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Behavioural Insights for Practice Change in Sugarcane:

A framework to inform practice change strategies in the Mackay Whitsunday and Lower Burdekin sugarcane regions

December 2022

Acknowledgement of Country

The Social Deck acknowledges the traditional custodians who have lived on and cared for Country for thousands of generations, and recognises their continuing connection to land, waters and community. We pay our respects to them and their cultures, and to Elders past and present.

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Executive Summary

This report describes the process to gain insights and develop a systems framework that will guide the design and implementation of water quality improvement practice change strategies for cane growers in the Mackay Whitsunday and Lower Burdekin regions in Queensland, Australia.

These strategies will be delivered as part of the Water Quality Component of the Reef Trust Partnership (RTP). Programs under the RTP aim to directly reduce nitrogen, sediment and pesticide loads from priority reef catchments.

In this report, we describe the key influences that impact the adoption of water quality improvement practices among sugar cane growers in the Mackay Whitsunday and Lower Burdekin regions. We also examined the factors that influence grower participation in practice change projects funded by the RTP program in these regions.

Developing a strategy to change farming practices in the sugar cane industry poses unique challenges compared to other behaviour change interventions, which often look to select and target one specific behaviour. The specific practices that can lead to water quality improvements are influenced by a wide range of factors within the broader system within which the cane industry sits. No single behaviour change theory adequately explains why a grower does or does not adopt the broad range of different practices, suggesting a top-down single theory-driven approach to behaviour change is likely to miss at least some of the key influences on behaviour. To address the complexity, we focused on three key areas of practice (nutrients, pesticides, irrigation), rather than the numerous specific behaviours associated with each area and utilised a variety of models to adequately map influences within the system.

Influences on behaviours associated these practice areas were identified from past research and interviews with growers, delivery providers, and other stakeholders. These influences were then categorised using the Theoretical Domains Framework and the complementary COM-B behavioural model.

A practice change framework has been developed that further categorises and maps the relevant insights and influences from a **systems perspective**, accounting for the contextual factors (moderators) and key mechanisms of action (intermediate outcomes) that lead to the overall practice change outcomes we are aiming for. We used a socio-ecological systems model to complete the framework, which allows us to organise the behavioural influences considering social and contextual factors and the interrelationships between different levels of the model that influence behaviour. Using the model, we can better understand which interventions are likely to be effective at different levels of system.

We found that a lack of awareness, knowledge, and understanding about the water quality projects and practices, as well as a perception that cane growers have been unfairly criticised for water quality issues and not recognised for implementing improvement practices, are key factors that influence grower participation in these projects. To encourage behaviour change, we recommend using strategies such as providing more accessible information, positive storytelling, and relevant case studies to demonstrate the benefits of water quality improvement practices.

Background

The Social Deck was engaged by the Great Barrier Reef Foundation (GBRF) to develop strategies and actions to encourage more practice change among cane growers in:

- the Mackay Whitsunday region (MW)
- the Lower Burdekin region (LB)

to reduce nitrogen, sediment and pesticide loads from reef catchments in these areas.

Actions within the strategies will be further developed by working with RTP-funded delivery providers, extension officers, cane growers and other stakeholders in the regions, to address barriers and enablers associated with adopting specific farming practices that benefit water quality.

The Social Deck will implement the strategies in partnership with stakeholders within the regions until June 2024. During this time, we will ensure local stakeholders develop the capacity to continue with effective and long term actions within the strategies.

The current report describes activities undertaken and the insights that were gained to inform the development of these strategies. It does not describe the strategies themselves, as they are outside the scope of this document, and will be detailed in further reports to GBRF as part of the contract agreement.

RTP-funded projects for practice change

The strategies will build upon the work already being undertaken by RTP-funded delivery providers in the regions. The practices in these projects have been built around a substantial body of research on best management practices in cane farming to improve water quality. The 11 projects are listed in Tables 1 and 2 below.

The broad range of specific practices (or behaviours) fall under three core practice areas that are particularly relevant to both regions. These are:

- reduction and management of Dissolved Inorganic Nitrogen (DIN)
- reduction of 'problem' pesticides and herbicides (including application practices to prevent run-off)
- irrigation management.

Key practice changes processes that are used by some of these projects include:

- 6 easy steps (developed by Sugar Research Australia (SRA) and promoted as an "Industry best-practice guideline").
- Precision agricultural techniques
- Smart Cane BMP (an accreditation BMP process promoted by CANEGROWERS)
- 9-step pathway for irrigation management (used by SRA in their Burdekin project)
- Minimum practice standards and record-keeping to comply with government regulations.

The practice change strategies will seek to drive participation and positive engagement in water quality improvement practice change projects and programs being delivered through the RTP and other stakeholders. A key assumption of this program is that increased engagement of cane growers with

projects and local stakeholders that are providing support for positive practice change will help more growers to take up new water quality improvement practices and sustain them over the long-term.

Table 1. RTP water quality projects in the Mackay Whitsunday region.

Delivery provider	Project name	Target practices
Mackay CANGROWERS	Mackay Irrigation Project	Irrigation
Catchment Solutions	Project Catalyst	Dissolved Inorganic Nitrogen & pesticides
Farmacist	A point of difference - Precision agriculture	Dissolved Inorganic Nitrogen
Farmacist	Project Bluewater 2	Pesticides
LiquaForce	LAND (Local Area Nutrient Datahub)	Dissolved Inorganic Nitrogen
Mackay Area Productivity Services (MAPS)	Nutrient Management Plans	Dissolved Inorganic Nitrogen
Reef Catchments	Major Grants Program	Dissolved Inorganic Nitrogen & pesticides
Sugar Research Australia (SRA)	Cane to Creek	Dissolved Inorganic Nitrogen & pesticides

Table 2. RTP water quality projects in the Lower Burdekin region.

Delivery provider	Project name	Target practices
Farmacist	Precision to Decision	Dissolved Inorganic Nitrogen (DIN)
Farmacist	Project Bluewater 2	Pesticides
Sugar Research Australia (SRA) (leading the consortium)	Burdekin Irrigation Project (BIP)	Irrigation

Methods to gain insights and develop the framework

Methods and activities to gain behavioural insights and develop the systems framework are detailed in Figure 1, in text boxes with solid lines in the process diagram. This work is located within the overall process to develop the practice change strategies. Steps in the process to develop the strategies that go further than the framework described in this report are defined within the boxes with dashed outlines.

Process to develop the strategies

Explore and engage
… to gain key behavioural insights

Analyse and define
… to further define insights in regions and different levels of influence

Develop, test and refine
… to ensure that behaviour change techniques work with the target audience

- Review of existing data, findings & WQ projects
- Interviews with RTP WQ program managers and delivery providers
- Interviews and discussions with extension officers and growers
- Survey of growers and other stakeholders to test concepts

- Identify key modifiable influences on practice change behaviours
- Select and prioritise landholder types to be targeted for each region
- Develop journey maps (using stages of change model) for each key type in each region

