ASSESSMENT OF THE ADDITIONAL CROPPED AREA RAINFALL RUNOFF OCCURRING DUE TO IRRIGATION

FINAL REPORT

October 2019

Barma Water Resources

BWR
Barma Water Resources

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Executive Summary

The Department of Planning, Industry and Environment (the Department) engaged Daren Barma of Barma Water Resources as an independent consultant to assess how well the current approach to determining floodplain harvesting take caters for the additional rainfall runoff occurring due to irrigation, and the significance of the issue. This assessment was prompted by a recommendation from the *Independent Peer Review of NSW Floodplain Harvesting Policy implementation* by Alluvium (2019), which expressed a need for a third party analysis on the quantum and significance of this issue and identification of the best methods of accounting for this form of take.

Importantly, this assessment does not relate to take associated with rainfall runoff from fallow and undeveloped areas, which are outside the term of reference for this study and are considered to be part of a water management areas long-term average annual extraction limit (LTAAEL).

This assessment specifically has two parts:

Part 1:

- Speaking with the authors of the NSW Floodplain Harvesting Policy Implementation review about their recommendations and expectations (the reviewers).
- Reviewing four the submissions received on the issue.
- Obtaining all relevant data and/or access to models from the Department to undertake the analysis.
- Presenting the significance of the issue at the valley and property scale to the reviewers.
- Considering reviewers feedback and adjusting the assessment if necessary.
- Presenting the significance of the issue at the valley and property scale to the Department.
- Considering Departmental feedback and finalising the draft report for reviewer comment.
- Revising the draft report following reviewer comments.

Part 2:

- Developing options to address the issue supported with data and evidence - showing outcomes at the valley and property scale.
- Testing options with reviewers.
- Presenting the Department with options.
- Considering feedback and finalising the draft report for reviewer comment.
- Revising the draft report following reviewer comments.

Based on the assessment the following conclusions can be drawn in relation to cropped area runoff, the take associated with it and the significance of its inclusion or exclusion as a form of take under a long-term extraction limit (LTAAEL):

- The proportion of rainfall that become cropped area runoff from submissions and the Department's modelling show substantial variation.
- All methods used to determine crop area runoff are based on limited calibration data and as such estimates remain highly uncertain.
- Notwithstanding the uncertainty of cropped area runoff amount, the likely cropped area runoff take is small and makes up a very small portion of total take at less than 5% at both the valley and property scale. This is within the measurement error of the measurements devices that are likely to be used to determine floodplain harvesting take amounts.
- Exclusion of cropped area runoff take under the LTAAEL will require a method to be developed to allow for floodplain harvesting take adjustment.
- There are valid arguments for both excluding and including cropped area runoff take as part of the extraction limit. There is no correct answer, and this assessment has not led to an obvious answer in relation to its treatment. Either choice will result in obstacles and challenges for government and stakeholders.

1 Introduction

1.1. Purpose of assessment

The Department of Planning, Industry and Environment (Water Division) engaged Daren Barma of Barma Water Resources (BWR) as an independent consultant to assess how well the current approach to determining floodplain harvesting take, caters for the additional rainfall runoff occurring due to irrigation, and the significance of the issue. This assessment was prompted by a recommendation from the *Independent Peer Review of NSW Floodplain Harvesting Policy implementation* by Alluvium (2019), which expressed a need for a third party analysis on the quantum and significance of this issue and identification of the best methods of accounting for this form of take.

Importantly, this assessment does not relate to take associated with rainfall runoff from fallow and undeveloped areas, which are outside the term of reference for this study and are considered to be part of a water management areas long-term average annual extraction limit (LTAAEL).

1.2. Assessment objectives

The objectives of the assessment were to:

1. Determine the significance of including the additional rainfall runoff created by converting fallow land to land under an irrigated crop as a form of take under a LTAAEL.

2. Develop defensible options to address the issue and its significance supported by data and evidence.

1.3. Approach to the assessment

This assessment specifically has two parts:

Part 1:

- Speaking with the authors of the NSW Floodplain Harvesting Policy Implementation review about their recommendations and expectations (the reviewers).
- Reviewing the four submissions received on the issue.
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2 Background

2.1 Reviewers recommendations and expectations

An independent review of the NSW floodplain harvesting policy implementation was finalised by Mr. Tony Webber and Mr. Greg Claydon in July of 2019 (Alluvium 2019). The key findings and recommendations of that review in relation to rainfall runoff harvesting were:

1. *"The justification and evidence provided around the use of the adopted parameters and model for rainfall-runoff is very limited, though an assessment of literature and likely runoff coefficients has been completed. It is therefore difficult to determine how the current approach is calibrated or validated and without further evidence it is a challenge to support the inclusion of rainfall-runoff volumes within the FPH take as currently modelled. We also reviewed further submissions from stakeholder groups and subsequent analysis by the department on this issue and have provided additional clarification and advice based on our assessments as part of this review. We note the contentious nature of the rainfall-runoff inclusion as part of the policy though we are unwilling to agree to the current method of accounting for rainfall-runoff until further considerations are undertaken.* ***We therefore recommend that a 3rd party complete analysis on the quantum and significance of this issue and identify the best methods of accounting for this form of take."***

2. "Significant further documentation and justification of the rainfall-runoff model used, and the parameters chosen in each valley, soil type, and farm enterprise is required before the inclusion of the rainfall-runoff component within the models can be considered suitable or not. This should not be seen as a decision as to whether rainfall-runoff should be included as part of licensed take, but that without documentation and justification, the current approach cannot be properly evaluated for suitability in estimating this component and further analysis is required to establish a way forward."

Mr Tony Webber was contacted in relation to the review findings and recommendations in order to provide additional information and context for this assessment. During the course of the interview Mr Webber made the following observations with respect to the review and the issue of rainfall runoff harvesting.

1. Rainfall runoff understanding in the Departments river system models was potentially the weakest component.
2. Neither stakeholders nor the Department comprehensively defined the issue of rainfall harvesting.
3. Runoff created through the application irrigation is a different category of runoff to that occurring naturally and as such may require different treatment.
4. Increase in runoff through cropping when compared to fallow or undeveloped land is likely subject to considerable uncertainty.

