Economic Assessment of Agricultural Pollution Management Options in Sugar Cane Production in Queensland: A Case Study Involving a Dugong Protection Area

Thesis submitted by

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Abstract

Sugar cane production inevitably creates off-site environmental impacts. This thesis addresses the joint production of an agricultural good and environmental externalities and investigates options to manage transboundary effects. Sugar production activities upstream of a marine protected area may alter the natural setting and impose costs on individuals and society that are not offset by commensurate increases in benefits. Expanding the Burdekin River Irrigation Area in North Queensland to supply the Molongle Block would bring areas adjacent to Upstart Bay Dugong Protection Area under cane production with the potential to create net social costs. Irrigated cane production might introduce dry season flows and pollution carried by water, affecting the ecological value of dugong (*Dugong dugon*) habitat. The thesis examines why environmental damage might occur in the coastal region and explores some of the mechanisms that might be used to better minimise problems. The original contribution is an economic analysis of Dugong Protection Areas, identifying appropriate mechanisms for intervention.

A case study of potential cane production adjacent to Upstart Bay is used to explore agricultural pollution mitigation policy options. Constructed wetlands are one option, employing biological processes to mitigate agricultural pollutants. The problem of handling variable loading rates to avoid intertemporal ineffectiveness would lead to high cost mitigation. Controlling the timing of pollutant loadings via retention ponds may be a more cost effective alternative. Retarding dry season flows and first flush events for release in subsequent high flow events is expected to provide reductions in environmental impacts. Subregional retention ponds allow for effective coordination of the timing of wastewater releases and may also have economies of scale advantages.

Integrating agricultural production and ecological criteria in economic analysis of policy options revealed shortcomings in available datasets. Gaps in knowledge constrain a full evaluation of mitigation policy, but reflect a situation commonly encountered in natural resource management. Some existing planning tools could be used as a basis for pollution mitigation. The *Coastal Protection and Management Act 1995* might be used to strengthen the environmental aspects of land and water management plans required by the *Queensland Water Act 2000*. Property level drainage outflow points may allow for effective monitoring of water quality. The strategic location of drainage outflow

points in a new irrigation development could address measurement problems hindering effective responses.

Instruments which might be worthwhile interventions include traditional regulatory approaches and market based instruments. Instruments such as tradeable permits linked to a regional mitigation infrastructure have the potential to further reduce the pollution risk at the lowest social cost. The first challenge in establishing a marketable permit system that creates an incentive to reduce pollution is the setting of limits for the aggregate quantity of pollution permissible.

In considering the potential implications of the case study for the sugar growing industry as a whole, more parameters become relevant for policy analysis. A whole of catchment approach similar to the Productivity Commission investigation of policy options for water quality and the Great Barrier Reef lagoon (2003) provides a framework to address complex land use issues affecting the land-marine interface. It is argued that policy options that inherently create incentives to reveal private information aligning private interests with desired environmental outcomes and allow for site variability must feature as part of the abatement policy mix. Finding ways to lever community capacity to implement policy options and ensure desired environmental outcomes through adopting some targeted regulatory options remains the challenge for agricultural pollution mitigation policy.

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STATEMENT OF SOURCES

DECLARATION

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

The following publications and communications have been derived from this work:

Jacobsen, B., 2002, "An Economic Analysis of Agricultural Pollution Mitigation Policy: Towards Protecting the Near Shore Marine Environment in New Development", National Student Essay Award Winner, Environment Institute Australia Annual Conference, Brisbane, 31 July – 2 August.

Jacobsen, B. and Mallawaarachchi, T., 2002, "Issues in the Implementation of Pollution Mitigation: A Case Study of Potential Expansion of the Sugar Industry in North Queensland", paper presented at 46th Annual Conference of the Australian Agricultural and Resource Economics Society, Canberra, ACT, 13-15 February.

Jacobsen, B., 2001, "Issues in the Implementation of Nonpoint Source Pollution Mitigation: A Case Study of Potential Expansion of the Sugar Industry in North Queensland", poster paper presented at Sustaining our Aquatic Environments – Implementing Solutions, Townsville, November 20 – 23.

Jacobsen, B., Lukacs, G. and Mallawaarachchi, T., 2001, "The Economics of Constructed Wetlands for Pollution Mitigation: A Case Study in the Burdekin River Irrigation Area", paper presented to Fourth International Conference on Geochemistry in the Tropics, Townsville, May 7-11.

Jacobsen, B. and Mallawaarachchi, T., 2001, "Policy Issues in Protected Area Management: An Examination of Dugong Protection Areas", paper presented at 45th Annual Conference of the Australian Agricultural and Resource Economics Society, Adelaide, South Australia, 23 - 25 January.

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Chapter 1

Economics and the Environment

1.1 Introduction

This thesis explores the economic causes of pollution problems, outlining why environmental damage can occur in the coastal region. The thesis then identifies policy options which may be employed to mitigate agricultural pollution mitigation using a case study. The efficiency of choosing more suitable mechanisms for controlling pollution over traditional responses is highlighted. The potential to apply more flexible and innovative solutions to problems of environmental impacts from agricultural expansion is then expanded to consider existing agicultural activities. This thesis demonstrates the interconnectedness between ecological and economic issues. How the characteristics of the production area and the marine protected area influence feasible mitigation options and consequently informs appropriate policy responses. The context of this analysis is presented in this Chapter.

In the past the development of our regions and the economic exploitation of natural resources has attracted government support from all levels. Encouragement of clearing and bringing land into 'productive' use (Land Settlement Advisory Commission 1959 p5, Royal Commission 1931 p51) is understandable in the context of a young state. Much of today's farming land in Australia has been developed with some type of government subsidy. For example, the Murray Darling Basin evolved with irrigation infrastructure development and 'rights' to use water. Because of the historical support for development, rural communities find it difficult to accept changed societal norms relating to the environment. Societal goals have changed rapidly with respect to how natural resources are used.

One of the drivers behind the changing nature of natural resource use is the growing economic value of areas that provide environmental benefits. As Reichelderfer and Kramer explain:

> "It was partly as a result of successful economic growth through resource development that the predominant view of natural resource value switched from focus on resources as raw materials to the demand by a higher income

> population for the recreational and amenity services offered by undeveloped resources" (Reichelderfer and Kramer 1993, p. 458).

Increases in the standard of living gained by exploiting natural resources have changed the relative scarcity. Scarcity has increased the value of remaining natural resources. And so, in a paradoxical way, the exploitation of natural resources allowed a standard of living that results in a preference not to continue depleting the quantity and quality of remaining natural resources. Community preferences for future states now include environmental values.

1.2 New Development

Anthropogenic activity such as new agricultural development may result in additional pollution loads with the potential to impinge on environmental values. Cane growing in Queensland is an intensive agricultural pursuit largely undertaken on the coastal plain. Some cane growing areas are thus located adjacent to world heritage listed environments bordering reef to the east and rainforest to the west. Many people enjoy the environmental attributes of locations in the world heritage area and other prominent areas near to cane growing areas. This close proximity raises many challenges for today's cane grower faced with heightened community awareness and appreciation of the environment. Widespread enjoyment of the benefits of a healthy near shore marine environment warrants consideration of alternatives to mitigate environmental impacts of sugar cane production. Community pressure is mounting over practices causing water quality changes and perceived downstream effects. Perceived detrimental impacts from agricultural pollution on high profile areas such as the Great Barrier Reef has resulted in a rapid and comprehensive response. Preventative management is a non-regret policy response to a disincentive for community support.

Responding to community concern about farming impacts involves investigating appropriate courses of action with economic, political and social aspects. Exploring mechanisms allows for further investigation or at least partially informed decision making.

> "… policy makers use information to make normative choices about what are acceptable levels of environmental and health risks and how to achieve those

> outcomes. Ultimately, policy makers make choices based on their assessment of public benefits and costs of a given policy" (Jackson and Villiuski 2002, p. 8).

Economics provides a framework for considering complex policy problems highlighting alternative solutions that allow policy makers to consider interrelated facets of the problem.

Policy responses to intervene between interest group positions involving agricultural activity and environmental protection must address both existing agricultural activity and new development. The sheer range of pertinent issues involved in pollution mitigation policy for existing agricultural areas is beyond the scope of a single study. By limiting the scope of the research to new development, pollution mitigation policy discussion can both be relevant and usefully analyse the interaction between agricultural production and environmental needs using a case study. Discussing the economics of agricultural pollution mitigation policy with reference to a single environmental issue demonstrates the utility of economic analysis for broader production-environment problems. Mitigation policy options broadly applicable to new activity with potential impacts on the Great Barrier Reef ecosystem may help to frame a way forward for obtaining a socially optimal policy to address current issues at the production environment interface.

1.3 Environmental Impacts

Farmers operate within boundaries set by natural resources and ecosystems for their livelihood. Living and working on the land often results in an affinity with the local area. Farmers may well be members of Landcare; support a relevant "Environmental Code of Practice", and have once enjoyed fishing in the creek now silted up at the bottom of their farm. If farmers have a close connection with the land, what would lead them to act in ways that reduce others' enjoyment of the environment?

A farmer derives economic benefit from using inputs to produce a commodity. If the use of inputs to grow a crop jointly results in environmental impacts, then an externality is produced. It is called an 'externality' as those who are disadvantaged by environmental impacts are not involved in the production decision, they are external to the production decision. The conventional view of the 'right to farm' has been suggested as a reason for allowing farmers to continue to produce externalities.

In a seminal paper Hardin explored the notion of rights to carry out activities being intimately connected with social responsibilities.

> "It is the newly proposed infringements that we vigorously oppose; cries of "rights" and "freedom" fill the air. But what does "freedom" mean? When men mutually agreed to pass laws against robbing, mankind became more free, not less so. Individuals locked into the logic of the commons are free only to bring on universal ruin; once they see the necessity of mutual coercion, they become free to pursue other goals" (Hardin 1968, p. 1248).

Thus the waste byproducts have unwanted effects. Hardin also noted that such externalities are caused because of economic motivations.

> "The rational man finds that his share of the cost of the wastes he discharges into the commons is less than the cost of purifying his wastes before releasing them." (Hardin 1968, p. 1245)

Demsetz (1967) also argued that private owners have responsibilities not to generate particular kinds of harms for others. The lack of convergence between private and public interests, between individual and social benefits and costs, illuminates how individual actions may not result in the common good. The research explores how such conflicts introduce a role for government intervention to correct the externality.

1.4 Externalities and Protected Areas

Through protected areas society seeks to minimise the impact of some particular action on some biological community or ecosystem. Traditionally, threats to specific resources have been conceptualised as direct use, for example clearing of terrestrial flora or harvesting of fish. Increasingly, the types of threats that managers of protected areas face are not direct use. Depletion in the ozone layer may produce global warming resulting in broader climate change. Similarly, external impacts from nearby activities may impact on the ecosystem. Activities in upper catchments have the potential to affect in-stream river habitat and, depending upon biological processing, may affect the near shore marine environment.

Near shore marine environments pose a particularly challenging management problem. Their high degree of connectivity closely links ecological and biological processes with nearby environments. Policy to address the transboundary aspect of the problem needs to find ways to reduce opportunities for adjacent uses to diminish values. Policy instruments for the marine-terrestrial interface may involve creating institutional support mechanisms for a market to provide for the environmental good. In this way the sensitivity of local communities with a vested interest in local economic activity can be balanced against the benefits from environmental goods and services that accrue to a much wider demography.

1.5 Managing Externalities: Agricultural Pollution Mitigation Policy

Agricultural pursuits on our coastal plains have the potential for spillover effects with impacts subtracting from the quality or quantity of the resource with causes and effects difficult to identify. Among the range of environmental concerns relevant to future cane development, the potential for impacts on the near shore marine environment is an emerging issue. Plans for expanding irrigation areas and possible additional impingement on water quality raise concern for potential environmental change and downstream effects on dugong (*Dugong dugon*) habitat.

Markets usually allow private interests to allocate resources efficiently, given certain assumptions about the good or service being traded, the actors and information held. The fact that markets fail to efficiently allocate environmental goods is due to the nature of the good or service and the actors' inability to exclude others from using them. Markets may also fail because of a lack of institutional and social support (unclear governance rules; lack of laws and judiciary to enforce laws). These contextual factors need to support the operation of markets and thus explicitly influence the design of policy instruments to internalise externalities.

Identifying appropriate management options for a Dugong Protection Area involves outlining the relevant costs and benefits: incremental changes in pollution mitigation costs (establishment, maintenance and enforcement), an increased chance of protecting the downstream environment and the opportunity cost of foregone production among others. Conflicts with adjacent land-users are usually the most important cause of concern in protected areas. Analysis of possible effects of a proposed land use at the planning stage of future development allows for the potential inclusion of environmental factors. Policy formulations based on the costs and benefits will likely require changes to usual practices because of the threat to the environmental values of the protected area.

1.6 Outline of Thesis

Chemical fertilisers and other agrochemicals have the potential to jointly produce an increase in agricultural productivity and off farm impacts. In order to provide enough fertiliser to compensate for natural variation in weather patterns, agricultural producers may apply amounts in excess of crop requirements and soil absorption capabilities. Risk-aversion thus leads agricultural producers to use agrochemical inputs in amounts that may lead to the degradation of downstream environments. Given that most agricultural chemicals are in-expensive, individual producers may overuse and currently do not have any incentive to minimise impacts on others from their production decisions. Spillover effects are caused by this lack of signal back to farmers about the negative consequence of chemical use. In Chapter 2 the economic basis of pollution mitigation policy for marine protected area management to reduce the joint production of agricultural goods and environmental diseconomies is outlined.

Over time managing conflicts arising from agricultural production has two facets, reducing impacts from current activity and ensuring that future development does not impinge on key characteristics of the protected area. The thesis identifies policy options applicable to future activity. New development adjacent to the near shore marine environment of Upstart Bay provides defined boundaries for an agricultural pollution mitigation policy discussion. A case study of the possible extension of the Burdekin River Irrigation Area to mainly greenfield sites south of the Burdekin River and likely downstream impacts on the near shore marine environment focuses the investigation.

The marine environment in the bay is a Dugong Protection Area. As a marine reserve it is a dynamic fluid environment subjected to waves, tides, currents, river flows and creek flows. Such openness to impacts reduces the level of protection usually endowed by declaration as a habitat sanctuary. In Chapter 3 the process used to select the case study area and the key features of the case study area that are germane to discussion of pollution mitigation policy is outlined.

