BRITISH COLUMBIA | Ministry of Agriculture

Hullcar Situation Review
Nutrient Management Practices: Technical Report

October 2017 **File No. 631.700-1**

Prepared for:

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EXECUTIVE SUMMARY

- There is a time lag between reductions in nutrient losses from farms and improvements in water quality, and in some cases the lag lasts several years.
- If water quality cannot be expected to improve fast enough to meet particular needs after nutrient losses are reduced from farms, then the assessment of whether nutrient management goals are met must be based on measures other than indicators of water quality.
- Currently in B.C., objectives for nutrient management to address nutrient losses from farms are established in voluntary guidelines and not regulation.
- Currently, voluntary nutrient management planning includes the objective of meeting an agronomic nitrogen balance of zero, a concept to determine if manure application rates exceed the 'carrying capacity of land' for nitrogen.
- In the future, the revised Agricultural Waste Control Regulation (AWCR) is expected to establish clear objectives for nutrient management against which compliance can be measured.
- In the future, the revised AWCR is expected to adopt a risk-based approach that accounts for the sensitivity of highly and moderately vulnerable aquifers to nitrate pollution.
- In the future, the revised AWCR will refer to phosphorus-based limits, which can be more stringent (i.e., lower maximum application rates) than nitrogen-based limits for manure application.
- There is no one-size-fits-all solution in the suite of practices and technologies available to producers to reach nutrient management targets.
- There is no scientific basis to suggest that using a scrape system instead of a flush system for manure handing will reduce the risk of nitrate leaching in the Hullcar situation.
- To reach nutrient management goals for environmental risk reduction, conventional beneficial management practices (BMPs) and innovative technologies are available to farmers, but neither has immediate benefits to remediating nitrate deep below the root zone.
- Technologies that can recover manure nutrients for export off farm are currently limited in their economic feasibility (based on current market and regulatory drivers), improvements in other BMPs (agronomic or cropping practices) may achieve nutrient management objectives without utilization of costly treatment technologies.

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1 INTRODUCTION

1.1 BACKGROUND

The loss of agricultural nutrients (nitrogen and phosphorus) to receiving waters has potentially detrimental effects on water quality. Agricultural practices have likely contributed to nitrate contamination of the Hullcar aquifer. To gather the information necessary to set a path forward, this report is provided as part of a review of lessons learned during the 'Hullcar situation'[1] with the purpose of informing approaches to future decision making to provide clean drinking water for British Columbians (Terms of Reference (TOR) for Review of Hullcar Situation).

The Project Charter of the Hullcar Situation Review assigns responsibilities to the Ministry of Agriculture (AGRI) to address the following objective:

- "Review current agricultural nutrient management practises [sic] from the perspective of environmental and economic sustainability while prioritizing the protection of drinking water, and in consideration of short and long term strategies for improvements of the aquifer water quality"

The specific responsibilities assigned to AGRI include the following, quoted from the Project Charter:

1. "Nutrient management plan requirements review"
    a. The scope includes "guidance provided by regulators for plan content, and qualifications for professionals developing nutrient management plans."
2. "Review of available treatment technology" ([Terms of Reference] TOR 2.d & 2.e)
    a. TOR 2d. "Review currently used and feasible waste management practices, focussing on use of agricultural waste that is economically and environmentally beneficial (e.g. composting, waste-to-energy such as bio gas and electricity generation, etc.)"
    b. TOR 2e. "Consider the time lag between improvements in nutrient management practices and their effects at the water table to inform short and long term strategies for reductions in nitrate pollution from agricultural lands. The goal is for the aquifer water quality to return to safe drinking water levels as soon as possible."
3. "Review of information that was provided to [Agricultural Waste Control Regulation, AWCR] review regarding nutrient management"
    a. The scope includes "addressing the carrying capacity of lands used to manage agricultural nutrients"
4. "Review current advice provided to producers" (TOR 2.g)
    a. TOR 2g. "Review the information that is relevant to nitrogen management that was considered during the Regulatory Review of the AWCR."
5. "Jurisdictional Scan on nutrient management requirements"

[1] http://www2.gov.bc.ca/gov/content/environment/air-land-water/site-permitting-compliance/hullcar-aquifer

1.2 REPORT ORGANIZATION

This report fulfills AGRI's responsibilities in three main sections (Table 1):

- **Section 2** presents briefly the principle of a time lag between improvements in nutrient management and improvements in water quality. This principle underlies the rationale for nutrient management objectives with respect to water quality protection.
- **Section 3** introduces the technical information that AGRI has provided about nutrient management that can be used to develop requirements. The information includes technical options to interpret the policy intention of addressing the concept of 'carrying capacity of lands.'
- **Section 4** outlines a number of practices and technologies producers can implement to meet nutrient management goals. This section introduces the information and support AGRI has provided about these practices and technologies, along with the programs that promote their adoption.
- Each section or subsection concludes with an annotated bibliography including the references cited within this report and supplementary documents provided along with this report.

Report Section	Project Charter Responsibilities Terms of Reference items in blue, italicized text
2. Nutrient Management to Protect Water Quality	*Consider the time lag between improvements in nutrient management practices and their effects at the water table to inform short and long term strategies for reductions in nitrate pollution from agricultural lands.*
3. Nutrient Management Requirements to Address Risks of Nutrient Pollution	#1 Nutrient management plan requirements review *With consideration on how agricultural nutrient management practices are conducted across BC, specifically review the requirements for nutrient management plans, including scope, guidance provided by regulators, and qualifications for professionals developing nutrient management plans.* #3 Review of information that was provided to Agricultural Waste Control Regulation Review regarding nutrient management *Review the information that is relevant to nitrogen management that was considered during the Regulatory Review of the Agricultural Waste Control Regulation* #4 Jurisdictional Scan on nutrient management requirements: *Assess how other jurisdictions are approaching agricultural nutrient management and drinking water protection in areas of intensive agriculture, including addressing the carrying capacity of lands used to manage agricultural nutrients.*
4. Practices and Technologies to Meet Nutrient Management Requirements	#2 Review of available treatment technology *Review currently used and feasible waste management practices, focussing on use of agricultural waste that is economically and environmentally beneficial (e.g. composting, waste-to-energy such as bio gas and electricity generation, etc.)* #4 Jurisdictional Scan on nutrient management requirements *Assess how other jurisdictions are approaching agricultural nutrient management and drinking water protection in areas of intensive agriculture…with consideration of a broad spectrum of beneficial management practises [sic].*

2 NUTRIENT MANAGEMENT TO PROTECT WATER QUALITY

- *Consider the time lag between improvements in nutrient management practices and their effects at the water table to inform short and long term strategies for reductions in nitrate pollution from agricultural lands.*

2.1 SECTION HIGHLIGHTS

- There is a time lag between reductions in nutrient losses from farms and improvements in water quality, and in some cases the lag lasts several years.
- If water quality cannot be expected to improve fast enough to meet particular needs after nutrient losses are reduced from farms, then the assessment of whether nutrient management goals are met must be based on measures other than indicators of water quality.

2.2 IMPROVEMENTS IN NUTRIENT MANAGEMENT TAKE TIME TO SHOW

There is a time lag between what happens on a farm and what happens to water quality. This time lag is sometimes referred to as a memory effect, which explains how it is possible for a farmer to discontinue applications of any nitrogen (N) inputs, yet nitrate loading to an aquifer continues for years because of historical N mismanagement. In other words, "**the deterioration of groundwater quality and its improvement following an intervention can be very slow**… especially where the unsaturated zone is relatively thick and the groundwater flow paths are long" (Rudolph 2015).

The unsaturated zone is the part of the subsurface between the surface soil and the groundwater table. In the case of the Hullcar Aquifer, recently collected evidence suggests that it might take several years, possibly in the order of decades, for nitrate to reach the water table from the soil root zone in which crops influence nutrient uptake (Associated Environmental 2017a,b,c). The possibility of the lag time lasting several years is not exclusive to the Hullcar Aquifer situation and is widely recognized (Fig. 1).

> "The results show that achievement of good water quality status in the Republic of Ireland for some [aquifers] **may be too optimistic** within the current timeframe of 2015 targets but improvements are predicted within subsequent 6- and 12-year cycles"
> (Fenton et al. 2011; Environmental Science and Policy 1: 419-431).

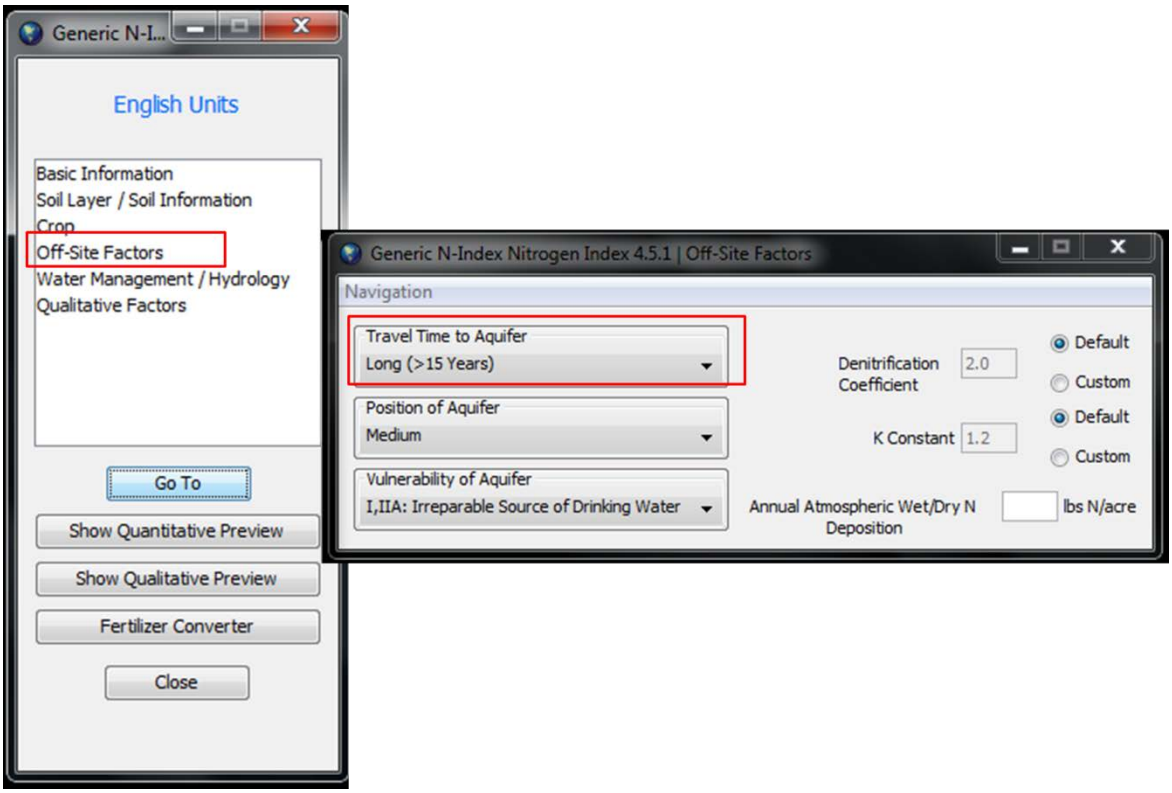


Figure 1. A screenshot from the Nitrogen Index tool describes the travel time from the soil root zone to an aquifer as an off-site factor. Source: United States Department of Agriculture 2015.

