



D-Risk

A planning tool to manage your irrigation abstraction and drought risks

User guidance and training manual

Ian Holman, Rishma Chengot and Jerry Knox

July 2021



Contents

1. Introduction.....	1
2. Description of the D-Risk inputs and outputs.....	1
2.1 D-Risk data entry tables	1
2.2 D-Risk outputs and their interpretation.....	2
3. Training section.....	5
3.1 Case Study 1: Business A.....	5
3.1.1 Developing baseline risk profiles.....	5
3.1.2 Scenario 1: Irrigation expansion.....	6
3.1.2 Scenario 2 : Abstraction licence reduction	6
3.2 Case Study 2: Business B.....	7
3.2.1 Developing baseline risk profiles.....	7
3.2.1 Scenario 3: Reservoir construction	7
3.2 Case Study 3: Collaborative water sharing between Business A and B.....	8
Appendix 1: Case Study 1: Business A	9
Baseline risk profiles.....	9
Scenario 1: Irrigation expansion	11
Scenario 2: Abstraction licence reduction	11
Appendix 2: Case Study 2: Business B.....	13
Baseline risk profiles.....	13
Scenario 3. Reservoir construction	13
Appendix 3: Case Study 3: Water sharing between Business A and B.....	14

1. Introduction

This guidance manual is an output of the project *D-Risk2: Multi-scale management of irrigation abstraction and drought risks in UK* (NE/S013997/1; NE/N017471/1), which received funding from the UK Natural Environment Research Council and industry support from key farming businesses and organisations, Natural England, the Environment Agency and reservoir design consultants.


D-Risk is a simple, free, user friendly webtool specifically designed to help you quickly understand complex abstraction management and drought related risks and to provide you with information to help make informed decisions regarding future irrigation and abstraction management and investment.

The D-Risk homepage (www.d-risk.eu) provides easy access to the webtool via the 'Start D-Risk' button and the 'D-Risk webtool' menu. In addition, the homepage menu ribbon provides links to:

- 'About D-Risk': the rationale of D-Risk; a description of the input data; explains how D-Risk works and provides an explanation of the D-Risk outputs;
- 'Resources': tutorial videos and the 'User guidance and training manual' to help end-users set-up, apply and interpret D-Risk outputs. Links to D-Risk related peer-reviewed scientific publications are provided;
- 'Case studies': provides exemplar applications with agribusinesses partners which highlight important decisions farmers often need to make in reconciling their irrigation deficits and abstraction license 'headroom' challenges, and;
- 'FAQs': provides answers to a wide range of frequently asked questions.

2. Description of D-Risk inputs and outputs

2.1 D-Risk data entry

The D-Risk webtool guides the user through a simple two-step data entry process, with tooltips (indicated by ) available to help the user at each step of the process:

1. The user first selects the gauging station, period of analysis and type of analysis, which are then used to retrieve relevant historical weather and hydrological data:
 - Gauging stations within Great Britain are structured by country and county, with an external link provided to the National River Flow Archive's interactive gauging station map which opens in a new tab. It is important to identify the appropriate gauging station as D-Risk calculates the abstraction constraints

- (e.g. Hands Off Flows) imposed by local river flow conditions based on this information;
- The analysis can be carried out for either the baseline climate (1977-2004) or for a Near Future climate (2022-2049) that incorporates the effects of climate change (Representative Concentration Pathway 8.5);
 - The analysis can be performed for a single farm (in which case a postcode is required) or for a group of farms. The tooltip provides further information on how different situations can be represented within these two options.
2. The user then enters data on irrigated cropping, soil types, abstraction licences and (optionally) reservoir storage:
- For each irrigated crop type (from a list of 19 options), the soil type (based on three classes of available water capacity, AWC), planting month and irrigated area are entered. If the theoretical 'design' (80%) dry year irrigation need for a given crop*soil AWC combination is higher/lower than expected, then it can be modified to reflect actual practice using the 'Irrigation correction factor'. The same crop can be entered multiple times to reflect different soil types, irrigation regimes etc.
 - For each abstraction licence held by the farm(s), the source (surface or groundwater), purpose (direct abstraction or storage), abstraction limits (annual, daily), period during which water can be abstracted (start and end months), and (if applicable) Hands off Flow (HoF) thresholds are entered. It is also possible to include mandatory emergency abstraction restrictions, based on Section 57 drought restriction rules for England, in the analysis.
 - Finally, the total 'live' on-farm reservoir storage (if applicable) is entered.

2.2 D-Risk outputs and their interpretation

D-Risk generates cumulative distribution functions (cdfs) for two key indicators:

- **Irrigation deficit** is defined as any proportion of the annual irrigation need not met by available supply either due to annual or daily licence limits, abstraction restrictions, and/or being unable to supply sufficient water from reservoirs.
 - In a given year, there is a much lower probability or likelihood of exceeding a larger irrigation deficit than exceeding a smaller irrigation deficit.
- **Licensed 'headroom'** is defined as the proportion of the total licensed volume that is not used in any given year. It is calculated from the sum of all available licences (direct and storage).
 - In a given year, there is a much lower probability or likelihood of exceeding a larger headroom than exceeding a smaller headroom.