Anthropogenic activity such as agricultural development in close proximity to the habitat of dugong involves risks to seagrass beds. New agricultural development and resulting additional pollution loads have the potential to reduce the recovery time between major flood events by introducing dry season flows and the potential to deliver pollutants closer to remnant seagrass beds. It is assumed that the risk of accelerated environmental change increases as a result of new development. Specifically, that new development may lead to decreases in the distribution, species diversity or density of seagrass meadows in Upstart Bay from potential dry season flows and higher concentrations of pollution due to proximity. Policy options available to mitigate social externalities arising from terrestrial land uses that impinge on dugong protection strategies will be influenced by characteristics of the area. In Chapter 4 the characteristics of the study area used as a basis for informed judgements of pollution mitigation options are outlined.

Agricultural pollution mitigation policy could involve the use of constructed wetlands to treat drainage waters or retention ponds to control the timing of pollution loads. Using constructed wetlands for treatment of irrigated area drainage employs biochemical processes by transforming pollutants to a relatively benign state.[1] An alternative is to use retention ponds to control the timing of pollutant loads. Using retention ponds to mitigate irrigated area impacts involves the containment of dry season flows and the holding of first flush rainfall events for later release. The level of environmental protection resulting from altering the timing of pollutant loads is uncertain.

Despite uncertainty about the level of environmental protection, public benefits are expected to accrue to society from an increased likelihood of lower environmental impacts. Sufficient detailed scientific information on the near shore marine ecosystem of Upstart Bay does not currently exist to make precise predictions for dugong habitat protection. However, informed judgements about likely pollutant concentrations, the

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[1] However transformation of phosphorous (a farming fertiliser and ecosystem nutrient) on a long-term basis is uncertain (Faithful 1997).

success of pollution mitigation methods, pollution effects on seagrass beds and the relative importance of the timing of flows provide the parameters for agricultural pollution mitigation policy analysis. Preventative management is a non-regret policy response to public costs. In Chapter 5 ways of sharing the burden of environmental management and explores policy options to minimise the externality burden are analysed.

The identification of policy options for the case study provides insights for the sugar growing industry as a whole, a broader scope in which more parameters become relevant for policy analysis. In Chapter 6 insights from the case study area are applied to diffuse pollution mitigation policy. The Productivity Commission investigated non-point source agricultural pollution abatement policy on the basis that diffuse sources are now the most significant sources of water borne pollutants in catchments draining into the Great Barrier Reef (Productivity Commission 2003). Examining pollution mitigation for a specific geographical area involves considering how the policy provided incentives for compliance. The Commission emphasised an integrated natural resource management approach, involving the community in setting targets and selecting economic instruments. Whilst local community involvement in such processes is acknowledged as a vital part of policy implementation, economists have further contributions to make in developing practically feasible policy options. The protection of environmental resources will likely require a combination of instruments such as regulatory options that can deal with nonpoint source pollution and market based instruments such as tradeable permits or auctions which provide incentives for compliance.

Chapter 7 contains a summary and conclusion. Further research to ascertain societal values for Dugong Protection Areas would inform policy design, allowing specification of implementation and administrative settings. Undertaking empirical investigation of the full range of environmental benefits is vital to balance private interests with social benefits when determining appropriate mitigation policy conjointly with significant public expenditure on irrigation infrastructure. However, undertaking such valuation for the environments adjacent to every future development would be cost prohibitive.

Chapter 2

Economics of Marine Protected Area Management: Why Mitigate Transboundary Effects

2.1 Introduction

The current agricultural production-environment interface creates a divide between interest group positions on the effects and risks posed by development. Policies to minimise potential environmental impacts mediates interest group positions. Economic input into policy deliberations seeks socially optimal responses attempting to consider the value of natural resources in agricultural development decisions. Land use activity upstream of a marine protected area may alter the natural setting and impose costs on individuals and society that are not offset by commensurate increases in benefits.

In order to identify appropriate pollution mitigation policy options, the economic aspects of the pollution problem are outlined. The economic analysis of protected area management involves several facets of which only three are discussed here. Firstly, it requires exploring the public good nature of environmental resources to explain overuse; secondly, examining externalities to conceptualise how other market transactions may impact on environmental goods and services; and lastly, describing how management of marine protected areas must address transboundary issues by examining property rights. The economic basis of mitigation policy for marine protected area management is the probable magnitude of the protected area's marginal environmental value.

Considering why environmental damage might occur in Queensland's coastal zone is an application of environmental economic theory. The field of environmental and natural resource economics is gaining mainstream acceptance. Keynes commented on the way in which economic theory appears to influence policy.

> "I am sure that the power of vested interests is vastly exaggerated compared with the gradual encroachment of ideas" (Keynes 1964, p. 383).

2.2 The Environment: a Public Good or a Common Pool Resource

Does social welfare depend upon consumption and the environment?

Economic growth can be based upon natural resource transformation. Using the environment as a resource includes harvesting natural substances such as mineral deposits or raw materials, cultivation of land and harvesting of forests and fisheries. In addition to being inputs to production, environmental goods and services provide benefits such as amenity value and waste assimilation (Hanley *et al.* 2001). Non-use values include the option to visit the area in the future, other option values, the enjoyment of knowing future generations will be able to enjoy an area and existence value (Pearce and Turner 1990; Tietenberg 2000). Thus society derives value from natural resources transformed for consumption as well as in their natural state. Management of resource use warrants investigation because social welfare depends upon the collective value of natural resources in these various forms.

Goods that are non-excludable and non-rival are termed public goods (Cornes and Sandler 1996). As public goods are indivisible and non-excludable they are available for use by all and thus often overused by individuals. An individual can benefit from use but his share of the cost of use is borne collectively by society, so private benefits will outweigh his portion of the social cost. For example, waste goods decrease social welfare because of the impairment of public good qualities of the receiving environment, just part of the economic cost of pollution. A particular individual who benefits from using open waterways as a waste sink has no motivation to protect them from harm or misuse. The decrease in utility an individual causes by polluting (only his share of the social cost) does not outweigh the private benefits from the polluting activity.

The value placed by society on our natural resources encompasses many public goods and services. Examples of valuable public environmental goods and services include; mangrove habitat's ability to process nutrients and filter silt; forests acting as a store of carbon; and watersheds retaining water to reduce the frequency and severity of floods. Public enjoyment of environmental goods and services means that creeks, rivers and marine resources are often owned collectively, and benefits from use or non-use are not restricted to a particular individual or group.

The economic nature of the benefits from environmental goods and services is thus somewhat different to goods that are traded in markets. The total societal enjoyment of public goods, such as the amenity of natural forest, cannot be discovered in the same way as enjoyment from consuming a tin of baked beans. Prices paid by consumers reveal the marginal value in consumption of goods that are frequently traded in markets. However, the absence of markets does not permit similar assessments to be made for most non-consumptive uses of natural resources.

If people have preferences for environmental assets, why is there no market where individuals can seek to enjoy the benefits? The inherent characteristics of goods and services such as those that flow from the environment do not lend themselves to private transactions. With no distinctive 'commodity' to trade, there is no market. The characteristics of being able to exclude others from free consumption and being able to specify exactly what is being consumed (the source of value), or rather the inability to exclude others and create rival goods is the key to the problems associated with public goods. If one individual seeks exclusive access to some part of a native forest for conservation, some aspect of that preservation allows others to derive benefit from knowing that it exists; thus free riding occurs. Non-excludable and non-rival goods are unlikely to ever be tradeable.

Public goods are often thought of as common property. The tragedy of the commons (common property) involves a resource to which a large number of people have access. Each user faces a decision about how much of the resource to use. If all users act with restraint then the resource can be sustained. The dilemma is if you limit your use of the resource and your neighbour does not, then the resource will collapse and you have lost the short-term benefits of taking your share without gaining any long-term benefits (Hardin 1968). If exclusion is costly and one person's use subtracts from what is available to others (divisible, rival or subtractable) then rules are needed to govern resource use. Common property differs from pure public goods in that they are rival. However the rules governing resource use can allow open access, failing to safeguard resource value as there is no incentive to avoid 'free riding'.

The economic discourse on common property describing resource use conflicts often doesn't explicitly recognise different facets of users' constraints as a quintessential component of the problem rather than just economic motivations (Dietz *et al.* 2002).

Where social norms and values are important mechanisms that can be used to control access, rather than creating property rights. 'Common-pool resources' is a multi-disciplinary definition of the situation where it is hard to exclude users from the resource. The cross-disciplinary discourse goes beyond assuming economic rational self-interest to describing the complexity of user interactions involving human motivation, rules governing the use of the resource and the characteristics of the resource. Common pool resource management recognises that human motivation is complex. Values and altruism can overcome free rider problems in social dilemma situations (Falk *et al.* 2002). Social norms can encourage individuals to act in a manner consistent with social goals, particularly where face-to-face interaction with the community occurs (Kopelman *et al.* 2002). The common pool resource management approach also highlights that a cooperative approach can be enhanced by a realistic individual vision of the future as it leads to a sense of what kinds of collective restraint are required (Wilson 2002). Decreasing perceptions of uncertainty about likely environmental consequences can increase cooperation by creating a situation where users see restraint as rational (Kopelman *et al.* 2002).

Public goods will not be provided by individuals, and thus if society values the benefits from environmental goods and services that are non-excludable and non-rival policy consideration is warranted. Because many pollution impacts are on public goods the government often intervenes. The economic benefits of environmental goods and services are not likely to be fully uncovered by free markets alone and so in considering the basis of mitigation policy the analysis next examines the problem of value.

2.2.1 Valuing Environmental Goods and Services: Ascribing Importance

The characteristics of many environmental goods and services do not facilitate trading in markets. Many environmental benefits are not traded in a market and thus are not valued by the normal market mechanism that determines prices and costs. Without trading in markets, estimating the value of the benefits and costs associated with the goods and services becomes problematic. Problematic not simply because estimation of the socially optimal level of provision is necessarily imprecise (and thus potentially costly) but because in the very act of attempting to measure something not traded in a market the results lose universal acceptance, particularly when comparing with private benefits. However, the economic value of environmental goods cannot be ignored just because the method of estimating the benefits is disputed. At the very least, environmental goods have value because of the opportunity cost of foregone benefits (Pearce 1983).

Economic analysis of policy options seeks to provide information for the efficient allocation of environmental resources amongst alternative uses. If society is to manage public costs from decreases in the flow of environmental goods and services then it needs to find a way to incorporate them into policy analysis. Economists faced with evaluating public goods (or common pool resources) and private goods with seemingly different spheres of value have derived ways of eliciting community preferences for these goods (Hanley *et al.* 2001). Eliciting preferences for utility derived from use or non-use (or both) is one way to estimate the economic value. Economic analysis of the marginal costs and benefits using elicited (stated) preferences can inform policy deliberations on environmental goods.

Stated preferences seek to reveal a consumer's desire for a particular attribute without a transaction taking place. A survey technique known as contingent valuation seeks to emulate a private goods market (Mitchell and Carson 1989). In its basic form a question is asked about how much a respondent is willing to pay for a particular change. For example, 'Would you pay $5 per week for the preservation of a unique wetland?' Asking people directly to value public goods is an approach that has been developed over the last forty years. Issues such as strategic behaviour by respondents (for example free riding discussed above), the novelty of valuing a public good and experimental bias have been debated (see Mitchell and Carson 1989 for a summary). A survey has to provide information about a good in order to ascertain preferences. Because consumers do not usually make decisions about purchases via information provided on a survey, they may have difficulty stating their true preference.

Another approach aims to estimate consumers' utility through more complex modelling of trade-offs, called choice modelling. By presenting a larger number of alternatives within different scenarios, the response of users to changes in goods or services can be observed. Choice modelling assumes the decision maker selects the alternative with the highest utility from the available set (Ben Akiva and Lerman 1985). This is a more comprehensive method, allowing consumers to consider bundles of goods. This approach may be more familiar to consumers, who are used to choosing between competing alternatives.

Tools such as contingent valuation and choice modelling rely on hypothetical considerations rather than actual compensation. Conflicts between private and societal interests often involve market benefits and unpriced environmental values. Because private transactions result in monetary benefits, it often happens that collective preferences for the environment do not always have the same influence on policy deliberations as private benefits. Perhaps partly due to the concentration of benefits from environmental goods being less than that for private interests. For example, preferences for preservation of unique desert marsupials might have widespread support, but when competing against a few agricultural producers with organised political influence, may lose out.

Given that the process of government policy formulation involves the interaction of interest groups, some policy decisions may impinge upon the preferences of many for the benefit of a few. Strategic behaviour by interest groups to secure private benefits may result in significant social costs (Mallawaarachchi 2000). There are many games involved in the governance and ongoing management of environmental resources (Dietz *et al.* 2002). The combination of a lack of individual incentives to contribute to the protection of environmental values and the different spheres of value increase the complexity of the governance problem, compounded by transactions for other goods and services affecting environmental goods.

2.3 Externalities

Why the production and consumption of some goods may not reflect their full social impact?

The characteristics of environmental goods and services not only imply the absence of markets but also indicate potential for the lack of accounting for impacts on environmental goods and services in the production of other goods and services affecting the quality and or quantity of natural resources. Private transactions to produce and consume goods and services can thus decrease social welfare. For example, the production of waste as a by-product of a process that yields valuable goods or services requires disposal or reuse. If such waste is disposed of as landfill, it may create external impacts such as smell and visual amenity at least in the short term. There are also other less apparent ways in which private transactions can impact upon public enjoyment. For example, if an agricultural activity impinges upon water quality resulting in contamination of a valuable fish habitat, then an individual who enjoys fishing will be disadvantaged to the extent that he may catch fewer fish as a result. Public benefits from the environment are prone to these spillover effects resulting in a change in public use and/or non-use values. As these effects do not feature in the economic transaction for the private good or service they are called externalities (Baumol and Oates 1988). If the net social benefit of the private transaction is less than the net private benefit, there is a public diseconomy, an externality with a net social loss.