2.3 Nutrient Management Focuses on Reducing Nutrient Losses from a Farm

The goal for aquifers with degraded water quality is to return to safe drinking water levels as soon as possible. However, in cases where the time lag is long because of hydrogeological factors, the "**long response time frames must be anticipated**… **to provide reasonable levels of expectation** when designing and recommending nutrient [best management practices]" (Rudolph 2015, p. 5). In these cases, safe drinking water levels are a long term goal, possibly in the order of decades, if short-term improvements at the water table cannot reasonably be expected.

In developing nutrient management requirements, realistic expectations must be considered to develop useful performance measures. The absence of water quality monitoring in these requirements would not necessarily indicate that water quality is unimportant. To the contrary, their absence could indicate that there are more reliable measures for determining whether nutrient management practices meet specific nutrient management objectives for reducing nitrate losses below the root zone. The following sections introduce documents describing key nutrient management objectives (Section 3) and practices and technologies to meet these objectives (Section 4).

2.4 ANNOTATED BIBLIOGRAPHY: NUTRIENT MANAGEMENT TO PROTECT WATER QUALITY

Reference	Contents
Associated Environmental. 2017a. Environmental Impact Study Report. H.S. Jansen & Sons Farms Ltd.	This technical report has estimates of travel times for nitrate from an agricultural field in the Hullcar Valley to move to the water table - "the time of travel for nitrate-N to move to the water table in field 103A would be between 3 and 55 years."
Associated Environmental. 2017a. Environmental Impact Study Report. Grace-Mar Farms Ltd.	This technical report has estimates of travel times for nitrate from an agricultural field in the Hullcar Valley to move to the water table - "the time of travel for nitrate-N to move to the water table at MW3 would be between 1.4 and 20 years."
Associated Environmental. 2017c. Environmental Impact Study Report. Ken and Brenda Regehr.	Technical report - "We do not expect concentrations [of nitrate] to decrease for several years given the unknown rate of nitrate-N movement… through the unsaturated zone, and the slow groundwater travel time."
Fenton et al. 2011. Time lag: a methodology for the estimation of vertical and horizontal travel and flushing timescales to nitrate threshold concentrations in Irish aquifers. *Environmental Science and Policy* 14: 419-431. (available upon request)	A peer-reviewed journal article - objective was to "estimate the hydrological time lag between implementation of nitrate mitigation measures in 2012 and improvement in groundwater quality… in a variety of Irish hydrogeological scenarios"
Rudolph 2015. Towards Sustainable Groundwater Management in the Agricultural Landscape.	A 5-page article written for a general audience in a publication by the Canadian Water Network - Describes research on farm lands in Ontario that were near public supply wells with high nitrate concentrations. - Soil testing provided a short-term (2-year) performance assessment of conventional Best Management Practices (reduction in fertilizer applications, cover cropping, substitution of nitrogen sources) - An on-site remediation practice was demonstrated to reduce nitrate concentrations in the aquifer in the short term, prior to long-term reductions achieved by more conventional Best Management Practices implemented by farmers.
Rudolph et al. 2015. Challenges and a strategy for agricultural BMP monitoring and remediation of nitrate contamination in unconsolidated aquifers. *Ground Water Monitoring and Remediation* 35: 97-109. (available upon request)	A peer-reviewed journal article that provides the technical basis for the article by Rudolph 2015.
USDA 2015. Nitrogen Index v 4.5	The homepage for a software tool that describes the travel time for contaminants from the soil root zone to an underlying aquifer as an "off-site factor." - Travel time to aquifer is classified as long (>15 years), medium (5 to 15 years), or short (<5 years)

3 NUTRIENT MANAGEMENT REQUIREMENTS TO ADDRESS RISKS OF NUTRIENT POLLUTION

- *With consideration on how agricultural nutrient management practices are conducted across BC, specifically review the requirements for nutrient management plans, including scope, guidance provided by regulators, and qualifications for professionals developing nutrient management plans.*
- *Review the information that is relevant to nitrogen management that was considered during the Regulatory Review of the Agricultural Waste Control Regulation*
- *Assess how other jurisdictions are approaching agricultural nutrient management and drinking water protection in areas of intensive agriculture, including addressing the carrying capacity of lands used to manage agricultural nutrients.*

3.1 SECTION HIGHLIGHTS

- Currently in B.C., objectives for nutrient management to address nutrient losses from farms are established in voluntary guidelines and not regulation.
- Currently, voluntary nutrient management planning includes the objective of meeting an agronomic nitrogen balance of zero, a concept to determine if manure applications exceed the 'carrying capacity of land' for nitrogen.
- In the future, the revised Agricultural Waste Control Regulation (AWCR) is expected to establish clear objectives for nutrient management against which compliance can be measured.
- In the future, the revised AWCR is expected to adopt a risk-based approach that accounts for the sensitivity of highly and moderately vulnerable aquifers to nitrate pollution.
- In the future, the revised AWCR will refer to phosphorus-based limits, which can be more stringent (i.e., lower maximum application rates) than nitrogen-based limits for manure application.

3.2 CURRENT STATE OF NUTRIENT MANAGEMENT IN B.C.

3.2.1 LACK OF CLARITY IN REGULATION

The Environmental Law Centre (2017, p. 4) identifies general limitations or inadequacies of B.C.'s current regulation that covers agricultural waste:

> "The [Agricultural Waste Control Regulation] is inadequate because it is so vague – and is so reactive, instead of proactive. The regulation only becomes relevant once the pollution is already occurring. But there is nothing enforceable until the pollution has happened" (ELC 2017, p. 4)

Similar limitations have been identified previously, particularly in the context of non-point source pollution from agricultural land (AGRI 2015, Technical Brief on Nutrient Management). The nature of non-point source pollution is that it can be a cumulative effect from multiple sources that individually might not cause pollution. Thus, the **regulation currently lacks the clarity required for an individual to know if he or she is meeting regulatory requirements** to protect water quality in an aquifer or watershed shared by the individuals**.** Furthermore, the regulation is indeed reactive and slowly reactive: it might take years or decades for nutrient management practices on agricultural land to impact the water quality in an aquifer or lake (Section 2).

3.2.2 VOLUNTARY EDUCATION ABOUT NUTRIENT MANAGEMENT

The Environmental Farm Plan (EFP) has been developed as a voluntary program to increase education among individual producers. An expected outcome is positive behaviour change on the farm towards compliance with environmental regulations and towards the reduction of environmental risks. The Nutrient Management Plan (NMP) in B.C. has been developed as a subcomponent of the voluntary EFP process.

Between the components of an EFP and an NMP, the various sources of potential water pollution by on-farm nutrients are addressed (Table 1). Completing the EFP is the first step, which can possibly trigger a recommendation to do an NMP.

Table 1. Components of Environmental Farm Plans (EFPs) and Nutrient Management Plans under B.C.'s EFP/ BMP program. Details are provided by BC AGRI (2017a, Review of Nutrient Management Planning in BC).

Environmental Farm Plan	Nutrient Management Plan (subcomponent of EFP)
Manure Storage – assessment of whether storage facilities are adequately sized to contain nutrient sources such as manure until they can be applied to land beneficially Managing Runoff – assessment of whether nutrient-rich runoff from solid manure storages and the farmstead is managed (e.g., treated, contained, diverted, etc.)	Land Application of Nutrients – assessment of whether there is adequate land for the nutrients planned for land application, based on suggested nutrient balance criteria.

The two core objectives of nutrient management planning support economic and environmental sustainability:

- "to supply crops with nutrients at the appropriate rate, timing, and with the appropriate method to produce an economically optimal crop in terms of both yield and quality; and
- to minimize the risk of pollution by loss of nutrients via runoff, leaching, emissions to the air or other loss mechanisms" (NMP Reference Guide 2010)

Note that animal density is effectively one of the EFP triggers to recommend the completion of an NMP (Fig. 2 "Worksheet 4"). That is, one *indicator* for the need for an NMP is a comparison of the number and type of animals against the area and type of crops receiving manure (Fig. 2). Then, in an NMP**, nutrient balance calculations – but not animal density – can determine whether an individual's nutrient application rates exceed the 'carrying capacity' of land** (BC AGRI 2017a).

Worksheet #4 **Manure Nitrogen Application Assessment for Farms that Generate Manure** **Workbook Question 217**

Question: Proceed through the following worksheet calculations to assess whether or not a Nutrient Management Plan (NMP) would be recommended for this farm.

Information:

Type of animal (Refer to Table 6.7*) [1]

Reset

Number of animals [2]

Portion of manure remaining on the farm after manure export (value between 0 and 1) [3]

Assumed annual N excretion per animal place (Refer to Table 6.7*) [4] kg N/animal

Calculations:

Step 1 Estimate the manure N excreted and remaining on farm, using Equations below:

Equation:						
Number of animals	**x**	**portion of manure left**	**x**	**Annual N Excretion/ animal place (kg)**	**=**	**Annual N Excreted and remaining on Farm (kg)**
[2]	x	[3]	x	[4] kg/Animal	=	[5] kg N

Step 2 Calculate annual baseline manure N application for crops grown on farm, using Equation below:

Equation:				
Area Manure Spread on (ha)	**x**	**Manure N Application Rate (kg N/ha)**	**=**	**Manure N Application for Farm (kg)**

non-forage area	[6]	ha x	*50*	kg N/ha	=	[10] kg N
forage grass (Fraser Valley) area	[7]	ha x	*300*	kg N/ha	=	[11] kg N
forage grass (rest of BC) area	[8]	ha x	*200*	kg N/ha	=	[12] kg N
forage corn area	[9]	ha x	*150*	kg N/ha	=	[13] kg N

Step 3 Calculate Annual Baseline Manure N application for whole farm (Sum of boxes 10 to 13) = [14] kg N

Answer:

Step 4 Is the annual N excretion remaining on the farm [5] less than [14] the baseline application value?