5. Runoff proportions from catchment scale studies are unlikely to be the same as runoff from a property scale and consequently are not directly comparable.

BWR also enquired as to whether the recommendation for third party review related to all rainfall runoff, or only to runoff from cropped area which is the subject of this assessment. Mr Webber confirmed that it was the runoff from the area that was under crop that he was most concerned about in terms of runoff estimation.

2.2 Submissions Received

Four stakeholder submissions, together with the Alluvium Peer Review, and the Department's analysis of methods used to calculate runoff amounts were received and made available to BWR. Stakeholder submissions were from:

1. Gwydir Valley Irrigators Association
2. Namoi Valley Water Users Association
3. New South Wales Irrigators Association
4. Northern Irrigator Groups – Border Rivers, Gwydir, Namoi, Macquarie & Barwon Darling

The major observations and recommendations from each of these stakeholder submissions are presented in Table 1. All submissions expressed a view that rainfall runoff harvested water should be excluded from licensed take. They acknowledged that it should be recognised in the farm water balance. Importantly, this view extended to runoff from all developed land and not just the areas under cropping which are the subject of this assessment. All submissions argued that runoff from developed land was not additional take, as it was created through water users developing their farms in a way that maximises water efficiency, and thus creates 'rainfall runoff'. Futhermore, submissions argued that its inclusion would complicate compliance and monitoring and likely remove the incentive for water efficient practices.

Table 1 - Submission comments on Rainfall Runoff Harvesting

Stakeholder	Rainfall Runoff Issue
Gwydir Valley Irrigators Association	1. *It has become apparent throughout this implementation process and the release of the draft FPH Monitoring and Auditing Strategy, that the inclusion of rainfall runoff evidently has complicated the communication, and monitoring and compliance of FPH rather than simplifying it, as suggested by government in March and April 2018. An assessment of these reported benefits after amendment to the policy in May 20183 and its subsequent interpretation, highlights that these benefits are over-stated, and government has not adequately addressed the local and state-wide inequities raised throughout this process.* 2. *Given that the draft report raised concerns around the model approach and whether rainfall can be accurately determined, in addition to the above uncertainties, it's unclear how a final report cannot provide guidance to the government on how they can progress this issue, they are intrinsically linked. We recommend that reconsideration of the inclusion of rainfall runoff from within an irrigation development area which has been largely artificially created through irrigation development and irrigation per se is not considered new take, rather it is re-distributed used agricultural water or tailwater and should be removed from the FPH licence process. This should provide a pathway to address issues around calculating and measuring rainfall, in addition to improving confidence in the traditional FPH component as well as future monitoring. We also support further refinements to the rainfall runoff assumptions within the models.*
Northern Valley Irrigators Association	1. *The inclusion of rainfall in the licencing package does not simplify monitoring or compliance but results in onerous and excessive data requirements to a level of accuracy that is far greater than the information used in the determination of licenced volumes in the first place.* 2. *A simpler approach is suggested by Northern Irrigators, applying a Rainfall Runoff Calculator tool on developed area would contextualise the concept of rainfall in relation to the overall farm balance.* 3. *Inclusion of rainfall in the accounting framework for only a selection of water users creates state-wide inequities that NSW did not communicate as part of the policy consultation nor have they communicated how they will address these into the future. For example, water users within a designated floodplain in the five-northern valleys from 1 July 2019 water users will be required to account for and report any rainfall. However water users on*

	4. *floodplains elsewhere in the state or those not on designated floodplains, either within the same valley or across NSW will not be required to meet this obligation yet will be intercepting the same source of water.* 5. *NSW communicated to stakeholders that including rainfall would ensure extractions remained within limits and would better secure floodplain flow for both the environment and downstream users. NSW failed to communicate that the implementation of a floodplain licencing program without rainfall included as part of the licence, still delivers on these outcomes. The inclusion of rainfall does not explicitly improve either of these outcomes, the introduction of a descriptive form of take into the contemporary legislative frameworks, combined with an effective and implementable compliance and monitoring regime results in capping of take as per agreed limits.* 6. *The inclusion of rainfall as a licence rather than a "right" issued by ministerial order map provide a more secure legislative protection and is perceived to provide a greater licence.* 7. *However, if the determination of that volume is uncertain the issue for the industry becomes whether the benefits of a more secure package is outweighed by the risk that access arrangements will be restricted, without any actual growth in take.* 8. *We therefore, recommend that the decision to combine rainfall in with floodplain license is reconsidered.* 9. *Rainfall runoff from irrigation development areas is predominantly created water either from irrigation being applied to a field or from field improvements, designed to re-distribute water and therefore, does not constitute take.* 10. *The uncertainty around how the valley based model can determine how much an individual may capture in rainfall and whether that rainfall has been accurately calculated, now or at either of the historical key dates of 93/94 or 2000, and whether that re distributed water would have ever made it to a river system in the first place.* 11. *We recommend any rainfall that falls within an area developed for irrigation is redistributed rainfall or used irrigation water and is not required to be included within the accounting framework. We recognise that it does form part of the irrigation farm water balance and therefore recommend the establishment of rainfall runoff calculators to determine an individual's allocation of this right to water on an annual basis.*
Namoi Valley	1. *There clearly needs to separation of the volume of water that is artificially created as runoff by farm development*

Water	*which is not take* 2. *Namoi Water request the assessment of Rainfall Runoff under natural conditions is assessed. This volume should be calibrated and validated to be included in FPH Take.* 3. *Artificial created runoff is not take see attached paper.*
NSW Irrigators Council	1. *That the Independent Reviewers – in identifying the lack of justification of the model's representation of rainfall runoff – recommend to Government the need to action more accurate modelling and investigate alternative options for regulating/accounting for this water.* 2. *At the minimum, the definition of rainfall runoff as take should be clarified as the natural conditions level.* 3. *Rainfall Runoff is relevant to the peer-review and should not fully be included in FPH licences.* 4. *NSWIC maintains the position repeatedly advocated for by water users, that it is inappropriate, impractical and illogical to include rainfall runoff in FPH licencing.* 5. *It has become apparent since the release of the draft FPH Monitoring & Auditing Strategy, that the inclusion of rainfall runoff evidently complicated monitoring and compliance rather than simplifying it.* 6. *For irrigation farmers, the preferred option is removing rainfall runoff from FPH licencing in entirety (Option A). However, should the current policy decision persist, which does include rainfall runoff, then at the very least the definition of rainfall runoff as take should be clarified as the natural conditions level (Option B).* 7. *Rainfall runoff is not a form of additional take. A significant proportion of rainfall runoff is the result of farmers developing their farms in a way that maximises water efficiency, and thus creates 'rainfall runoff' as water can then be recycled and reused multiple times on the farm to maximise water efficiency. Rainfall runoff is thus artificially created / recycled water. This does not involve additional take. Given the difficulties with modelling rainfall runoff (as found in the draft report), and thus the difficulties in effectively implementing this policy with rainfall runoff included, other options to regulate/account for rainfall runoff are required.* 8. *Whilst not the ideal option, an improved method of regulating rainfall runoff would involve only the volume of*