The evolution apparent in economic thought conceptualising the problems of externalities is highlighted by the seminal work of Pigou and Coase. Pigou (1932) argued that taxes could be used to correct the externality for a net social benefit. The externality could be internalised by recognising joint production and seeking the social optimum by imposing a tax giving guidance as to the social costs. Setting a tax so that the quantity of the good produced falls to a level where the social costs are met results in an efficient outcome, if one can accurately identify the social cost. This recognition of the externality and proposed action to maximise social welfare was a significant policy revelation. The limitations of such taxes are further explored in Chapter 5. However, this first best approach has limitations in applied analysis. Where policy makers do not have full information, or in the presence of market distortions, policy tools will be second best in their attempt to produce socially optimal results (Lipsey and Lancaster 1956).

Recognising that owners of private goods claim the rights for their possession and are motivated to protect them from harm and misuse, Coase (1960) introduced the allocation of property rights as the key issue. He argued that in a world with full information, low transaction costs, and strict enforcement of contracts, the distortions resulting from an externality could be resolved by defining the rights and obligations of individuals entering a transaction. Creating a market by adequately defining and specifying property rights could result in an efficient outcome regardless of who (the polluter or the beneficiary) was allocated the property right. The role of government therefore was not to respond with direct regulation and control but rather establish the institutional framework to support property rights. A property right exists when the community supports and protects the exclusive use and enjoyment of that entitlement (National Competition Council 2001). Even if property rights can be established transaction costs can inhibit the socially optimal allocation of the good. Legal action provides one avenue for interaction between polluters and those with an interest in pollution control. However, the nature of pollution impacts on public goods with non-rival and non-exclusive characteristics implies that rarely will private interests be individually large enough to exceed the transaction costs of such an approach.

A marginal analysis of the cost of mitigation versus the marginal benefits of control reveals that the optimal quantity of pollution is unlikely to be zero in any case. For example, assume that the marginal damage caused by a unit of pollution increases with the amount emitted and that the marginal costs of control increase with the amount controlled. Inspecting Figure 2.1 it can be seen that moving along the marginal control cost curve from right to left corresponds to greater control and less pollution. The efficient allocation is easily identified at Q*, the point at which the damage caused by the marginal unit of pollution is exactly equal to the marginal cost of avoiding it. The nature of the marginal damage costs, costs to environmental goods and services, involve non market values and pose particular problems for protected area management. The potential production of agricultural commodities adjacent to a marine protected area warrants further discussion of possible externalities.

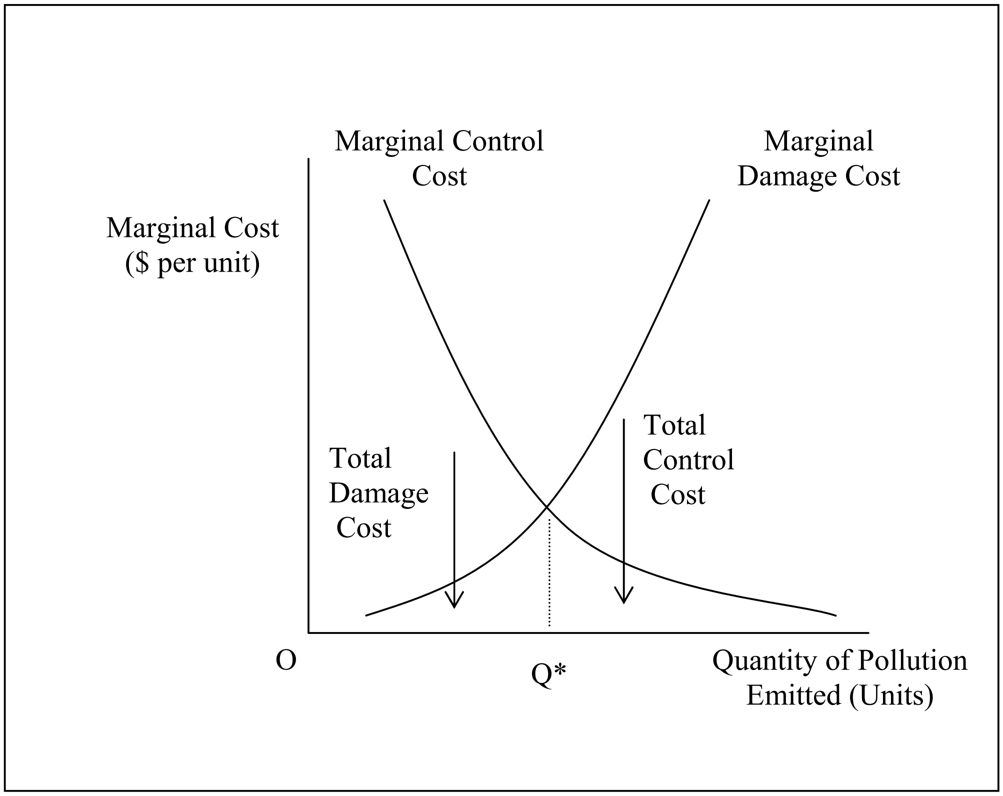

Figure 2.1 Efficient Allocation of a Pollutant

2.3.1 Agricultural Production Externalities

Increasing land area under irrigation supply fosters the development of agriculture and other activities. This development may result in positive individual economic impacts in the short term; it may also impact on the productivity of land under cultivation as well as nearby ecosystems in terms of both lost productivity and environmental quality. While such development may have private and social benefits from the production activities to justify the establishment and maintenance costs of irrigation supply, when the social costs from off site pollution (environmental costs) are included development often yields a net social cost (Mallawaarachchi and Quiggin 2001). The potential for unmitigated externalities provide a rationale for considering intervention.

As a land-augmenting technology, irrigation provides a means to enhance the productivity of land that is often considered marginal because of its location in arid environments (Jacobsen *et al.* 2002). Addition of water transforms marginal land with economic and environmental effects. The productivity of irrigated agriculture is usually enhanced by the use of chemical fertilisers and other agro-chemicals that affect geo-chemical and micro-environmental processes. Risk-aversion leads producers to overuse agrochemical inputs such as fertiliser so as to compensate for natural variation in weather patterns. Therefore artificial inputs associated with maintaining production may exceed crop requirements and soil absorption capabilities, potentially leading to the degradation of downstream environments (Jacobsen *et al.* 2002). Individuals in these situations, such as in the Australian Sugar Industry, do not currently have any economic incentive to minimise impacts on others arising from production decisions.

Irrigation externalities received government policy focus when the escalating costs of water use by all sectors attracted attention. Below cost water provision produced allocative inefficiencies aggravating the environmental damage of water use, both through inappropriate allocation of water away from the environment and through not encouraging efficient water use (Shadwick 2002). The Australian Heads of Government endorsed the Agricultural and Resource Management Council of Australia and New Zealand guidelines for incorporating externalities in the price of irrigation water as part of reform (Council of Australian Governments 1994), reinforced by National Competition Policy in 1995 (National Competition Council 2002). So called 'full cost pricing' of water used in irrigated agriculture includes the costs of its provision plus the cost of environmental harm that the use of the water (or its removal from the stream) could cause, including wastewater (Beare and Heaney 2002). Where irrigated area expansion for cane production may affect the values of a protected area, the possible net social cost from externalities warrants policy analysis of pollution mitigation. Current policy recognises the potential of mitigation alternatives to result in a net social benefit by resolving externality problems. Recent research by Shadwick (2002) into environmental externalities reveals policy remedies take a long time to achieve societal benefits.

Classifying irrigated agricultural production externalities as nonpoint unilateral externalities highlights characteristics which have impeded effective policy responses (Quiggin 2001). Nonpoint externalities typically involve many users contributing to the effort that results in environmental effects. Unilateral externalities as there is not a comparable decrease in individual utility from the action as opposed to congestion externalities in which everyone suffers.

Policy to remedy irrigated agricultural production externalities also potentially incurs transaction costs due to strategic behaviour (Mallawaarachchi 2000). Impinging upon the existing practices of agricultural producers would provoke interest group action to avoid implementation. New agricultural producers may not have established a pattern of ignoring externalities and thus policy should face less opposition. Existing agricultural producers might argue a right to pollute based upon current practices. Such an argument would carry no weight for new production activity. Mitigation policy will involve costs, exploring how to match the burden of marginal costs with the marginal beneficiaries is a practical consideration that may help to avoid strategic action by interest groups. Understanding agricultural production externalities enhances analysis of mitigation policy for the protection of areas with high environmental values.

2.4 Protected Area Management

An area is usually declared protected to minimise the impact of a particular action on a biological community or an ecosystem. Incorporating use and non-use values in policy decisions requires setting aside some portion of our natural resources to safeguard benefits that flow from the environment. Contemporary protected area management draws on these concepts and restricts access. The public good characteristics of parks and the difficulty of apportioning benefits provides the economic basis for setting the area aside (Cornes and Sandler 1996; Worboys *et al.* 2001). Designation of the boundaries to the protected area, based usually on administrative demarcations with geographic reference, do not necessarily isolate it from an ecosystem viewpoint. Therefore, despite its assignment of protective status, the asset remains exposed to forces of nature, whether influenced by humans or not, and thus faces the risk of change.

Development has led to a reduction in natural areas and a progressive build up of waste materials that pose a threat to natural ecosystems. Contraction of supply and increase in demand due to scarcity has meant that the world's protected areas have increasing value to society. However mere designation of such areas as protected areas does not ensure effective protection. Designation of areas was intended to preserve natural habitats and their species among other reasons (Jacobsen and Mallawaarachchi 2001). Activities that may impinge on the functioning of the designated ecosystem pose a threat to its management. These include both natural events such as fires, floods, droughts and cyclones, and predominantly human assisted events such as industrial pollution, soil erosion and chemical contaminations linked to agricultural land use.

2.4.1 Marine Protected Area Management

A marine protected area is an area of intertidal or sub tidal terrain, together with its overlying waters and associated flora, fauna, historical and cultural features, reserved by law (Kelleher and Kenchington 1992). Marine reserves may afford protection to species in specific ways or at critical life cycle stages rather than the full range of habitat because of high degrees of connectivity. Marine ecosystems' high degree of connectivity closely links ecological and biological processes with nearby environments (Fairweather and McNeil 1993). Natural impacts such as floods and cyclones and human events such as pollution pay no heed to artificial boundaries. Even a very large marine park such as the Great Barrier Reef Marine Park is subjected to significant ecological interactions such as oceanic upswelling, waves, tides, currents, river flows and atmospheric deposition. Agricultural activities in upper catchments have the potential to affect in-stream river habitat, and depending on biological processes may affect the near shore marine environment.

Major biophysical linkages provide a challenge to management, in terms of how to reduce opportunities for adjacent uses to diminish values. One way of achieving conservation goals under growing resource use pressures may be to allow multiple uses to continue in Marine Protected Areas. The protected area manager would seek to ensure that ecosystem processes and species lifecycles are not compromised, allowing areas for use within operating constraints, such as licences, input control, bag limits, monitoring and compulsory reporting. Other parts of protected areas might be closed off completely to public use and used for research and monitoring. This multiple use zoning is standard practice in the Great Barrier Reef Marine Park (GBRMPA undated). Managers may also seek to maintain compatible uses and to discourage incompatible uses through exclusionary mechanisms, joint ownership structures, and penalty regimes (Tietenberg 2000). Such attempts can work well within particular areas but may fail to account for transboundary aspects such as terrestrial influences effectively.

The primary problem facing policy for protected area management is that there are no effective ways of internalising the externalities across the marine-terrestrial interface.

The economic aspect of this transboundary problem is finding ways to reduce opportunities for adjacent uses to diminish values. Transboundary pollution management seeks to link inshore agricultural management activities with the value of the near shore marine environment to minimise the impacts of terrestrial activities. The proximity of the Great Barrier Reef Marine Park to extensive tracts of land used for intensive sugar cane production *prima facie* provides opportunities for joint production of agricultural goods and environmental effects. The environmental economics concepts of externalities, public goods and joint production outcomes provide a rationale for government intervention (Dasgupta 2000).

The second issue that constrains effective management is the uncertainty attached to information that relates to various processes of the complex ecosystem under management (Costanza *et al.* 1993). The natural variability of an extensive natural system such as the Great Barrier Reef makes definitive evidence of pollution effects difficult to uncover. The common law principle of testing evidence based upon the 'balance of probabilities' applied to scientific evidence favours action to prevent manifestation of detrimental impacts from pollution (the precautionary principle) (Harding and Fisher 1999). Mitigation policy for marine protected area management will not have full information, but the magnitude of the marginal benefits at risk with no action, should provide enough incentive for corrective action.

2.5 Conclusion

Free markets fail to trade many environmental goods and thus do not encourage their efficient provision. Environmental goods yield use and non-use benefits and are often overused as a result of difficulty in excluding users. Government policy consideration for the socially optimal provision of such goods is thus warranted. However policy analysis must compare the value of private benefits with the social worth of goods and services that are not traded. Differences in the sphere of value often result in under-provision of the environmental good. Market transactions in other goods and services can result in external impacts on environmental resources due to the characteristics of environmental goods and services. Agricultural production adjacent to near-shore marine protected areas has the potential to jointly produce agricultural goods and environmental diseconomies. Finding ways to reduce opportunities for adjacent uses to diminish values is a transboundary problem. The likely net social cost from externalities warrants policy consideration of pollution mitigation options that result in an increased chance of protecting the downstream environment. Policy formulations based on the social costs and benefits will likely require changes to usual agricultural practices because of the threat to the environmental values of the protected area.

A case study will be used to highlight the pertinent ecological, geochemical and production characteristics for pollution mitigation policy analysis. The process of selecting a case study area and its key features will be discussed in Chapter 3. The characteristics of the case study area are investigated in Chapter 4. Consideration of pollution mitigation policy options in Chapter 5 will extend the property right discussion here to examine the potential for creating a market based on some of the characteristics of pollution.

Chapter 3

Land Development for Cane Production in a Coastal Environment: A Case Study

3.1 Introduction

Increasing degradation of environmental systems has made society more aware of the consequences of environmental misuse and those responsible for such activities. The economic basis of policy analysis to ensure socially optimal levels of environmental goods and services was discussed in Chapter 2. A case study is used to examine the joint production of an agricultural good and environmental externalities. Irrigated area expansion for cane production may affect the values of a Dugong Protection Area through artificial inputs associated with maintaining production exceeding crop requirements and soil absorption capabilities leading to degradation of the downstream environment. In this chapter the links between dugong habitat, water quality and agricultural production are established. Current dugong protection efforts centre on seagrass meadows, which are susceptible to water quality impacts. This chapter outlines the process used to select the case study area and presents the key features of the case study area germane to discussion of agricultural pollution mitigation policy. Defining the key features of the case study lays the foundation for investigating feasible mitigation alternatives in the next chapter.