NO **a NMP is recommended**

or *YES* **a NMP is Optional**

A Nutrient Management Plan (NMP) is suggested to optimize nutrient utilization and protect the environment.

Note: *Refer to Tables in BC Environmental Farm Plan Reference Guide

Figure 2. A worksheet from the Canada-BC Environmental Farm Plan Reference Guide (AGRI 2010a) is part of one criterion for determining whether a Nutrient Management Plan (NMP) is recommended.

3.2.3 'ZERO NITROGEN BALANCE'

The voluntary NMP program is clear in its guidance about a particular nutrient management objective: "aim to keep all nutrient application rates at or below the the agronomic rate for nitrogen" (BC AGRI 2010b, p. 13). The agronomic nitrogen rate is the amount or rate of "plant available nitrogen recommended for a crop on an annual basis to produce an economically optimal and environmentally sustainable yield" (AGRI 2010b, p. 11).

The above guidance was effectively adopted as a requirement of mandatory nutrient management plans in Pollution Abatement Orders (PAOs) that the Ministry of Environment issued to farmers in the current Hullcar situation: "The [Nutrient Management Plan] must be designed to meet an agronomic nitrogen balance of zero (0) for each field receiving nutrient application."[2] **If a nitrogen balance of zero is met on each field receiving manure, then there is no excess of manure nitrogen**. In addition, the scope of the PAOs included the Manure Storage, Managing Runoff, and Land Application of Nutrients components that are split between the EFP and NMP portions of voluntary program in B.C. (Table 1).

How does one know if the objective of 'zero nitrogen balance' is met? Best practices for nutrient management planning provide several means of knowing (Section 4). Note that an objective of **agronomic nitrogen 'balance of zero' does not equate to an objective of zero post-harvest soil nitrate** (Fig. 3). Post-harvest soil nitrate is the amount of nitrate not used by the most recently harvested crop (AGRI 2010b; Sullivan and Cogger 2003). The amount of nitrate in the soil at any time depends on both management factors and environmental factors that are outside the influence of farmers' practices (AGRI 2010b; Sullivan and Cogger 2003). A 2007 study in the Okanagan Valley of B.C. found that "fields that had low [post-harvest soil] nitrate could have indicated [nitrogen] deficiency and limited crop production" (Kowalenko et al. 2009).[3]

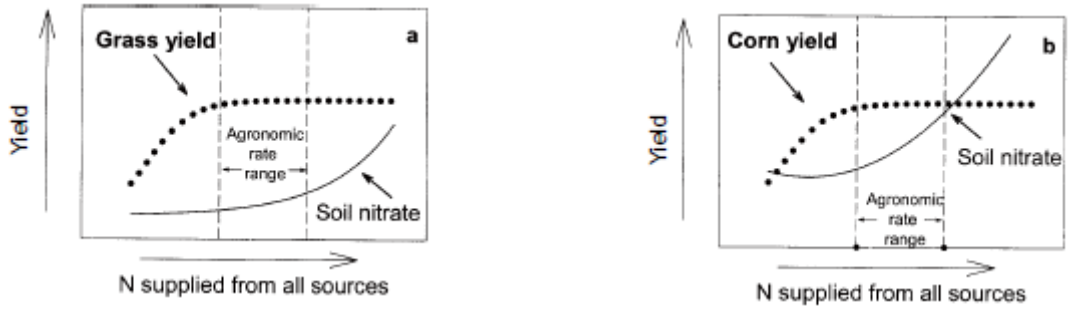


Figure 3. The agronomic nitrogen (N) rate minimizes but *does not eliminate* nitrate remaining in the soil at the end of a cropping year. Source: Sullivan and Cogger (2003).

[2] Example of a Pollution Abatement Order in the Hullcar Situation: http://www2.gov.bc.ca/assets/gov/environment/air-land-water/site-permitting-and-compliance/hullcar/pao/2017_03_01_grace_mar_pao_amendment.pdf

[3] Kowalenko et al. 2009. 2007 Okanagan Agricultural Soil Study. http://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/agricultural-land-and-environment/environmental-farm-planning/okanagan_soil_study_report_2007.pdf

3.2.4 ANNOTATED BIBLIOGRAPHY: CURRENT STATE OF NUTRIENT MANAGEMENT

Reference	Contents
AGRI 2010a. Reference Guide: The Canada – British Columbia Environmental Farm Plan Program	Guidance document for Planning Advisors in the EFP program. -provides technical information for evaluating on farm environmental risks and comprehensive BMP recommendations to address them
AGRI 2010b. Nutrient Management Reference Guide.	The Nutrient Management Reference Guide is for planners and agricultural producers in British Columbia who would like to do a Nutrient Management Plan for their farm - a user manual or reference guide for those using AGRI's software tools for calculations important to a nutrient management plan under the EFP/BMP program - gives guidance to monitor the effectiveness of nutrient management
BC AGRI 2017a. Review of Nutrient Management Planning in BC.	Overview of voluntary Nutrient Management Plan under the Environmental Farm Plan / Beneficial Management Practices program - Criteria for deciding who will do a Nutrient Management Plan (Triggers in the EFP process that lead to recommendation of an NMP), with supporting technical worksheets - Components of a Nutrient Management Plan - Steps To Develop a Nutrient Management Plan - Guidance for Recognized Nutrient Management Planning Advisors: eligibility criteria for those who prepare NMPs under the BMP program -Other instances where NMPs are required in BC: Anaerobic Digesters and specific ENV Pollution Abatement Orders
Kowalenko et al. 2009. 2007 Okanagan Agricultural Soil Study.	A technical report of an "Agronomic and Environmental Survey of Soil Chemical and Physical Properties" - 173 fields in the Okanagan-Similkameen Valley were sampled for soil nutrient status during the post-harvest phase after crop nutrient uptake has effectively stopped for the season - fields that had low post-harvest soil nitrate could have indicated nitrogen deficiency and limited crop production - soil test interpretations were developed further to derive implications for environmental risk
Sullivan, D. and Cogger, C. 2003. Post-harvest soil nitrate testing for manured cropping systems west of the Cascades. Oregon State University-Extension Service. EM-8832-E.	Technical guidance document for consultants and farmers, directly applicable to coastal British Columbia - Main sections include the following: - What the post-harvest [nitrate] test measures - How to collect soil samples - Units used in soil nitrate testing - How to interpret soil nitrate test results for grass and silage corn crops

3.3 FUTURE STATE OF NUTRIENT MANAGEMENT IN B.C.

Starting in 2010, the Ministry of Environment has been reviewing the AWCR in a 5-stage process (Table 2). The intent is to repeal the current AWCR regulation and replace it with a new Code, with the aim to provide "clear enforceable rules" and "clear, consistent and achievable standards" (ENV 2017). Section 3.3 introduces the information that AGRI provided during the AWCR Review.

Table 2. Five stages of the Agricultural Waste Control Regulation (AWCR) review and supporting references (Section 3.3.3).

Phase of AWCR Review	References (Section 3.3.3)
1. Scoping	- BC AGRI 2017b. - McDougall 2010.
2. Intentions Paper	n/a
3. Consultation	- AWCR Review WG Members - BC AGRI 2015. 'Technical Briefs': a series of discussion papers from AGRI on Nutrient Management, Land Application, Permanent Storage, and Temporary (Field) Storage - ENV 2016. -Working Group Consultation with Industry_timeline_meeting topics
4. Drafting (current phase of the AWCR Review)	n/a
5. Implementation	n/a

3.3.1 CLEAR OBJECTIVES UNDER A RISK-BASED APPROACH

The information AGRI that provided or discussed during the AWCR Review addressed two key features of ENV's policy:

1. A risk-based approach
2. Clear objectives

Feature 1: a risk-based approach for more stringent requirements in areas that warrant a higher level of environmental protection, such as vulnerable aquifers like the Hullcar Aquifer (Table 3).

Table 3. Proposed policy regarding a Risk-Based Approach, from the Ministry of Environment (ENV 2016, p. 1) based on consultation with Ministry of Agriculture and industry.

Proposed Policy	Explanation/Comments
"Each agricultural operation would **refer to a 'High Risk Schedule' to see if they need to follow more stringent requirements** for a higher level of protection."	"**High risk areas** defined - e.g., high rainfall (600 mm or more); all highly vulnerable aquifers and moderately vulnerable aquifers that are drinking water sources; sensitive receiving environment… … e.g., with i) a list describing names or locations of aquifers, and/or ii) a provincial map showing aquifers, and their classifications; and iii) a map and/or a list of sensitive receiving environments for specific sensitivities, such as phosphorus loading"

Feature 2: Clear nutrient management objectives (Table 4) based on agronomic nitrogen balance (ENV 2016, p. 12), instead of being based on measures of water quality impacted by multiple sources (Section 3.2).

Table 4. Proposed policy regarding Nutrient Management Objectives directly related to nitrogen, from the Ministry of Environment (ENV 2016, p. 12) based on consultation with Ministry of Agriculture and industry.

Proposed Policy	Explanation/Comments
Environmental Risk Indicator For Nitrogen/nitrates - is **a Post-Harvest Nitrate Test (PHNT)** for outdoor field-based crops.	"Rationale: - need to know how much is left in the soil (after crop harvested) that is at risk to leach down or runoff; If applied at an agronomic rate, there is enough for the crop, and should not leave excessive amount in the soil. PHNT is also used as a performance measure to assess how well agronomic application rate is being met."
In High Risk Areas for nitrate pollution, "**If the PHNT is 100 kg N/ha or greater, a nutrient application plan must be prepared** by a [Qualified Professional]."	"Difference between being in high risk area and not being in high risk area… For the Nutrient Application Plans, an explicit requirement [in high risk areas] for sampling and laboratory analyses, crop production recommendations and crop yield records, signed off by a [Qualified Professional], … unless otherwise specified by the Director."
"The nutrient application **plan must be designed to meet an agronomic nitrogen balance of 0,** for all fields… If a nutrient application plan is required, a producer must be able to demonstrate compliance with the plan, and actions to decrease annual PHNT and minimize losses to the environment."	"The policy is that records can be requested, should a particular concern arise – based on concern, complaint or during an inspection."

