisions with the hydrogen and enable an estimation of the amount of water in the soil.

After the potato crop has been planted holes are drilled in the ground, usually three per field and aluminium tubes inserted. At regular intervals during the growing season, the neutron probe is lowered down the tubes and readings taken at various depths to produce a profile of soil moisture.

However, the technique has limitations when used for scheduling irrigation. The probe needs to be calibrated when the soil is at field capacity and often potato fields do not naturally return to field capacity following planting, so an estimate would have to be made. Any measurement

When to irrigate decision tree.
A licence is required to use a neutron probe due to the radioactive source.

3.4.1.2 Tensiometers
These are relatively cheap instruments that measure the tension of the water held in soil. The greater the tension the drier the soil. The measurement is useful as it directly relates to the crop uptake and ability to extract water from the soil at the time of the reading. The tensiometer consists of a porous ceramic cup filled with water, placed in the soil and attached to an upright tube of water with a vacuum gauge. As soil dries, water is drawn out of the cup causing a vacuum in the tube.

Tensiometers are used in pairs. One sited in the upper third of the root zone and the other in the lower third. Irrigation timing can then be determined by reference to the soil tensions measured on the vacuum gauge. The system aims to allow the application of water before critical tension is detected in the upper third of the root zone. The lower sited tensiometer helps to determine how much water is needed to re-wet the soil profile.

The main limitations of tensiometers are:

- They only provide point measurements of the soil water content.
- They require in-field servicing during the growing season.
- They provide little advance warning of when irrigation is needed so planning ahead as regards equipment and where it’s needed can be an issue.

3.4.1.3 Capacitance probes
These probes consist of an electrode connected to an oscillator circuit. They are inserted vertically into the soil within a PVC tube at a range of depths within the soil profile. A signal is sent to the probe and the returning signal is altered by the water content of the soil. After calibration the output from the probe can be converted to measurements of soil moisture. This system has the ability to continuously monitor soil moisture changes at a range of depths using a data logger and a power unit.

The data gathered can describe soil moisture conditions throughout the rooting profile and assist in the scheduling of irrigation. Limitations again occur when irrigation is applied unevenly, a single point reading is of little use when planning irrigation. The volume of soil measured is even less than for the neutron probes which can lead to inconsistencies, especially where there are lots of stones or variation in soil texture.

3.4.1.4 Time Domain Reflectometry (TDR) and Frequency Domain Reflectometry (FDR)
These techniques estimate the volumetric water content of the soil. High frequency pulses are sent to parallel electrodes placed in the soil. The TDR system has microprocessors used to measure the time taken for these pulses to travel to the end of the probes and then be reflected back to their origin, which is affected by soil moisture. In FDR systems, changes in frequency are measured which again are affected by soil moisture. The information is then used to calculate the average soil water content over the length of the probes.

Accuracy is dependent on the maintenance of a constant distance between the two probes and a good contact between the soil and the probes. If this doesn’t happen the readings tend to be a measure of the probe’s contact with the soil instead of the moisture status. A number of readings will be needed to gain a representative picture of a whole field. Neither of these methods are commonly used for commercial irrigation scheduling of potatoes.

3.4.2 Indirect methods
3.4.2.1 Manual water balance sheet
This approach is based on the concept of water balance. Water entering the soil, either by rain or irrigation, is treated as credit and water that exits as evapo-transpiration, drainage or run off is a debit. The difference between the two is used to calculate the SMD. Rainfall and irrigation has to be recorded on a daily basis. Evapo-transpiration figures can be purchased or estimated from charts.

Adjustment is needed where crops have not attained full leaf cover and there are several methods of estimating this. Unfortunately, there is a loss of accuracy and manual balance sheets often have significant errors which increase as the season progresses. The main errors are estimating evapo-transpiration and assumptions that the crop is able to extract soil water at a constant rate no matter what the SMD is; whereas the crop has increasing difficulty abstracting water from drying soil. An accumulation of errors can lead to significant inaccuracies in the estimation of SMD and consequently irrigation water applications.
3.4.2.2 Computerised water balance methods

These are sophisticated manual balance sheets that are capable of dealing with the complexities which manual sheets can’t.