3.2 Dugong Protection Areas: Marine Protected Areas for Dugong Habitat Conservation

3.2.1 Dugong and Seagrass: An Introduction

Dugongs are marine mammals that inhabit shallow waters of tropical seas off the coasts of East Africa, Australia, India, the Philippines, and other islands in the South Pacific. Due to long gestation and suckling periods dugongs breed very slowly (Anon. 1999b). Although dugongs can live over 70 years they are particularly susceptible to environmental pressures because of their slow population growth rates (estimated at 5%) and specific habitat requirements. The maximum sustainable mortality from all impacts is estimated to be one to two percent of adult females per year (Anon. 1998).

Marine plants are the primary source of food for dugong. Adult dugong consume approximately 25 kg of seagrass per day (Anon 1999b). Dugong preferentially feed on seagrass species such as *Halodule* and *Halophila* that are low in fibre and high in available nitrogen (Preen 1995 in Lee Long *et al.* 1999). Environmental factors determine the species of seagrass that grow at particular sites. For example, *Halodule* species are pioneer plants that inhabit areas seasonally as water quality changes due to natural wet season turbidity fluxes. The presence of feeding trails indicates shallow seagrass meadows, found near shore and in estuaries, are important habitat that may be vulnerable to development activity in coastal areas.

Being relatively mobile, dugongs are known to travel hundreds of kilometres in search of food (Preen and Marsh 1995). The series of seagrass habitats along the Queensland coast may collectively allow dugong to traverse long distances and maintain genetic diversity. Habitat connectivity and distance between habitats occupied by dugong may be an important factor in maintaining genetic resilience (Marsh 2000). Dugong genetic diversity may be threatened through increased habitat fragmentation along the Queensland coastline.

Kuo (1993) explored the role of bacteria in nitrogen fixation and uptake by tropical seagrasses. Kuo suggests a synergistic relationship in the root area of seagrass whereby seagrass roots act as hosts to bacteria that fix nitrogen from the water column and may allow for its uptake in seagrass. Moriarty and O'Donahue (1993) found that among other sources, bacteria in the rhizosphere (root zone) contributed most nitrogen fixing activity. This relationship explains how seagrass ecosystems are adept at surviving in oligotrophic (nutrient poor) ecosystems (Koike *et al.* 1993)[1]. Healthy seagrass ecosystems may be susceptible to nitrogen pollution and other anthropogenic influences (Lee Long *et al.* 1993).

Nutrient enrichment causes epiphytic[2] growth, and combined with decreased light intensity due to turbidity, can result in seagrass degradation. Turbidity, sedimentation, herbicide runoff, sewage, detergents, heavy metals, and other pollutants are threats to seagrass ecosystems (Marsh *et al.* 1999). Extreme weather events such as cyclones and

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[1] Tropical oceans are typically nutrient poor.

[2] Epiphytic – in the canopy. Seagrass meadows can be thought of in the same way as terrestrial forests. They have similar structural characteristics. In seagrass ecosystems algae grow on seagrass trunks and leaves.

floods can cause large-scale seagrass loss (Preen and Marsh 1995). Stressors such as pollution increase seagrass susceptibility to disease and impinge upon its ability to regenerate after natural perturbations.

Queensland's tropical seagrass ecosystems exhibit variability in abundance and distribution (McKenzie *et al.* 1998 in Lee Long *et al.* 1999). In addition, Queensland's tropical seagrass species (eg. Halophila, Halodule and Zostera spp.) appear to recover from losses more quickly than temperate species (Clarke and Kirkman 1989, and Poiner and Peterken 1995 in Lee Long *et al.* 1999). Thus it is not a simple matter to discern anthropogenic impacts from natural perturbations.

3.2.2 Protecting Dugong Habitat

Threats to dugong include habitat degradation and loss, mesh-nets, shark nets set for bather protection, hunting, boat strikes and defence training activities. Examples of direct impacts are; netting (dugongs breathe air, being caught in a net causes death by drowning) and mortality from boat impact (dugongs are relatively slow movers through the water and surface for air frequently). Land use impacts on seagrass beds (sewerage and other pollutants) include altering seagrass meadow distribution and composition. Increased rates of habitat change as a result of human activity may exceed the ability of dugongs to evolve and adapt to accelerated environmental changes.

Dugong decline around the world has been attributed to accidental death, human harvesting and habitat destruction. Although their protection is widely supported, dugong habitats in Asian, African and Pacific regions are less well targeted for protection due to other conflicting human development priorities (Jacobsen and Mallawaarachchi 2001). Australia's economic development status places it in an opportune position to contribute to dugong conservation. Fortunately significant remnant populations occur in Australian waters. The Great Barrier Reef World Heritage Area contains an estimated 15% of Australia's known populations of dugongs.

A sharp and significant decline (50%) in dugong numbers was inferred from aerial surveys in the Great Barrier Reef World Heritage Area south of Cooktown in the decade from the mid 1980's (Anon 1999d). The Great Barrier Reef Ministerial Council responded to these reports by seeking to protect known dugong habitat areas. In August

1998 the Great Barrier Reef Ministerial Council finalised the establishment of dugong sanctuaries in the southern Great Barrier Reef region (Anon 1999c). Sixteen Dugong Protection Areas (DPAs) along the Queensland coast were declared in January 1998. Seven of these areas are zone 'A' with restrictions on types of netting aimed at reducing fatalities from drowning. Offshore set and drift nets, foreshore set nets and river set nets can be used with altered practices in zone 'B' DPAs.

Selection of the DPAs and their boundaries were on the basis of scientific advice that considered species abundance, seagrass status and geo-spatial issues that required some connectivity to facilitate gene flow, re-colonisation of depleted areas and access to remote food sources in the event of local fluctuations. However, these decisions were taken within constraints imposed by a paucity of relevant scientific information (Oliver and Berkelmans 1999).

The Great Barrier Reef Marine Park Authority recently conducted a risk assessment of Dugong Protection Areas. The factors they considered could impinge on the health of seagrass beds (Schaffelke *et al.* 2001) were:

- Presence of the mouth of a major river inside the DPA,
- Influence of the Burdekin or Fitzroy Rivers,
- Presence of an urban area close to the DPA,
- Presence of an industrial area or port close to the DPA,
- Fertiliser use on adjacent catchments (kg N/1000 ML^{-1} & kg P/1000 ML^{-1}),
- Pesticide use on adjacent catchments (g/ha), and
- Sediment export from adjacent catchments (estimates).

The assessment of threats to seagrass ecosystems underscores the nature of pollution threats – primarily carried by water. Environmental factors determine the species and extent of seagrass that grow at particular sites. Agricultural pollutants such as dissolved nutrients, pesticides and suspended sediment have the potential to affect the species composition of seagrass and the extent of seagrass beds that may serve as dugong habitat. Declaration of the DPAs was a significant step recognising the social values of dugong protection, but did not afford habitat protection from pollution. If habitat within the DPAs becomes degraded, dugong will not frequent those areas and the public benefits of these protected areas will diminish.

3.3 Selecting A Case Study of New Agricultural Development

Anthropogenic activity such as agricultural development in close proximity to habitat of dugong involves risks to seagrass beds; thus, in selecting a study area, several areas likely to involve future agricultural activity were considered. There are seven zone 'A' sanctuaries and eight zone 'B' sanctuaries (Anon 1999a). To find the most suitable setting, this study compared dominant characteristics, information availability and close location of a potential cane production area. If the area was to be selected solely on the basis of its importance as dugong habitat, the extensive seagrass beds of Hervey Bay (Preen *et al.* 1995) might figure as a prime study area. To perform an economic analysis of policy options for pollution mitigation it is more important that agricultural sources have the potential to significantly affect the ecosystem of concern. Furthermore, it is vital that a broad knowledge of agricultural pollution pathways from source to DPA is available. Probable pollution pathways from a potential irrigated area extension are likely to impact seagrass beds due to proximity. Upstart Bay Dugong Protection Area, a Zone 'A' sanctuary, provided an example of pertinent characteristics for policy analysis. This choice was also driven by the availability of information on pollution pathways and some mitigation options for a nearby irrigated cane production area with similar geochemical attributes. The potential expansion of irrigation infrastructure to Molongle Block adjacent to Upstart Bay Dugong Protection area was therefore chosen for the study.

3.4 Key Features of Molongle Block and Upstart Bay Dugong Protection Area

The nearby Burdekin River Irrigation Area is an agricultural production area where pollution pathways have been investigated. Irrigation farming in the Burdekin Agricultural Area located 90 km southeast of Townsville is based on the Burdekin Falls storage, which has a capacity of 1.86 million megalitres. Being predominantly furrow irrigated, the annual water consumption is estimated to be around 237,000 megalitres. In 2000 approximately 46,000 ha of irrigated land was used for agricultural production.

Most of the Burdekin river floodplain is irrigated and predominantly used for sugarcane production, with mango, citrus, tropical fruit and vegetable growing being the other significant farming activities. The middle and upper reaches of the Burdekin River catchment (approximately 140,000km^2) are used for beef cattle production, and in comparison the area under cane is relatively small (0.2 % of the land area; Tesiram and Broadbent 1998, and Rayment and Neil 1997). However, cane farming is an intensive activity with a high level of fertiliser and herbicide use per unit area. Significant water quality impacts are often produced as a direct result of cane production (Simpson *et al.* 2001; Hunter and Walton 1997).

The existing production area has been extensively monitored for pollution outflows. Intensive cropping in the existing irrigation area is likely to have impacted on the creek and wetland systems downstream of the irrigation area (Butler & Lukacs 1999). The Burdekin River Irrigation Area storage services limited areas to the south of the Burdekin River. Extending the Elliot Main Channel on the south bank would include supplying Molongle Block, adjacent to Upstart Bay. Molongle block is an area of potential development surrounding and between Rocky Ponds Creek and Molongle Creek (see figure 3.1). Extension of the Burdekin River Irrigation Area to these largely greenfield sites could increase downstream impacts being much closer to near shore seagrass meadows. Potentially, production could be within 2 kilometres of remnant seagrass habitat. Further expansion of the area under cane, close to Upstart Bay, would be of high environmental interest due to the proximity of the Dugong Protection Area.

The Molongle Block would probably involve development of land for sugar cane production in the order of 5,000 to 10,000 ha. Irrigation rates and methods would need to account for the likely proximity of saline groundwater. Standard irrigation application rates for sugar cane growing in the BRIA would indicate delivery in the range of 10 mL/ha. The potential design of farm drainage points for the irrigation area is further discussed in Chapter 4. Establishing appropriate drainage control structures could allow for individual farm outflow water quality measurement, a potential point source of pollution.

In Upstart Bay, seagrass beds occur in shallow intertidal waters mostly in the southern end of the bay (Rasheed and Thomas 2002, Map 2.4 and Map 2.6 reproduced below). Pollutant impact pathways in shallow intertidal areas are likely to be sediment based (high turbidity/decreased light availability), with combined impacts from nutrients and pesticides (dissolved and attached to sediment) likely to be important, particularly if they occur in the dry season. Irrigated areas have the potential to cause these types of effects by altering natural flow patterns in watercourses, producing dry season flows in streams that would otherwise dry completely. Wet season pollution events are likely to involve a significant volume of storm water and thus be diluted. The exception is the first rainfall event that results in overland flow reaching the sea. So-called first flush events are likely to contain a significant amount of sediment bound pollutants (Simpson *et al.* 2001).

New agricultural development and resulting additional pollution loads have the potential to reduce the recovery time between major flood events by introducing dry season flows and the potential to deliver pollutants closer to remnant seagrass beds. Potential expansion of the irrigation area could impact on the creek and groundwater systems adjacent to seagrass beds with possible impacts on the distribution, species diversity or density of seagrass meadows and the stability of the dugong populations dependent on suitable habitat. The Halodule and Halophila meadows can be identified on Figure 3.2 near the Rocky Ponds and Molongle Creeks. The increased risk of accelerated environmental change as a result of new development may decrease the societal value of Upstart Bay Dugong Protection Area.

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Fig 3.1 Location of Seagrass Meadows in the Upstart Bay Dugong Protection Area
(Reproduction of Map 2.4 from Coles *et al.* (2002))

Fig 3.2 Seagrass Communities in Upstart Bay Dugong Protection Area
(Reproduction of Map 2.6 from Coles *et al.* (2002))

3.5 Conclusion

Potential irrigation area expansion and associated agricultural production activities are likely to impinge on water quality. Water quality is a key determinant of the health of near shore marine ecosystems. Water transported pollutants can affect species composition, density and location of seagrass in near shore marine environments. Dugong Protection Areas recognise seagrass meadows as having unique attributes and by implication are socially valuable. A case study is used to demonstrate agricultural pollution mitigation policy analysis involving potential expansion of irrigation supply. Selecting the study area required information to be available on the potential impact pathways of irrigated agricultural pollution and mitigation alternatives. Molongle Block and the Upstart Bay Dugong Protection Area were chosen as information about water quality monitoring of irrigation drainage outflow from nearby cane production on similar soils, pilot wetland mitigation projects and recent seagrass mapping was readily available. The key features of the Molongle Block, close to the Upstart Bay DPA are; potential agricultural production will be adjacent to seagrass meadows, and seagrass meadows are sensitive to pollutants carried by water, particularly combinations of pollutants and altered timing and magnitude of flows. The characteristics of the study area will be elaborated upon, enabling the feasibility of pollution mitigation alternatives to be assessed in Chapter 4.

Chapter 4

Agricultural Pollution, Pollution Pathways and Potential Impacts

4.1 Introduction

Potential irrigated area development in close proximity to dugong habitat may lead to externalities, placing dugong and seagrass beds at increased risk. Feasible pollution mitigation alternatives considering the specific characteristics of Molongle Block, Upstart Bay Dugong Protection Area and likely production techniques is investigated in this chapter. The biogeochemical attributes of particular interest in mitigating the effects of irrigated intensive cropping include the nature of the crop, soils, irrigation method and the ecology of the downstream environment. The site's biological and geochemical features yield specific pollutant pathways pertinent to mitigation design. Agricultural pollution mitigation alternatives considered involve using constructed wetlands to treat drainage waters or retention ponds to control the timing of pollution. Use of constructed wetlands for treatment of irrigated area drainage would employ biochemical processes to mitigate pollutants but transformation and capture of all nutrients on a long-term basis is uncertain. A lower cost alternative is to use retention ponds to control the timing of pollutant loads. Using retention ponds to mitigate irrigated area impacts involves aiming to contain any dry season flows and the first flush of seasonal rainfall for later release. The level of environmental protection resulting from altering the timing of pollutant loads is uncertain. The characteristics of the study area are used as a basis for informed judgements of the preferred mitigation alternatives for environmental outcomes, the foundation of economic analysis of agricultural pollution mitigation policy options in Chapter 5.