AGRI provided rationale for why the Post-Harvest Nitrate Test (PHNT) could be a reasonable trigger for further action (i.e., preparation of a nutrient management or application plan). However, AGRI recommends that **PHNT not be used to provide firm targets** against which compliance is assessed, because the results reflect both management practices and environmental factors that are outside of a producer's control. Nutrient management experts in Washington State use the PHNT similarly:

> Rather than using the PHNT soil test levels as firm regulatory values, "[those in the Dairy Nutrient Management Program] use corrective and weighting factors to assess a site for compliance."
> (Nichole Embertson, Whatcom Country Conservation District, Personal Communication, July 11 2017 email)

> "The [Dairy Nutrient Management Program] **recognizes the challenges in meeting [the target levels for post-harvest nitrate test] with the multitude of variables**… (variable nutrient levels in dairy nutrients, mineralization, weather, irrigation, etc.)"
> (Michael Isensee, WA State Department of Agriculture, Personal Communication, July 11 2017 email)

3.3.2 PHOSPHORUS-BASED LIMITS ADDRESS NITROGEN EFFECTIVELY

AGRI provided technical options to address the intention of 'carrying capacity' of agricultural land for phosphorus (P), and more specifically concerns with the impact of agricultural P on surface water quality. Key messages included the following (AGRI 2015a; Technical Brief on Nutrient Management):

- **P-based limits can be more stringent (i.e., lower maximum application rates) than N-based limits for manure application.**
- This is because applying manure (without some form of treatment) at agronomic N rates leads to a buildup of P in soil, eventually resulting in excess manure P even if there is no excess manure N.

The options presented in the Technical Brief were based on an analysis of regulatory limits in other jurisdictions and evidence collected in B.C., and the options were analyzed for their implications for the agriculture industry and the regulatory authority. These were only a starting point that led to policy to address P concerns in the Policy document by ENV (2016).

Accountability and Effectiveness Considerations

The discussion of P-based limits in Technical Brief (AGRI 2015a) is significant from the perspective of how effectively regulatory limits on nutrient application rates can be enforced:

> "Compared to… the determination of agronomic N rates, the Field P balance report… has the most realistic chance of being verified for plausibility with the least amount of subjectivity and involvement (by a regulatory authority or qualified professional)"
> – Opinion from AGRI (2015a)

Related questions emphasized by AGRI during the AWCR review include (AGRI 2015a):

- How or when maximum application rates would need to be demonstrated?
- Would producers be able to increase animal numbers before accessing cost-share funding, crop insurance, or something else?
- Who will be eligible to determine if regulatory limits (in a Nutrient Management Plan) are met?

3.3.3 ANNOTATED BIBLIOGRAPHY: FUTURE STATE OF NUTRIENT MANAGEMENT

Reference	Contents
AWCR Review WG Members	List of the Industry Working Group Members engaged during the Consultation phase of the Agricultural Waste Control Regulation Review - The "Consultation" phase is described by ENV (2017)
BC AGRI 2017a. Review of Nutrient Management Planning in British Columbia: Sections 2 and 3	Draft recommendations for those agencies such as the Agricultural Land Commission and Ministry of Environment who were interested in AGRI's advice on how to approve, permit, or authorize the nutrient management aspects related to anaerobic digester operations - The recommendations include requirements for a nutrient management plan to facilitate approval/permit of a new anaerobic digester or changes to an existing anaerobic digestion - The recommendations also include requirements for annual reporting, to facilitate verification that operations have stayed within the conditions under which their approval/permit were granted
BC AGRI 2017b. Jurisdictional Scan on Nutrient Management Regulations.	A summary of Nutrient Management regulations across jurisdictions - Includes excerpts from a Jurisdictional Scan prepared by Ruth McDougall in 2010 as part of the Scoping phase of the review of the Agricultural Waste Control Regulation
AGRI 2015a. Technical Brief for Nutrient Management for the AWCR Review.	A draft discussion paper for the working group led by Ministry of Environment to consider technical options for the Agricultural Waste Control Regulation; should not be considered a final product - discussion of options to interpret Nutrient Management policy intentions related to "Right Rate" and Right Source" - "Right Rate" is the widely-accepted principle that relates to the concept of carrying capacity of agricultural land for nutrients
AGRI 2015b. Technical Brief for Land Application for the AWCR Review.	A draft discussion paper for the working group led by Ministry of Environment to consider technical options for the Agricultural Waste Control Regulation; should not be considered a final product - discussion of options to interpret Nutrient Management policy intentions related to "Right Time" and Right Place"
AGRI 2015c. Technical Brief for Permanent Storages for the AWCR Review.	A draft discussion paper for the working group led by Ministry of Environment to consider technical options for the Agricultural Waste Control Regulation; should not be considered a final product - discussion of options to interpret Nutrient Management policy intentions related to permanent storages of manure and other nitrogen sources
AGRI 2015d. Technical Brief for Temporary Storages for the AWCR Review.	A draft discussion paper for the working group led by Ministry of Environment to consider technical options for the Agricultural Waste Control Regulation; should not be considered a final product - discussion of options to interpret Nutrient Management policy intentions related to temporary (field) storages of manure and other nitrogen sources
ENV 2017. AWCR Review - Synopsis Memo_final	Synopsis of the Five-Stage Process of the Agricultural Waste Control Regulation Review - Main topics include Context, Review Process, and Industry Working

	Group engagement
ENV 2016. Policy Underlying Proposed Revisions to the Agricultural Waste Control Regulation (DRAFT).	This policy document was shared with working group (this document is not a public document and is attached for reference only) - a final product of the Consultation stage of the Agricultural Waste Control Regulation review
Jurisdictional Scan summary table-1.pdf	A document provided by the Ministry of Environment (date unknown). - a table comparing regulations covering agricultural operations in 12 jurisdictions in North America and Europe - likely prepared at the end of the Scoping phase of the Agricultural Waste Control Regulation review.
McDougall 2010. AWCR Jurisdictional Review Report Final April 9 2010	A contractor's report completed for the Ministry of Environment as part of the Scoping phase - "Scoping" phase is described by ENV (2017)
Personal Communication, July 11 2017 email.	Personal communication with nutrient management experts regarding the use of post-harvest nitrate (soil) test. - Experts are 1) Nichole Embertson, Ph.D. Nutrient Management and Air Quality Specialist with the Whatcom Conservation District and 2) Michael Isensee, Washington State Department of Agriculture
US Environmental Protection Agency (US EPA). 2014. Yakima Dairies Consent Order Update. December 2014. http://tinyurl.com/ycl74wro found at https://yosemite.epa.gov/r10/water.nsf/gwpu/lyakimagw	- In the Lower Yakima Valley of Washington State, the Post-Harvest Nitrate Test target was effectively set at 350 kg N ha^{-1}* by the US EPA in a 2013 order received by three dairy operations to address nitrate contamination in groundwater - A professional agronomist hired by the dairies began implementing field-specific plans that decreased Post-Harvest Nitrate Test levels towards or below the target level, depending on field - * the target of 45 ppm of nitrate-N in a 2-foot soil sample indicates 315 lb N ac^{-1} (or 350 kg N ha^{-1}) because "the number of pounds of nitrate per acre… can be estimated by multiplying the amount of nitrate in parts per million by a factor of 3.5… Factors of 3.5 or 4 are rules-of-thumb for converting parts per million to lbs/acre for one foot of soil. The actual conversion factor is dependent on soil bulk density" (page 5)
Working Group Consultation with Industry_timeline_meeting topics	A summary of topics discussed by the Industry Working Group during the Consultation phase of the Agricultural Waste Control Regulation Review - The "Consultation" phase is described by ENV (2017).

4 PRACTICES AND TECHNOLOGIES TO MEET NUTRIENT MANAGEMENT REQUIREMENTS

- *Review currently used and feasible waste management practices, focussing on use of agricultural waste that is economically and environmentally beneficial (e.g. composting, waste-to-energy such as bio gas and electricity generation, etc.)*
- *Assess how other jurisdictions are approaching agricultural nutrient management and drinking water protection in areas of intensive agriculture… with consideration of a broad spectrum of beneficial management practices.*

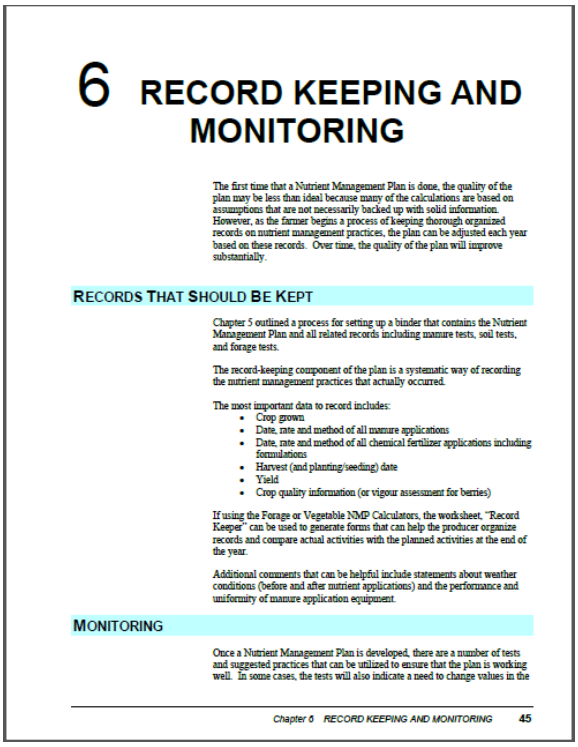
4.1 SECTION HIGHLIGHTS

- There is no one-size-fits-all solution in the suite of practices and technologies available to producers to reach nutrient management targets.
- There is no scientific basis to suggest that using a scrape system instead of a flush system for manure handing will reduce the risk of nitrate leaching in the Hullcar situation.
- To reach nutrient management goals for environmental risk reduction, conventional beneficial management practices (BMPs) and innovative technologies are available to farmers, but neither has immediate benefits to remediating nitrate deep below the root zone.
- Technologies that can recover manure nutrients for export off farm are currently limited in their economic feasibility (based on current market and regulatory drivers), improvements in other BMPs (agronomic or cropping practices) may achieve nutrient management objectives without costly treatment technologies.