	rainfall under natural conditions (pre-development) be included on the FPH licence. The additional rainfall runoff (the result of water use efficiency developments), on top of this pre-development baseline amount should be considered/accounted for as tailwater return, and as a system loss. Including the post-development amount of rainfall runoff would disincentives water use efficiency, risk the accuracy of the modelling, create equity issues between those on and off floodplains, and is widely criticised amongst irrigation farmers as being inappropriate and impractical. *9. There is implementation risk of including rainfall runoff (as it currently stands) in the FPH model, as it will likely lead to a change in irrigator behaviour and remove the incentive for water efficient practices, and the unnecessary complexities reduces the accuracy.*

2.3 Methods of estimating runoff

During the course of this assessment two main methods for estimating runoff from cropped areas were presented. This first, the Curve Number (CN) method was developed by the USDA Natural Resources Conservation Service, which was formerly called the *Soil Conservation Service* or *SCS.* The second is based upon a soil moisture store water balance model developed by the Department for the Border Rivers System.

2.3.1. CN Method

As stated in Purdue (2019), the Curve Number (CN) method is a simple, widely used method for determining the approximate amount of runoff from a rainfall even in a particular area. Although the method is designed for a single storm event, it can be scaled to find average annual runoff values. The data requirements for the method are low with only rainfall amount and curve number required. The curve number is based on the area's hydrologic soil group, land use , treatment and hydrologic condition. The main parameters and formula for the method is presented in Figure 1.

Ogden et al (2017) observed that the method was invented to solve an immediate need in the 1950s associated with construction of soil conservation dams in small agricultural watersheds. The method is an equation form that on average fits observed storm-total rainfall and runoff data from small agricultural watersheds. In some regards, the method has been a fantastic success in that it allows a very simple calculation of how many inches of runoff will result from a certain number of inches of rainfall. The method was introduced by the USDA without peer review. Its success led to extrapolations and extensions, each one further and further from the simple original purpose of the method. At its heart, the curve number method is a static one- or two-parameter model that is a regression fit.

Ogden et al go on to say that the CN method has some utility, primarily in an engineering design context, for small agricultural watersheds. Importantly they note that the basic form of the equation often fits observed total rainfall versus total runoff data sets pretty well if the CN-values (or S-values) are calibrated.

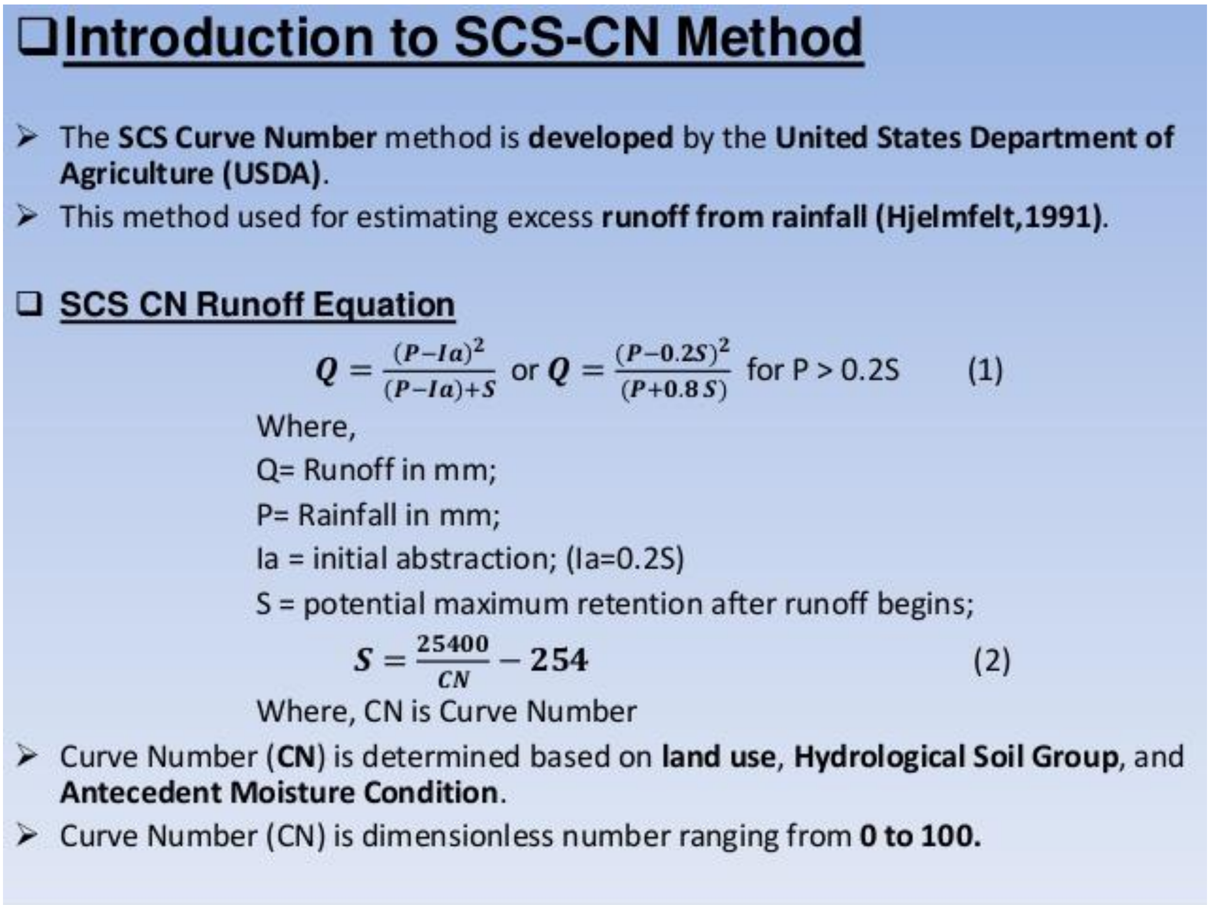

Figure 1: SCS-CN Method (Ref: https://www.slideshare.net/vishvamPancholi/analysis-of-runoff-for-vishwamitri-river-watershed-using-scs-cn-method-and-geographic-information-system)