- Develop Practice Change Framework (categorising influences on behaviour)
- Select and prioritise key moderating influences for each region/ landholder type
- Selection of appropriate Behaviour Change Techniques (tactics and actions)
- Practice change strategy for Mackay (-Whitsundays) region
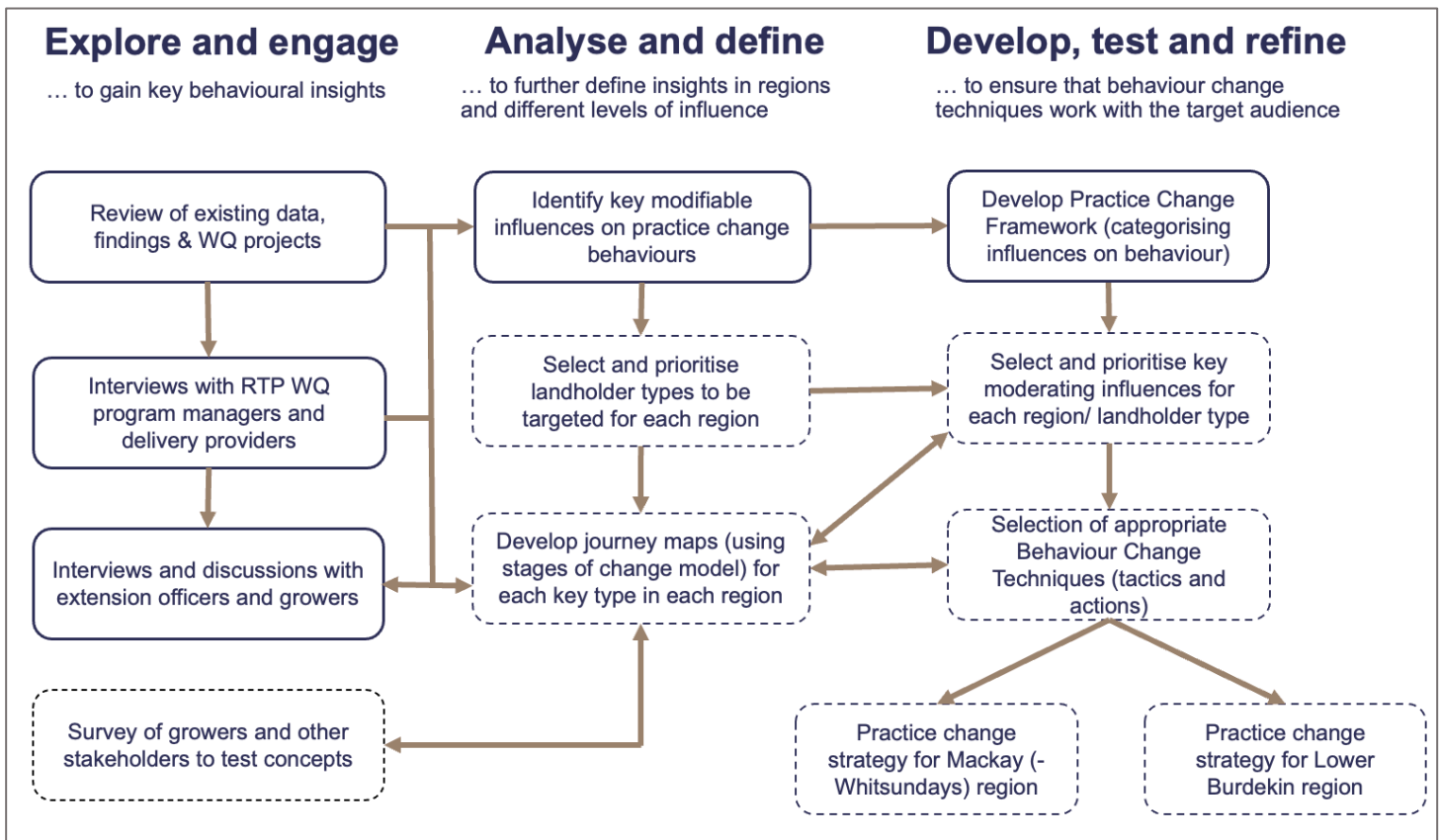- Practice change strategy for Lower Burdekin region

Figure 1: Process to develop the practice change strategies for the MW and LB regions. Note that steps defined by dashed outlines are not covered in detail by this report.

A more detailed explanation of key activities relevant to this report is provided below. These activities were undertaken to gain insights and develop the systems framework that will guide the design and implementation of water quality improvement practice change strategies.

Review of documents

We reviewed a variety of documents (e.g., proposals, monitoring and evaluation plans) for existing RTP-funded water quality projects in the Mackay Whitsunday and Lower Burdekin regions, to understand what practices are being targeted in each project, and how delivery providers are engaging with and recruiting growers (see Appendix 1 for full list of documents).

Desktop review of behaviour change (human dimensions) projects and research

In addition to the review of research and reports available, The Social Deck reviewed a number of recent past behavioural change interventions in the cane industry to further understand behavioural drivers and behaviour change techniques and assess (as much as possible in a desktop review) their efficacy in achieving practice change. This included:

- the Burdekin and Wet Tropics Major Integrated Projects
- Project Cane Changer
- Project Bluewater
- NESP Project 25
- evaluation reports that the Office of Great Barrier Reef (OGBR) have commissioned across projects.

Alongside this review we also looked at knowledge and information from relevant research relating to the behaviours of cane farmers, including:

- relevant information from the OGBR human dimensions research projects
- past landholder typology research and research investigating the influences on cane grower farming practices
- measurement tools and methods that have been developed to track behavioural/ social outcomes of projects.

Key influences (i.e., barriers and enablers) on cane farming practices that were identified in these reports and research papers were recorded and then manually organised into themes (using the framework described in detail in the following section – see Figure 2 and Table 3). The themes identified from the desktop review were used to inform the development of the discussion guide used in interviews and the behavioural analysis. Given the time limitations for this work, a full literature review was not included in the scope of the project.

Stakeholder identification

Delivery of the strategies will rely heavily on effective engagement with stakeholders in each region. Initial identification of stakeholders was completed for the purposes of selecting appropriate interviewees, and to further understand the landscape of 'who' and 'what' is involved in delivering or supporting water quality improvement practices in the Mackay Whitsunday and Lower Burdekin regions.

To identify and prioritise key stakeholders and intermediaries across each region, we used:

- our initial review of data and information provided by GBRF, including project communication and engagement plans, and other reports
- meetings with GBRF program managers, OGBR staff and CANEGROWERS
- interviews with delivery providers and other local stakeholders.

Stakeholder groups and individuals were also mapped against the different levels of the socio-ecological model (see Figure 4).

Qualitative interviews and engagement

We undertook 17 structured interviews and a number of additional unstructured discussions with local experts, stakeholders, and growers to gain insights about barriers and enablers associated with engaging with the RTP water quality projects and practices that can improve water quality in local catchment areas.

Discussion guides used in the structured interviews were tailored to the role of the interviewee and were adapted where required to incorporate new insights as they emerged throughout the project. Interviews were conducted via online video and were recorded with permission from interviewees. A full transcript of each interview was generated, and a note-taker was also present at each interview to take detailed notes of the discussion.

Unstructured discussions were undertaken over a two-day period at the Mackay AG Trade Expo to engage with more-difficult-to-reach growers and stakeholders.

These engagements included[1]:

- 3 x interviews with cane growers
- 2 x interviews with RTP Water Quality program managers in both regions
- 11 x interviews with Water Quality project delivery providers in both regions and other industry experts (e.g., SRA, CANEGROWERS, Farmacist, Liquaforce, and Catchment Solutions)
- 6 x interviews with other stakeholders, including government stakeholders and institutions and local productivity boards
- 10 x conversations with growers, delivery providers, extension officers and mills at Mackey AG Trade Expo (August 2022).

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[1] Some interviewees had more than one role (e.g., delivery provider and grower).

Influences on practice change

Influences on behaviours associated with the three core practice areas (nutrients, pesticides, irrigation) were identified from past research and interviews with growers, delivery providers, and other stakeholders. Past research has indicated that the many specific practices that can lead to water quality improvements are influenced by a wide range of factors within the broader system within which the cane industry sits. No single behaviour change theory adequately explains why a grower does or does not adopt the broad range of different practices, suggesting a top-down single theory-driven approach to behaviour change is likely to miss at least some of the key influences on behaviour.

To capture the nuance and wide range of influences on farming practices among different growers, we compiled a detailed inventory of influences from the interviews conducted in the current project and from analysis of past research. This long list of influences was then manually organised into broader themes using the Theoretical Domains Framework (TDF) (Cane et al. 2012). The TDF is a list of constructs (grouped into 14 domains – see Figures 2 and 3) that influence behaviour, which have been identified from 33 theories judged (by 18 psychological theorists in collaboration with 16 health service researchers and 30 health psychologists) to be the most relevant to behaviour change (Michie et al. 2005). This integrative framework of theories of behaviour change overcomes the limitations of using a single behaviour change theory by including a wide range of possible influences on behaviours.