When nutrient management objectives are clear, producers can determine the combination of practices and technologies that are best suited for their farm and fields to meet those objectives. Producers may decide on the most appropriate combination themselves, or they may enlist the help of consultants. Some consultants are trained under a voluntary education program in B.C., the 'EFP' program referred to in Section 3. This section introduces the material and information that AGRI has collected or provided about practices and technologies to address nutrient management challenges.

4.2 PRACTICES AND TECHNOLOGIES TO MEET NITROGEN OBJECTIVES

With 'zero nitrogen balance' as an objective for nutrient management (Section 3.2.3), the post-harvest (soil) nitrate test (PHNT) is a tool to help producers assess their nutrient management performance. The EFP and NMP programs provide guidance on this and other tools to help reach this objective (Fig. 4).



6 RECORD KEEPING AND MONITORING

The first time that a Nutrient Management Plan is done, the quality of the plan may be less than ideal because many of the calculations are based on assumptions that are not necessarily backed up with solid information. However, as the farmer begins a process of keeping thorough organized records on nutrient management practices, the plan can be adjusted each year based on these records. Over time, the quality of the plan will improve substantially.

RECORDS THAT SHOULD BE KEPT

Chapter 5 outlined a process for setting up a binder that contains the Nutrient Management Plan and all related records including manure tests, soil tests, and forage tests.

The record-keeping component of the plan is a systematic way of recording the nutrient management practices that actually occurred.

The most important data to record includes:

- Crop grown
- Date, rate and method of all manure applications
- Date, rate and method of all chemical fertilizer applications including formulations
- Harvest (and planting/seeding) date
- Yield
- Crop quality information (or vigour assessment for berries)

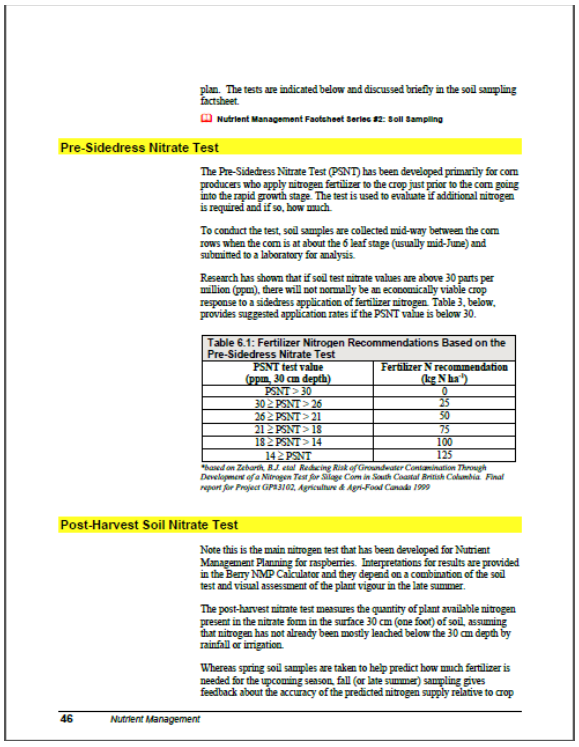
If using the Forage or Vegetable NMP Calculators, the worksheet, "Record Keeper" can be used to generate forms that can help the producer organize records and compare actual activities with the planned activities at the end of the year.

Additional comments that can be helpful include statements about weather conditions (before and after nutrient applications) and the performance and uniformity of manure application equipment.

MONITORING

Once a Nutrient Management Plan is developed, there are a number of tests and suggested practices that can be utilized to ensure that the plan is working well. In some cases, the tests will also indicate a need to change values in the

Chapter 6 RECORD KEEPING AND MONITORING 45



plan. The tests are indicated below and discussed briefly in the soil sampling factsheet.

Nutrient Management Factsheet Series #2: Soil Sampling

Pre-Sidedress Nitrate Test

The Pre-Sidedress Nitrate Test (PSNT) has been developed primarily for corn producers who apply nitrogen fertilizer to the crop just prior to the corn going into the rapid growth stage. The test is used to evaluate if additional nitrogen is required and if so, how much.

To conduct the test, soil samples are collected mid-way between the corn rows when the corn is at about the 6 leaf stage (usually mid-June) and submitted to a laboratory for analysis.

Research has shown that if soil test nitrate values are above 30 parts per million (ppm), there will not normally be an economically viable crop response to a sidedress application of fertilizer nitrogen. Table 3, below, provides suggested application rates if the PSNT value is below 30.

Table 6.1: Fertilizer Nitrogen Recommendations Based on the Pre-Sidedress Nitrate Test

PSNT test value (ppm, 30 cm depth)	Fertilizer N recommendation (kg N ha^{-1})
PSNT > 30	0
30 ≥ PSNT > 26	25
26 ≥ PSNT > 21	50
21 ≥ PSNT > 18	75
18 ≥ PSNT > 14	100
14 ≥ PSNT	125

**based on Zebarth, B.J. and Reducing Risk of Groundwater Contamination Through Development of a Nitrogen Test for Silage Corn in South Coastal British Columbia. Final report for Project GP83102, Agriculture & Agri-Food Canada 1999*

Post-Harvest Soil Nitrate Test

Note this is the main nitrogen test that has been developed for Nutrient Management Planning for raspberries. Interpretations for results are provided in the Berry NMP Calculator and they depend on a combination of the soil test and visual assessment of the plant vigour in the late summer.

The post-harvest nitrate test measures the quantity of plant available nitrogen present in the nitrate form in the surface 30 cm (one foot) of soil, assuming that nitrogen has not already been mostly leached below the 30 cm depth by rainfall or irrigation.

Whereas spring soil samples are taken to help predict how much fertilizer is needed for the upcoming season, fall (or late summer) sampling gives feedback about the accuracy of the predicted nitrogen supply relative to crop

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Figure 4. Information about record-keeping and monitoring to minimize excess soil nitrate remaining after crop harvest (AGRI 2010b).

4.2.1 BENEFICIAL MANAGEMENT PRACTICES IN THE 'EFP AND NMP PROGRAM'

Reviewing a farm's practices can be conducted by the producer using the many resources available on-line, provided by the Ministry of Agriculture or a producer can obtain the services of a trained Planning Advisor (consultant) through the BC Agricultural Research and Development Corporation (ARDCorp) to evaluate the operation's practices and recommend actions to address environmental risks.

EFP Planning Advisors use a Planning Workbook along with the BC EFP Reference Guide to lead producers to identify environmental risks and evaluate their farm operations. A portion of the materials are featured in this report (Table 5). The first step of the assessment is for a producer to describe their farm (i.e. size; description of what is produced; land features; important separation distances, crop or animals raised etc.). The second step is to review the farm practices or procedures which is a series of questions where the response could be "yes" his potential issue has been addressed, "no" this issue has not been addressed within procedures, "?" don't know or "n/a" this practice does not apply to the particular operation. The questions are then evaluated from already addressed to must correct or referral to an EFP Management publication. The workbook also provides a useful worksheet to determine if storage facilities are adequate in size or if the nitrogen in manure generated on the farm requires a Nutrient Management Plan. The final step is the development of an Action Plan where the risks are identified and action dates are noted.

The EFP and associated NMP subprogram provides reference material and a process to reinforce producers' knowledge of the effects of agronomic practices on environmental risk. Some practices can be complemented by financial investments in innovative technologies. Many other practices can help meet nutrient management objectives such as 'zero nitrogen balance' simply through conventional or 'low-tech' farming practices, with minimal or beneficial impacts on crop yield and quality – an important consideration for economic sustainability. Conventional practices include the following:

- Reducing plant-available nitrogen rates (from all nutrient sources) to agronomic nitrogen rates
- Redistributing manure to fields on the farm by crop need, instead of by distance from the manure storage facilities
- Splitting nitrogen sources into multiple land applications to match timing of crop uptake, and potentially adjusting rates based on a (pre-sidedress nitrate) soil test (only for corn)
- Exporting manure to meet the agronomic nitrogen rate (zero nitrogen balance) objective
    - Not feasible if there are no recipients of manure within reasonable distance
- Establishing a cover crop to 'catch' nitrate remaining in the soil in the fall
    - Not feasible everywhere if the growing season is too short
- Incorporating legumes into the crop rotation to facilitate reductions in nitrogen applications, provide a form of slow-release nitrogen after plough down
    - Not feasible if climatic conditions do not allow the legume to be grown economically
- Calibrating manure spreading equipment for application rate and uniformity of application
- Knowing soil test levels to account for nitrogen credits in the soil
- elsewhere
- Etc.

Note that the above practices are not restricted to reducing nitrogen application rates. The 4 Rs of nutrient management[4] are all important: in addition to the *right rate*, nitrogen applications need to consider the *right source, right time* and *right place*. The EFP and NMP provide guidance to cover the 4 Rs holistically, which is required to meet the objective of 'zero nitrogen balance'.

4.2.2 Effect of Manure Handling System on Nitrate Leaching Risk

The manure handling system describes how manure and other materials on a farm (urine, bedding, waste feed, etc.) are moved into storages, for export or use on other parts of the farm including land-application on fields. Flush systems and scrape systems are examples of manure handling systems. Although flush systems increase the overall liquid manure volume compared to that of a scrape system, the choice of a scrape system or a flush system has no significant effect on the nitrogen balance for a cropped area receiving manure. Thus, the amount of water that enters the soil from a manure application is the factor that directly influences the nitrate leaching risk.

[4] http://www.ipni.net/4R;
https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/landuse/crops/npm/

Application of liquid manure would only leach nitrate in the soil to a depth below the crop root zone if the manure has so much water that the soil's water holding capacity is exceeded, causing water to move below the root zone. In the context of the Hullcar situation, it was unlikely there was enough water in any manure application in 2017 to exceed the soil's water holding capacity, based on the evidence applicable to the 'Jansen' dairy farm, which uses a flush system for manure handling (AGRI 2017e). Thus, **there is no scientific basis to suggest that using a scrape system instead of a flush system for manure handing will reduce the risk of nitrate leaching** from manure applications in the Hullcar situation.

Indeed, no evidence was found from other jurisdictions that scrape systems are a recommended management tool to improve nutrient management over flush systems. Additionally, no jurisdictions have been identified to restrict or ban in-barn manure handling systems, such as flush systems, to address agricultural nitrate leaching risks (AGRI 2017e).

4.2.3 Best Practices Evolve

Beneficial management practices (BMPs) change as new information is learned and innovative practices are trialed. For example, the principle of right time and right place for manure application (Case Study: Application Risk Management Pilot Project).