2.3.2. Soil Water Balance Method

The soil water balance method is described in the eWater Source User Guide 4.19. Runoff estimation using the soil water balance method is modelled using a single layer moisture store (Equation 1), as outlined in FAO56 – Chapter 8. The Equation represents the water balance of the rootzone.

$$D_{r,i} = D_{r,i-1} - P_i - I_i + RO_i - CR_i + ET_{c-adj} + DP_i \qquad \text{(Equation 1)}$$

where:

$D_{r,i}$ root zone depletion at the end of day *i* [m],

$D_{r,i-1}$ water content in the root zone at the end of the previous day, *i-1* [m],

P_i effective precipitation on day *i* [m],

I_i irrigation depth on day *i* [m],

RO_i runoff from the soil surface on day *i*, including rainfall and irrigation [m],

CR_i capillary rise from the groundwater table on day *i* [m],

$ET_{c\text{-}adj}$ crop evapotranspiration on day *i* [m],

DP_i water loss out of the root zone by deep percolation on day *i* [m].

Rainfall runoff occurs when rainfall results in soil moisture exceeding saturation as shown in Equation 2.

$$\boldsymbol{RainfallRunoff} = \boldsymbol{max}\left(0, \boldsymbol{min}\left(0, \boldsymbol{Target}_{op}\right) - (\boldsymbol{Dr}_{t-1} - \boldsymbol{P}_e + \boldsymbol{DeepPercolation})\right) \quad \text{(Equation 2)}$$

where:

RainfallRunoff = the amount of rainfall runoff depth for cropping area (m)

$Target_{op}$ = the opportunistic target depletion level for a cropping area (m)

Dr_{t-1} = soil water depletion at the beginning of the time-step (m)

P_e = the amount of effective rainfall (m)

DeepPercolation = amount of deep percolation (m)

Runoff occurs from both cropped and fallow areas. In addition, runoff occurs from an undeveloped area if configured.

3 Significance of the issue

3.1 Rainfall that becomes cropped area rainfall runoff

Estimates of the proportion of rainfall that either becomes runoff from a cropped area subject to irrigation, or from areas developed for irrigation were made available to BWR from four Sources:

i) Cropped Area Runoff Calculations from the Departments River System Model for the Border Rivers.

ii) SCS-CN Cropped Area Runoff Calculations for a number of Representative Farms by Tahlee Consulting Pty Ltd. Results have been presented for Narrabri from using Soil Group D, Irrigated Crops – Straight Row, Good Hydrologic condition and a KII value of 87.

iii) SCS-CN Cropped Area Runoff Calculations for two fictional farms with 250 ha of irrigated cotton located at Mollee (Narrabri) and Haddon Rig (Warren) from Aquatech Consulting Pty Ltd (June 2019). Results are based on Soil Group C, Irrigated Crops – Straight Row, Good Hydrologic condition and a KII value of 83.

iv) SCS-CN Developed Area Runoff Calculations for six trial farms in the Northern Murray Darling Basin by FSA and Aquatech consulting for the Murray Darling Basin Authority (MDBA 2011).

All SCS-CN runoff estimates used 5 day antecedent rainfalls, and time of year (growing and dormant seasons) to select the appropriate Curve Number (CN) for runoff calculations. The FSA consulting estimates modified SCS-CN parameters through calibration to observed on farm storage volumes for the six trial farms.

In the case of the Aquatech estimates, the method was selected due to their previous work comparing measured catchment performance against the USDA modelled results, where they found annual performance correlated well. Importantly they note that *"Like all rainfall runoff models, individual event results will vary predominantly because of rainfall intensity. Until rainfall intensity is measured and recorded, the USDA model is considered as good as any other model currently used."* The Soil Water Balance method used by the Department has been calibrated to reproduce runoff coefficients from available literature. In an effort to ensure that long-term average runoff was reasonably represented.

DPIWater have indicated for the river system model, that use of relevant available literature was supported by analysis of runoff coefficients from nearby gauged inflows to inform the model development. This assessment has found that the soil water balance model calibration and therefore results rely heavily on data from Connolly et al. (2001). The Connolly study found that for a site near Warren in NSW with 625 mm of rainfall, that rainfall runoff under conventional irrigation is around

8.5% of rainfall. This result is based on a 30 year simulation using a GLEAMS model which was calibrated using field data collected over a 1-2 year period with 9 events at the site (DPIWater 2019). The 8.5% was assumed to be based on a whole of year analysis including the area under crop and fallow.

A summary of the cropped area runoff results based on the submissions received is presented in Table 1. A breakdown of the proportion of rainfall that becomes crop runoff by property in the Departments Border Rivers Model is also presented for completeness in Figure 2. FSA estimates (MDBA 2011) have not been presented in the table, as they related to developed areas. However, it should be noted that these runoff proportion estimates were substantially lower than any other estimates assessed in this study (most often less than 5%). Reasons for this remain unclear, it is recommended that the base data used to derive these estimates are obtained by the Department to confirm estimate veracity.