The 14 domains can be further simplified by grouping them into the three broad influences on behaviour – Capability, Opportunity, and Motivation - as described in the COM-B model of behaviour (Michie et al. 2011). **Capability** refers to physical and psychological factors such as skills, strength, and knowledge. **Opportunity** refers to environmental and social factors such as time, resources, social and cultural norms, and interpersonal influences. **Motivation** refers to reflective and automatic processes such as beliefs, attitudes, wants and needs, and impulses.
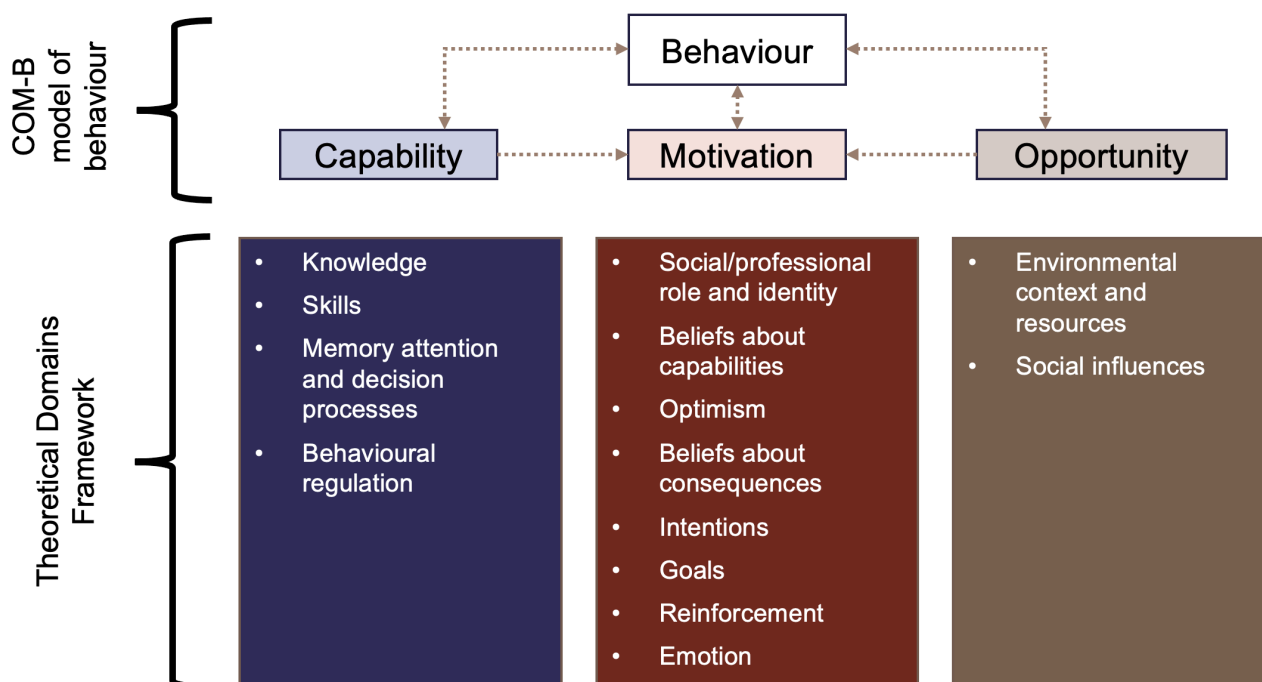

Figure 2. Influences on behaviour from the COM-B model of behaviour and the Theoretical Domains Framework.

Table 3. Domain definitions from the Theoretical Domains Framework (Cane et al. 2012)

14 DOMAINS THAT INFLUENCE BEHAVIOUR (THEORETICAL DOMAINS FRAMEWORK)	
KNOWLEDGE	An awareness of something
SKILLS	An ability or proficiency acquired through practice
SOCIAL/PROFESSIONAL ROLE AND IDENTITY	A coherent set of behaviours and displayed personal qualities of an individual in a social or work setting
BELIEFS ABOUT CAPABILITIES	Acceptance of the truth, reality, or validity about an ability, talent, or facility that a person can put to constructive use
BELIEFS ABOUT CONSEQUENCES	Acceptance of the truth, reality, or validity about outcomes of a behaviour in a given situation
REINFORCEMENT	Increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus
INTENTIONS	A conscious decision to perform a behaviour or a resolve to act in a certain way
ENVIRONMENTAL CONTEXT AND RESOURCES	Any circumstance of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence, and adaptive behaviour
SOCIAL INFLUENCES	Those interpersonal processes that can cause individuals to change their thoughts, feelings, or behaviours
EMOTION	A complex reaction pattern, involving experiential, behavioural, and physiological elements, by which the individual attempts to deal with a personally significant matter or event
BEHAVIOURAL REGULATION	Anything aimed at managing or changing objectively observed or measured actions
OPTIMISM	The confidence that things will happen for the best or that desired goals will be attained
GOALS	Mental representations of outcomes or end states that an individual wants to achieve
MEMORY, ATTENTION AND DECISION PROCESSES	Ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives

The influences that were identified in this work are presented below, grouped into themes defined in the Theoretical Domains Framework and further categorised into the COM-B model of Capability, Opportunity and Motivation influences that affect behavioural outcomes.

Key <u>capability</u> influences

Knowledge

The key capability influences related to a need for more **knowledge and understanding** were about:

- which RTP water quality projects are **available** to growers in their region
- the **small grants and other incentives** that are associated with projects
- how poor practices can and are **impacting water quality** in local catchment areas
- knowledge relating to **specific best practices**, including irrigation practices, pesticide options and application techniques, and the impact of reducing nitrogen application rates on yield in different types of cane crops (e.g., older ratoons)
- how best to **keep records**, including what specific data needs to be recorded.

Skills

The key capability influences related to need for **skills** were:

- **technical and digital** skills required for some practices (e.g., precision agriculture, record keeping)
- **literacy** skills that may be required to read and understand complex practice change documents and research papers.

Key <u>motivation</u> influences

Beliefs about consequences

The key motivation influences related to beliefs about **consequences** were that:

- grower practices are heavily influenced by their own beliefs, in particular about **consequences of changing practices** on productivity/profit and whether farming practices have any impact on water quality in surrounding catchments and the reef, i.e. growers need to view new practices as beneficial or advantageous in some way, relative to their current practices.
- **time and effort** are significant factors for some growers, especially smaller and older growers, e.g., it is a motivator if a practice change saves time and a barrier if a practice change adds time
- growers need to believe that their practice change efforts **will be recognised** by government and the broader community.

Reinforcement

The key motivation influences related to **reinforcement** indicated that:

- rules and **regulations are effective for encouraging practice change**; however, this needs to be backed by appropriate **compliance monitoring** and support for growers to implement changes

- **providing something to growers for free** early on in **extension support** to help them implement practice changes (e.g., spray equipment assessment and correct nozzles) may build a sense of trust and reciprocity (e.g., towards delivery providers)
- **financial incentives** associated with WQ programs, such as having small grants available for equipment upgrades can be an important motivator/enabler; however, growers need to be aware of this funding associated with the projects
- **having accreditation within programs** that provide exemption from compliance audits can support maintaining practice change if growers are truly exempt from audits.

Emotions

The key motivation influences related to **emotions** indicated that:

- a significant number of growers have negative emotions associated with regulation and compliance
- some growers also have a **strong lack of trust in government** and government run/funded projects, which can undermine practice change
- some growers feel that they have been the 'scapegoats' for reef impacts **and are not recognised** when they make efforts to implement environmentally sustainable practices.

Social/professional role and identity

The key motivation influences related to growers' social/professional role and identity indicated that:

- some growers have a **strong sense of identity** as a cane grower and **do not want to get left behind in a changing industry**, including some older growers who are planning to leave their farm to children
- there is a **strong desire to be recognised by the wider community** for practice change efforts, including practices not necessarily aligned with existing RTP water quality projects
- some growers who are involved with certain water quality projects can be viewed by other growers as **'selling out'** or 'sucking up' to **government**
- demonstrating and being identified for responsible land stewardship is a motivating factor for some growers.

Beliefs about capabilities

The key motivation influences related to growers' beliefs about their capabilities indicated that:

- some growers do **not believe they have the capability to implement high-end precision agriculture practices**, indicating that practice change can be a slower, evolving process to build confidence
- once growers begin to make practice changes, they tend to want to continue on the practice change journey
- higher self-efficacy and being able to control/regulate one's own farming practices tends to be associated with **innovative practices.**

Key opportunity influences

Social influences

The key opportunity influences related to **social influences** indicated that:

- some growers are heavily influenced by **perceived injunctive norms** (what their peers think of their farming practices) and **perceived descriptive norms** (what practices other growers are implementing).
- growers are more likely to implement water quality improvement practices if they are **perceived to be common** in their region and expected among peers and industry experts, e.g., shed meetings and farm tours are key settings where growers' perceived practice norms are influenced
- **a grower's partner or other family** can influence farming practices, particularly if they are involved in the day-to-day running of the farm and/or responsible for farm accounts.
- **relationships with commercial contractors and resellers** may impact practice change, especially if resellers try to provide growers with inappropriate products that may contradict extension advice (this is typically due to resellers not having the recommended product available).
- **pressure from mills** to produce high volumes of cane for mills to remain viable may undermine practice change (e.g., reducing nutrient application), and conversely, lack of crushing capacity among mills can act as a disincentive for growers to produce more cane
- some **regulation compliance** officers **do not have the required expertise** to help enable growers to meet regulation practices (e.g., officers can identify poor practices, but are unable to recommend a better practice/solution), so growers may not respect compliance officers and the regulations they are seeking to enforce
- the **quality of extension support provided** to growers influence practice change; growers tend to respect extension providers who are willing to challenge growers, even if growers are initially resistant to the practice changes being recommended
- growers tend to be more **resistant** to receiving extension support if they **believe the provider is working towards a government-directed water quality outcome** (e.g., reduction in DIN), rather than providing tailored advice to benefit the individual grower
- growers tend to mistrust government and there is widespread frustration in the industry about the negativity associated with water quality report cards and regulations.