Figure 1 below shows a set of typical outputs from D-Risk for irrigation deficit and licensed headroom, although the grey shaded areas representing an uncertainty zone or envelope have been omitted. The left and right panel figures have each been labelled to indicate where

different types of weather years would sit on the risk profiles – it is immediately obvious that high irrigation deficit and high headroom are associated with very different conditions, as years with high irrigation deficit (e.g. dry years) are associated with low headroom and *vice versa*:

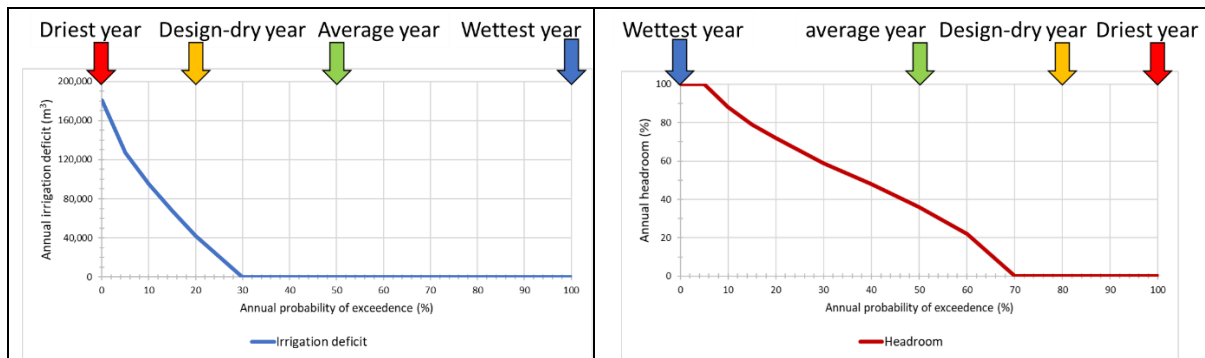


Figure 1 Exemplar annual cumulative distribution functions for (left) irrigation deficit and (right) licensed headroom with annual probabilities associated with key weather years

D-Risk provides two sets of the risk profiles of annual irrigation deficit and licensed headroom, without and with HoFs and Section 57 restrictions (as appropriate), as shown in Figure 2. Comparing the outputs allows the relative importance of ‘on-farm’ constraints (e.g. due to licence limits and reservoir storage) and ‘off- farm’ constraints (e.g. flow-based abstraction restrictions) to be assessed:

1. Considering only volumetric licence limits (upper left figure), there is a risk of having an irrigation deficit of any size of 50% and a ‘design’ dry year (20% annual risk) irrigation deficit of 36,000 m³;
2. Comparing this figure with the irrigation deficit when river flow constraints are also taken into account (lower right), it can be seen that river flow constraints (i.e. s57 and HoFs) increase the risk of having an irrigation deficit of any size from 50% to 70%, and approximately double the ‘design’ dry year irrigation deficit (from about 36,000 m³ to 63,000 m³);
3. According to the upper left figure, there is an irrigation deficit in 50% of years. However, comparing this with the headroom risk (upper right), it can be seen that there is available headroom in 90% of years. This shows that (when considering only the volumetric licence conditions) the irrigation deficit in most years is not caused by the annual licence limit (as there is headroom), but by the daily abstraction limit being insufficient to meet peak irrigation demand.
4. Finally, when river flow constraints are taken into consideration (lower right), there is always at least 5% headroom available so that the overall irrigation risk profile (lower left) is solely caused by the daily licence limits, HoFs and S57 restriction.