Table 1 - Proportion of Rainfall that Becomes Cropped Area Runoff (long-term Average)

Source	Proportion of Annual Rainfall that Becomes Cropped Area Annual Runoff (long-term Average)	Proportion of Spring and Summer Rainfall that Becomes Cropped Area Sping and Summer Runoff (long-term Average)
Tahlee Consulting (Narrabri results)	26%#1	39%#1
Aquatech (Narrabri)	21%#2	29#2
Aquatech (Warren)	12%#4	Not Available
DPIWater Border Rivers		13.7%#3

#1 Based on an irrigation application rate of 800mm over October to February Using rainfall from 1900 to 2018
#2 Based on an irrigation application rate of 800mm over September to February, using USDA KII Value of 83 and rainfall from 1900 to 2018.
#3 Calibrated to available literature runoff proportions. This result is based on the full DPI Border Rivers river system model. The model plants different areas every year, with greater areas in wetter years. The longterm average is somewhat biased towards wetter years due to larger areas and runoff in those years.
#4 Based on an irrigation application rate of 800mm over September to February, using average of driest, dry, wet, and wetest year values.

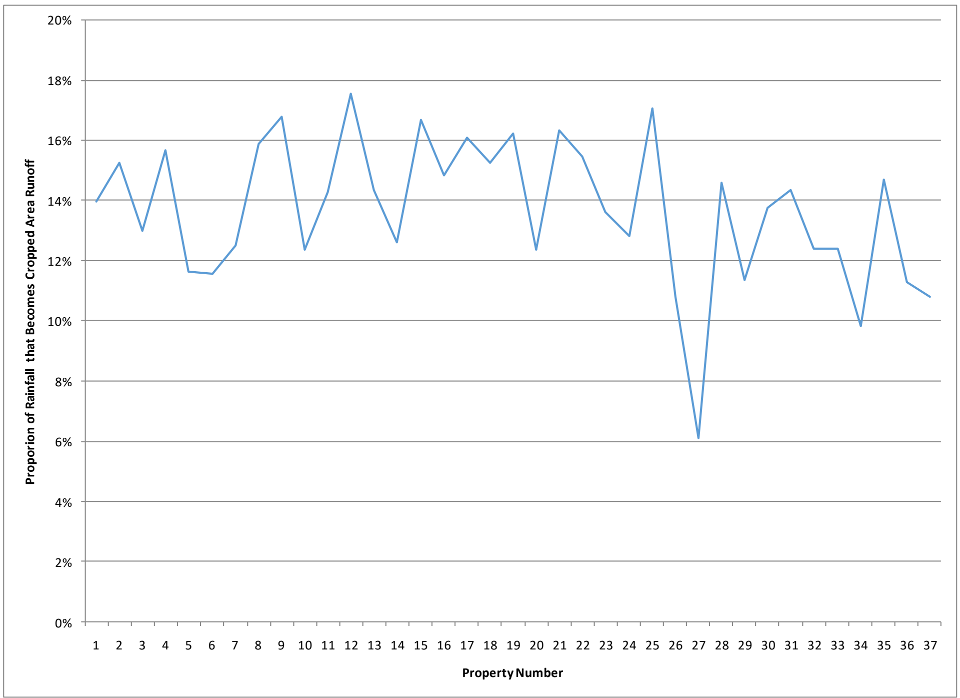

Figure 2 - Proportion of Cotton Season Rainfall that Becomes Cotton Crop Area Runoff (NSW Border Rivers DPI Model)

The results of Table 1 and Figure 2 indicate a wide range of cropped area runoff proportions. Proportions appear to vary widely with both the calculation method applied (Table 1) and for the same method across properties (Figure 2). Proportions are noticeably higher when derived for the irrigation season only as opposed to annually.

The method used by the Department represents a step forward from the SCC-CN method, however the application of both methods to determine cropped area runoff have relied on very little direct measured information to be calibrated to, both in a spatial and temporal sense. The Tahlee and Aquatech estimates implicitly rely on some form of calibrated Curve Number estimate. The Tahlee estimate use the Queensland Farm Water Supplies Design Manual, which adapted the SCS CN data on the basis Queensland data. The Aquatech estimates are believed to be based upon previous work (MDBA 2011) where Curve Numbers K1, K2 , and K3 were derived through calibration to observed on farm storage behaviour to six study in Northern NSW and Queensland. Calibration results are also likely to include the effects of irrigation, and the veracity of transposing these estimates to other farms where irrigation scheduling will differ is questionable.

Given the above, all runoff proportions presented in the submissions and in the Departments model are still subject to a high level of uncertainty. The assessment has concluded that it remains unclear as to what a sensible long-term cropped area rainfall runoff proportion is and how it may vary with location.

3.2 The additional runoff created through irrigation and its frequency

The assessment has found that the proportion of cropped area runoff also varies greatly with the amount of irrigation application. As an example, the variation in annual and summer season runoff proportions with irrigation application volume for the Tahlee Consulting Narrabri site is presented in Figure 3. As can be seen, on an annual basis, cropped area runoff proportions are halved when no irrigation is applied relative to the full irrigation application of 800mm. The difference is even greater when runoff proportions are compared for just the Summer season (refer to Figure 4) , with the runoff proportion under no irrigation being a third of that when full irrigation is applied. runoff Information from the NSW the Departments model also suggests that the proportion of runoff from a cropped area under irrigation is twice that of the same area under fallow.

The frequency of runoff from the area under crop relative to other areas has been assessed using a 1Ha crop model with a soil water store. Results are presented in

Table **2**, and indicate that runoff frequency is greater for copped areas when compared to fallow and undeveloped land. However, the increase in frequency is less than twenty percent.