A number of computerised systems are available that use crop, meteorological, rainfall and irrigation data to calculate rates of evapo-transpiration and soil moisture deficits. They are all based on a modified Penman-Monteith equation which has been shown from research to accurately predict rates of evapo-transpiration across a range of conditions.

Their main limitation is that they calculate estimates of soil moisture status which are not verified by actual measurements. Care must be taken to ensure that the data fed into the programme is accurate otherwise discrepancies will occur.

3.4.2.3 New innovation

The use of new monitoring technologies has resulted in improved scheduling of irrigation and combined with the technical advances in the delivery and control of water, opportunities to get the most out of irrigation systems has improved.

Two new innovations are:

- **Precision Irrigation**: The efficient and accurate delivery of different amounts of water across a field to precisely meet the needs of the plant
- **Fertigation**: Fertigation (supplying nutrients via irrigation water) supplies nutrients on an almost continuous basis through regular irrigated applications.

Both methods aim to meet the plants needs in order to increase crop yield and quality and ultimately, profit. Monitoring and control are important factors for both approaches.

3.5 Precision irrigation

Yields vary across a field due to differences in soils, available water, vigor, pests and plant varieties. Precision irrigation is used to meet the specific requirements of the plants in different management zones across a field to ultimately achieve higher production, better quality and increased water use efficiency. Scheduling for precision irrigation deals with several questions such as ‘when, how, and where to irrigate’ by relying on real time information of whatever may be limiting production at all times and all parts of the field.

Precision irrigation relies on:

- Acquiring accurate data by monitoring the soil, plants, and weather and their variations across the field
- Interpretation: often using computer models
- Controlled application: via automatic controllers linked to sensors the rate or length of time of irrigation is varied according to need
- Evaluation: monitoring the applications, soil-water and crop response to fine tune future applications of water.

Precision irrigation has been found to improve water efficiency by 8-20%. It has the potential to increase yield but the variation is so great that no conclusive results can be drawn. Thus the profitability of precision irrigation is also uncertain. Large in-field variability in the yield or quality may be necessary to justify the use of this innovation.

3.6 Fertigation

Fertigation is where the nutrients are provided as mineral salts dissolved in the irrigation water via drip/trickle irrigation. The nutrient solution is usually adjusted to a specific pH. The placement of the drippers and the frequency of water delivery restrict the active root zone to a much smaller volume than is usual. The soil is held near field capacity at all times by regularly pulsing water through the system or operating the system continuously throughout the day.

This type of system seeks to match the supply of mineral nutrients to the plants needs and growth stages and has the potential to significantly increase production, improve quality and allow earlier harvesting. However, the downside to this system is that it requires close management. Losses in production, leaching of nutrients, acidity and root zone salinity can result if not managed correctly.
Section 4

Crop and soil management

Plant Performance – understand crop growth and development cycles, seasonal requirements and how to maximise tuber numbers. Determine and meet plant nutrient requirements, while ensuring no wastage of fertiliser.

4.1 Plant growth

Understanding the development stages of potatoes, how they change through the season and how they function is crucial to effective, efficient irrigation. Knowing how the potato plant develops allows the application of water to be timed and measured according to the plants needs and allows the grower to manipulate the crop to improve yield and/or quality.

4.2 Nutrition

With modern irrigation techniques the precise delivery of water has made it possible to use the same technology for the precise delivery of dissolved nutrients within the irrigation supply.

Fertigation is increasingly common within the soft fruit sector and can be used for those potatoes irrigated via trickle/drip method. Fertigation can lead to greater efficiency and opportunities to fine tune plant nutrition, reduce traffic and fuel savings. It can also reduce nutrient loss through leaching and runoff where they can pollute water courses and aquatic ecosystems.

The trade-offs include high capital costs for mixing tanks and injection equipment, the time to mix the fertiliser and having to use high grade materials to avoid blockages. The more applications made, the more complex the decisions that have to be made about rates and timing and it is essential that incompatible nutrients are not mixed together, resulting in precipitation and blocked drippers.