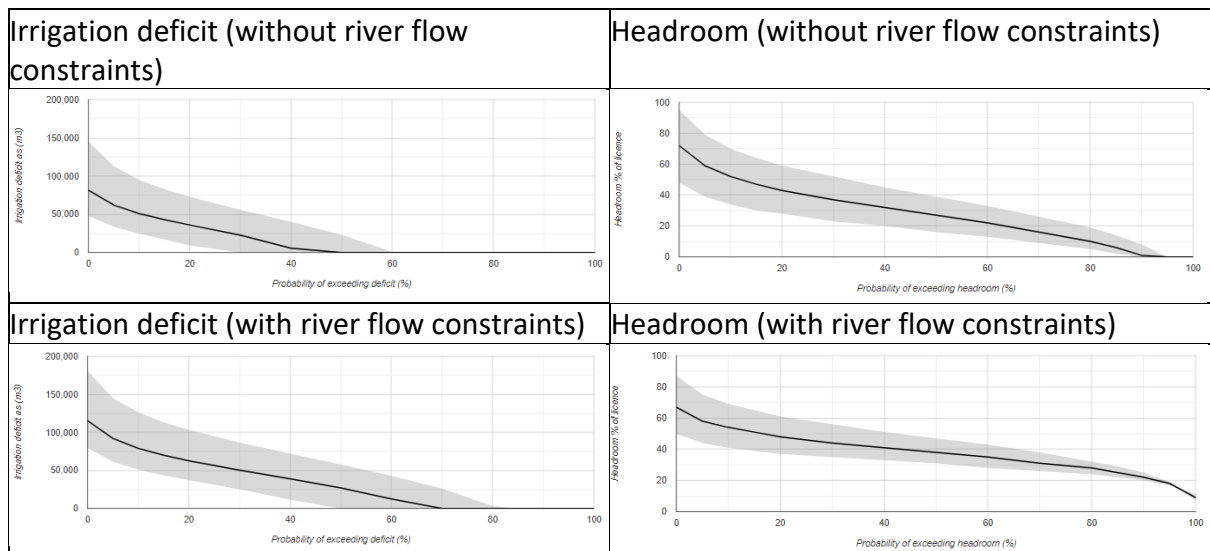


Figure 2 Exemplar complete set of **annual cumulative distribution functions for (left) irrigation deficit and (right) licensed headroom**

Further details on the D-Risk inputs and outputs are provided on the D-Risk website.

3. Training section

In this section, you will generate D-Risk risk profiles for two contrasting hypothetical farms and assess the effects of different scenarios on the risk profiles. You can compare the risk profiles you obtain and your interpretations with those provided in the Appendix.

3.1 Case Study 1: Business A

3.1.1 Developing baseline risk profiles

Generate risk profiles for the following hypothetical case study and interpret the outputs to answer the different questions posed.

Business A:

- The farm (postcode MK45 1LX) is located in the county of Bedfordshire within the Flit catchment.
- The business typically grows 70 ha of maincrop potatoes on fine sandy loam soils – these are planted in March and have a 300 mm ‘design’ dry year irrigation need. The business also grows 65 ha of onions on loamy coarse sands, which are planted in March and have a 224 mm ‘design’ dry year irrigation need.
- The business has a surface water storage licence with an annual volumetric limit of 190,000 m³ with a peak daily abstraction limit of 1800 m³. The abstraction period is limited to November to March, and is subject to a Hands off Flow restriction at the Shefford gauging station on the River Flit of 0.86 m³/s. They also have a groundwater direct abstraction licence with an annual volumetric limit of 210,000 m³ and a peak daily limit of 5400 m³ with abstraction allowed between 01 April and 31 October.
- The farm has an irrigation reservoir, with a live storage of 180,000 m³.
- As the farm is located in England, it is subject to emergency drought restrictions i.e. Section 57.

Please follow the following steps:

1. Fill in tool with the location details, cropping data, licence data and reservoir storage provided for Business A – look at the on-screen tooltips if needed. The completed data entry screen is provided in Appendix 1
2. Click on “Calculate” to run the D-Risk webtool
3. View and consider the risk profiles
4. **Export the output results as a comma separated file (“generate .csv” for loading into Excel or similar) and pdf files (“Print”) in order to be able to compare the results after the scenario modification.**

Question 1: Does the business have any risk of an irrigation deficit?

Question 2: If there is a risk of an irrigation deficit, is it caused by volumetric licence limits or abstraction restrictions?

Question 3: Is there an irrigation deficit in a ‘design’ dry year?

Question 4: What is licensed 'headroom' available for a 'design' dry year?

3.1.2 Scenario 1: Irrigation expansion

Business A wants to expand their irrigated crop area by irrigating 25 ha of wheat (spring cereals) on their low AWC soils. Planting the crop in March, they are planning on a dry year irrigation need of 50 mm.

Please follow the following steps to understand how business expansion may change the risk profile:

1. Modify the Business A crop data input by adding 25 ha of wheat (as "spring cereals"), alongside the pre-existing irrigated maincrop potatoes and onions to reflect the new scenario of crop area expansion. You will need to apply the irrigation correction factor to limit the dry year irrigation need.
2. Press "Calculate" to the update the risk profiles

Question 1: What is the 'design' dry year irrigation deficit after expanding the cropped area?

Question 2: What is the impact of cropped area expansion on licensed headroom for a 'design' dry year?

3.1.2 Scenario 2 : Abstraction licence reduction

The abstraction licenses of Business A are time limited and are coming up for renewal. There is risk that the annual and daily volumetric limits of the renewed surface water storage licence and the ground water direct licence may both be reduced by 15%.

Please follow the following steps to understand the impact of licence reduction to the business:

1. Either remove the area of spring cereals (by clicking on the blue cross at the end of the row) or re-start the webtool and fill in the location and crop details provided for Business A
2. Modify the licence data input by reducing the annual and daily limits of both the surface and ground water licences by 15 %.
 - a. If you are continuing from Scenario 1, add new licences with the revised annual and daily limits and then delete the original licences
3. Press "Calculate" to the update the risk profiles

Question 1: Does the business experience any irrigation deficit during a 'design' dry year due to this licence reduction?