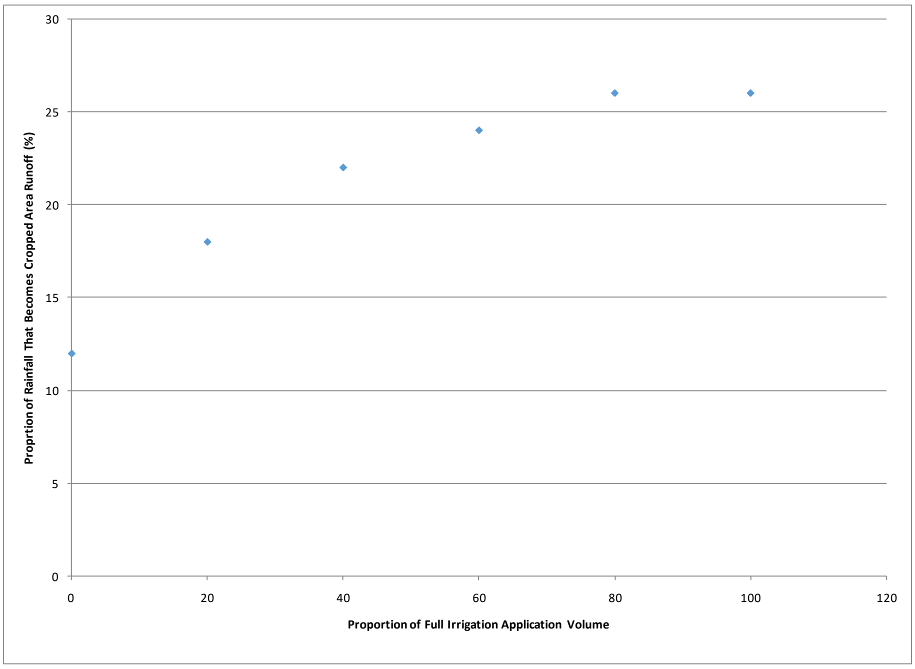

Figure 3 - Change in cropped area annual runoff proportion with irrigation application volume

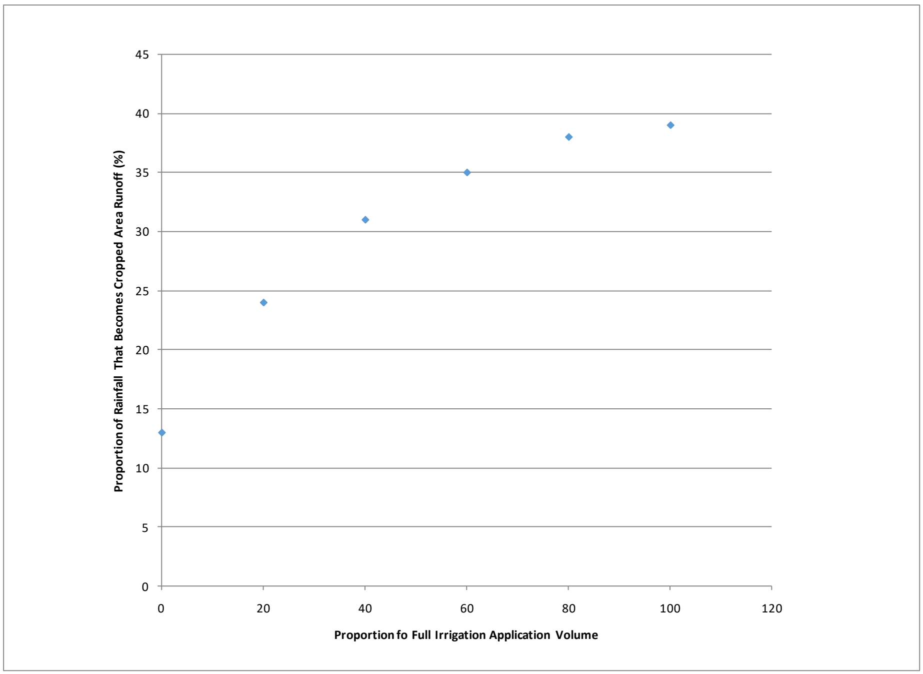

Figure 4 - Change in cropped area Summer Season runoff proportion with irrigation application volume

Table 2- Cropped Area Runoff and Harvested Volume as a Proportion of Farm Runoff and Take

Runoff Type	Number of Events
Cropped Area	471
Fallow Area	406
Undeveloped Area	407

3.3 The magnitude of additional crop area runoff and take

An assessment of the quantum of cropped area runoff relative to total farm rainfall runoff and harvested volume relative to different components of take at the valley scale are presented in Table 3. The assessment has initially been based upon results from the Department of Industry Border Rivers model for two scenarios. The Baseline Diversion Limit (BDL), and Pre Basin Plan (PBP) scenario. Row 1 of Table 3 indicates that cropped area runoff accounts for around half the rainfall runoff runoff at valley scale. However, there is substantial variation to this average across properties as illustrated by the results in Figure 5.

Row 2 of Table 3 indicated that the amount of cropped area runoff that becomes take is small at around 12% of the total floodplain harvesting take volume. This reduces to 3% when compared to total valley take. Futhermore, as shown in row 4, the additional crop runoff volume harvested as a result of irrigation application is only 2% of total take (assuming that additional runoff created through application of irrigation is assumed to be double that which occurs without its application).

The variation in cropped area runoff take as a proportion of total take does not very greatly from property to property as illustrated in Figure 6 and Figure 7. As can be seen cropped area runoff take as a proportion of total take does not exceed 5% for any property.

Importantly, even if copped area runoff and take in the analysis of Table 3 has been underestimated, a doubling of the amount of additional runoff created through the application of irrigation would still result in cropped area runoff take volumes less than 5% of total take at the Valley scale.

Table 3- Cropped Area Runoff and Harvested Volume as a Proportion of Farm Runoff and Take

Item	Baseline Diversion Limit Model Scenario	PBP
1) approx irrigated crop runoff as % total rainfall runoff	56%	55%
2) approx irrigated crop runoff harvested as % total floodplain harvesting	12%	12%
3) approx irrigated crop runoff harvested as % total floodplain harvesting + reg diversions	3%	3%
4) approx additional irrigated crop runoff harvested as % total floodplain harvesting + reg diversions	2%	2%