4.3 Soil condition

Soil structure and texture are key elements in determining the rate of water infiltration, the amount of readily available water in the soil and consequently root growth and root function.
4.4 Infiltration

Water should not be applied at a rate faster than the soil can absorb it or in a manner that damages the soil surface, as ponding and soil erosion could follow. Soils with low infiltration rates (less than 1mm/hr) results in poor uptake of water and are prone to extended periods of waterlogging.

The fate of water that passes beyond the root zone and lost as ‘deep drainage’ should also be considered as ground water can be contaminated. Drains may be needed and efforts to improve the water holding capacity of the soil such as adding organic matter would be recommended.

Soils with penetration resistance of 0.5MPa result in unrestricted root growth but those soils with values of over 2.0MPa are almost impenetrable. Those soils where the pores are plentiful enable the roots to grow unimpeded and also ensure that there is enough oxygen for the roots to respire. Measured as air-filled porosity, the amount of oxygen should be above 10% for adequate aeration.

By having a good soil structure the ability of plants to make best use of water is greatly increased. Poor structured soils are either too dry and hard or too wet and soggy, depriving the plants of oxygen.

Infiltration can be improved by cultivation systems where the soil tilth is left slightly rough (or as a pressed surface where appropriate). There are a number of ways in which water infiltration can be improved:

- Compaction and rutting caused by previous cultivations should be minimised
- Tyres and pressures should be chosen to suit loads being carried, to exert as low a ground pressure as possible
- Avoiding compaction should be an integral part of a strategic soil plan for any business. Once caused it can be difficult to correct, because of a lack of opportunity, or power for subsoiling (as well as the cost)
- Maintaining the correct rain gun pressure will ensure correct atomisation and limit the production of large droplets
- Boom irrigators produce a larger proportion of fine droplets, which reduces erosion risk
- Growing crops in flat-topped or centre-dished beds allows the soil to receive the water with less run-off and erosion risk and some extra benefit follows from more water being held in the soil and available for root uptake

- The addition of organic matter can improve infiltration rates and the aeration of soil promoting root growth.

4.5 Slopes

Sloping land, particularly when compacted by wheelings, will lead to water run-off. Irrigation layouts should be assessed for the amount of surface run-off produced and, where sloping land is present, the differences in infiltration rate between different soil types may be accentuated. Where practical, crop row or bed alignment across a slope should be adopted to limit run-off.

4.6 Reduce run off and soil erosion

Run-off can also be limited by the use of tied ridges. These are small dams of soil formed approximately every metre to bridge the gap between beds. These hold irrigation water and rainfall and allow it to then infiltrate slowly into the soil. Slopes as steep as 10° have shown good water retention following the use of tied ridges. The frequency of these tied ridges along the row ensures that retained water does not accumulate in a large enough mass to start erosion by itself. A simple front mounted single tine or hoe on the harvester tractor can then be used to break down the dams and thereby allow the harvester passage.

A cultivation tool developed to assist infiltration is the ‘Aqueel’ (Simba International Ltd.), which can be used over the whole soil surface a raised bed surface, or on the top of potato ridges. Small depressions are created on the soil surface, which act as reservoirs (of about 1 litre) to intercept the water and allow infiltration into the soil with less chance for lateral displacement and run-off. Just under 200,000 mini reservoirs are formed per hectare and the effect can persist over the whole season, depending on soil type and amount of water intercepted. The polymer wheels are self-cleaning and can be fitted to cultivators, bed formers, drills and planters.

The wheel track roller is another cultivation tool that is currently under development. Tines run to the side of the compaction caused by the tractor, imparting minimal surface disturbance but generating a channel through which the surface water can escape into the adjoining crops. The unique self-cleaning, plastic roller forms angled, elongated reservoirs to hold the surface water and at the same time creates fissures enabling the dissipation of the water into the soil, which remains soft around the channels generated by the tines.
Monitoring – Monitor and respond to aspects of the system performance, management, production and environment. Every farm is different – by picking key performance indicators that are of most use eg production, finances (gross margins), the environment (water quality) and human aspects (number of accidents), then performance can be measured.

All aspects of an irrigation enterprise need to be monitored so management can be fine-tuned.