AGRI provided information to the AWCR Review about how best practices change over time, and **non-regulatory guidance about BMPs was distinguished from policy** during the AWCR Review:

> **"Non-regulatory guidance** would include … the Manure Spreading Advisories and an application risk assessment (e.g., such as the Application Risk Management (ARM) tool pilot project)" (ENV 2016, p. 16)"

Case Study: **Application Risk Management System**

- In Washington State, rigid calendar dates that restrict manure spreading have led to spreading occurrences at times of high environmental risk (e.g., right before a high rainfall event on April 2)
- In a 5-year research study, a standardized assessment of real-time soil, crop, and weather conditions informed spreading decisions that reduced the potential for leaching in Whatcom County, WA State, relative to rigid calendar dates
- Even some manure applications in January were economically and environmentally beneficial under certain conditions
- The assessment system provided flexibility and accountability to farmers for maximizing crop production and protecting water quality
- A pilot project was started for coastal B.C. (currently on hold); a similar tool for the Interior of B.C. would require significant modifications
- Reference: Embertson 2016.

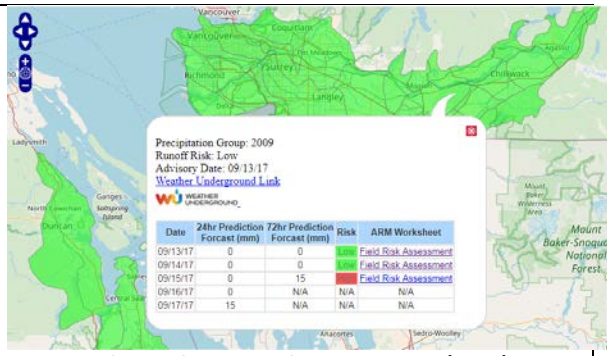

Figure 5. The Application Risk Management (ARM) System pulls in real-time precipitation forecasts to assess manure application risk. A screenshot from B.C.'s ARM pilot project for coastal B.C. is shown here.

Table 5. An excerpt from B.C.'s Environmental Farm Plan Workbook related to land applications of nutrient sources. Other relevant sections of the 'Workbook' include Manure Handling and Storage and Soil Management.

Nutrient Application (Manure, Fertilizer & Compost) Does not apply to this EFP		Yes	No	?	N/A
198	*Environmental Management Act, Code under the Agricultural Waste Control Regulation, Section 12* ***Are manure application rates and timing selected so as to match but not exceed crop nutrient requirements?***				
199	*Environmental Management Act, Code under the Agricultural Waste Control Regulation, Section 11* ***Is application done in a manner that prevents manure or fertilizer from being directly discharged into a watercourse or ground water?***				
200	federal *Fisheries Act, Section 36(3)* (nutrients could be a "*deleterious substance*") ***Is the direct or indirect deposit of deleterious substances into a watercourse avoided?***				
201	*Environmental Management Act, Code under the Agricultural Waste Control Regulation, Sections 13 and 14* ***Is application done in a manner, and timed (NOT on frozen land, in diverting wind, on areas having standing water, or on saturated soil) so as to prevent runoff or the escape of agricultural wastes from causing pollution, of a watercourse or ground water, and preventing it from going beyond the farm boundary?***				
202	*Environmental Management Act, Code under the Agricultural Waste Control Regulation, Section 14* ***When applying liquid manure to tile-drained fields, are application practices adjusted so that manure will not directly flow into tile drains?*** (use of practices such as pre-tillage within 7 days and/or injection and/or an application rate appropriate to soil conditions)				
203	When using manures or other soil amendments, have nutrient levels, (including C:N ratios) been tested to ensure that amendment is being applied appropriately (tested within the last 2 years)?				
204	Are nutrients applied only to cropland, avoiding sensitive areas (such as wildlife habitat)?				
205	Is manure application and timing selected so that emissions are reduced? (such as using injection methods and selecting time of day or day of week least offensive)				

206	Is the nutrient application equipment selected and operated in a manner to apply nutrients uniformly and in a controlled manner?				
207	Has the nutrient application equipment been calibrated within the past year for rate and uniformity?				
208	Is the nutrient application equipment operated to minimize soil compaction or erosion?				
209	Are soil fertility levels known for each field? (tested within the past 2 years)				
210	Are crop yields and quality known for each harvest?				
211	Are there records for application rates, times, and methods of various nutrient sources?				
212	When liquid manure is being delivered to a field through pipes that pass within 10 m [30 ft] of any ditch or watercourse, is there secondary containment for the pipes?				
213	Complete a Nutrient Management Plan if answering "No" or "?" to any of the sub-questions below:				
	• As a livestock producer or an intensively managed outdoor horticulture crop producer, using nutrients over moderately to highly vulnerable aquifers (refer to Table 6.6) used for drinking water, has a Nutrient Management Plan been completed and is it being followed? (e.g., berry, nursery, tree fruits, vegetable crops over aquifers such as in Abbotsford-Sumas, Hopington, Grand Forks, Vedder Fan Aquifer)				
	• Based on the Calculations in Worksheets 4 or 5, (pages 66 and 67) are annual manure nitrogen application rates less than the baseline application values (for the whole farm) that would trigger a Nutrient Management Plan?				
	• For farms located in phosphorus sensitive areas, is the soil phosphorus level less than 80 µg/g? (e.g., areas where surface water eventually flows to a lake or pond)				
	Background for these questions and steps to develop a Nutrient Management Plan are outlined in the **Reference Guide**, Chapter 6, Nutrient Management Planning. Specific nutrient management information is described in detail in the **Nutrient Management Reference Guide** publication.				

4.2.4 TECHNOLOGIES TO IMPROVE NITROGEN MANAGEMENT

If there is an excess of manure nutrients that prevents a farmer from meeting the 'zero nitrogen balance' objective, one option to meet the objective is to export manure off the farm. **It should not be assumed that a farm has excess manure N without calculating the farm fields' nitrogen balances.** It should also not be assumed that manure export is not the most cost-effective option overall for the individual farm.

Highlights of an analysis on treatment technologies (AGRI 2017d, Summary of Nutrient Management Technology Options in the Context of Hullcar) include the following:

- Anaerobic digestion (AD), composting and manure injection technologies are not considered nutrient recovery technologies (NRTs). They do assist in manure upgrading and improved nutrient management if implemented with a proper Nutrient Management Plan (NMP).
- In order to increase biogas productivity AD operations in B.C. import additional nitrogen sources for optimal operation. On its own, AD is often a net-importer of nitrogen based feedstock onto a farm operation.
- The AD process converts the nitrogen to a form that is able to be more readily converted to nitrate in soil.
- AD or composting can produce a feedstock which is better suited for nutrient recovery by an NRT
- NRTs vary considerably in their process, cost, application and nutrient recovery capabilities.
- NRTs can concentrate nutrients into a soil amendment product or fertilizer, and can also make transport more economically viable compared to the untreated manures, particularly if the untreated manure is a liquid.
- The majority of NRTs are designed for liquid manure (dairy manure) or AD digestate and not solid manure (beef manure and poultry litter).
- Most NRTs are focused on P recovery and are not specifically designed to remove nitrogen.
- Biological NRTs, centrifuges, flocculation and ultrafiltration technologies appear to be the most technically feasible, cost –effective and best suited for B.C. farm practices. These technologies could be examined further for operation or site specific feasibility.
- Biological NRTs provide the most direct option for nitrogen removal.
- A site-specific analysis would need to be done to determine the viability of NRTs; however, it is likely that many technologies are not financially viable based on current B.C. market and regulatory conditions. Markets for end-products are emerging and value is unknown; ultimately, the nutrient rich end-product would need to be exported to a destination that requires the nutrient to have a positive impact.
- One way to reduce the cost and thereby improve economic feasibility for any of the technologies considered is to use economies of scale and for several farms to take part. Although, only some of the technologies that were investigated are suitable as mobile units
- There are many common and novel practices for nitrate treatment of groundwater after it is removed from the aquifer. Most nitrate treatment systems are geared toward treating groundwater in above-ground water treatment systems.

Groundwater Remediation Technology

The practices and technologies introduced in the previous sections can contribute to nitrate water quality goals by helping the producer meet the objective of 'zero nitrogen balance' or agronomic N rate. This is an objective that the producer can meet. However, there is little a producer can do to treat or move nitrate once it has leached below the crop root zone, unless the water table rises again.

In preparing this report, there was one example of remediation technology in the literature that was successfully piloted to remove nitrate from drinking water in an aquifer. The technology is "in situ groundwater remediation that can prove effective as an interim solution before the full influence of the BMPs arrive at the wells" (Rudolph 2015,p. 99). This remediation technology or technique is outside the area of expertise of the AGRI authors. However, interim solutions might be needed if the nitrate in the unsaturated zone will end up in the aquifer for years to come.

4.3 COST-SHARE INCENTIVE PROGRAMS

As in other Canadian provinces, there is cost-share funding to incentivize farmers to adopt BMPs that can help them meet their nutrient management objectives.

The Canada-British Columbia EFP program complements and enhances the current stewardship practices of producers. The EFP program applies to all types and sizes of farm operations throughout the province. From 2004 – 2017, B.C.'s Planning Advisors have conducted 4727 Environmental Farm Plan assessments on BC farms and ranches. The EFP program is voluntary, confidential and is of no cost for the producer. The EFP process increases awareness and enhances environmental stewardship by addressing water quality, water quantity, adaption to climate change and mitigation of greenhouse gases. As a participant in this program, producers are able to identify their farm's environmental strengths, prioritize any potential risks to the environment, and take advantage of tools and techniques available to manage those risks.

Producers who develop and have a completed and current EFP are eligible to apply for cost-shared incentives through the BMP Program to implement actions identified in their on-farm environmental action plans. There is a lengthy list BMP categories and practices eligible for cost-shared funding in British Columbia. The BMPs with linkages to Nutrient Management and Water quality are listed in Table 6. Each Category or Practice Code specifies the percentage of the project costs and the maximum amount of funds payable from the program. Each producer is able to access a maximum total amount of $70,000 over the life of the program to address the action items identified in their EFP.