4.2 Pollutants of Interest

Pollutants from land based activities with the potential to impact dugong populations are firstly those pollutants which affect dugong directly and secondly those pollutants which affect dugong habitat. Direct pollutants include chemicals such as polychlorinated dibenzodioxins (PCDDs). A recent study reported the levels of PCDDs found near two Dugong Protection Areas (Newry Bay and Cardwell sites) were at levels high enough to be of concern for mammal health. PCDD levels found were comparable with levels found in stranded dolphins in New Zealand (Haynes *et al.* 1999). A type of PCDD, octachlorodibenzodioxin, was also found in the topsoil of sugarcane farms. Although the exact nature of the usual spatial distribution and impact of this chemical has not been established, a preliminary study indicated that there was sufficient information to warrant further investigation (Muller *et al.* 1999) as persistent organochlorines (such as PCDDs) may pose a health risk to dugong populations. The risk may be from sediment transportation of a naturally occurring compound. As dugong feed by using their hardened upper lip to dig up the whole seagrass plant, roots and all, they may ingest PCDDs from sediments or seagrass. As the investigations did not include Upstart Bay, whether or not this pollutant is relevant is unknown.

The broad categories of commonly used chemicals that may affect habitat are fertilisers with components such as nitrogen and phosphorous and herbicides such as Diuron and Atrazine. Chemicals used previously in agriculture have included some significantly persistent and detrimental compounds. Nowadays, chemical registration regulations aim to ensure that use is restricted to designated activities and to chemical compounds with low potential for undesirable impacts (NRA 2000). The fate of a chemical applied to plants or soil depends upon its properties. Persistence is a measure of a chemical's rate of degradation and is usually measured in terms of a chemical's half-life. Solubility, sorption and volatility determine whether the compound is moved primarily with water, sediment or lost to the atmosphere.

In the aquatic environment, phosphorous suspended in the water column can provide nutrition for algae whose subsequent growth can further inhibit sunlight reaching seagrass leaves. Algae tend to have an epiphytic role in seagrass beds. In unpolluted seagrass ecosystems algae do not shade seagrass leaves enough to inhibit growth; however, with both turbidity and nutrient enrichment (phosphorous and or nitrogen) algae may overcome their host (Pollard and Kogure 1993). Anthropogenic impacts that increase water column sediments and nutrients, and thus phytoplankton or epiphyte density can lead to light attenuation and reduced seagrass survival (Dennison *et al.* 1993 in Lee Long *et al.* 2000). Elevated nutrient levels in isolation may increase the extent of seagrass beds but the combined effects of light attenuation from suspended sediments and simultaneous elevated nutrient levels can cause fatality or stress making plants susceptible to disease.

Herbicides are chemicals specifically developed to constrain the ability of a plant to function efficiently. Seagrass employs the same photosynthesis process as terrestrial plants to produce energy. As a photosynthetic inhibiting agent, Diuron has the potential to directly affect seagrass productivity. Concentrations of Diuron have been found in sediments (0.2-10.1 μg kg^{-1}) and in seagrasses (0.8-1.7 μg kg^{-1}) along the Townsville to Port Douglas coastline. As a relatively persistent herbicide (with an aquatic half life of 120 days (Howard 1991)) the potential impacts of Diuron are of sufficient magnitude to result in seagrass ecosystem impacts (Haynes, Muller and Carter 2000; Haynes, Ralph, Pranges and Dennison 2000).

Sediment has a dual effect both as carrier for herbicides and nutrients (such as nitrogen and phosphorous) and as a direct inhibitor of sunlight. All plants need light to photosynthesise. Preen *et al.* (1995) state that the minimal light requirements of seagrasses are 10-20% of incident light at the surface, much higher than terrestrial plants (0.5-2%). Seagrasses are sensitive to variation in light and mortality can occur as a direct result of reduction in light penetration. Seagrass survival at depth is directly related to the availability of light for photosynthesis. In clear seas seagrass meadows can be found in deep water (to 60 m). Dugong feeding trails have been observed at depths of 33 m (Lee Long, Coles and McKenzie 1996). Long periods of turbid water kill seagrasses.

Herbicides used in cane production close to seagrass beds have the potential to impact on seagrass beds. Fertilisers used in cane production have the potential to provide nutrients to seagrass beds. However, nutrients transported to seagrass beds are likely to be attached to or accompanied by soil particles. Suspended sediment in the water column reduces light penetration. Additionally the combination of sediment and nutrient pollution alters the competitive advantage of seagrass with algae, potentially leading to seagrass mortality.

4.3 The Seagrass Community in Upstart Bay

The type of seagrass species growing in particular locations may indicate the environmental conditions. Seagrass species in Upstart Bay include: *Halophila ovalis*, *Halodule uninervis*, *Halophila spinulosa*, *Halophila decipiens*, *Halophila ovata*, *Cymodocae serrulata*, *Halodule pinifolia*, *Zostera capricorni*, and *Halophila tricostata*

(Lee Long, Mellors and Coles 1993). Compared with seagrasses areas in waters adjacent to the Queensland coast between Cape York and Hervey Bay, Upstart Bay had the maximum recorded above ground biomass (102.9 g m^{-2} for *Zostera capricorni*), and the highest leaf area index (1.81 for *Zostera capricorni*) (ibid). The dominance of this species in Upstart Bay may reflect the ability of *Zostera capricorni* to cope with episodic high turbidity from Burdekin River outflow (ibid).

Seagrass in Upstart Bay is regularly exposed to considerable pollution events during wet season flows from the Burdekin River. Agricultural activity in the catchment (including extensive grazing and agriculture) delivers an estimated average of 2.4 million tonnes of sediment per annum (GBRMPA 2001). The freshwater plume laden with pollutants fills the bay before the prevailing winds assist mixing and distribution. Rasheed and Thomas (2002) recently surveyed seagrass distribution in Upstart Bay. The lack of a discernable reduction in seagrass extent in the Bay over the last fifteen years is taken to imply that current water quality is not causing currently detectable changes to seagrass extent in Upstart Bay. It is possible that the current environmental conditions are within critical limits for seagrass ecosystem impacts.

The seagrass distribution in Upstart Bay includes significant seagrass beds in shallow intertidal areas. Pollutant impact pathways in shallow intertidal areas are likely to be sediment based with combined impacts from nutrient and pesticides. The impacts of these pollutants would be exacerbated by their timing. Pollution delivery during the dry season would interrupt recovery from existing fluxes.

> "Chronic discharge into inshore areas during the dry season may become more significant as irrigation expands " (Congdon and Lukacs 1995, p. 86).

Irrigation drainage water alters natural flow patterns in watercourses by producing dry season flows in streams that would otherwise dry completely. Although the extent of seagrass beds in Upstart Bay appear not to have been affected by the historical pollution load, it is considered unlikely that they could cope with additional pollution events. Especially events that would reduce the recovery time between major flood events such as dry season stream flows (caused by irrigation supply or drainage) that enhance the risk of disrupting seagrass health. Reducing the duration between pollution events increase the chances that the seagrass ecosystem would not cope with existing perturbations.

4.4 Potential Agricultural Development Adjacent to Upstart Bay

Turbidity is a critical pollutant for seagrass ecosystem health (section 4.2) particularly important due to the close proximity to seagrass meadows (section 3.4). The potential is for irrigation area development to impact hydrological interactions including natural flows into seagrass habitat areas. How soil characteristics might play a role in the relative risk of new agricultural production is examined in this section. The probability of sediment transport is a function of soil characteristics (such as cohesion, dispersion, water penetration) and rainfall intensity.

The Molongle block has only been partially mapped but the initial indications are the soil is similar to north bank soils with sodic duplexes and cracking clays. Thompson (1977) mapped the soils of the area of interest at 1:100,000. Donnollan's (1993) sugar cane land suitability study (mapped at 1:50,000) disagreed with much of Thompson's interpretation as to the location of soil types. However both agreed the dominant soil types that could possibly be useful for agriculture were sodic duplexes and grey cracking clays. Sodic soils have limitations that must be addressed to allow for intensive agricultural production.

Sodicity refers to exchangeable cations and is measured as the exchangeable percentage of cation exchange capacity taken up by one ion. Soil with an exchangeable sodium percentage (ESP) greater than 6 is sodic and an ESP greater than 15 is strongly sodic. The presence of sodium as an exchangeable cation has implications for soil structure and characteristics. In particular, because of the soil structure effects, the soil's suitability for growing crops is severely limited. Cations in solution are called salinity. The properties of saline soils can offset some of the disadvantages of sodic soils. However, mobile salts require management.

Following Nelson (2001), sodic soil presents various challenges to the agriculturalist. Water permeability decreases as the surface sets hard. Sodic soil also typically has a high percentage of fine particles which limits water dispersion through the soil profile. The plant available water (PAW) content with ESP > 15 by 0.9 m depth with moderate salinity is PAW 100 – 130mm with rooting to .6 - .9 m. At ESP > 25 by 0.6 m depth and strongly saline properties leads to PAW of 70-95 mm and rooting to .4 - .6 m. Sodicity also affects cultivation practices with a narrow wetness range for effective cultivation (large clods when too dry, and boggy when wet). Sodic soil is susceptible to surface (sheet) erosion if cultivated, easily dispersing in solution. Sodicity leads to less water penetration, fine particles decrease dispersion, sodicity and salinity lead to low plant available water and shallow plant rooting. The soil is difficult to cultivate and is susceptible to sheet erosion.

Depending on the severity of these limitations, sodic soil can be economically cultivated with amelioration. Sodic soils are ameliorated with a low cost source of calcium such as gypsum to replace the sodium cations. Calcium cations have more attraction power than sodium cations and so displace them. The displaced sodium must be leached out of the crop rooting depth to improve crop growth potential. This displaced sodium, which has not disappeared, presents a long-term disposal problem. If the water table subsequently rises the salt will be brought back to crop rooting depth.

Thompson (1977) found that the sodic duplexes have a shallow B horizon with an impermeable upper band due to sodicity. ESP reached 20 – 40 at 30 – 60 cm depth. Nelson (2001) notes a yield relationship based on Burdekin soils with ESP ranging from 0 to 80 of: Yield (tonnes cane) = 175 – 2.1875*ESP. If with treatment the ESP is lowered, yields will still be affected. At ESP 6 the yield is expected to fall by 13.1 tonnes cane per hectare and at ESP 15 by 32.8 tonnes cane per hectare. Therefore the effect of limitations including low plant available water, surface crusting and susceptibility to sheet erosion is expected to be significant on the sodic duplexes of the Molongle Block.

Thompson (1977) also found that in general the cracking clays have lower sodicity but are saline at depth. The percent of fine particles in the soil would potentially lead to water logging especially given the 'intense nature of the wet season rainfall' (p54). Thompson concludes that the difficulties for managers are not confined to dealing with one soil type in a particular location. Significant soil variability would present a challenge to amelioration strategies and irrigation practices. Donnollan (1993) on the other hand was more oriented towards supporting irrigation development, noting that 70 % of suitable land (from Yellow Gin Creek to the Elliot River) was cracking clays. Donnollan counted large contiguous areas between Rocky Ponds and R.M. Creeks as suitable for furrow irrigation, whilst acknowledging that these areas are not uniform with prior streams and fans dissecting the cracking clays. Such complexity raises doubt about whether irrigation area design could incorporate viable size farm divisions coincidentally with contiguous parcels of suitable soils.

Bohl *et al.* (2000) developed a nitrogen budget for a small catchment in the Ingham area (on flood-plain soils). Of the 170 kg N/Ha average applied to the crop, 15 % was lost to groundwater recharge, 5% moved through the soil profile and by difference 37% was lost in gaseous form and in runoff. Given a nitrogen loss ratio of around 50%, the potential for clay particles to adsorb nitrogen, and sodic duplex susceptibility to sheet erosion, there is a significant likelihood of nutrients attached to sediment being important non-point source pollutants from sugar cane production in the Molongle Block.

Artificial inputs associated with maintaining agricultural production may exceed crop requirements and soil absorption capabilities, potentially leading to the degradation of downstream environments. The type of agricultural pollutants of interest for seagrass health are those transported via water transported pollutants. Overland transport of pollutants is considered here although seawater-groundwater interaction / intake areas may be implicated. Soil characteristics such as the percentage of fine particles, sodicity and soil type complexity increase the risk of environmental impacts. Sodic soils present many challenges for irrigated agricultural production, including reduced infiltration which translates to higher pollutant availability for transport.

4.5 Irrigated Agricultural Pollution Mitigation Alternatives

The implications of the characteristics of the Molongle Block for interventions are considered in this section. The offsite environmental effects of irrigation development depend on the method of irrigation delivery, irrigation application and the management of wastewater flows. Focusing on management practices of irrigated activity is an important component of pollution mitigation policy. Impacts relevant to seagrass protection associated with the nature of irrigation water supply and the nature of wastewater management are considered here. Impacts from wastewater flows will depend on pollution concentration, a function of land use and management practices. For example return flows from irrigation contain a large proportion of the salt load in the Murray River (Heaney and Beare 2001). In past irrigation developments three water supply delivery mechanisms have been used: constructed channels, existing waterways and groundwater management. Groundwater management can involve the direct use of soakage (intake) areas to recharge groundwater for use by pumping, or accounting for losses through the soil to groundwater and allowing pumping.

Irrigation delivery via existing waterways has the potential to alter natural flow patterns in watercourses by introducing dry season flows in streams that would otherwise dry completely. The particle size of suspended sediments in Burdekin River Irrigation Area water is very small and soil chemical properties allow particles to remain in suspension for long periods (Fleming *et al.* 1981). If turbid Burdekin irrigation water is delivered to farms via streams then stream ecosystems will be affected and the near shore marine environment would be at higher risk of pollution. Introduced flows will increase the proportion of fine sediments in the streambed. In seasonal flood events the nutrient and sediment load delivered to the near shore marine environment would likely be increased due to this build up.