5.1 Record-keeping of water use

A comprehensive farm irrigation water plan can have a number of aims but all of them should contribute to an overall objective of improving farm management and profitability. The primary need of the plan, though, is to simply keep an accurate record of water used on the farm. (Most abstraction licences carry a condition that requires the use of a meter to measure the amount of water that is abstracted.) **THIS IS A LEGAL REQUIREMENT FOR ABSTRACTION LICENCES.**

From this set of records, many other benefits will follow, in particular a plan should be able to:

- Record actual water use compared with planned and so provide a basis for increasing efficiency
- Demonstrate the responsible use of water
- Take account of environmental considerations such as Sites of Special Scientific Interest (SSSI)
- Meet the requirements of Crop Assurance Protocols
- Provide a comprehensive record of management and staff training.

Such record keeping is now essential on farms and there is a greater reliance placed upon it when demonstrating the environmentally responsible and sustainable nature of farming to the wider community.

The Environment Agency has developed a new online reporting system for abstractors. This system is called Generic Operator Returns (GOR) and more can be found out about it on their website at www.environment-agency.gov.uk/business/topics/109520.aspx

5.2 Basic farm irrigation planning

The range of information that it is advisable to keep falls into two categories. The first can be considered the minimum set of background information that will be useful accumulated over many years to demonstrate the efficient use of water on farm and will help to justify the need for water for crop production at that location.
Section 5

5.2.1 Daily work planning

The second category of information is an expanded dataset that can be kept for only a little more effort. This provides additional information valuable in the efficient daily management of both soil and water. The starting point for this information is ‘day sheets’, which encourage both the daily management and oversight of irrigation and the habit of record keeping. Such a dataset may comprise the information listed below.

5.2.2 Background information

- Farm information; including soil types and cropped and irrigated areas
- Abstraction licence information; licensed amounts and rates for abstraction, together with actual amounts abstracted; should include stored water as well as seasonal
- Actual meter readings to calculate above information and for licence checking (how much water the business is actually using)
- Annual summary of irrigation water applied and on which fields and crops (including that for aiding germination, transplanting/crop establishment and harvesting), including dates of application
- Soil management and environmental considerations
- Training records of all operators.

There is now a need in many assurance schemes to demonstrate that appropriate training is undertaken by both those who manage irrigation and by operators. Annual training records, including certificates of attendance, are valuable in demonstrating water use efficiency and in supporting irrigation abstraction licence renewal. In addition, a map should be kept showing the location of water courses, reservoirs, conservation areas, nature reserves, SSSIs, etc.

This information may comprise of:

5.2.2.1 Daily soil and water management information

- Daily rainfall, accumulated over months and years (multiple sheets)
- Daily record of irrigation amounts applied; according to field areas and crops, and details of equipment used and timing
- Daily maintenance checks on equipment

5.2.3 Additional useful information

Other information such as that listed below may be useful in planning water use on the farm and demonstrating that all possible outcomes of management actions have been considered. At least six years of records should be kept, in accordance with the (CAMS) review cycle, and preferably 12 years (which will be the normal renewal period).

5.2.3.1 Additional management information

- Farm/field map showing water courses, water disposal and potential risks and infield drains
- Timing and amount of application are compatible with infiltration rate
- Weather data (daily rainfall and Evapo Transpiration) to aid calculation of irrigation need
- Evidence that irrigation scheduling system data inputs are accurate, the system is delivering the required information and that it is cost-effective.

• Occasional record keeping of longer-term maintenance of pumps and meters, including any repairs to the system.

At less frequent intervals, it will be necessary to keep a record of all maintenance and calibration work carried out on the pump station and application equipment. Guidance for irrigators about metering abstractions can be found: www.environment-agency.gov.uk/business/topics/water/123416.aspx
# 6.1 Irrigation essentials – Environment Agency