Environmental context and resources

The key opportunity influences related to **social influences** indicated that:

- **sugar and fertiliser prices influence practice change** and market uncertainty can reduce growers' appetite for risk and act as a barrier to practice change
- **pesticides that are more expensive** can encourage growers to use less and work to ensure what is applied is not washed away
- **perceived and actual costs associated with participation in a WQ project** or practice change more broadly can be a barrier, particularly upfront costs of implementation. Larger and more profitable landholders are more likely to invest in, or can at least trial, practice change. Smaller growers can

find practice change costs prohibitive (e.g., the cost of high-rise spray rigs, electricity and water costs for irrigation in the Mackay Whitsunday region).

- **government financial incentives** are clear practice change enablers; however, some growers are unaware of funding allocated to WQ projects
- unseasonable weather can encourage growers to revert to old practices when faced with uncertain weather conditions
- **wet weather** is an opportune time to provide growers with **practice change communications,** as they are more likely to be indoors and have access to a computer or hard copy communication materials
- **lack of access to equipment required for practice change**, or to measure yield to determine if practice change is impacting productivity, can be a barrier to implementing and/or maintaining practices
- **issues with capacity and turnover of extension officers** in the industry can be a barrier to growers introducing and maintaining new practices
- **lack of time** for growers to learn about and implement new practices can be a barrier, particularly during busy harvest periods.

Practice change framework

A practice change framework has been developed that further categorises and maps the relevant insights and influences from a **systems perspective**, accounting for the contextual factors (moderators) and key mechanisms of action (i.e. intermediate outcomes that lead to the overall practice change outcomes we are aiming for).

When developing and evaluating a behaviour change strategy, it is important to understand the "mechanisms of action" (MoAs) through which interventions, and the specific behaviour change techniques used, bring about change in behaviour (Carey et al. 2019) (see Figure 3). By understanding the MoAs, behaviour change strategies can target key influences on behaviour. Furthermore, an understanding of the MoAs being targeted can be used to develop a robust framework for evaluating the effectiveness of specific behaviour change techniques being used, providing answers as to why a given technique is or is not effective at changing behaviour. The key MoAs that will be targeted in the current practice change strategy are described in the next section.

In this model, behaviour change techniques are not limited to interventions that seek to educate, train, or persuade individuals; interventions can also include techniques that include incentivisation, coercion, restrictions, environmental restructuring, modelling, and other forms of enablement (Michie et al. 2011).
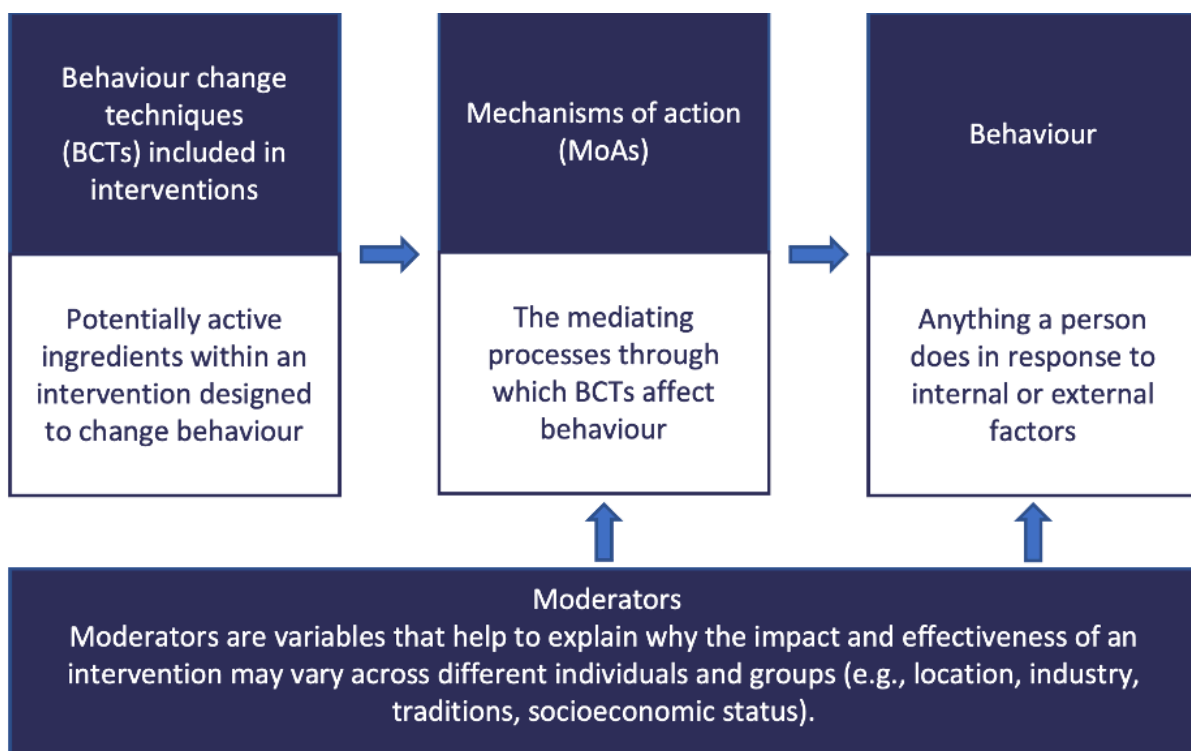
Figure 3. The pathway through which behaviour change techniques bring about change in behaviour through MoAs.

Mechanisms of action

From the wide range of influences on farming practices described in the previous section, we have identified key MoAs that the strategies should seek to target. These are informed by the initial data review, the interviews and discussions with stakeholders, and by relevance to the current practice change project being conducted by The Social Deck. These MoAs include:

- improved access to key information about the water quality projects and water quality improvement practices, previously limited by **digital and literacy skills and/or lack of time among growers** (i.e., by having key information presented in engaging bite-sized communication)

- increased **awareness and understanding** among grower of the water quality projects, including details of the projects and how to get involved, as well as among productivity services, mills, compliance officers and other influential stakeholders

- increased **awareness of the small grants** associated with water quality projects

- increased **knowledge among growers of water quality improvement practices and processes**

- **improved attitudes among growers about water quality improvement practices**

- **improved attitudes towards the WQ projects**, including perceived benefits to growers

- increased **social diffusion** to demonstrate how growers in the region are making or have already made changes

- an increase in perceived positive **descriptive norms (what practices other growers are using) and injunctive norms (what important others think of practices)** among growers and the broader communities

- **increased self-efficacy and beliefs about capabilities** among growers about water quality improvement practices

- **increased motivation and intentions** among growers to join water quality projects and adopt water quality improvement practices

- **increased access to support** to implement and sustain water quality improvement practices

- **increased pride and sense of identity** as an innovative/ leading edge grower and industry

- **increased local collaboration** between projects /other stakeholders driving WQ improvement practices

- **increased understanding among stakeholders of local factors and influences** on implementation of WQ improvement practices.

Socio-ecological moderators

As shown in Figure 3, 'moderators' are contextual factors that help to explain why the impact and effectiveness of an intervention may vary across different individuals and groups, for example, depending on geographic location, culture and traditions, socio-economic status, industry type, and many other factors.

The socio-ecological model (McLeroy et al. 1988) provides a way to categorise these moderating factors or influences to demonstrate that behaviour can be situation-dependent and influenced at a range of different socio-ecological levels, i.e., individual, interpersonal, organisational, public, and government (see Figure 4 for a detailed description of the socio-ecological levels relevant to the current practice change strategy).

We know that interventions or policies that are implemented in isolation at one socio-ecological level may not produce positive outcomes, due to factors at other levels that prevent intended outcomes (e.g., a government policy may lack efficacy if it is undermined at the industry and/or community level, or if practical support is not provided to growers to aid implementation). For this reason, it is important that all influencing factors are considered and interventions at various levels are designed to complement and build upon one another.