Wastewater from flood irrigation is water that collects at the end of crop rows and is usually collected in a drain. Farmers may prefer to construct tailwater recycling pits to collect and reuse this water. Wastewater can contain suspended sediment, nutrients, herbicides and organic matter originating from the cropped areas. Without wastewater drains rain falling on cropped land may also result in runoff containing these pollutants. The rainfall event may be of sufficient magnitude to carry pollutants directly to streams, or may collect previously mobilised particles and deliver to streams (Post *et al.* 2001). First flush events typically occur early in the wet season and cause higher concentrations of pollutants (sediment, nutrients and herbicides) to reach streams and the near shore marine environment (Armour, Hunter and Simpson 1999).

> "… increased nutrient concentrations have been detected (in the BRIA) following major storm events, and storm runoff makes the greatest nutrient contribution to the coastal marine environment at present. Also associated with storm events is a large increase in total suspended solids" (Congdon and Lukacs 1995, p. 93).

The risk of environmental pollution associated with infiltration would be lower than that of run-off because of the potential for filtration and bioremediation as it moves through the soil profile. The focus of this analysis is on management of pollutants carried by overland flow.

Any type of pollution control system seeks to intervene in one of three critical elements; availability, transport or delivery. If intervention in the availability, transport or delivery of pollution is successful, the effect of pollution can be minimised. As production of pollution obeys the law of conservation of matter, waste production can be reduced by more effective use. Focusing on management practices as a way to reduce the availability and transport of pollutants is an important component of mitigation policy considered further in Chapter 5. Finally pollution may be captured before it reaches the protected area.

The pollutants of interest that may be available include fertilisers and herbicides. Another potential impact would be from introducing dry season flows via irrigation delivery instream or groundwater interactions. The transport of pollutants is likely to be overland, carried in wastewater. Thus mitigation alternatives involve intervening in the delivery of pollutants.

4.5.1 Constructed Wetlands

The biophysical properties of natural processes may be manipulated for mitigation. Constructing wetlands aims to simulate natural environmental conditions in which filtration and bioremediation can occur, seeking to transform pollutants to benign forms. Constructed wetlands are commonly used to treat urban wastewater such as effluent, general drainage and runoff. The ability of constructed wetlands to remove levels of pollutants found in these and industry environments is well documented (Mitsch 1993; Moshiri 1993; Lawrence and Breen 1998; Cardoch *et al.* 2000). Indeed they have been applied in agricultural settings (Raisin 1995; Hunter and Lukacs 2000; Interagency Workgroup on Constructed Wetlands 1999). However, the ability of constructed wetlands to filter out lower levels of pollutants, particularly over longer time frames with the geochemical characteristics of the study area, is not well established.

Given appropriate residence times, wetlands have the potential to remove significant amounts of nitrogen products (Moshiri 1993). The natural processing of nitrogen by plants into nitrogen gas and ammonium requires lead times for the levels of dissolved nitrogen (nitrate) to reach acceptable limits. Wetlands have been used to transform phosphorous in peat soils in Florida (Mitsch and Gosselink 2000). However, the ability of wetlands to transform phosphorous is uncertain over a long time period in sodic soils. The physical properties of the soil in the study area allow fine particles to remain in suspension for long periods of time as they have very slow settling rates. Conventional settling rates based on Stoke's Law do not adequately represent the ability of the fine clay particles to remain in suspension despite long residence times. The characteristics of suspended sediment in the study area indicate very long residence times would be required. This would lead to a larger wetland volume and thus higher costs. During wetland establishment phosphorous is used for plant growth. As the amount of phosphorous used by algae is limited, after the wetland is established, pathways for phosphorous transformation are limited (Faithful 1997).

Biological processes in natural wetlands have the potential to transform, use and retain some level of nonpoint source pollutant flows. Processes such as adsorption of fine particles on biofilm (attachment) and transfer to sediment, and epiphyte uptake of dissolved nutrients take time (Lawrence and Breen 1998). Without strict regulation of loading rates and consideration of the storage capacity of wetlands, using wetlands to treat wastewater can result in the wetland using pollutants as well as being a net source of nutrients from time to time (Hunter and Lukacs 2000). Using systems specifically designed and constructed to treat irrigation drainage water could result in more efficient harnessing of these processes (through control of the flows and concentrations entering the system) but may not diminish the intertemporal variation of effectiveness. Thus a retention pond may provide more control over the timing of pollutant loadings at lower cost.

Wetlands have the potential to be highly effective in treating relatively high levels of pollutants as found in effluent wastewater. However environmental levels of agricultural pollutants are quite low and wetlands are not as effective in 'polishing' lower levels of pollutants. Constructed wetlands may not lead to effective mitigation of irrigated agricultural pollution as: at times they can be sources of pollution; they may not transform phosphorous after the wetland is mature; and, fine sediment particles may remain in suspension through the wetland. Thus alternatives to constructed wetlands may be more reliable at lower cost.

4.5.2 Retention Ponds

One alternative to capturing wastewater flows for treatment is to merely contain wastewater and the first flush of rainfall for later release. Retention ponds may allow for limited sediment settling, but the main benefit is derived through controlling the timing of pollution. Ponds designed to retain water would have lower maintenance costs than constructed wetlands. Capturing and storing dry season flows and first flushes allows control over release, giving opportunities to mix with high flow events, reducing the concentration of pollutants. Yet, seagrass ecosystems are adept at trapping sediment and as one pollution transport pathway for nutrients includes attachment to sediment, simply lowering the concentration of suspended sediment may not provide certain ecosystem protection.

4.6 Irrigated Agricultural Pollution Mitigation Scale

Of the pollution delivery intervention options retention ponds are likely to be at lower cost, the question of at what scale remains. Intervention could be achieved on farm or at a regional level through control of drainage outflow. Retention ponds as a mitigation device can be applied at multiple scales in the Molongle Block, ranging from one pond for the whole block to one pond per cane paddock. Given the natural drainage contours of Molongle Block and the presence of two main creeks it appears that there are two feasible scales, farm level and sub-regional level.

4.6.1 On-farm Water Storages

On farm water storages can improve irrigation management and reduce off farm impacts (Lisson *et al.* 2002). Tailwater recycling systems can be designed to incorporate drainage features to capture wastewater and the first flush of rainfall on-farm. The notable limitation in this approach is the need to rely on tailwater dams to efficiently capture and dispose of farm runoff. Managing this system would require diversion of water draining from a farm paddock into a tailwater dam. When a rain event occurs the first flush is diverted to the dam until the storage reaches capacity. Subsequent runoff that contains lower concentrations of farm pollutants would then bypass the storage. The most effective disposal method of captured water would be reuse on-farm, as it would allow an opportunity to enhance production, however this may lead to increased impacts through groundwater pollution.

Should farmers need to release this water, such releases need to be coordinated to ensure maximum dilution to minimise downstream impacts. Thus the main constraint to farm level mitigation is the costs involved in the establishment of storages and ongoing management costs in managing the coordination and timing of wastewater releases. Ongoing monitoring of farm level drainage water discharge would establish individual pollution contributions and offer an avenue to apportion costs. This could allow farmers to benefit from management practices that reduce off farm pollutant impacts.

4.6.2 Regional Treatment Facilities

An alternative to mitigation at the farm level is regional devices. If the area under development were typically designed, each farm would be approximately 100 hectares. Dividing the potential lots into sections that could share a common wastewater retention pond, there would be four sections of approximately ten farms in the Molongle Block. To establish the size of the retention ponds local data pertaining to the required volume would need to be collected. The necessary volume is dependent upon local infiltration and runoff coefficients. For example, to capture the first 40 mm of runoff in our storage would involve measuring the time it takes for the 40 mm from the most distant point in the catchment area to reach the storage intake point. By that time falls on nearer surfaces would have contributed significant volumes. This may be reduced slightly by infiltration during transit.

The costs of establishing regional mitigation structures would include construction of a set of ponds and outlets. The total cost would also include the cost of land use foregone (opportunity cost of land not available for cropping). For the purpose of illustration, the volume of a tailwater dam capable of capturing the first flush of significant rain events early in the wet season is assumed to be 40 ML (40 mm over 100 ha) per farm. At a depth of 4 metres, land foregone would be in the order of 1 per cent of cultivated land. The potential for significant groundwater interaction would occur at that depth. Also involved in mitigation are maintenance costs of reclaiming sediment from drains and the pond and water quality monitoring of farm outflow.

Management of a regional retention mitigation system would require controlled timing of wastewater release, the most difficult task in mitigation management. It is likely that either significant capital expenditure to allow remotely / automatically operated gates in the drainage system or employing labour to manually control the system would be required. There are possibly economies of scale in the control of the timing of wastewater releases, thus sub regional retention ponds may lower costs and provide a higher degree of certainty about the affects of pollution.

Monitoring farm level emissions would capture flow and water quality data for auditing and analysis. Planning for the establishment of farm outflow points does not overcome the potential for interference with water quality monitoring devices. Monitoring the downstream environment including the seagrass ecosystem, its extent and distribution would be necessary to relate the level of mitigation effort to achieve a given level of protection of sensitive downstream environments.

4.7 Conclusion

Pollution increases the risk of accelerated environmental change. When considering proposals for agricultural development in the absence of specific and detailed information about pollution effects (critical ecosystem limits and or thresholds), identifying feasible mitigation alternatives highlight pertinent issues for policy analysis. Sugar cane production in Molongle Block would most likely introduce dry season flows, and increase herbicide, nutrients and sediment pollutants in the first flush event affecting nearby seagrass meadows in Upstart Bay. Intervention in the delivery of wastewater flows is feasible. Constructing wetlands is one way to mitigate potential externalities. However the nature of wetland treatment of pollution, being to use nutrients and trap herbicides, does not permanently transform pollutants. Management of wetlands to treat agricultural pollution is therefore likely to be costly. Constructing retention ponds is another way to mitigate potential externalities from potential irrigation area extension for cane production. Retention ponds aim to control the timing of pollutants, allowing release during high flow events, reducing the concentration of pollutants. This method has the potential to be at lower cost. The policy response must be able to cope with site specific variations. How to implement feasible mitigation alternatives is the subject of analysis of policy options in Chapter 5.

Chapter Five

Policy Perspectives

5.1 Introduction

In an established agricultural production system, such as sugar cane farming in Queensland, some farmers perceive a 'right to farm' based on current practice (National Farmers Federation 2002) whilst the broader community view certain off-farm impacts as undesirable. Existing agricultural pursuits present many challenges for pollution mitigation policy, not the least of which is that the effects are generally diffuse. Diffuse agricultural pollution pathways to riverine and near shore marine ecosystems are well known yet normally present a challenge for mitigation policy because of their complexity (Productivity Commission 2003). The diffuse nature of the effects of intensive farming does not yield easily to measurement and quantification and thus it is often difficult to identify individual contributions to pollution (Intergovernmental Steering Committee 2003). Identifying individual contributions to pollution has been the foundational information set for pollution policy approaches to date in Queensland (Productivity Commission 2002). Considering environmental externalities when designing the irrigation area, allowing individual contributions to be measured, seeks to avoid some non-point source complexities. For example, output control devices such as wastewater drainage points would minimise the risk of pollution while also making ongoing monitoring and assessment feasible at reasonable cost (relating to sampling, testing and analysis).

The ability to monitor both marginal contributions to pollution loads and the effect on an ecosystem of pollution accumulation would make mitigation policy accountable and transparent, accomodating equitable cost-sharing mechanisms. For instance, if certain concentrations of nutrients or pesticides sourced off a particular farm were directly linked to a decline in an environmental good then that farm would have a clear and unambiguous duty of care to avoid actions that are endangering the environment. However, evidence of marginal changes in environmental goods is unlikely to be available given the variability inherent in natural systems. Even if it is not possible to identify the extent of environmental diseconomies associated with marginal pollutant contributions, instituting mechanisms to share the costs of mitigation may still be desirable to avoid a do-nothing outcome (Byron 2000).

In this chapter mitigation policy options that are available to address agricultural pollution in potential development of a cane farming area in Upstart Bay are explored. An economic framework is established acknowledging data limitations, qualitative factors such as addressing information asymmetry, the means of providing incentives for private actors to meet pollution mitigation obligations and the policy instrument's ability to cope with site specific variations form the basis for comparing policy options. There is an opportunity to apply more flexible instruments that the usual regulatory approaches as part of a policy response to agricultural pollution. Lessons from the case study of agricultural pollution mitigation policy are then examined in the broader context of agricultural diffuse pollution mitigation policy in Chapter 6.

5.1.1 Data Limitations

Digital data sets such as soil characteristics in geographical information system (GIS) format for the potential production area are not available. This limits the operational scope of the analysis and prevents the development of an all-encompassing case study. Additionally, sufficiently detailed scientific information on the near shore marine ecosystem of Upstart Bay does not currently exist to make precise water quality target predictions for dugong habitat protection. Therefore, anecdotal evidence for a case study area comprising informed judgements about likely pollutant pathways, the success of pollution mitigation methods, possible effects on seagrass beds and the importance of altering the timing of flows determines the parameters for policy analysis of agricultural pollution mitigation.

5.2 Economic Framework

The main lines of enquiry in economic analysis are equity and efficiency. Broadly speaking, the equity dimension of analysis involves consideration of social welfare whilst efficiency focuses on creating the necessary conditions for cost effective allocation of resources. Both lines of enquiry require information on the situation, possible policy options and the likely effects of intervention. The inherent uncertainty of ecological systems is a constraint to the development of effective environmental management options (Costanza *et al.* 1993). Lack of information is a pervasive problem in natural resource management, particularly relevant for mitigating agricultural pollution impacts. The spatial extent of agricultural activities makes gathering information difficult and costly. As a result the impact of agricultural activities on the environment is difficult to measure in a form that is suitable for scientific scrutiny. The inability to establish the scientific validity of anecdotal evidence leaves analyses subject to controversy and at risk of sustained opposition by organised lobby groups representing polluter interests. Despite such expected opposition, if government does not intervene to address externalities, the quantity of environmental goods and services available will likely be suboptimal.