<table>
<thead>
<tr>
<th>Expectation</th>
<th>Benefit to the farming business</th>
<th>Improvement to the environment</th>
<th>Action (dependent on local situation)</th>
<th>Access to advice and support</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manage your water usage effectively</strong></td>
<td>Reduce the costs of using water on your farm.</td>
<td>Water is a valuable resource. Using excessive amounts deprives others and the environment of much needed water. Wasting water costs you money and could trigger early restrictions. Failure to have water at the right time reduces crop yields.</td>
<td>Check for leaks, insulate pipe work. Schedule your irrigation and ensure that water is applied to crops efficiently. Record the volume of water you use with a well-maintained meter (if you have an abstraction licence this is required).</td>
<td>Water wise booklet from the Environment Agency Use a free bench marking tool. To register, go to the UKIA homepage – <a href="http://www.ukia.org">www.ukia.org</a></td>
</tr>
<tr>
<td><strong>Plan for your longer term water needs</strong></td>
<td>Find out what risks less water will pose to your business.</td>
<td>Climate change threatens to change the availability of water you can abstract. For example, we may experience more droughts or sudden high flows. Watercourses are important for water supply and for drainage.</td>
<td>Consider planting drought tolerant crops, harvesting rain water, or developing a high flow storage reservoir, especially with other abstractors. Increase the connectivity of existing sources. Consider buying water from another abstractor and setting up a Water Abstractor Group with your neighbours. Use more efficient irrigation techniques such as scheduling, trickle irrigation, and applying at night. Apply to extend your licensed abstraction season to match your irrigation season. Consider whether you can take high flows in summer if you already have a reservoir. Consider the targeted planting of shelterbelts to reduce water stress on crops during drought periods. Get advice and apply for consents and registering for exemptions to undertake your own watercourse maintenance.</td>
<td>National Permitting Service or Area Environment Planning teams. Telephone 03708 506506. Leaflets on Water Rights Trading, Rainwater harvesting – an on farm guide, Water Abstraction Groups and Reservoirs are available from the Environment Agency Farming &amp; Forestry Improvement Grants (Defra), CSF grants Woodland for Water (Forestry Commission and Environment Agency) Contact Environment Agency partnership and strategic overview teams (to obtain flood defence consents and advice on maintenance). Register for waste licence exemptions at <a href="http://www.environment-agency.gov.uk/business/sectors/32779.aspx">www.environment-agency.gov.uk/business/sectors/32779.aspx</a></td>
</tr>
</tbody>
</table>
### 6.2 General farm irrigation template

<table>
<thead>
<tr>
<th>Farm contact and address</th>
<th>Environment Agency Region and CAMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main contact</td>
<td>EA Region</td>
</tr>
<tr>
<td>Farm name</td>
<td>CAMS catchment</td>
</tr>
<tr>
<td>Address</td>
<td><strong>Abstraction licence entitlement and pumping capacity for 20</strong></td>
</tr>
<tr>
<td></td>
<td>Total licensed volume (m$^3$)</td>
</tr>
<tr>
<td></td>
<td>Total abstracted volume (m$^3$)</td>
</tr>
<tr>
<td>Postcode</td>
<td>Peak abstraction rate (m$^3$/day or m$^3$/month)</td>
</tr>
<tr>
<td>Telephone or email</td>
<td>Are there any constraints on irrigation (eg in-field equipment, pump capacity, licence)?</td>
</tr>
</tbody>
</table>

#### Irrigation water sources

<table>
<thead>
<tr>
<th>Water sources</th>
<th>% of total volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>River abstraction</td>
<td></td>
</tr>
<tr>
<td>Borehole</td>
<td></td>
</tr>
<tr>
<td>Mains water</td>
<td></td>
</tr>
<tr>
<td>Other (please specify)</td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL**

#### Reservoir storage

<table>
<thead>
<tr>
<th>Type</th>
<th>Number</th>
<th>Total capacity (m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unlined or earth-lined reservoirs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reservoirs with synthetic lining</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL**
<table>
<thead>
<tr>
<th>Variety</th>
<th>Location</th>
<th>Crop calendar</th>
<th>Irrigated area (ha)</th>
<th>Cropped area (ha)</th>
<th>Market</th>
<th>Harvested yield</th>
<th>Irrigation method</th>
<th>Irrigation scheduled</th>
<th>Volume of water used</th>
<th>Soil type</th>
<th>Irrigation area (ha)</th>
<th>Irrigated area (ha)</th>
<th>Irrigation method</th>
<th>Volume of water used</th>
<th>Soil type</th>
</tr>
</thead>
</table>
6.3 Pests and diseases associated with irrigation

Common scab
Common scab leads to major financial losses within the potato industry, due to the reduction in tuber quality. The disease is caused by Streptomyces spp. Soil moisture during and shortly after tuber initiation has a dramatic influence on common scab infection. The disease is more common on light sandy soils.