The socio-ecological approach allows us to organise the influences listed above to consider social and contextual factors and the interrelationships between different levels of the model that influence behaviour. Using the model, we can better understand which influences are likely to moderate behaviour at different levels of the socio-ecological system. These include:

- **Individual level**: influences that are variables for individual growers, such as grower demographics, personal traits, socio-economic circumstance, attitudes, beliefs and knowledge.
- **Interpersonal level**: the social circumstances, including family, friends, peer and community influences on farming practices.

- **Organisational/industry level**: the economic and industry influences on farming practices, such as influence of mills, resellers and industry and membership groups, as well as innovations and developments in the industry.
- **Public level**: the broader cultural and socio-economic norms that influence behaviour, such as mainstream media discourse.
- **Government level**: the influence of policy settings, including regulation and compliance settings, as well as incentives such as grant opportunities.

The model also provides guidance on how interventions can target different levels of the system to support consistent, long term behaviour change outcomes. For example, it is important to provide clear and accessible information about the water quality projects to influential industry experts such as productivity services, sugar mills, and government regulation compliance officers, as well as accessible information directly to growers.

The following diagram at Figure 4 shows the key moderating factors and influences at each level of the socio-ecological model.

Government
- Impact of regulations
- Influence of DAF extension
- Grants for practice change
- Compliance officers' influence
- Influences on costs (e.g., energy tariffs)

Public
- Environmental groups influence on perceptions
- Media discourse, including both anti-science rhetoric and positive practice change stories

Organisational settings/ industry
- Mills operational influence– seeking to maximise cane production and potentially undermining practice chance
- Productivity Services Groups
- Resellers influence product selection and occasionally practices
- CANEGROWERS influence grower knowledge and awareness (e.g. The Billet for the MW region)
- Scientific developments (e.g., SRA developing new pesticides or cane varieties)

Interpersonal/communities
- Influence of family and close friends on practices (including partners who manage manage or process farm finances).
- Influence of other growers can encourage or inhibit practice change
- Influence of extension (including that provided via WQ projects)

Individual level factors that influence practices (as above)
- Knowledge, skills and beliefs about consequences
- Financial security, including additional income streams
- Farm size
- Education and age
- Succession options and planning
- Personal history and personality type (including cultural background and desire to engage with other growers)
- Past farming practices (including time in cane industry)
- Beliefs about capabilities and identity
- Appetite for innovation and risk
- Trust in government

Circular diagram labels (outer to inner): Government and policy; Public / Cultural norms; Organisational settings (Institutions and industries); Interpersonal/community; Growers / Behaviour Change Techniques; Influence and enabling action; Engagement & Support; Communication & Awareness; Policy change. Right side: Who / What.

Other key external moderators
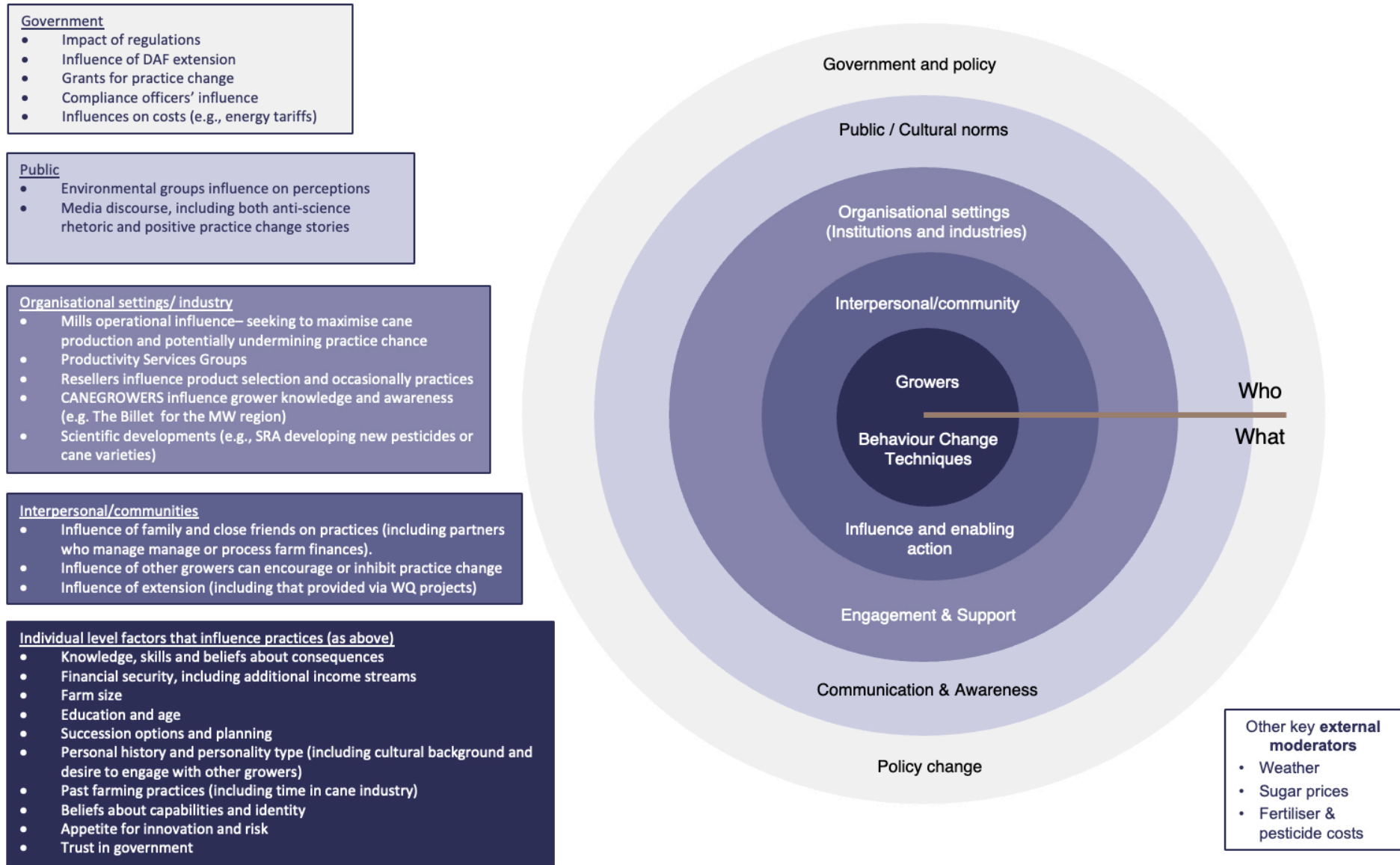- Weather
- Sugar prices
- Fertiliser & pesticide costs

Figure 4: Socio-ecological model showing key moderating factors on grower behaviour. Influences and moderating factors were identified from the interviews conducted as part of the current project and past research.

Contextual differences between regions

In preparation for developing separate strategies that target specifically the MW and LB communities, it is also important to consider the differences that exist between the two different communities, or 'settings' as these are additional contextual moderators that will affect whether the interventions are effective in encouraging water quality improvement practices in the regions.

Interviews conducted as part of the current project, in addition to insights generated from the desktop review, indicated the following there are key differences (described in Table 4) between the two target regions.

Table 4. Key cane farming differences between the two target regions.

Mackay Whitsunday	Lower Burdekin
Socio-economic	**Socio-economic**
• Smaller farm sizes (larger total number of farm businesses). • Some small cane farms have been converted to "lifestyle blocks", which has resulted in a decrease in cane growing in the region. • Higher proportion of growers with additional income streams from work "off-farm" (e.g., mining). This can make it difficult to find the right time to implement practice change.	• Larger farm sizes (smaller total number of businesses) • Slight reductions in yield can result in significant reduction in revenue (but not necessarily overall profit).
Culture and family	**Culture and family**
• Multicultural (e.g., Italian ancestry, 3rd to 4th generation). • Strong family-run culture of farms	• European (large proportion with Italian-Sicilian ancestry – multi-generational growers); however, some larger holdings are managed outside of family or sold to larger corporations. • More 'independent' growers/businesses that are less aligned to particular peak bodies/networks (e.g. CANEGROWERS).
Farming practices	**Farming practices**
• Higher rainfall, less sunlight than in the LB region • Most (>80%) do not irrigate. Energy costs, set up costs, time, ageing growers, lack of access to irrigation water, and the fact that it is possible to grow cane successfully without irrigation are barriers to irrigation. Landscape is variable and undulating so irrigation is via overhead sprinklers rather than furrow flooding.	• Lower rainfall and more sunlight than the MW region • Growers use furrow flooding to irrigate, which results in high yield. • Currently significant interest in the region to fully automate irrigation practices to save time and ensure irrigation practices are efficient and effective.
Industry practice landscape	**Industry practice landscape**
• >80% of growers are CANEGROWERS members • Productivity Services exist in Mackay, Proserpine, and Plane Creek • 5 mills (Companies: Mackay Sugar and Wilmar) • 8 RTP WQ projects that largely work independently from one another.	• Large/corporate businesses may be driven by corporate social responsibility to meet reef targets. • Can be difficult to get high quality, affordable employees. • Most growers are members of Burdekin Productivity Services, which delivers the Smartcane BMP program (20approx. 30% are CANEGROWERS members). • NRM (NQ Dry Tropics) provides training and extension support. • There are 3 RTP WQ projects that work together to cover the three broad practice areas (nutrients, pesticides, irrigation).