Equitable reasons for government intervention include irreversibility and ecological sustainability (Bishop and Woodward 1994, Pezzey and Toman 2002). Pollution resulting from the uncoordinated actions of many individuals can produce cumulative pollutant loads that trigger observable ecosystem reactions following prolonged exposure at or above critical limits. Potential irreversibility of ecosystem reactions makes policy analysis crucial. Resource managers will inevitably face such decisions without the best possible information, thus precluding first-best policy options. Undertaking no-regret policy measures aimed at sustainable outcomes are the next best alternative. The important ecological and economic result of any policy will be that total pollution is constrained (Brunton 1999). Government intervention in the absence of the information necessary for optimality is based on the notion of sustainable natural resource use (Tientenberg 2001).

Policies addressing the tradeoffs between economics and the environment help to achieve sustainability (Bishop and Woodward 1994). National Competition Policy lists economic viability and ecological sustainability as twin tests in determining the social acceptability of commercial undertakings (National Competition Council 2002). Further, the National Competition Council endorses Queensland Government Guidelines for New Water Infrastructure (Queensland Treasury 2000), which also identifies environmental impacts and costs of implementing management plans as matters for consideration. Irrigated area extension falls within this purview and thus irrigated agricultural pollution mitigation policy options are based on equity considerations endorsed by government policy.

Governments might find it politically attractive to encourage new developments that offer agricultural production opportunities without full information on the magnitude of public costs. To achieve a net gain in social welfare from new irrigation development, considering both financial benefits and environmental impacts on the downstream environment, mitigation of downstream externalities is likely to benecessary. In the Upstart Bay example, while the irrigation development would have direct private and social benefits from production activities, such activities may impose direct and indirect private and social costs by affecting community values for Dugong Protection Area's through potential impingement on water quality. The marginal benefits from mitigating agricultural pollution in Upstart Bay from new development will accrue to commercial and recreational fishers, the Great Barrier Reef Marine Park Authority (as managers of the marine protected area), the local community and the broader community (state, country and worldwide indicated by world heritage status). Abatement policies would be socially efficient when the costs of abatement incurred by a number of producers are equal to the benefits of environmental protection achieved through abatement.

The geophysical resource and production characteristics at the project scale indicate feasible mitigation alternatives. As discussed in Chapter 4, incorporating mitigation devices in the irrigation development involves additional expenditure in terms of capital and recurrent costs as well as opportunity costs such as the direct costs of altered production techniques in terms of reduced production. In the case of a combined regional and farm-level interception scheme the establishment and ongoing costs are likely to be significant. This raises the question of appropriate cost sharing and benefit appropriation mechanisms. Given that the costs of establishing mitigation and ongoing operating, monitoring and enforcement costs are likely to be significant it is vital to investigate appropriate ways for community and private interests to share costs to avoid a do-nothing outcome.

Establishing mitigation facilities would contribute public benefits. One argument is that the public benefits arising from mitigation may be of sufficient magnitude to warrant public funding of establishment costs such as construction of farm drainage points and retention ponds. However the private benefits of irrigation development include the economic value of cane production. If irrigation infrastructure costs are to be recovered (following COAG guidelines) then so too could the costs of establishing mitigation devices, which are bulky and allow benefits over a long period of time. Ongoing mitigation costs have close linkages to private land use activity and it is desirable for those costs to be allocated to those contributing to the impacts being mitigated (polluter pays principle).

How ongoing operating, monitoring and enforcement costs could be allocated amongst producers is not immediately apparent as the production of agricultural pollution is unlikely to be uniform. Agricultural production is a function of land area under crops, soil characteristics, amelioration costs and other inputs such as fertiliser and irrigation. Off-farm transport is a function of many things, for example, soil characteristics including the propensity for surface erosion and dispersive properties, which in turn can be influenced by agronomic management. In this context, measuring individual farm wastewater drainage outflow gives rise to a number of policy options for instituting equitable cost sharing arrangements.

In determining appropriate cost-sharing arrangements attention also needs to be paid to the potential impacts of altering the structure of costs on future resource use and management strategies. For instance, asking producers to bear the costs of preventive action can increase their costs of production and lead to cut backs in pollution generating activities. Such policies can also provide incentives for technological innovations to generate environmentally efficient practices via cost avoidance. During this transition phase from cut backs in environmentally harmful activities to the availability of efficient technologies, there is often an additional cost burden on the actors with cleaner production (Jacobsen *et al.* 2002). This can affect producers, suppliers and the users of final goods if the production costs were to rise substantially as a result of environmental management costs. In the case of a globally traded commodity such as sugar which is often in global oversupply, the cost burden is likely to be far less than the benefits of environmental care that would accrue to many. However applied to a subset of producers, such policies may lead to competitive disadvantages.

Exploring policy options without full information is second best. However the potential economic cost of doing nothing is likely to be too high. Preventative management is a non-regret policy response to the threat of heightened public costs. Despite uncertainty about the optimal level of environmental protection, public benefits are expected to accrue to society from a possible reduction in environmental impacts by implementing mitigation. Pollution mitigation policy features pertinent to potential irrigated development in Molongle Block are examined next.

5.2.1 Property Rights

Chapter 2 established that property rights or the lack of them contribute to the pollution mitigation policy problem. Where existing use is percieved to bestow property rights including to pollute, mitigation policy needs to redefine the boundaries of existing property rights. There is clearly a public interest in intervention where development with greater potential to cause environmental effects occurs. The challenge for policy design for sustainable management of environmental goods is to signal the true value of the resource. Traditional policy responses such as legislating acceptable pollution limits, impose a limit on actors by the threat of penalties and prosectuion. Policy instruments such as marketable permits create property rights providing incentives for pollution mitigation.

Economic instruments are underpinned by environmental considerations and therefore the most effective approach is likely to involve a blend of incentives based approaches and regulation (Davis and Gartside 2001). Planning controls may be used to establish farm drainage points and pollution monitoring whilst a tradeable permit scheme might allow trading of pollution which is contained in regional ponds. Such a combination seeks to establish property rights for pollution where there are none existing. Thus the characteristics of property rights introduced by the policy mix include elements of exclusivity, enforceability, transferability and the right to determine use (following Scott and Johnson 1985.

5.2.2 Information Asymmetry

The information asymmetry problem contributes to difficulties in determining the optimal level of compliance for new farm developers to ensure protection of the marine environment. Policy investigations within the context of a new irrigation development where farm drainage outflow points can be part of the initial design are well positioned to eliminate some aspects of the information asymmetry problem. However, installing farm drainage outflow water quality monitoring devices is not necessarily justified for all situations. Regulatory mechanisms differ in their information requirements and costs of acquiring information, and the benefit depends upon the nature of the control mechanism (Cabe and Herriges 1992). Policy makers have access to information about the desireability of mitigation while landholders have information about the options and costs of achieving mitigation. Agricultural producers have beliefs about the desirability of mitigation efforts as well as knowledge of management techniques to reduce pollution. However they have a disincentive to reveal the least cost of particular courses of action. Policy that creates private incentives to apply such management techniques allow agricultural producers to reduce pollution up to the point where the marginal cost of abatement is greater than the gain from pollution reduction. Policy responses to externalities considered in the section 5.3 differ in the way that they deal with information asymmetry. Market based incentives such as tradeable permits create incentives to reveal private information whereas legislating pollution limits creates incentives to keep such information from policy makers, because with increased uncertainty about costs pollution limits are likely to be lower.

5.3 Assessing Mitigation Policy Options

Economic policy options include direct regulation, incentives (taxes and subsidies), information approaches and market based instruments (permits). Using the characteristics of specific situations economic analysis considers a range of economic responses to address identified diseconomies. Each situation requires analysis of which policy instruments are feasible and may result in environmental benefits (Claassen *et al.* 2001). Environmental policy objectives can only be met if mechanisms are capable of engaging the relevant agents and if they are capable of dealing with the specific characteristics of the environment under consideration (Stoneham 2000). Aspects of information assymetry and incentive alignment for each policy option will also be explored.

The option to do nothing and let the market innovate to incorporate the full social costs is not likely to reduce externalities in the case of sugar cane production. Marketing products as environmentally sustainable can be a way that markets adapt to address environmental concerns. However standards systems such as ISO 14000 accreditation and ecolabelling may not be effective in the Australian sugar industry as 95% of sugar produced is exported and competes with countries whose environmental performance may not be efficient, for example Thailand and Brazil. Thus it is expected that

Australian produced sugar already captures preferences for environmentally more sustainable practices and social concerns over production from less developed countries.

5.3.1 Direct Regulation

Direct regulation, also referred to as command and control, has historically been a measure employed after a resource is severely threatened. The command and control mitigation policy seeks to control polluting activity by direct intervention, specifying pollutant target levels and fines for breaches. Additionally regulation often specifies processes and/or equipment that must be used, allowable discharge quantities or how wastes must be treated and disposed. This approach requires intensive information about the pollutants, their effects and the technologically feasible level of pollution control. Agricultural producers have knowledge of management techniques to reduce pollution and a disincentive to reveal the least cost of particular courses of action. If via witholding such information there is some probability that the policy maker will set the acceptable pollution limit high and thus require no mitigation action, the producer has much to gain.

The command and control approach often allows pollution within attainable limits using current control methods. Regulations impose the same standard on all individuals irrespective of their ability to meet the standard or cost (Stoneham 2000). Such prescriptive regulation is relatively inflexible and can provide limited incentive (or even barriers) to the development of innovative solutions to address environmental problems. Due to their inflexibility regulations can impose high costs on land-owners, industry and the community. Prescriptive regulation can also be costly to monitor and enforce, and can be difficult to revise as technology develops and new information becomes available. Other policy approaches are usually established by statute, but their incentive mechanism is not direct control.

Regulation typically involves a government agency taking a hands-on role in monitoring and enforcement. The costs of environmental monitoring, policy administration and enforcement are borne wholly by a government agency. There is currently no explicit regulation of sugar cane production, as it is not listed as a relevant activity under schedule 2 of the *Queensland Environmental Protection Act 1994* (see also exemption in Queensland Government 2000). This is a familiar situation as non point source agricultural pollution has largely been exempt from regulation in the United States (Ribaudo *et al.* 1999, Environmental Law Institute 1998). Direct regulation of agricultural activity in Molongle Block is not feasible given the inequity of regulatory distinction between cane farming near Upstart Bay and production in other locations.

A regulatory approach that could maintain some flexibility for site specific factors are planning controls. Existing Queensland legislation such as the *Coastal Protection and Management Act 1995* could be used to enhance planning required under the *Water Act 2000* and the *Integrated Planning Act 1997*. Currently water sold at auction requires an approved land and water management plan before irrigation is supplied. The environmental requirements of this plan are not sufficiently detailed in the *Water Act 2000*. The Coastal Protection and Management Act offers an opportunity for approval of a property management plan addressing catchment issues (Intergovernmental Steering Committee 2003). Mitigating potential impacts on downstream areas at the farm level could thus be facilitated at the development stage of new agricultural production. Planning controls may provide a cost-effective and politically most acceptable solution at present given the familiarity of farmers with farm level planning tools. However, the design of coordination, monitoring and enforcement is not specifically addressed by the planning approach and thus it may best be used in conjunction with other tools. Endorsed farm level plans incorporating environmental issues such as wastewater pollution management may be an effective prerequisite for pollution mitigation.

5.3.2 Incentives and Subsidies

Incentives seek to specifically address environmental problems by providing monetary reward for changed behaviour leading to improved outcomes. The defining feature of an incentive is that the rate is fixed but the payment varies with the quantity of pollution. An example is taxes on pollution. The Pigovian tax on emissions equates the marginal private cost with the marginal social cost. To move society towards its optimal position requires price adjustment reflecting the true cost of input provision as well as an adjustment for the waste stream (Weinberg *et al.* 1991). Underpricing of the input good implies that the social cost caused by higher levels of the waste good needs to be incorporated into input taxes. That is introducing a cost of pollution provides an incentive through changing the cost structure of production functions. Thus taxes place a burden on the polluter internalising changes in environmental quality.

In Chapter 2 it was argued that the first best policy relies on full information which is not available. A second best approach is to attempt to implement pollution mitigation without full information on the costs and benefits. A tax defines the property right as pollution at a cost. Thus a tax on pollution may increase the attractiveness of mitigation practices on-farm. Encouragement of more effective management practices or installation of water storages capable of holding high pollutant concentration runoff would yield social benefits. A tax on inputs such as herbicides and fertiliser is also possible, however this approach does not provide a limit to pollution, it merely establishes a cost. Thus a tax on runoff could be levied based upon the pollution concentration and volume. However this would be very difficult to monitor because it creates an incentive for avoiding measurement.

In administering such taxes it is difficult to distinguish the specific use of farm chemicals (for the new development area) and thus such taxes are vulnerable to avoidance at the point of sale. Moreover changing the competitive advantage against the same activity in other nearby locations may give rise to political opposition. Because the land is more likely to create externalities governments can respond to those off site impacts despite competitiveness effects.

Intervention in the market for water may be a means to achieve full cost recovery. The Council of Australian Governments agreed in 1994 that irrigation water prices should reflect the full cost price incorporating externalities (Council of Australian Governments 1994). The external costs of water remain an area needing attention (ABARE 2002). Slow progress reflects the complexity of issues involved in effectively internalising externalities (National Competition Council 2002). A tax on water delivered would decrease the market value of allocation, a possible impediment to implementation. The implication of existing farming activities in the environmental diseconomy yields taxes inappropriate on its own, but may be useful in a coordinated policy response.

Taxes seek to use prices to signal more fully the opportunity costs. Effective internalisation of the social costs of pollution requires detailed information on the foregone environmental benefits (Freebairn 2000). The lack of certainty about the magnitude of marginal environmental damage makes setting a tax rate on externality production difficult. Additionally the magnitude of the abatement response to a given per unit tax by different producers is unknown leaving the aggregate quantity of abatement uncertain (Stoneham 2000).

Subsidies and rebates are payments to agricultural producers for particular actions. A rebate is to compensate for an on-farm action whilst a subsidy tries to link on-farm actions with reduced off-site impacts. Designing subsidy schemes involves selecting a mechanism for payment, specifing environmental quality outcomes and a minimum period of provision, all complex tasks. Making an incentive payment for environmental outcomes are not well suited to address transboundary externalities as there is the potential for existing production areas and other activities to affect seagrass beds. That means there are no feasible linkages to environmental goods for subsidies or direct payments in the case study area as other activities can affect the environmental good. Merely rebating control measures leaves the level of mitigation uncertain and the environmental effects unknown.