Recommendation
• Maintain a soil moisture status close to field capacity during 4-6 weeks following tuber initiation, to inhibit infection.

Late Blight
Late Blight is the most economically important disease of potatoes in the UK. It is caused by Phytophthora infestans. All parts of the plant become infected. Prolonged periods of surface wetness or 100% RH and moderate temperatures (10-25°C) will encourage the spread.

Recommendations
• Control foliage regrowth on waste dumps
• Fungicide programmes should begin well before blight becomes established
• Plan irrigation and blight control programmes to operate in harmony during the growing season.

Powdery scab
Powdery scab is caused by Spongospora subterranea. It develops best under damp conditions and produces pimple like swellings that enlarge and erupt releasing spores into the soil. The organism survives many years in the soil. Can also be transmitted via infected seed.

Recommendations
• Avoid planting infected seed in fields which will be irrigated
• Avoid growing irrigated crops of susceptible varieties in soils with a history of the disease
• Avoid over irrigation.

Fungal rots (Pink rot, Watery wound rot, Rubbery rot etc.)
Pink rot (Phytophthera erthroseptica), Water wound rot (Pythium species) and Rubbery rot (Geotrichum candidum), are all produced by soil borne fungi. Pink rot is a particular problem in the West Midlands where it can cause severe yield losses. The rots develop in soils approaching field capacity, especially when temperatures are high. Poor drainage or soil compaction can worsen the severity of these diseases.

Recommendation
• Where there is a history of one or more of these diseases in the field, irrigate to leave a significant SMD in the mid-late summer period.

Blackleg and bacterial soft rots
Blackleg and soft rots are caused by Erwinia species. These bacteria are carried in or on tubers. Contaminated tubers show no symptoms until they become stressed or damaged in the field or when stored. Rotting is encouraged under conditions where a film of water is present around the tuber and temperatures are >20°C. In the field, rotting tubers release bacteria into the soil.

Irrigation can compound the situation by allowing movement of Erwinia across the field. Blackleg develops when the pathogen is moved up the xylem into the stem. Bacteria can be brought in from nearby potato crops, dumps or contaminated irrigation water. Overhead irrigation and rain can also spread the disease by splash and aerosol effect.

Recommendation
• If Blackleg becomes a problem in a crop, consider reducing or even stopping irrigation.
Silver scurf and Black dot
Silver scurf (*Helminthosporium solani*) and Black dot are blemish diseases. Especially important in the pre-pack market. Infections of the skin occur prior to lifting so harvesting in a timely manner is important. There is some conflicting information that disease levels increase or decrease due to irrigation, so its best to focus on methods other than irrigation management to minimise these diseases.

**Recommendation**
- Timely harvest rather than irrigation management offers a better means of disease minimisation.

Spraying
Spraying manifests itself as brown arcs in the flesh of the tuber and in severe cases on the tuber surface. It is caused by Potato Mop Top Virus (PMTV), transmitted by the spores of Powdery scab or by Tobacco Rattle Virus (TRV) transmitted by free living nematodes. The free living nematodes depend on moisture for movement. Wets soils soon after tuber initiation can increase the risk of spraying where TRV nematodes are present.

**Recommendation**
- Irrigation, especially for common scab control, can increase the risk of spraying, so where this is a threat, take necessary precautionary measures to control it.

Cut worm
Cutworms are the caterpillars of several moth species. Newly hatched caterpillars initially feed on leaves but then move down to the soil where they feed on tubers, producing large holes. Young cutworms die in wet soil so irrigation can be effective control.

**Recommendation**
- Correctly timed overhead irrigation can largely eliminate the risk of cutworm damage.

Slugs
Slugs cause damage by penetrating the tubers and excavating cavities in the flesh. The risk of damage is increased if soil is kept moist by irrigation. Heavier soils tend to have the greater populations of slugs. Early harvest reduces the period of feeding available to slugs.