Question 2: What is the impact of licence reduction to the business in terms of irrigation deficit at a 5% annual probability?

Question 3: What could be the reason for this increase in the deficit?

3.2 Case Study 2: Business B

3.2.1 Developing baseline risk profiles

Business B: The farm, neighbouring Business A, is also located in the River Flit catchment in Bedfordshire, with the postcode of MK45 1LX. The business plants 40 ha of maincrop potatoes on medium AWC soil in March, with an estimated ‘design’ dry year irrigation need of 300 mm. The business has a surface water direct licence with an annual volumetric limit of 90,000 m³ and daily limit of 1100 m³. Abstraction is allowed between April to October, inclusive, without any Hands off Flow limits, although the licence is subject to emergency drought restriction (e.g. Section 57) based on river flows at the Shefford gauging station on the River Flit.

Please follow the following steps:

1. Fill in tool with the location details, crop data, licence data and reservoir storage provided for Business B
2. Click on “Calculate” to run the webtool
3. View and consider the risk profiles
4. **Export the output results as a comma separate file (“generate .csv” for loading into Excel or similar) and pdf files (“Print”) in order to be able to compare the results after the scenario modification.**

Question 1: What is the annual risk (in percentage) of Business B having an irrigation deficit?

Question 2: What is the ‘design’ dry year irrigation deficit of the business?

3.2.1 Scenario 3: Reservoir construction

Business B is considering constructing a reservoir with live storage of 120,000 m³ to reduce its vulnerability to surface water abstraction restrictions. However, as no further surface water is available for licensing, an application has been made for a new groundwater storage licence with a 49,000 m³ annual volumetric limit and a daily limit of 800m³ with an abstraction period of November to March, inclusive.

Please follow the following steps to understand the potential benefit of the new reservoir and storage licence:

- Add the new groundwater storage licence
- Add the new reservoir storage volume
- Press “Calculate” to the update the risk profiles

Question 1: How does the new reservoir and licence affect the irrigation deficit risk profile?

Question 2: What is the volume of unused licence in a ‘design’ dry year after constructing the reservoir?

[NB Although we have not used it in this tutorial, D-Risk also includes a reservoir module which automatically evaluates the cost and irrigation deficit reduction benefits of a range of reservoir sizes and construction. This is accessed through the tab [D-Risk reservoir](#)]

3.2 Case Study 3: Collaborative water sharing between Business A and B

As Business A and B are neighbours, they are considering connecting their irrigation distribution networks so they can more-efficiently utilise their licensed water. They are interested in knowing how such informal and collaborative water sharing might change their irrigation deficit.

Please follow the following steps to understand the potential benefits of water sharing to the two businesses:

1. Either run D-Risk separately for Business A and B and export the output results as csv files or locate your original csv files from Case Study 1 (Business A) and Case Study 2 (Business B)
2. Load the csv files into Excel and calculate the combined annual irrigation deficit (with and without abstraction restrictions) for each exceedance probability.
3. Run the D-Risk tool again as a single run with combined crop data, licence data and reservoir storage for Business A and B.
4. Press “Calculate” to get the combined risk profiles and export the output results as csv and pdf files.

Question 1: What is the combined annual irrigation deficit at 20% annual probability ('design' dry year), if the two businesses works separately without any water sharing?

Question 2: Does aggregation of licenses of the businesses have any impact on irrigation deficit?

Question 3: What is the 'design' dry year available headroom after aggregating the licences?

Appendix 1: Case Study 1: Business A

Baseline risk profiles

The data entry screens should have looked as below, with the Shefford gauging station being the “Flit at Shefford” (gauging station ID 33028). From the tooltips, the fine sandy loam soils are “medium” Available Water Content (AWC) and the loamy coarse sands are “low” AWC soil

Country	County	Gauging station ID and catchment name (see locations)	Period of Analysis	Type of Analysis	Postcode
England	Bedfordshire	33028 (Flit at Shefford)	Baseline	Individual farms ->	MK451LX

Submit

Crop	Irrigated area (ha)	Soil AWC	Typical planting month	Theoretical 80% dry year irrigation need (mm)	Irrigation correction factor (%)	Your estimated "design" dry year irrigation need (mm)	Your estimated average-year irrigation need (mm)	
Onions	65	Low	March	230	97.5 %	224	176	✘
Maincrop potatoes	70	Medium	March	316	95 %	300	225	✘
Volumetric demand (m ³)						355600	271900	

Water source	Licence purpose	Annual licence volume (m ³)	Daily licence limit (m ³)	Start month	End month	Hands Off Flow percentile	
Surface water	storage	190000	1800	November	March	Q33	✘
Groundwater	direct	210000	5400	April	October	No HOF	✘

Include emergency drought restrictions (e.g. S57) Yes

Storage capacity (m³)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Estimated average distribution of farm irrigation demand	0%	0%	0%	0%	17%	31%	31%	19%	0%	0%	0%	0%

Irrigation deficit and licensed headroom risk profiles

Figure 1(a). Annual probability distribution of irrigation deficit (dark line) and uncertainty (shaded) assuming abstraction is not constrained by river flow levels