BMPs currently accessible through an Ag-Environmental Group Plan

The BMPs that are currently available to individual producers are eligible to a group of producers or a geographical area that have similar environmental risks to be addressed. Figure 5 outlines the process of making a group or area application for cost-share funding. Where an approved group- or area-based environmental farm plan has been completed, individual BMP applications from group plan participants may be eligible for an incentive premium equivalent to a 10% lift in the individual practice code cost share or a $10K lift in the funding cap, whichever is lesser. To be eligible to receive the group plan

incentive premium, projects undertaken by the group participants must be approved to be eligible, identified as a potential BMP in the Group Plan report, and must demonstrate that the cumulative impact of the project or projects will have a positive outcome. Group Plans and incentive funded projects are evaluated to determine positive outcome, with general guidance being that the impact must cover more than 50% of the area covered by the participants of the group or area based plan.

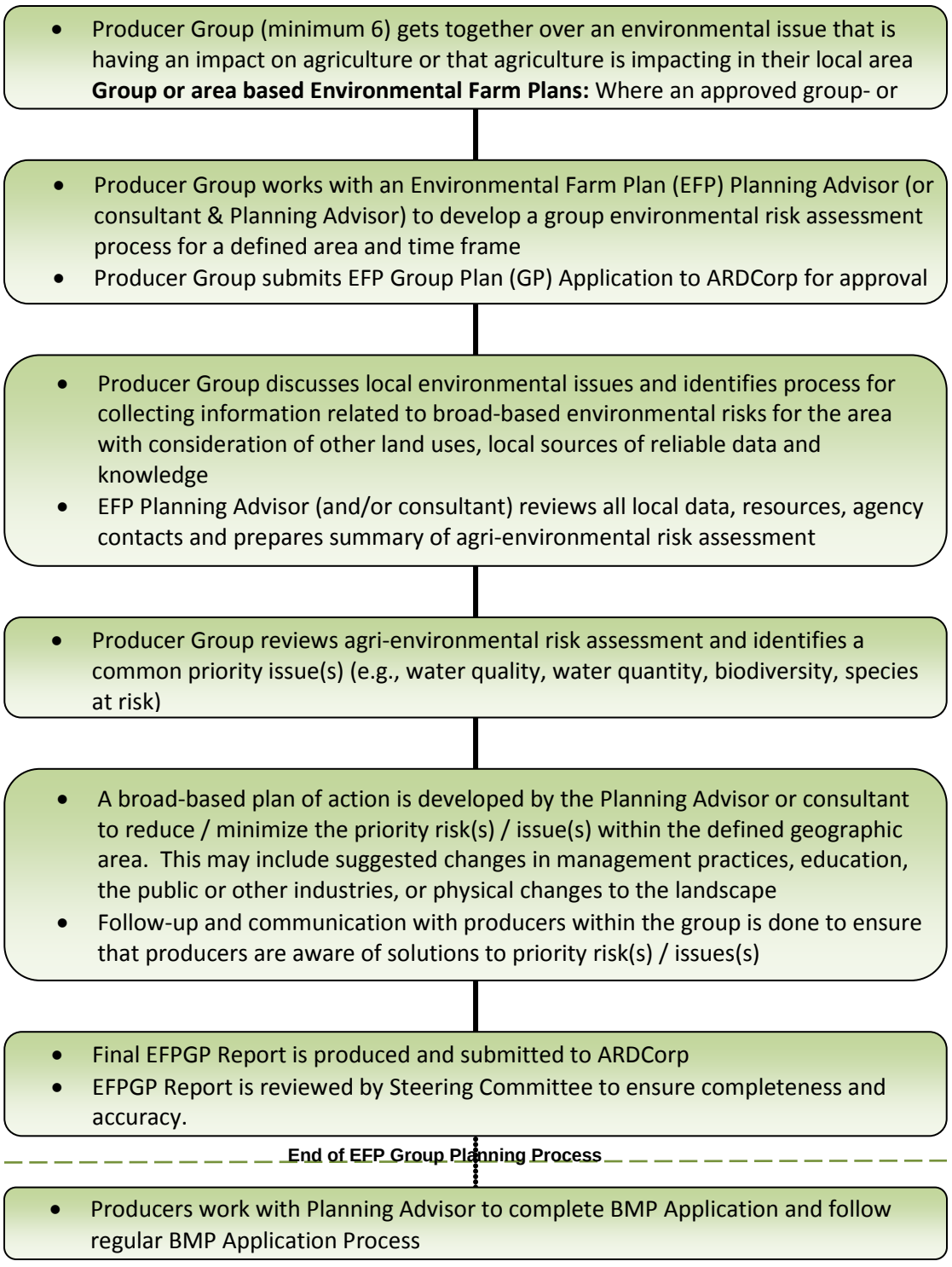

Figure 5. Group/Area Application Process for the BC Beneficial Management Practices (BMP) Program, delivered by the BC Agricultural Research and Development Corporation (ARDCorp).

Table 6. 2017-2018 Beneficial Management Practices (BMPs) with linkages to Nutrient Management. These BMPs are eligible for Growing Forward 2 Cost-Share Funding in B.C.

BMP Category	Target Area and Commodity	Practice Code (Individual Cost Share & Funding Cap)	Eligible BMPs and Costs	Linkages to other plans or actions e.g., need for Nutrient Management Plan
Farmyard Runoff Control / Storm water Management (05)	**Province-wide livestock**	0503 50% $20K	**Engineering or technical design work** • This practice code will stand alone if project does not proceed for economic, technical or environmental reasons	Consideration should be given to design and operation parameters identified in the BC Agricultural Drainage manual and/or the EFP Drainage Management Guide
Relocation of Livestock Confinement (06)	**Province-wide livestock**	0601 50% $30K	**Relocation of livestock facilities** such as corrals, paddocks and wintering sites away from riparian areas. *Existing site must be decommissioned.*	
		0603 50% $15K	**Engineering or technical design work** • This practice code will stand alone if project does not proceed for economic, technical or environmental reasons	
Wintering Site Management (07)	**Province-wide livestock**	0704 50% $15K	**Field access improvements for livestock winter feeding areas** • Examples include: alleyway / access lane upgrades to improve distribution of feed and manure away from riparian areas or high risk ground water areas	
Product and Waste Management (08)	**Province-wide, with some sector limitations**	0802 (A) Incinerators 30% $5K	**Improved on-farm storage, handling, and disposal of agricultural waste** Improved storages or handling for livestock mortalities, culled fruit and vegetables, crop residue and wood waste. The following conditions are for specific waste handling practices: A. **Poultry mortality incinerators:** These are eligible as long as the incinerator uses *best available technology* and meets appropriate air emission standards	
		0802 (B) Mulching Mowers 30% $1.35K	B. **Orchard and vineyard mulching mowers:** Heavy duty mulching mowers for dealing with prunings. Application must describe how the new equipment provides an improved or incremental benefit	

BMP Category	Target Area and Commodity	Practice Code (Individual Cost Share & Funding Cap)	Eligible BMPs and Costs	Linkages to other plans or actions e.g., need for Nutrient Management Plan
		0802 © On-Farm Processing 30% $5K	C. **On-farm processing:** These are considered farm operations where the majority of the material being processed or marketed is produced on the farm or the majority of the output of the processing operation is used on the farm. Waste management from these activities is eligible for funding. Where wastes are not agricultural wastes, the farm must ensure that appropriate authorizations for disposal have been obtained	
		0803 **30%** **$25K**	**Composting of agricultural waste** • **Composting technologies that are appropriate for the composting of on-farm generated agricultural wastes including livestock mortalities, manure, fruit and vegetable culls, crop residues, wood, and straw** • **A technical or engineering design (eligible under practices code 0804) must be completed and included with the application for these projects**	**For Practice Code 0803 Nutrient Management Plan (NMP) required prior to accessing funding**
		0804 30% $5K	**Engineering or technical design work** • This practice code will stand alone if project does not proceed for economic, technical or environmental reasons	
		0805 50% $25K	**Wood residue management** • On-farm or portable chippers or forced air assistance burners. Burners must meet the conditions of the BC Ministry of Environment and meet appropriate air emission standards.	
Water Well Management (09)	**Province-wide**	0901 50% $7.5K	**Well abandonment** • For small diameter wells (less than 12 inches) decommissioning by licensed well driller) • For larger diameter wells (greater than 12 inch diameter) decommissioning by licensed well driller or producer with technical support) **Well Protection (existing wells)** • Earthwork at well head or runoff diversion • Installation of pit-less adaptor • Upgrading or maintenance to well head or well casing, fittings, seals and connections to prevent seepage • Flow control for artesian wells and backflow prevention • Casing extensions to elevate well head	
Irrigation Management Planning (29)	**Province-wide**	2901 Up to $1K per plan Limit of one plan per eligible farm operation	**Consultative services to produce an irrigation management plan with recommendations that include a certified design layout, material list and maintenance requirements** • *Irrigation System Assessment Worksheets* from EFP Planning Workbook must be included as with the Irrigation Management Plan	Linked to Category 18. All projects except 1802 require certified plans

BMP Category	Target Area and Commodity	Practice Code (Individual Cost Share & Funding Cap)	Eligible BMPs and Costs	Linkages to other plans or actions e.g., need for Nutrient Management Plan
			• Site investigation by certified irrigation designer prior to plan and quote preparation • Designer to identify areas where maintenance required • Certified designer must sign and seal each plan for project to be eligible to program • Certified designer must inspect project after completion and send a signed completion form to program before payment for plan preparation and project costs are made • An invoice from Certified Irrigation Designer must be submitted to producer outlining services	
	Province-wide	2902 up to $2K per plan limit of one plan per eligible farm operation	**Water Management Planning** • Consultative services for water management planning to deal with issues arising from excess water (including mapping of existing subsurface drainage systems) and other water related issues resulting from climate change Submit a CV or Resume of expert preparing the plan	Linked to BMP 5 and 3201
Irrigation Management (18)	**Province-wide**	1802 50% $5K	**Weather stations or improved irrigation management** • Weather stations capable of linking to BC Ministry of Agriculture approved web network • Irrigation scheduling equipment such as soil moisture sensors and moisture meters • Controllers, electric valves and low voltage wiring to valves when identified as part of an improved irrigation system management project that installed in combination with soil moisture probes and/or a weather station • Climate Station data transmission unit – using cell, internet or satellite. Annual data transmission costs as required by program, contact BC Ministry of Agriculture for details	Climate station must be connected to the Farmwest web site or similar web network as approved by BC Ministry of Agriculture
	All Interior, Vancouver Island and Gulf Islands Regional Districts **Not offered for Metro Vancouver, Fraser Valley Regional Districts**	1804 60% $15K	**Irrigation Infrastructure Improvement – Forage** • Primary target of this practice code is beef forage producers in the Interior of the province • Producers who produce forage for other livestock or vegetable growers in the Interior will be also eligible • **An existing irrigation system must be in place** • Eligible items include (if identified in plan): o replacement of 28 aluminium and/or steel mainlines nozzles, gaskets, sprinklers, suction screen, and intake pipes	A certified irrigation designer must inspect the site and prepare a report on the required improvements prior to the project being approved Site inspection must be completed and signed off by certified irrigation designer Irrigation Management Plan is required for all applications under this category. Cost