Discussion

In this report, we have described the results of our investigation of the influences on implementation of water quality improvement practice among cane growers in the Mackay Whitsundays and Lower Burdekin regions. We also identified influences on grower participation in the RTP-funding water quality projects in each region. These influences were used to determine which mechanisms of action should be targeted by the strategies to encourage behaviour change (i.e., participation in the water quality projects and the use of water quality improvement practices supported by these projects).

Our initial review of current research and project documentation, as well as the results of our qualitative interviews, indicated that the development of a cane farm practice change strategy poses challenges that are less likely to occur in other behaviour change interventions. A critical step in the development of a behaviour change intervention is to identify the specific behaviours and audiences to target in the intervention (Michie et al. 2011), and then investigate the influences on each of these specific behaviours. In the current project, however, there are numerous specific and interrelated behaviours that relate to water quality improvement practices, and it is well beyond the scope of this strategy to identify and target each of these behaviours. Furthermore, the expert delivery providers responsible for the implementation of the current water quality projects are best placed to encourage growers to adopt specific practices.

For the purposes of the strategy, we focused on three key practice areas (DIN, pesticides, and irrigation) that are relevant for both MW and LB regions, rather than the numerous specific behaviours associated with each of these practice areas. One specific behaviour that is particularly relevant to the development of the strategies is **grower participation in the water quality projects and in other water quality improvement practices or programs related to DIN, pesticides and irrigation**. As discussed in this report, we investigated barriers and enablers to participation in water quality improvement practices and identified a wide range of influences on this behaviour.

One key theme that emerged that is critical to participation in the water quality projects and the practices targeted in these projects, is lack of awareness, knowledge and understanding of the water quality projects and practices. This lack of knowledge contributes to misinformation and misperceptions about the water quality projects and the consequences of implementing water quality improvement practices (e.g., elevated risks of reduced profits). A lack of time and digital literacy among some growers also supports the need for more accessible, bite-sized chunks of information about the water quality projects, how to implement specific practices, and the positive consequences of implementing these practices.

A second key theme that emerged from the data was a widespread perception amongst growers and other cane stakeholders that cane growers have been unfairly criticised for poor water quality outcomes, and that when growers implement new water quality improvement practices, they are not recognised for doing so. These findings indicate that a key focus of the strategies should be positive storytelling and case studies to demonstrate and role-model water quality improvement practices. Our results also indicate that current stories and recognition often concentrate on the same few growers, so there is a need to diversify and show a range of more relevant stories that connect with growers. Such strategies would seek to improve attitudes towards water quality improvement practices and support a perception that such practices are normative among growers in each region.

Strategy development (next steps)

The current report focuses on the practice change framework that will inform further development of the strategies for each region, via the steps detailed in this section (see Figure 1 above). These steps and the strategies themselves are further detailed in reports commissioned by the GBRF, as they are not part of the scope and focus of this report.

Step 1: Select and prioritise landholder types for each region

The strategies will draw on a 'phase 1' complementary project funded by GBRF and undertaken by Mosaic Insights to "conduct social science research to build a deeper understanding of the social context of landholders and how different social factors might enable or inhibit practice change."

This work resulted in Mosaic Insight's 'Reef Sugarcane Landholder Characterisation Report', which we will use as a basis to better understand how to target tactics and actions to each region. The characterisation describes five types of cane growers within Great Barrier Reef catchment areas (Table 5).

Table 5. Landholder Characterisation (From Mosaic Insights Report to the Great Barrier Reef Foundation: Reef Sugarcane Landholder Characterisation Report. September 2022)

Typology name	Typology characteristics
Traditionalists	High 'production-ist' value, lower levels of innovation. Tended to have low levels of financial capacity, smaller farms, highly motivated to keep the farm in the family. Tend not to be involved in agri-environmental schemes. Low trust in government programs.
Experimenters / Diversifiers	Mixed crops, high risk threshold, high trust in government programs.
Enterprise farmers	High financial capacity, no off-farm income, large farms, strong profit/expansion values, high risk threshold.
Conservationists	High environmental values, small farms, no off-farm income, high engagement in agri-environmental programs.
Lifestyle / hobby farmer	High incidence of off-farm income but low financial capacity, strong lifestyle values, low risk threshold.

There is a need to prioritise grower types in each region, so that behavioural interventions are appropriately targeted and relevant, considering both the contextual factors of each region (as per Table 4 above) and the characteristics of growers present.

Building on Mosaic Insights' work on the landholder characterisation profiles, we will identify, prioritise, and select landholder types that have most relevance to practice change in the two regions. This selection will be

based on qualitative information about grower characteristics, influences and behaviours that were gained from the interviews and discussions with experts, delivery providers, extension officers and growers in each region.

The selection and prioritisation process will consider:

- proportional representation of each grower type in the relevant region
- the risk profile of grower types, i.e., the need to target change strategies towards grower types that may have a higher risk of contributing to poor water quality outcomes.

Step 2: Develop journey maps for each region

Journey maps will be developed for **each of the selected grower types, in each region**. These maps will use the initial data and research reviews, stakeholder interviews and interviews with growers and will be validated and updated using a grower survey (see Figure 1, and further explanation of the survey in Step 4 below).

We will map the relevant insights we have gathered (including key influences and moderating factors described in the framework above), to describe what is currently happening, as well as barriers and enablers to change, against broad 'stages of change' that are relevant for the selected types/regions.

The stages of change are modified for relevance to this project from the "Transtheoretical Model of behaviour change", also known as the "Stages of Change" model (Prochaska et. al., 1994), which proposes that individuals go through a series of stages as they work to change a behaviour: precontemplation, contemplation, preparation, action, maintenance, and termination. The stages of change most relevant for the strategy outcomes include the following.

- **Awareness**: Increasing grower awareness of GBRF water quality projects and other practice changes, projects or programs that improve water quality.

- **Motivation and intention**: Increasing grower knowledge, capability and opportunity to engage with GBRF water quality projects and other positive practice changes, projects or programs.

- **Behaviour change**: Taking action to change behaviour, test new practices or comply with best practice standards.

- **Maintenance**: Maintaining positive practice changes over time.

We will map the influences that are related to these stages of change (including all relevant influences across the COM-B model), to make sure that we are appropriately targeting interventions (tactics and actions) to account for growers that are at different stages of the practice change journey, and with a view to helping growers move through the stages to make long lasting changes. Therefore, the journey mapping will aid the selection and prioritisation of key moderating influences for each region and landholder type.

Step 3: Selection of behaviour change interventions and development of the practice change strategies

The journey maps will be used to develop tactics and actions that target the most relevant mechanisms of action MoAs for the MW and LB regions.

Behaviour Change Intervention Ontology

We will use the Behaviour Change Intervention Ontology (BCIO) (Michie et al. 2021) to map out how the interventions will influence farming practices via MoAs, and how exposure to the interventions (i.e., reach and engagement) and context (i.e., grower type and setting), will moderate the impact of strategies on practice change (Figure 5). The BCIO was developed to provide a systematic way to characterise behaviour change interventions across disciplines, the context within which interventions occur, and the evaluation of interventions.

Some of the behaviour change interventions we develop to influence practice change are likely to be directed at key intermediaries in the cane growing industry, rather than just growers. As shown in the lower half of Figure 5, these interventions are intended to influence farming practices via MoAs and enabling behaviours performed by intermediaries, which influence growers. For example, an intervention designed to encourage compliance officers to promote the RTP WQ projects to growers, is likely to increase knowledge and intentions (among other MoAs) within compliance offers, which may then increase the likelihood that compliance officers encourage growers to join or at least enquire about the water quality projects.