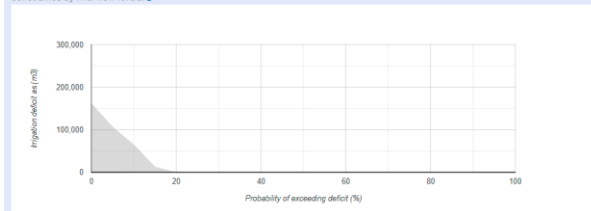


Figure 1(b). Annual probability distribution of irrigation deficit (dark line) and uncertainty (shaded) assuming abstraction is constrained by river flow levels (e.g. due to HOFs and/or emergency drought restrictions, as specified).

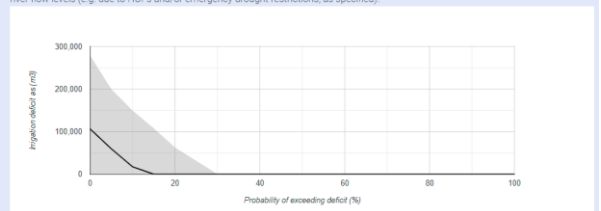


Table 1(a). Annual probability distribution of irrigation deficit assuming abstraction is not constrained by river flow levels.

Deficit (m ³)	Annual probability of exceeding deficit (%) & lower and upper boundaries of the uncertainty region														
	0	5	10	15	20	30	40	50	60	70	80	85	90	95	100
Lower boundary	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Median	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper boundary	162,000	107,000	66,000	13,000	0	0	0	0	0	0	0	0	0	0	0

Table 1(b). Annual probability distribution of irrigation deficit assuming abstraction is constrained by river flow levels (e.g. due to HOFs and/or emergency drought restrictions, as specified).

Deficit (m ³)	Annual probability of exceeding deficit (%) & lower and upper boundaries of the uncertainty region														
	0	5	10	15	20	30	40	50	60	70	80	85	90	95	100
Lower boundary	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Median	106,000	60,000	17,000	0	0	0	0	0	0	0	0	0	0	0	0
Upper boundary	278,000	199,000	148,000	107,000	63,000	0	0	0	0	0	0	0	0	0	0

Figure 2(a). Annual probability distribution of headroom (dark line) and uncertainty (shaded) assuming abstraction is not constrained by river flow levels.

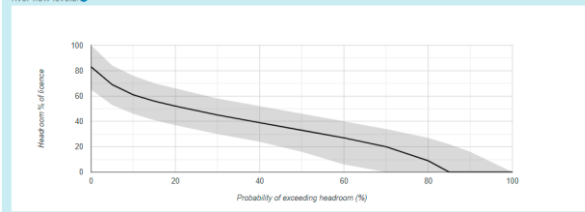


Table 2(a). Annual probability distribution of headroom assuming abstraction is not constrained by river flow levels.

Headroom (% licence)	Average annual probability (%)															
	0	5	10	15	20	30	40	50	60	70	80	85	90	95	100	
Lower boundary	65	53	46	41	37	30	24	16	6	0	0	0	0	0	0	
Median	83	69	61	56	52	45	39	33	27	20	9	0	0	0	0	
Upper boundary	100	84	76	70	66	58	52	46	40	34	27	22	16	8	0	

Figure 2(b). Annual probability distribution of headroom (dark line) and uncertainty (shaded) assuming abstraction is constrained by river flow levels (e.g. due to HOFs and/or emergency drought restrictions, as specified).

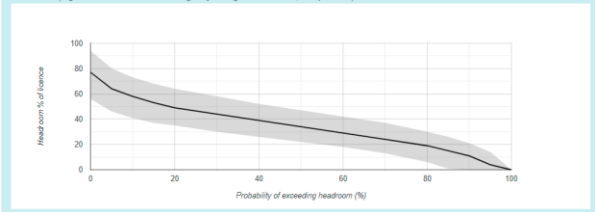


Table 2(b). Annual probability distribution of headroom assuming abstraction is constrained by river flow levels (e.g. due to HOFs and/or emergency drought restrictions, as specified).

Headroom (% licence)	Average annual probability (%)															
	0	5	10	15	20	30	40	50	60	70	80	85	90	95	100	
Lower boundary	56	46	41	37	35	30	26	22	18	13	6	1	0	0	0	
Median	77	64	58	53	49	44	39	34	29	24	19	15	11	4	0	
Upper boundary	94	80	73	68	64	58	52	47	42	37	30	26	21	14	0	

Question 1: Does the business have any risk of an irrigation deficit?

Yes, though the annual risk of an irrigation deficit of any size is very low – less than 15%.

Question 2: If there is a risk of an irrigation deficit, is it caused by volumetric licence limits or abstraction restrictions?

If the abstraction is not constrained by river flow levels (upper left Figure and Table) and if the future distribution of annual irrigation need is consistent with the long-term D-Risk profile (e.g. the black line), then the business does not have any risk of an irrigation deficit.