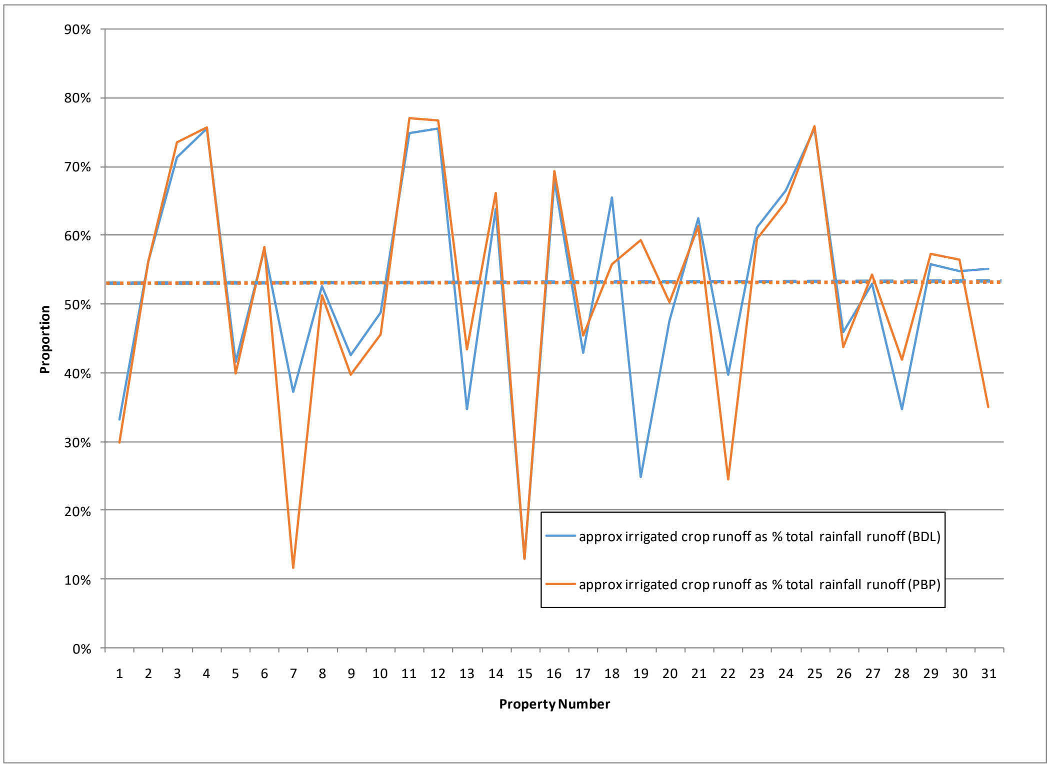

Figure 5 - Crop Runoff as a Proportion of Total Rainfall Runoff

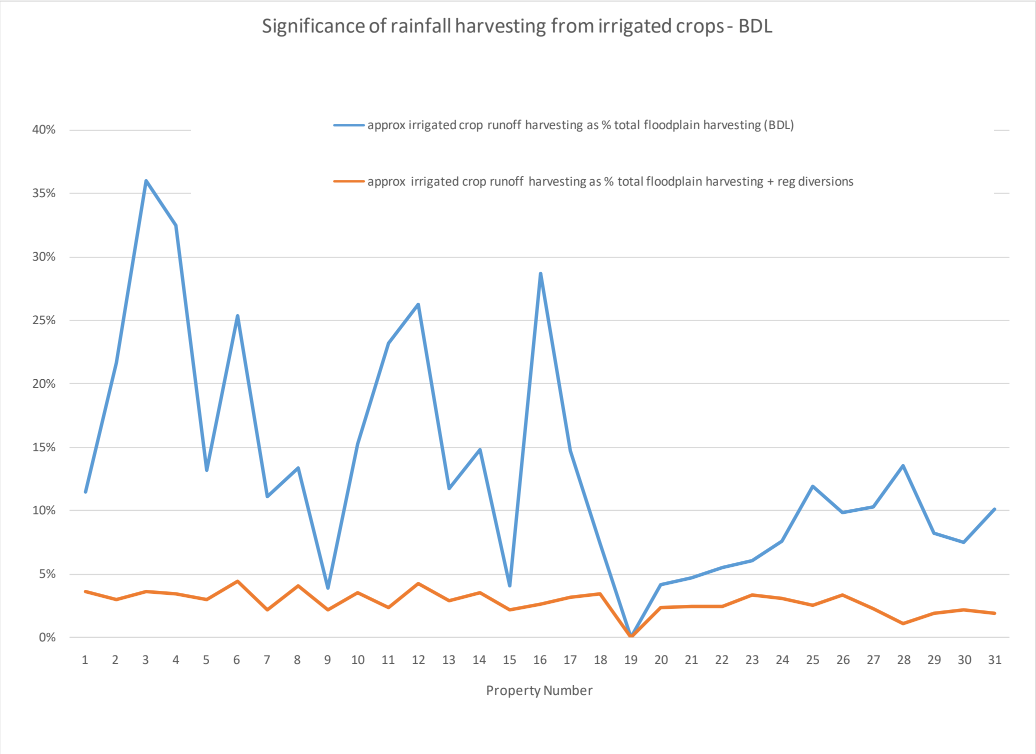

Figure 6 - Crop Runoff as a Proportion of Total Floodplain Harvesting Volume and Total Take