Constructs described in the blue boxes in the strategy diagram below will be used to evaluate the delivery and effectiveness of each regional strategy (see Step 4).
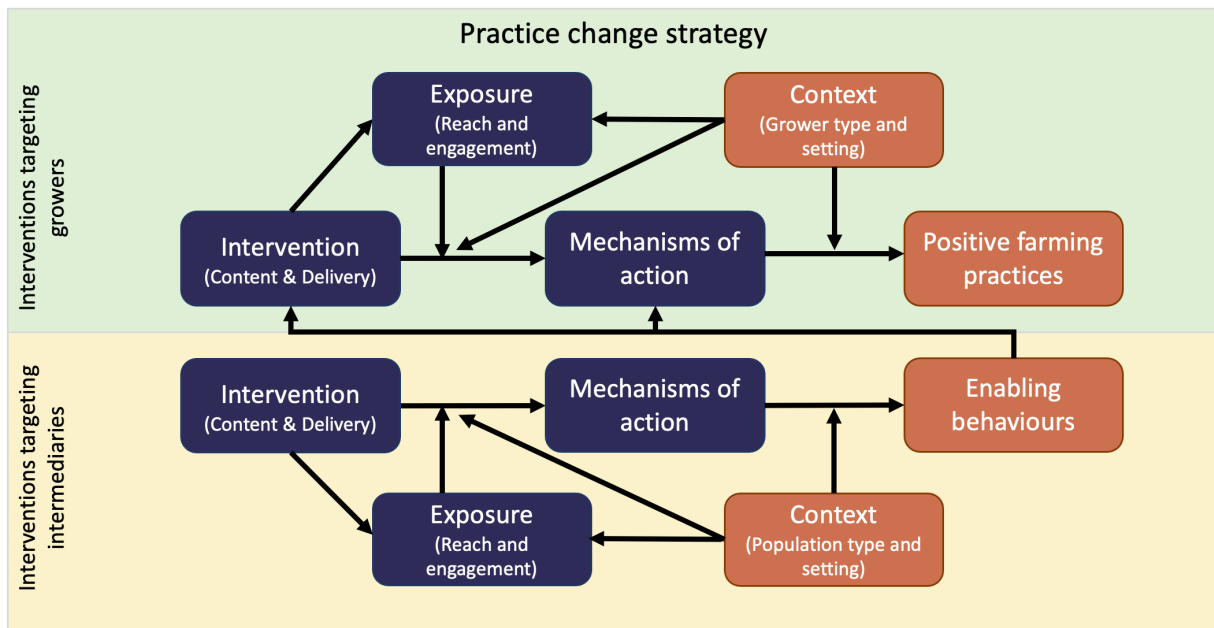

Figure 5. How the practice change strategies will influence farming practices via key mechanisms of action (adapted from the Behaviour Change Intervention Ontology).

Principles for selecting interventions for the strategies

In developing the intervention concepts, we follow the 'APEASE' principles for good intervention design. These are:

- **Affordability**: Are the design and implementation costs appropriate?

- **Practicability:** Can the interventions be delivered as designed?

- **Effectiveness and cost-effectiveness:** Are the interventions likely to be effective and cost effective?

- **Acceptability**: Are the interventions going to be acceptable to the target audience and relevant stakeholders?

- **Side-effects/safety**: Are there likely to be any unwanted side-effects or other unintended consequences of the interventions?

- **Equity**: Will the interventions reach the intended recipients without disadvantaging some groups, particularly those already experiencing disparities in standard of living, wellbeing, or health?

Key selection factors

The selection of interventions will be based on the following key criteria:

- There is sufficient evidence **that interventions will affect the Mechanisms of Actions and lead to both enabling behaviours and direct practice change for the priority grower types in each region**, considering the contextual factors for each region, and various levels of moderators in the socio-ecological model
- The interventions **meet the requirements of the APEASE principles** described above
- The interventions **can be implemented within the scope, timeframes and budget** of the GBRF funding for this work.

Step 4: Design of evaluation, and delivery of Monitoring, Evaluation and Learning (MEL) plan

Due to the complex nature of the program, a phased approach to implementation and the limitations to utilising research techniques that require a representative sample of growers (see Limitations section below), the evaluation approach will be emergent, i.e., based on continual testing and refining of the strategies with growers and stakeholders in the regions.

This is consistent with evaluating complex social interventions because as the system diagrams have shown, outcomes of the interventions may be multifaceted and due to the complex stakeholder environment (e.g. need for partnerships and trust-building in the region), there is still some uncertainty about what will happen and how the strategies will progress. Therefore, the evaluation process will need to be flexible and adaptable, and the evaluation design and methods may evolve over time as the strategies unfold.

There are several key principles that will guide the emergent evaluation approach:

1. Focus on learning and generating new knowledge and understanding about the program, rather than simply assessing whether it has been successful.

2. Use of multiple methods, including both qualitative and quantitative approaches, to ensure a comprehensive understanding of the project.

3. Engage stakeholders, including growers, delivery providers and other key stakeholders or partners, to ensure that the evaluation is grounded in the experiences and perspectives of those who are most closely connected to the strategies.

4. Being flexible and adaptable and prepared to adjust the evaluation plan as the strategies progress and new information becomes available.

To support this approach, a **Monitoring, Evaluation and Learning (MEL) plan** will be developed for each region, using the following.

- Defining a clear **Theory of Change (program logic)** for the practice change strategies, with causal pathways to indicate how interventions should lead to outcomes (noting that this will evolve over time as intermediate outcomes (expected or unexpected) are defined. The Theory of Change will include:
  - detailing evidence and key assumptions that underly the causal links in the program logic
  - consideration and details of external factors that may impact the implementation of behaviour change activity, outputs or outcomes that can't be mitigated within the scope of the program
  - identifying and tracking any potential unintended consequences.
- Developing **key evaluation questions** (KEQ) that will be used to frame evaluation and reporting across the regional programs.
- Testing and refining the strategies with the input of growers and key intermediaries in each region, including by:
  - interviews with growers and other key stakeholders to refine and inform implementation of this strategy
  - workshops and discussions with delivery providers, extension officers and other stakeholders to ensure the implementation of actions is effective
  - a short survey targeted at growers, as a 'pulse check' on whether interventions and overall strategies for each region are effective.

Limitations

It is important to note that a number of limitations should be considered when reading this report.

1. A comprehensive, systematic literature review of past research was not included in the scope of this project. However, the large range of documents that were considered in the desktop review are included in Appendix 1.
2. Project timeframes and limited availability of interviewees (especially as timing of engagement coincided with the harvest season), limited the number of interviews and engagement activities that it was possible to undertake to gain and collate insights.
3. While interviewees were carefully chosen to represent the regions and key stakeholders within them, they have mostly focused on intermediaries with a knowledge of growers in the region, rather than growers themselves. This was primarily due to difficulties in being able to engage with a representative sample of growers across the regions (for reasons detailed in point 2 above). Prior to the development of the strategies, an online survey for growers will be used to gather additional insights and confirm the influences on practices identified in the current report.
4. It has been, and will be, difficult to engage with growers who are not already engaged in water quality projects. Innovative and emergent engagement techniques will need to be considered to reach and engage these growers, who are a high priority target for the strategies if there is to be a significant impact on water quality outcomes.

Appendix 1. Past research and projects reviewed

Past research and practice change projects were used to inform the lines of questioning used in interviews and the practice change strategies more broadly. The research and projects reviewed, including documents relating to the current RTP water quality projects, are listed in this table.