As the business’s abstraction has a HoF and is subject to Section 57 restrictions, it is constrained by river flow levels (Figure 1(b) and Table (b)). These cause the business to have a less than 15 % annual risk of an irrigation deficit, with an expected 5% annual probability (or 1 in 20-year risk) of having a deficit above 60,000 m³. The irrigation risk is therefore dominantly due to the abstraction restrictions, which the reservoir is unable to fully buffer.

Question 3: Is there an irrigation deficit in a ‘design’ dry year?

If the future distribution of annual irrigation need is consistent with the long-term D-Risk profile (i.e the black line), then there is no risk of an irrigation deficit in a ‘design’ dry year (20% annual probability of exceedance)

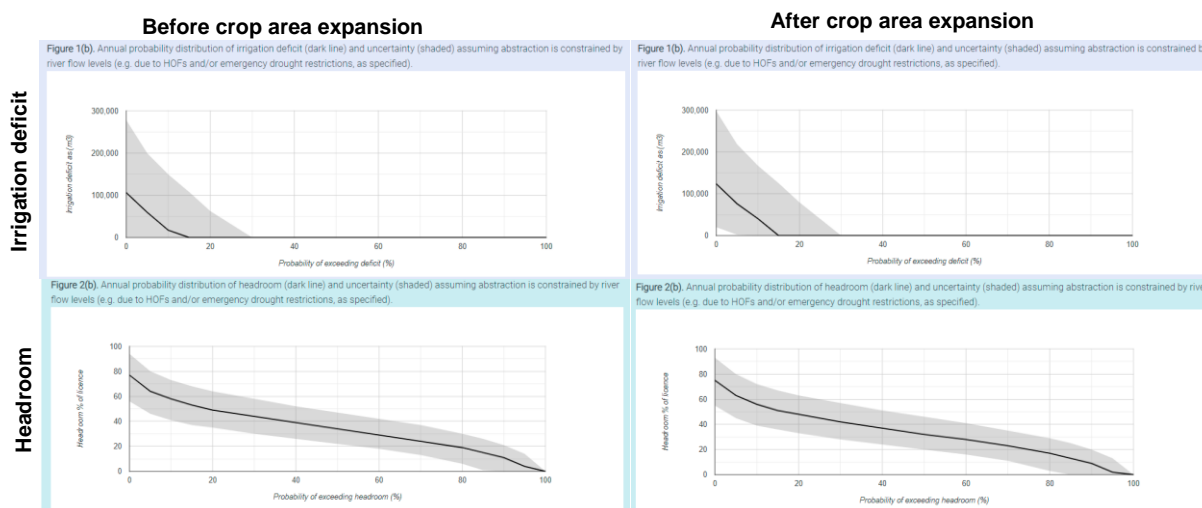
However, if the coming years are generally drier and/or more variable than the long-term average, then there is a 20% annual probability of an irrigation deficit of up to 63,000 m³, which is solely due to the abstraction restrictions.

Question 4: What headroom is available for a ‘design’ dry year?

If the abstraction is not constrained by river flow levels (lower left Figure and Table), there would be 9% headroom in a ‘design’ dry year (80% annual probability of exceedance). This increases to 19% when the additional constraints due to HoFs and Section 57 restrictions are considered due to the resulting reduced abstraction.

Scenario 1: Irrigation expansion

Business A wants to expand their irrigated crop area by irrigating 25 ha of wheat (spring cereals) on low AWC soils with a dry year irrigation need of 50mm. The baseline risk profiles (below left) showed that there was a very low pre-existing annual risk of an irrigation deficit that increases (below right) due to crop area expansion.



Question 1: What is the design dry year irrigation deficit after expanding the crop area?

Currently, if the distribution of annual irrigation need follows the long-term average D-Risk profile (i.e. the black line), Business A is likely to have irrigation deficit of 17,000m³ at 10% annual probability without any crop area expansion. However, if Business A expands their irrigated crop area with the 25 ha of irrigated cereals (receiving 25mm), then the irrigation deficit at 10% annual probability increases to 41,000 m³.