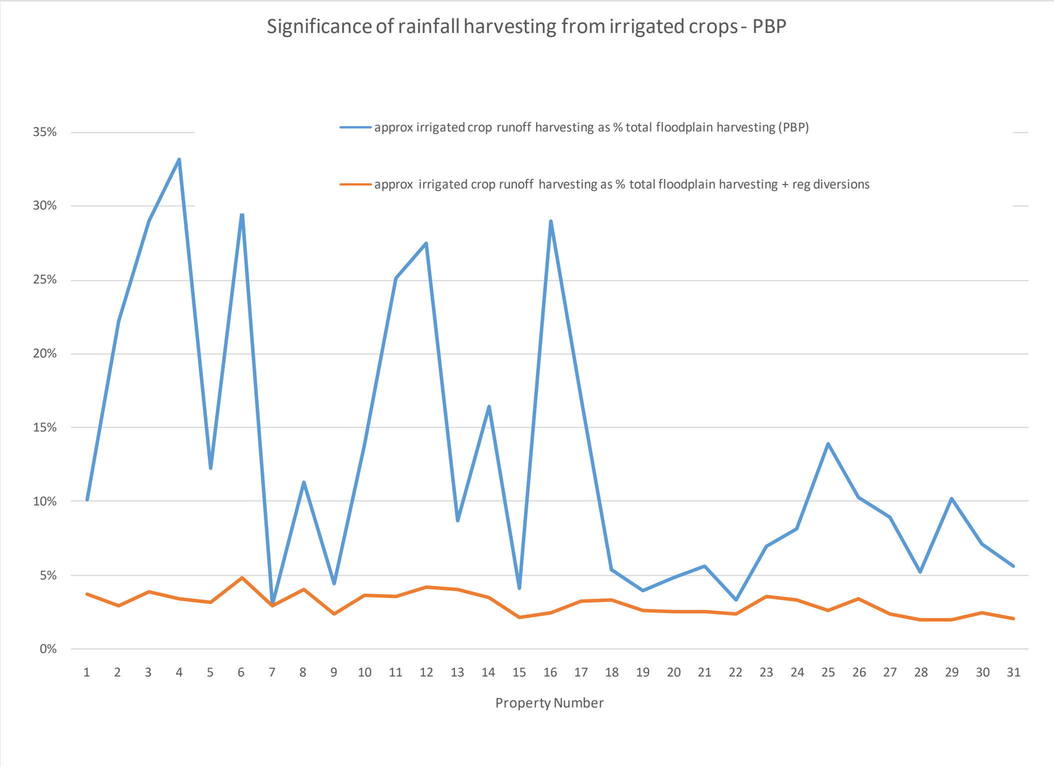

Figure 7 - Crop Runoff as a Proportion of Total Floodplain Harvesting Volume and Total Take

3.4 Accounting of cropped area rainfall runoff as take

Runoff that is captured from a cropped area forms part of the on farm water balance and goes towards meeting crop demands via tailwater recycling. Consequently, its volume should be accounted for. The issue is that given its small size and its ability to be influenced by water user irrigation behaviour, whether accounting should extend to it being considered as a form of take under a long-term average annual extraction limit? This would then entail that it is subject to licensing, measuring, monitoring, arrangements and growth in use provisions that apply to other forms of take.

A summary of the issues that arise as a result of its inclusion or exclusion as a form of take under a long-term extraction limit are presented in Table 4 for a number of attributes.

Table 4 - Issues arising from including or excluding cropped area runoff take under an LTAAEL

Attribute	Significance if Included	Significance If Excluded
Measuring	By including the measuring effort would be reduced. ie one less component of the on farm water balance that would need to be measured or calculated.	Potentially increased measuring or calculation effort. By excluding it in the total take the amount of rainfall runoff from cropped area would need to be measured or calculated in order to adjust the total land surface diversion. A suitable adjustment method would need to be developed. Note previous studies have highlighted that existing BOM rainfall gauges are insufficient to capture on farm rainfall variability. So measurement or calculation of the cropped area runoff amount will in all likelihood require additional on farm instrumentation.
Monitoring	Runoff from a cropped area is more frequent than runoff from fallow and undeveloped areas consequently there will be some increase in monitoring frequency	Potentially less frequent monitoring if runoff from cropped areas occurs more frequently than runoff from fallow and undeveloped areas.
Third Part Impacts	Reducing the impact of growth in cropped area runoff on the current distribution of runoff and infiltration, and thus third party impacts. Including it in theory allows for water resource managers to reduce changes to the	Growth in cropped area runoff potentially changes the distribution of runoff and infiltration that existed previously thereby causing a greater third party impact than if it was included.

	proportions of the rainfall infiltration runoff water balance that existed prior to cropping through a growth in use response if required. This would in turn allow for no third party impacts. This also assumes that the growth in use will be applied to the rainfall runoff component of the land surface diversion and not the total. If it is applied to the total then some third party impact will remain but will be potentially less than if it is excluded.	
Growth in Use Compliance	If cropped area runoff is included as take and there's growth, issues with how it can be reduced need to be considered. Users would either: i) have to scale back areas by an unknown amount. This may be difficult to justify if the area increase has been through efficiency without growth in the other components of take (FPH included). ii) forgo capture of this additional runoff potentially having to discharge it into the river system beyond which provisions allow for. This maybe environmentally adverse. iii) reduce floodplain harvesting take. This would not reinstate the original runoff, infiltration	Compliance not required.

	proportion.	
Equity	Extractive users on floodplains in the Northern Basin will have cropped area runoff take included in a LTAAEL whilst other users in will not potentially creating perceived equity issues.	All floodplain extractive water users treated the same.
Water Use Efficiency	May act reduce the extent to which for water use efficient practices can increase agricultural production. For example: 1 Users expanding cropped areas through reduced on farm losses such as on farm storage evaporation. 2 May encourage users to alter their irrigation practices to minimise crop area runoff.	Users can increase area and production through more efficient practices without penalty.

3.5 Conclusions

Based on the preceding analysis the following conclusions can be drawn in relation to cropped area runoff, the take associated with it, and the issues associated with its inclusion or exclusion as a form of take under a long-term extraction limit:

- The proportion of rainfall that become cropped area runoff from submissions and the Department's modelling show substantial variation.
- All methods used to determine crop area runoff are based on limited calibration data and as such estimates remain highly uncertain.
- Notwithstanding the uncertainty of cropped area runoff amount, the likely cropped area runoff take is small and makes up a very small portion of total take at less than 5% at both the valley and property scale. This is within the measurement error of the measurements devices that are likely to be used to determine floodplain harvesting take amounts.

- Exclusion of cropped area runoff take under the LTAAEL will require a method to be developed to allow for floodplain harvesting take adjustment.

- There are valid arguments for both excluding and including cropped area runoff take as part of the extraction limit. There is no correct answer, and this assessment has not led to an obvious answer in relation to its treatment. Either choice will result in obstacles and challenges for government and stakeholders.

4 References

1 Aquatech (2019) *NSW Department of Industry Floodplain Harvesting Monitoring and Auditing Strategy Sensitivity Analysis Final Report – Milestones 1 - 6.*

2 Alluvium (2019) *Independent Review of NSW Floodplain Harvesting Policy Implementation Final Report.*

3 eWater 2019 *Source User Guide 4.19.*

4 Ogden et al (June 2017) *Comment on "Beyond the SCS-CN method: A theoretical framework for spatially lumped rainfall-runoff response" by M. S. Bartlett et al.*

5 MDBA 2011 *Estimating Land Surface Diversions Stage 2*

6 NSW Department of Industry (2019) *Review of Tahlee Consulting Services Rainfall Runoff Analysis.*

7 Purdue 2019 https://engineering.purdue.edu/mapserve/LTHIA7/documentation/scs.htm)

8 Qld Department of Primary Industries Water Resources Commission *Farm Water Supplies Design Manual Volume 1*