**Recommendation**
- Irrigation increases the risk of slug damage, so other control measure such as slug pellets need to be used.

Internal Rust Spot
Internal Rust Spot (IRS) appears to be a stress related disorder associated with restricted calcium uptake. PCL research has shown that periods of drought can reduce calcium uptake into tubers, therefore a well scheduled and executed irrigation regime can reduce the level of IRS. Other factors that can cause IRS are nematodes (free living and PCN).

**Recommendation**
- Use well scheduled irrigation to reduce the risk of IRS.

Growth cracking
High internal pressure within the tuber during rapid growth, often following a period of slower growth, splits the surface tissues. Uneven water supply is one of the prime causes of growth cracking. Significant rainfall/irrigation which pushes soils above field capacity can induce growth cracking. This emphasises the need to marry irrigation management to weather forecasts.

**Recommendation**
- Use well scheduled irrigation to reduce the risk of significant growth cracks.

Raised lenticels
The lenticels become white and raised and enlarged in partially waterlogged soil. They are a symptom of water management that has broken down. Lenticels which are raised for any length of time leave obvious spots on the tuber surface at harvest and detract from the appearance. These can become sunken and infected with bacteria causing rots.

**Recommendation**
- Avoid pushing soils above field capacity, especially from mid season onwards.

Greening
Greening occurs when tubers are exposed to light and produce chlorophyll. This also means that the potatoes have also been producing glycoalkaloids which both taste bitter and are mildly toxic. Greening occurs because of erosion of the ridges before full canopy and as the canopy senesces. Action can be taken at the planting stage to minimise greening in terms of planting depth and the ridge profile (flatter and wider). Erosion is made worse by the rain gun nozzle being too big and the pressure at the gun too low.

**Recommendation**
- Irrigation increases the risk of slug damage, so other control measure such as slug pellets need to be used.
Section 6

**Recommendation**
- The right irrigation equipment operated at the right pressures
- Avoid irrigation during canopy senescence.

**Bruising and mechanical damage**

The risk of bruising can be made worse by ending irrigation too early in the season and allowing SMD’s to rise prior to desiccation. Turgor pressure decreases as the tubers have difficulty extracting moisture. Then during harvest cell deformation more easily occurs resulting in damage to cell membranes leading to enzymic reactions causing black melanin pigments to be formed.

Levels of bruising/mechanical damage can be high in the absence of a cushion of soil on the harvester when conditions are dry. Irrigation just ahead of harvest, can alleviate these problems.

**Recommendation**
- Irrigate up to desiccation and again prior to harvest if necessary, to reduce bruising and external damage.

**Brown rot**

This is a quarantine disease of potato that is listed in the EC Plant Health Directive and is notifiable in the UK.

Yield losses are mostly caused by tuber rotting and, in many warmer areas of the world, it is one of the main limiting factors in potato production. The effect on our seed-potato industry could be substantial, especially for exports, if the disease became established in the UK. Once established, the costs of control could also be high. Control of this disease requires vigilance from all sectors of the industry, from growers through to merchants, packers and retailers.

The bacterium can cause wilting of the potato plant but the symptoms you are most likely to see are in the tuber, the initial symptom is brown staining of the vascular ring (hence the name ‘brown’ rot) that starts from the stolon (heel) end. A pale, creamy bacterial exudate may ooze from the cut vascular tissues. In severe infections the vascular tissues rot away completely. Bacterial exudate may ooze from the eyes and the heel end (where the tuber was attached to the stolon). Wilting of the leaves starts towards the top of the plant and may be initially confined to one side of a leaf or to only one stem. This can lead to rapid drying and death of the whole plant, although wilting has rarely been observed in European crops.

**Recommendations**
- Plant only classified seed
- Do not irrigate with contaminated water
- Control groundkeepers
- Good hygiene. Don’t dump waste on agricultural land.

6.4 References


Manning L et al, 2013. *Simply Sustainable Water*


While every effort has been made to ensure that the information is accurate, no liability can be accepted for any error or omission in the content of this guide.