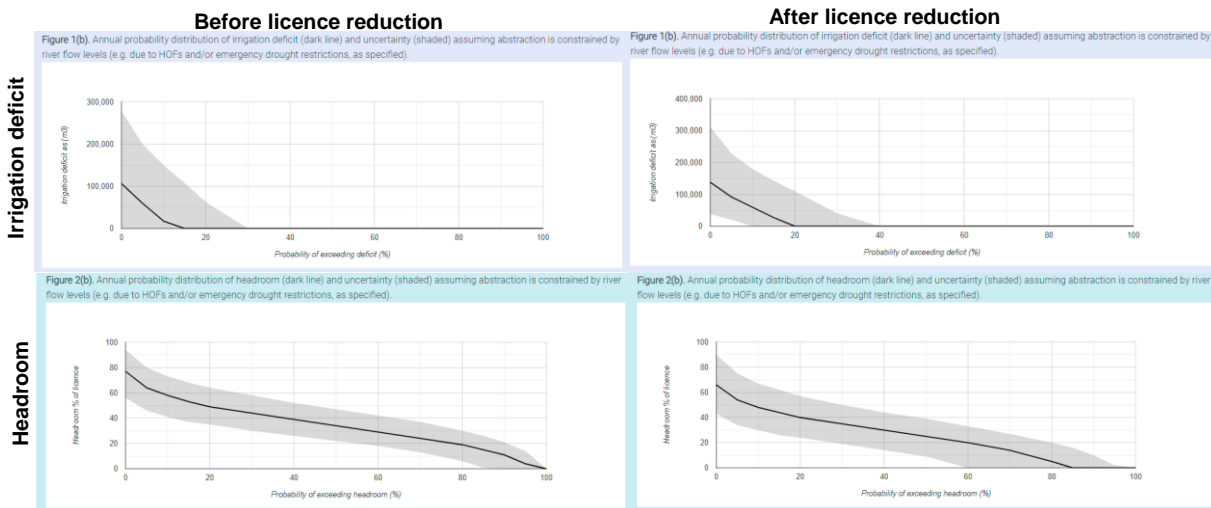
However, if the coming years are generally drier and/or more variable than the long-term average (shaded uncertainty zone), then the annual irrigation deficit could be up to 167,000 m³.

Question 2: What is the impact of crop area expansion on headroom for a design dry year?

If the distribution of headroom follows the long-term average D-Risk profile, then the design dry year headroom (80th percentile) decreases from 19% to 17 % due to the irrigated crop area expansion.

Scenario 2: Abstraction licence reduction

There is a risk that the annual and daily volumetric limits of the surface water storage licence and the ground water direct licence may both be reduced by 15%. With these reduction in licence limits, the risk profiles change as shown below.



Question 1: Does the business experience any irrigation deficit during a design dry year due to this licence reduction?

If the licences of Business A get reduced by 15% and if the distribution of annual irrigation need follows the long-term average D-Risk profile, Business A will not experience any design dry year irrigation deficit due to licence reduction. However, if the years are generally drier and/or more variable than the long-term average (uncertainty region), then annual irrigation deficit within a 20% annual probability of exceedance will increase from 63,000 m³ to more than 110,000 m³.

Question 2: What is the impact of licence reduction to the business in terms of irrigation deficit at a 5% annual probability?

The irrigation deficit with a 5% annual probability of exceedance will increase to 92,000 m³, but could increase to as much as 228,000 m³ if future years are generally drier and/or more variable than the long-term average (uncertainty region)

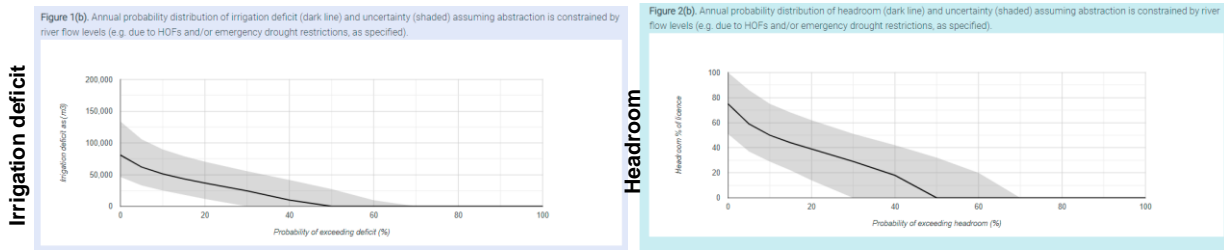
Question 3: What could be the reason for this increase in the deficit?

With the business’s surface water abstraction being constrained by river flow levels, the business’ baseline risk of an irrigation deficit is dominantly due to the flow-related abstraction restrictions. However, there is a small risk of an irrigation deficit when assuming abstraction is not constrained by river flow levels, indicating the consequence of the reduced volumetric licence limits.

If the licence of Business A gets reduced by 15%; then the 5% annual probability (or 1 in 5-year risk) of a irrigation deficit increase from 60,000 m³ to over 90,000m³. This increase in irrigation deficit is a consequence of both utilising the whole annual licensed volume (0% headroom available during extreme dry years) and being unable to meet peak irrigation needs.