BMP Category	Target Area and Commodity	Practice Code (Individual Cost Share & Funding Cap)	Eligible BMPs and Costs	Linkages to other plans or actions e.g., need for Nutrient Management Plan
				of plan is eligible under category 29 Projects must target at least a 15% increase in water use efficiency
		1805 30% $20K	**Irrigation System Improvement – extensive systems** • This category is solely for the conversion of lower efficiency irrigation systems to high efficiency pivot systems with drop tube rotors • **An existing operational irrigation system must be in place** • **Proof of existing water license and use of irrigation system is previous cropping year must be provided** o Eligible systems to be upgraded are stationary guns, travelling guns, hand-move and wheel-move, flood irrigation Also upgrading overhead sprinklers on a pivot to drop tube rotors	A certified irrigation designer must inspect the site and prepare a report on the required improvements prior to the project being approved Irrigation Management Plan is required for all applications under this category. Cost of plan is eligible under category 29 **Projects must target at least a 15% increase in water use efficiency**
	Eligible areas of the province are the following Regional Districts: Bulkley-Nechako, Fraser-Fort George, Cariboo, Thompson-Nicola, Columbia-Shuswap, North Okanagan, Central Okanagan, Okanagan-Similkameen, Kootenay-Boundary, Central Kootenay, and East Kootenay	1806 50% $10K	**Irrigation System Improvement – Conveyance Ditch** • This category is solely for replacing a ditched irrigation supply to a piped irrigation supply • An existing conveyance ditch authorized by a water licence must be in place Water Management, FLNRO, needs to be informed of change in the diversion	A certified irrigation designer must inspect the site and prepare a report on the required improvements prior to the project being approved Cost of plan is eligible under category 29
Grazing Management Planning (26)	**Province-wide**	2601 up to $1K per plan limit of two plans per eligible farm operation	**Consultative services to develop range and grazing management plans, planning and decision support tools**	

BMP Category	Target Area and Commodity	Practice Code (Individual Cost Share & Funding Cap)	Eligible BMPs and Costs	Linkages to other plans or actions e.g., need for Nutrient Management Plan
Nutrient Management Planning (NMP) (24)	**Province-wide**	2401 Up to $3K for costs associated with first plan Up to $1.5K for costs associated with second plan to be completed within the next three subsequent years Actual costs associated with development of plan must be submitted for review and approval	**Consultative services to develop nutrient management plans, planning and decision support tools** • First Plan: Maximum of $1000 can be used for laboratory analyses (e.g. manure, soil, leaf tissue or compost) as part of the eligible costs of the nutrient management plan (on the condition that raw nutrient data – free of farm identification – will be collected for environmental health indicators reporting purposes) • Second Plan: Producers may be eligible for funding to complete a second nutrient management plan in the subsequent year. Maximum of $500 can be used for laboratory analyses • NMPs should include required elements (appropriate record keeping and reporting standards –see Information sheet at BCEFP.ca) • Plan must be completed by individual approved to complete nutrient management plans by ARDCorp and BC Ministry of Agriculture	
Manure Treatment (02)	**Province-wide Limited to poultry and livestock**	0201 30% $50K	**Treatment systems for solid or liquid manure** • Dewatering for liquid manure • Nutrient and bedding recovery systems for solid and liquid manure • Pathogen and vector attraction reduction treatment systems which would permit solids to meet protocols identified in the BC Good Agricultural Practices Guide (for food safety)	Nutrient Management Plan (NMP) required prior to accessing funding
		0204 50% $10K	**Engineering or technical design work** • This practice code will stand alone if project does not proceed for economic, technical or environmental reasons	
Manure Land Application (03)	**Province-wide**	0301 30% $20K	**Specific equipment components for land application of manure** Examples of eligible projects include specialized modifications to equipment for improved manure application to land • Solid manure spreaders: funding may be provided for the incremental costs of cyclone spreading attachments. Other types of spreaders will be reviewed, on a case by case basis, to determine components that can be funded from the program • Liquid manure spreaders: funding may be provided for modification to existing spreaders or a portion of the components of a new spreader. Low trajectory, sleighfoot, band or injection spreading technology is preferred	Nutrient Management Plan (NMP) required prior to accessing funding
Nutrient Recovery from Waste Water (17)	**Province-wide**	1701 30% $40K	**Recycling of waste water streams** • This could include waste water streams from milk houses, fruit and vegetable washing facilities, and greenhouses in order to recover nutrients	Nutrient Management Plan (NMP) required prior to accessing funding

BMP Category	Target Area and Commodity	Practice Code (Individual Cost Share & Funding Cap)	Eligible BMPs and Costs	Linkages to other plans or actions e.g., need for Nutrient Management Plan
		1702 30% $20K	**Engineering or technical design work** • This practice code will stand alone if project does not proceed for economic, technical or environmental reasons	
		3102 30% $20K	**Engineering design work or technical feasibility studies** This practice code will stand alone if project does not proceed for economic, technical or environmental reasons.	
Nitrous Oxide (N_2O) Emission Reduction Projects must reduce nitrous oxide emissions from agricultural operations by prevention or suppression (32)	**Strathcona, Comox Valley, Cowichan Valley, Alberni-Clayoquot, Capital, Nanaimo, Metro Vancouver and Fraser Valley Regional Districts**	3201 50% $10K	**Improved drainage on forage corn and forage grass fields as proposed by a water management plan** • Additions to existing sub-surface drainage tile systems • Cleaning or repair of existing subsurface drainage systems and associated on-farm surface drainage channels	Nutrient Management Plan (NMP) required prior to accessing funding Water Management Plan (not an irrigation plan) refer to EFP Drainage Management Guide and/or BC Agricultural Drainage Manual for Guidance
	Province-wide	3202 30% $10K	**Precision farming applications that reduce input application and overlap** • GPS guidance systems • On-line field mapping equipment • On-line input application control systems guided by high resolution electronic field maps and GPS	
	Province Wide	3203 30% $20K	**Specific equipment components for land application of fertilizer.** • Examples of eligible projects include specialized modifications to equipment for improved fertilizer application to land • Fertilizer Application Equipment: funding may be provided for the incremental costs of attachments or funding may be provided for modification to existing application equipment or a portion of the components of the new application equipment	Nutrient Management Plan (NMP) required prior to accessing funding

4.4 ANNOTATED BIBLIOGRAPHY: PRACTICES AND TECHNOLOGIES

Reference	Contents
AGRI 2010b. Nutrient Management Reference Guide.	The Nutrient Management Reference Guide is for planners and agricultural producers in British Columbia who would like to do a Nutrient Management Plan for their farm - a user manual or reference guide for those using AGRI's software tools for calculations important to a nutrient management plan under the EFP/BMP program - gives guidance to monitor the effectiveness of nutrient management
BC AGRI 2017a. Review of Nutrient Management Planning in British Columbia.	Overview of voluntary Nutrient Management Plan under the Environmental Farm Plan / Beneficial Management Practices program - information about beneficial management practices related to nutrient (nitrogen) management, irrigation management - includes Sample EFP Workbook questions related to Nutrient Application and Manure Storage and Handling
AGRI 2017c. Jurisdictional Scan of Agricultural Cost Share and Support Programs	Jurisdictional Scan - across Canada, the principle support mechanism for improving nutrient management practices is cost share funding - each province has its own variation of the programs (Environmental Farm Plan/ Beneficial Management Practices funding).
AGRI 2017d. Summary of Nutrient Management Technology Options in the Context of Hullcar	A review of treatment technologies for animal manure - In order to increase biogas productivity AD operations in B.C. import additional nitrogen sources for optimal operation. On its own, AD is often a net-importer of nitrogen based feedstock onto a farm operation. - Nutrient recovery technologies (NRTs) can concentrate nutrients into a soil amendment product, and can also make transport more economically viable. - The majority of Nutrient Recover Technologies are designed for liquid manure (dairy manure) or AD digestate and not solid manure (beef manure and poultry litter). - Biological NRTs, centrifuges, flocculation and ultrafiltration technologies appear to be the most technically feasible, cost –effective and best suited for B.C. farm practices. These technologies could be examined further for operation or site specific feasibility. - There are many common and novel practices for nitrate treatment of groundwater after it is removed from the aquifer. Most nitrate treatment systems are geared toward treating groundwater in above-ground water treatment systems.
BC AGRI 2017e. Summary of Manure Handling Systems in the Context of Hullcar	A review of manure handling systems, their effects on the characteristics of manure including manure volume and water content, and the link between water applied in manure and nitrate leaching risk. - the choice of a scrape system or a flush system has no significant effect on the nitrogen balance for a cropped area receiving manure.
Embertson, N. 2016. PROJECT REPORT: Protecting Puget Sound Watersheds from Agricultural Pollution Using a Progressive Manure Application Risk	A project report for the United States Environmental Protection Agency - this study developed an innovative Application Risk Management (ARM) System targeting the transport of manure pathogens and

Management (ARM) System. March 2016. (available upon request)	nutrients (N, P) via runoff and leaching - the study was conducted on dairy forage fields from 2010-15 in Whatcom County, WA - soil and water monitoring, including lysimeters, validated a web-based, easy to use worksheet that farmers use to evaluate manure application risk on a specific field and day using real-time forecast, soil and field parameters. - the ARM system provided flexibility and accountability to farmers for maximizing crop production and protecting water quality - the ARM system is still used at the time of writing in Washington State and Oregon (areas west of the Cascade mountains)
Kowalenko et al. 2011. Draft manuscript sent in an email to Cindy Meays, ENV on May 6, 2016 (available upon request)	A manuscript prepared for a peer-reviewed scientific journal - The manuscript was provided to ENV for consideration of how soil nitrate testing needs to be customized and interpreted as a beneficial management practice and monitoring tool - For soil testing to assess the effectiveness of nitrogen management in the B.C. Okanagan Valley, soil sampling time and depth need to be adjusted from the guidelines used in coastal B.C.