RTP water quality programs and projects
RTP WQ Regional Plan and M&E Plan for Mackay Whitsunday
RTP WQ Regional Plan and M&E Plan for Lower Burdekin
Project Proposal for the Mackay Irrigation Project by Mackay CANEGROWERS (WQ-MW-001)
Project Proposal for Project Catalyst by catchment Solutions (WQ-MW-002)
Project Proposal for A Point of Difference – Precision Agriculture by Farmacist (WQ-MW-003)
Project Proposal for Project Bluewater 2 by Farmacist (WQ-MW-004)
Project Proposal for LAND (Local Area Nutrient Datahub) by LiquaForce (WQ-MW-005)
Project Proposal for Nutrient Management Plans by MAPS (WQ-MW-006)
Project Proposal for the Major Grants Program by Reef Catchments (WQ-MW-007)
Project Proposal for Cane to Creek by SRA (WQ-MW-008)
Project Proposal for Precision to Decision by Farmacist (WQ-LB-002)
Project Proposal for Project Bluewater 2 by Farmacist (WQ-LB-005)
Project Proposal for the Burdekin Irrigation Project (BIP) by SRA (WQ-MW-004)
Project Proposal for Project Bluewater 2 by Farmacist (WQ-MW-004)
On-ground validation of projects for the Great Barrier Reef Foundation Mackay Whitsunday Water Quality Program
On-ground verification of projects for the Great Barrier Reef Foundation Lower Burdekin Water Quality Program
Landholder typologies
Schwarz, I., McRae-Williams, P., & Park, D. (2009). Identifying and utilising a farmer typology for targeted practice change programs: A case study of changing water supply in the Wimmera Mallee. *Extension Farming Systems Journal*, *5*(1), 33-42.
Summary of information provided by GBRF contained in: Nicholson, C. (2018). Agronomists as drivers of practice change. Retrieved from Grains Research and Development Corporation (GRDC) website: https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2018/03/agronomists-as-drivers-of-practice-change.
Future of Farming survey developed by NC Economics
Redefining and reconfiguring Reef catchment land use for better long term outcomes (March 2022) by NC Economics
Appendix E - Survey Results to report Redefining and configuring reef catchment land use for better long term outcomes
Emtage, N., & Herbohn, J. (2012). Implications of landholders' management goals, use of information and trust of others for the adoption of recommended practices in the Wet Tropics region of Australia. *Landscape and Urban Planning*, *107*(4), 351-360.
Emtage, N., & Herbohn, J. (2012). Assessing rural landholders diversity in the Wet Tropics region of Queensland, Australia in relation to natural resource management programs: A market segmentation approach. *Agricultural Systems*, *110*, 107-118.

Emtage, N., Herbohn, J., & Harrison, S. (2006). Landholder typologies used in the development of natural resource management programs in Australia—a review. *Australasian Journal of Environmental Management*, *13*(2), 79-94.

Emtage, N. (2009). Market segmentation study of rural landholders in relation to the promotion of natural resource management on private land in the Wet Tropics region of Queensland.

OGBR social monitoring methods and results

Video of a training session from the Social Monitoring lead at OGBR, which explains the intent of the framework, how it works and some of the results they have found to date in cane and grazing. https://youtu.be/dD11y4P9Opo

Human dimensions: social factors influencing agricultural management practice adoption. Methods

OGBR Paddock to Reef – Social monitoring questions CANE

Hobman, E., & Taylor, B. (2018). Understanding the human dimensions of landholder innovation and stewardship.

Jarvis, D., Taylor, B., & Hobman, E. (2018). Towards a human dimensions baseline: a synthesis of social research data on farming practice adoption and environmental stewardship in reef catchments.

Paddock to reef social monitoring report for project proponents - CANE (June 2019 - June 2021)

Paddock to Reef Social Monitoring Report - CANE BASELINE WQ-MW-001 Baseline P2R Social Data Report_Bluewater_ October 2020 v1.0

Understanding motivations and barriers to change – Extension Officer Survey

Coggan, A (2020) Understanding the human dimensions to land management practice change in Great Barrier Reef catchments. A review of current knowledge and synthesis of critical gaps. CSIRO, Australia.

Coggan A, Fielke S, Hay R, Thorburn P and Smart J (2021) Understanding the human dimensions to land management practice change in Great Barrier Reef catchments. Synthesis Report.

https://www.reefplan.qld.gov.au/tracking-progress/reef-report-card/2020/social-monitoring/cane

RP225 Building a policy instrument impact model for the reef Final project report, October 2021.

Project Cane Changers

Cane Changer 2.0 Final report

Cane Changer 2.0 Monitoring and evaluation Plan

Pickering, J., McIntosh, T., Moore, S., Priwitzer, S., Haanterä, K., Preston, G., ... & Kealley, M. (2019). Project Cane Changer: using behavioural science to create practice change. In *Proceedings of the 2019 Conference of the Australian Society of Sugar Cane Technologists, held at Toowoomba, Queensland, Australia, 30 April-3 May 2019* (pp. 101-107). Australian Society of Sugar Cane Technologists.

Pickering, J., Haanterä, K., Jenner, A., McIntosh, T., Wright, N., Porta, M., ... & Telford, D. (2019). Behavioural-skills training for extension officers: an approach built on behavioural science. In *Proceedings of the 2019 Conference of the Australian Society of Sugar Cane Technologists, held at Toowoomba, Queensland, Australia, 30 April-3 May 2019* (pp. 92-100). Australian Society of Sugar Cane Technologists.

Kealley, M. J., & Quirk, M. F. (2016). Smartcane BMP–understanding drivers and building momentum for best management practice uptake in the Queensland sugarcane industry. In *Proceedings of the International Society of Sugar Cane Technologists* (Vol. 29, pp. 445-453).

Pickering, J. A., Hong, J., Hong, D., & Kealley, M. (2017). Applying behavioural science to the Queensland sugar cane industry and its relationship to the Great Barrier Reef. *Rural Extension and Innovation Systems Journal*, *13*(2), 1-10.

Pickering, J., Hong, J., Stower, R., Hong, D., & Kealley, M. (2018). Using psychology to understand practice change among sugar cane growers. *Rural Extension and Innovation Systems Journal*, *14*(1), 62-72.

Other research papers and projects
Coggan, A., Thorburn, P., Fielke, S., Hay, R., & Smart, J. C. (2021). Motivators and barriers to adoption of Improved Land Management Practices. A focus on practice change for water quality improvement in Great Barrier Reef catchments. *Marine Pollution Bulletin*, *170*, 112628.
Wet Tropics Major Integrated Project - Putting Local Knowledge into Reef Action. Year 3 Performance Report November 2020
Sugarcane Water Quality Risk Framework 2017-2022
Engaging with farmers and demonstrating water quality outcomes to create confidence in on-farm decision-making (also known as Project 25)
Fielke, S., Taylor, B., Coggan, A., Jakku, E., Davis, A. M., Thorburn, P. J., ... & Smart, J. C. (2022). Understanding power, social capital and trust alongside near real-time water quality monitoring and technological development collaboration. *Journal of Rural Studies*, *92*, 120-131.
Great Barrier Reef Marine Park Authority 2013 Coastal ecosystems management – case study: water management, GBRMPA, Townsville.
GBRMPA water quality position statement
Behavioural drivers key to agriculture's sustainable transition (By Aditi Mankad, Emilie Roy-Dufresne, Ann Seitzinger, Anu Kumar, 2021)
Kancans, R., Ecker, S., Duncan, A., Stenekes, N., & Zobel-Zubrzycka, H. (2014). Drivers of practice change in land management in Australian agriculture: Synthesis report-Stages I, II and III. *ABARES Research Report*, (14.05).
RP225 Building a policy instrument impact model for the reef Final project report, October 2021.
Building a policy instrument impact model for the reef (RP225). Summary of key findings.
1RP226 Contribution of partnerships to water quality outcomes in Great Barrier Reef Catchments. Milestone Report 3: Partnerships Review and Synthesis. Interview findings, synthesis, and guidance material.
Sugarcane, experimental regional estimates using new data sources and methods. Experimental statistics on sugarcane for 2020, highlighting the use of alternative data sources and methods for producing agriculture statistics: https://www.abs.gov.au/statistics/industry/agriculture/sugarcane-experimental-regional-estimates-using-new-data-sources-and-methods/latest-release
Alluvium 2019. Effective and Efficient Pathways for Investment in Improved Water Quality in the Great Barrier Reef: Final Report. A report for the Great Barrier Reef Foundation, Brisbane.
NQ Dry Tropics 2016, Burdekin Region Water Quality Improvement Plan 2016, NQ Dry Tropics, Townsville.
Queensland Reef Water Quality Program. Prescribed methodology for sugarcane cultivation. https://www.qld.gov.au/__data/assets/pdf_file/0016/113146/prescribed-method-sugarcane.pdf
Queensland Reef Water Quality Program. Reef protection regulations in the Great Barrier Reef regions Sugarcane requirements. https://www.qld.gov.au/__data/assets/pdf_file/0018/113490/factsheet-sugarcane-all-regions.pdf
Rundle-Thiele, S.R., Smart, J.C.R., Roemer, C., David, P. Hasan, S., Anibaldi, R., and Shawky, S. (2021) *Measuring cost-effectiveness and identifying key barriers and enablers of lasting behavioural change in the cane industry.* Report to the National Environmental Science Program. Reef and Rainforest Research Centre Limited, Cairns (48 pp.).

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