Appendix 2: Case Study 2: Business B

Baseline risk profiles



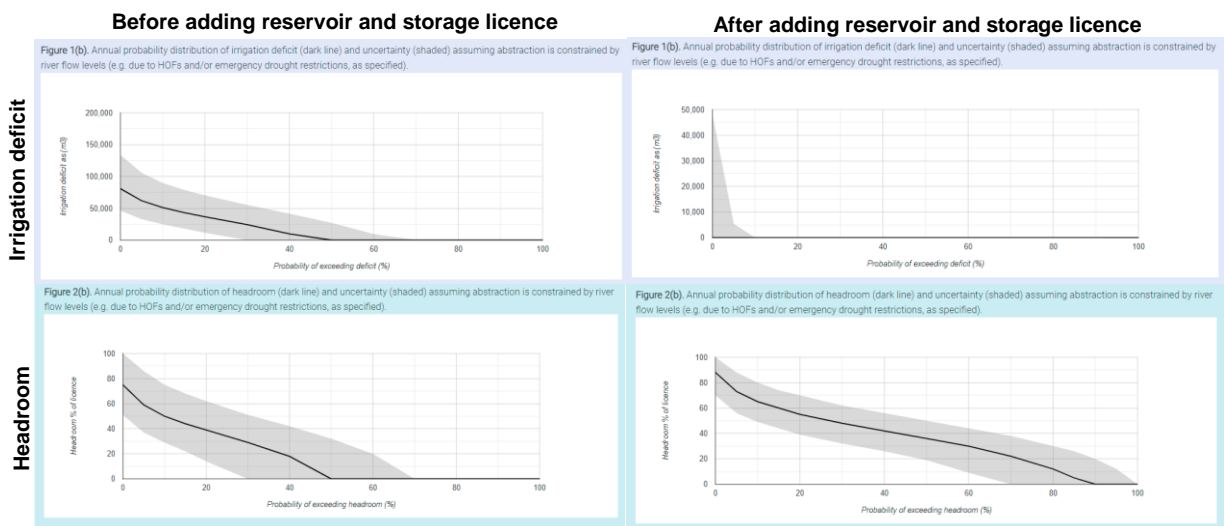
Question 1: What is the annual risk (in percentage) of Business B to have the irrigation deficit?

If the distribution of annual irrigation need follows the long-term average D-Risk profile, Business B currently has a 50% annual risk of having an irrigation deficit.

Question 2: What is the design dry year irrigation deficit of the business?

If the distribution of annual irrigation need follows the long-term average D-Risk profile, Business B has an expected 20% annual probability (or 1 in 20 year risk) of having a deficit above 37,000 m³. If the years are generally drier and/or more variable than the long-term average (uncertainty region), then the annual irrigation deficit with a 1 in 20 year risk could increase to more than 70,000 m³.

Scenario 3. Reservoir construction



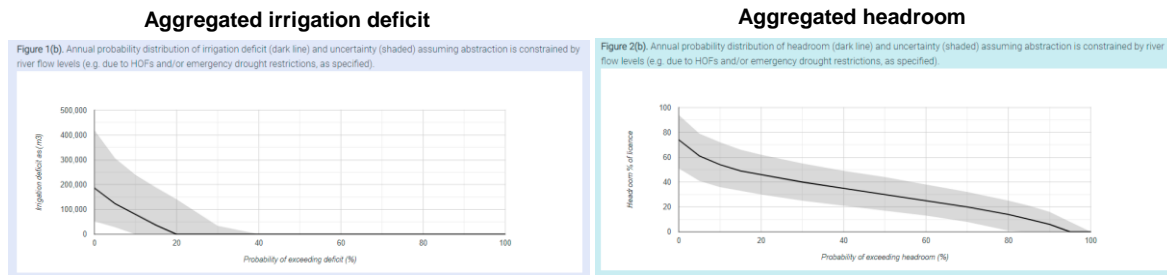
Question 1: How does the new reservoir and licence affect the irrigation deficit risk profile?

The addition of the on-farm reservoir and new groundwater storage licence reduces the annual risk of an irrigation deficit to zero.

Question 2: What is the volume of unused licence in a ‘design’ dry year after constructing the reservoir?

If the distribution of annual headroom follows the long-term average D-Risk profile, then the business will have a 12% headroom available in a ‘design’ dry year after constructing the reservoir.

Appendix 3: Case Study 3: Water sharing between Business A and B



Question 1: What is the combined annual irrigation deficit at 20% annual probability (design dry year), if the two businesses work separately without any water sharing?

With no water sharing, the two businesses have a combined annual irrigation deficit of around 37,000 m³ at a 20% annual probability, although this ranges between 12,000-133,000 m³ across individual ensemble HOFs members (shaded uncertainty zone). The 37,000 m³ design-dry year irrigation deficit is composed of 0 m³ from Business A and 37,000 m³ from Business B

Question 2: Does aggregation of licenses of the businesses have any impact on irrigation deficit?

Yes. As seen above, water sharing between Business A (which has no irrigation deficit during a design-dry year and significant headroom) and Business B (with a significant design-dry year irrigation deficit) shows that the design dry year irrigation deficit can be removed (zero deficit with a 20% annual probability).

Question 3: What is the design dry year available headroom after aggregating the licences?

If the businesses work together and if the distribution of headroom follows the long-term average D-Risk profile, then 14% headroom (equivalent to 68,600 m³ of the three combined licences) is available in a design dry year (80% annual probability). This compares to 19% headroom for Business A (equivalent to 76,000 m³ on its two abstraction licences) and 12% headroom for Business B (equivalent to 10,800 m³ on its single abstraction licence) when the two farms operate independently.