5.3.3 Information and Extension

Mitigation policy options are designed to raise awareness in the polluter but differ in the way of motivating the polluter. The incentive to change behaviour may be non-compulsory such as in most information type approaches. Information dissemination through education, extension and/or technical assistance employs moral suasion to affect behaviour. Wheeler (1997) outlines the importance of information in pollution management. The extension approach to mitigating policy is to work collaboratively with stakeholders in an effort to improve outcomes in some way. Motivational and voluntary instruments aim to increase knowledge and understanding by sharing information to contribute to improved management (Intergovernmental Steering Commitee 2003).

Information provision and extension about the nature and extent of agricultural nonpoint source pollution has not been extensively trialled in Queensland. Perhaps partly because the science of riparian buffer effectiveness in the Australian context has been slow to develop. While some studies exist citing widths for buffer effectiveness (Karssies and

Prosser 1999; Abernethy and Rutherford 1999), there is little quantitative evidence across the variety of Queensland cane farming catchments.

Given the potentially high costs involved in mitigation, on its own an extension program is not likely to achieve an acceptable level of environmental protection. Information strategies are best used as complementary policy instruments in order to achieve improvements in firms' environmental performance (Foulon et al. 1999). Davies et al. (1996) examined major voluntary programs in the US and concluded that a successful voluntary program must have a statutory base, a clear and measurable environmental objective, and be coupled with substantial financial incentives. Of the five programs they examined only two could be said to have achieved worthwhile outcomes.

5.3.4 Endorsed Voluntary Self Regulation

The community expects those industries located at the fringe of marine protected areas to demonstrate a general duty of care for the environment as required under the *Queensland Environmental Protection Act 1994*. Following an environmental audit in 1996 the sugar industry developed a 'Code of Practice for Sustainable Cane Growing' (Canegrowers 1998). Although the cane farming industry is not directly regulated, the code sought to reduce uncertainty of the definition of duty of care applicable to cane production. The Queensland Government endorsed the Code of Practice in 1999. The code is aimed at mitigating the adverse environmental effects of on-farm practices. The code is voluntary and aimed at a general level of compliance within the guidelines available in existing legislation for land clearing, soil conservation, environmental protection and waste management. The Code does not provide for independent auditing of compliance. Canegrowers Queensland have developed a workshop program to facilitate farmer application of the Code and other legislative requirements (Canegrowers undated).

Voluntary acceptance of the need to take action to protect environmental values may help to avoid future states where offending activities need to be abandoned with the associated high costs. Individual farm operators' consider investment in strategies to minimise external impacts of their land use decisions. However, voluntary action may not provide adequate environmental outcomes if the costs of implementing controls are high, especially in the presence of uncertainty about the level of compliance required to bring an effective level of protection on the marine environment.

5.3.5 Education and Incentives

A synergistic blend of education and incentives has been employed by the United States Federal Government to improve environmental performance of agriculture, focused on nonpoint source pollution. Long standing extension services provided by the US Army Corps of Engineers, the US Department of Agriculture, the US Department of the Interior, the US Fish and Wildlife Service, the US Geological Survey and the US Environmental Protection Agency administer over 28 financial assistance programs (USEPA 2001). Additionally over 29 state organisations provide financial and technical assistance (USEPA 2001). The main US government programs available to help farmers design and pay for management approaches dealing with nonpoint source pollution fall under section 319 of the Clean Water Act and section 6217 of the Coastal Zone Act Reauthorizing Amendment (Federal Legislation). These acts establish management measures such as constructing and restoring wetlands and riparian areas, and using vegetated filter strips to address nonpoint source pollution.

Management measures are defined in section 6217 of the Coastal Zone Act Reauthorizing Amendment as economically achievable measures for the control of pollutants which reflect the greatest degree of pollution reduction achievable. The objective is to settle the settleable solids and associated pollutants in runoff delivered from the contribution area for storms up to and including a 10 year 24 hour frequency event (USEPA 1993). Such management measures are implemented appropriate to the source, location and climate. Despite a vast deployment of resources and incentives to address agricultural nonpoint source pollution, it may have increased during the 1990s (Freeman 2002).

5.3.6 Market Based Instruments

Another economic policy tool is the creation of markets for environmental goods to reduce the risk of environmental damage. Economic instruments have the potential to meet social objectives more readily than regulatory options by aligning private interests with the common good. Market based instruments such as tradeable entitlements have been the focus of recent policy approaches (OECD 1999, Brunton 1999, Tietenberg

2000 and Hamilton *et al.* 2002). Tradeable permits are quantity based tools which affect the relative prices of alternative activities. Targeting the relative price should then result in changed production activity. By changing incentives appropriately designed economic instruments can encourage conservation and more efficient use of resources and hence limit undesirable environmental impacts. Markets act as a means of exchanging information where individuals respond to the marginal costs and marginal benefits of a wide range of resource use decisions (Stoneham 2000). Policies using market forces can also provide incentives for technological innovations to generate environmentally efficient practices via cost avoidance (Tietenberg 1985).

In contrast to prescriptive regulation, market based instruments do not specify a particular process or technology that may be used but allow decision makers to determine which is the best method in their particular circumstances to meet a desired environmental objective. Thus their main advantage over prescriptive regulation is that they provide consumers and industry with greater flexibility for responding to environmental concerns and they also encourage technical innovation. Policy that incorporates flexibility to allow for local differentiation can provide higher efficiencies than uniform policies for abatement (Braden and Segerson 1991).

5.3.6.1 Competitive Tendering

The Conservation Reserve Program run by the United States Department of Agriculture is an example of a subsidy tool as farmers bid for payments to provide conservation benefits for a specified period of time. The auction mechanism can be successfully used to allocate subsidies for conservation outcomes where payments are contractually tied to the protection of the environmental attributes (Stoneham 2000). In this way agricultural producers have a direct incentive to reveal the least cost of particular courses of action, specifying management management techniques to reduce pollution. However there is the problem of other activities impacting upon the environmental outcome of interest leading to no feasible measurement of environmental quality. A limit to the level of pollution is desirable, thus quantity based economic instruments may be more effective in reducing pollution.

5.3.6.2 Tradeable Permits

Market based instruments such as permit schemes effectively create new markets so that producers have incentives to control pollution at socially desirable levels (Ribaudo *et al.* 1999). Tradeable permit schemes create markets for environmental services by assigning property rights (use rights) to natural resources or environmental services. As quantity based instruments, tradeable permits have been widely deployed to target various environmental objectives such as access to fisheries, air pollution control (Tietenberg 1999) and salinity (Environmental Protection Agency 2001).

Baumol and Oates (1988) outline the essential features of a tradeable permit system. The starting point of a permit scheme involves setting a cap on pollution. A limit defined by a total quantity of pollution acceptable within spatial or temporal limits (expressed in an applicable unit). The ownership of a permit to discharge thus has value. A permit is then a property right which allows emission of a quantity of pollution in a given time period within a spatial boundary. The permit is an access right to a common good and is allocated either by auction or to existing users. Auctions involving bidding for the right, encourages firms and individuals to reveal their marginal cost of abatement (Stoneham 2000). Allocation can also be distributed to existing users (called grandfathering) to alleviate pressure from interest groups.

Jung et al. (1996) found that auctioned permits have the greatest potential for encouraging technological advances. Choosing the allocation method has a political dimension. If there are existing users, grandfathering may offer a path of less resistance. Gordon and Hatfield-Dodds (2000) examine the issue of allocation and how to best capture the benefits of tradeable permits. They found:

- 'Grandfathering' permits on the basis of historical emissions has the appeal of minimising the change that current emitters face in adapting to emission reductions.

- The use of 'grandfathering' has potential problems from high transaction costs, anti-competitive effects, and the creation of perverse incentives to increase emissions.

- Auctioning permits is more efficient as they require all emitters to pay a competitively determined price for all their emissions and minimises distortions in prices and incentives.

- Auctioned permits would place a greater financial burden on firms than ‘grandfathered’ permits as firms would have to pay for abatement control costs, as well as for the permits themselves.

- A mixture of ‘grandfathered’ and auctioned permits has the advantage of facilitating price discovery while providing an option for firms to enter the market.

Even though there are no existing users of the new development allocating permits to purchasers of irrigation in the new development could reduce the initial cost to emitters and allow agricultural producers to learn about the marginal costs of abatement.

In the Hunter River Scheme permits allow discharge of saline wastewater when the river has sufficient flows to allow mixing. The scheme started by allocating credits to existing licence holders. These credits permitted discharge for a specific length of time. Some 200 of the 1000 permits expired in 2003 from whence each two years 200 more will expire to by auctioned off (Environment Protection Authority 2003).

In the case study initial permits allocated to purchasers of land as an entitlement attached to the title encourages individuals to invest in mitigation if trade is allowed. Pollution is expected to be a function of soil characteristics and management practices, leaving opportunities for heterogenous output. Production areas, having different soils and production limitations, will allow employment of management actions to produce cane and different levels of pollution. The presence of significantly different soil properties (between sodic duplexes and grey cracking clays) should be sufficient to motivate trading. Some producers will have the ability to produce less pollution and some will require additional capacity to mitigate pollution beyond the access given by their permit. Trade determines a price for different levels of pollution, thus incentives to reduce pollution may be created. Demand for the permits is a function of individual costs of pollution control. Individual firms, not government, make the decision to reduce environmental damage based on the marginal cost of abatement (Stoneham 2000).

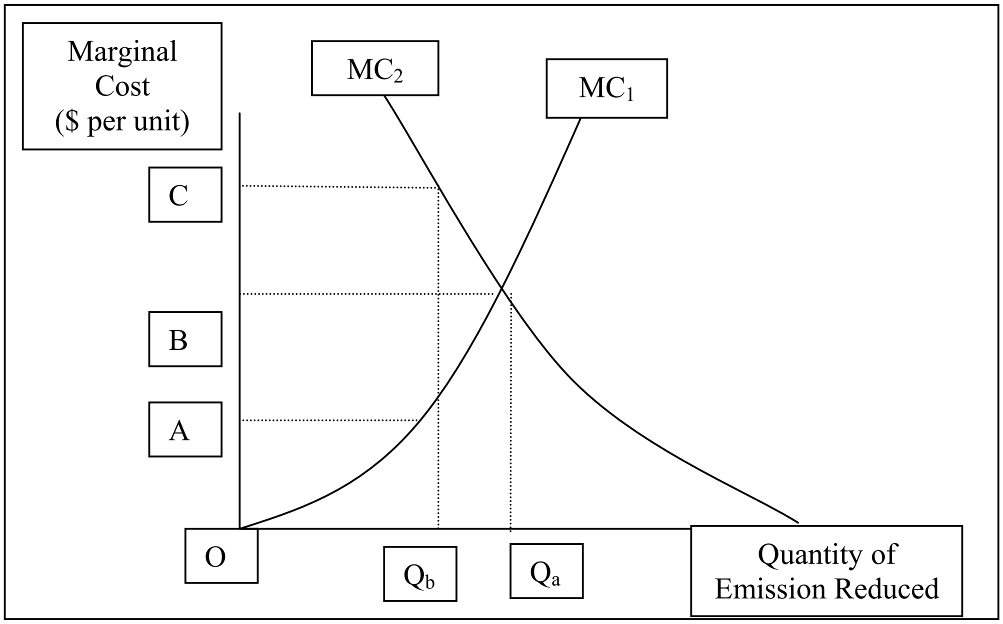

Figure 5.1 Differing Pollution Abatement Costs Among Producers

Through trading of permits amongst polluters, the use of the market mechanism has the potential to achieve any given target reduction at the lowest cost. By introducing an agricultural production cost for a level of pollution the producer has an incentive to change practices to reduce pollution because unused balances have value with a tight cap on pollution. Financial incentives ensure that degradation reductions are made by whoever can do so at least cost, and rewards them for doing so, while penalising those producers who continue to degrade the environment. Firms with relatively high costs of reducing degradation (MC_2) could buy additional permits from those firms that are able to reduce degradation more cheaply (MC_1), to mutual benefit (figure 5.1). Thus market-based instruments try to harness private interest to reduce emissions (Stavins 2001).

Low transaction costs are paramount in generating the minimum social cost of meeting a given level of pollution. Features of trading schemes such as requiring agency approval have been found to increase the transaction costs and reduce the number of trades. One way to reduce transaction costs is to provide public information on prices (Tietenberg 1998). There remains the possibility of strategic action by low marginal cost of abatement producers. Should they retain the permit then other producers would face relatively high total costs and thus be disadvantaged. Other important variables for successful trading include a sufficient cumber of actors, uncertainty and the availability of cost data (USEPA 1996). If transaction costs are kept to a minimum producers will trade their pollution permits to maximise returns.

The number of trades can be hindered by trading ratios. In point nonpoint schemes, where industrial sources are trying to adjust for factors such as relative values, leaks, safety margins and differential impacts, the trading ratio may be set higher than one (USEPA 2003). Where the scheme is only going to involve nonpoint sources within a small catchment, setting the ratio higher than one will discourage trades for no significant reason. Point nonpoint schemes also are usually employed in one watershed. Relative to agricultural pollution, the Burdekin catchment has no major industrial point source pollution.

OECD (2001) identifies key variables in the design of a transferable permit system, among which is that a reliable, cost effective and transparent system for monitoring pollutant emissions, and a means to encourage participants to comply with requirements and not to exceed the emission or abstraction level beyond allowed by the permit, such as enforcement of penalties and fines be employed. The powerful motivation of private interests will seek out any weaknesses in proposed policies. Thus control, auditing and management are crucial components of any environmental policy, particularly pertinent where uncertainties and high costs are involved.

If the government undertook the irrigation area development and regional mitigation devices were installed, a tradeable permit scheme could facilitate individual attempts at abatement. Agricultural producers within the development area would need a permit to use the mitigation facility. The first challenge of establishing a marketable permit system as a policy response to the case study is to set the limits for the aggregate quantity of pollution permissible. Following Wilson (2002) broad parameters for habitat protection to mitigate risks from agricultural production are used. Given that the location of the potential production area close to the near shore marine environment leaves little opportunity for instream biological processing of pollution, the aim is to capture all dry season flows and capture high pollution concentration events such as the first flush of rainfall of the wet season. If a regional retention pond scheme was employed some allowance (volume per hectare of arable land) would be used to establish the capacity of the pond. Emmission reductions below this limit (for example by on farm containment) could be certified as excess pollution control available for trading.

The main source of efficiency gains of tradeable permits over command and control options is due to marginal variation in nonpoint source pollution mitigation costs. Private actors' possess the detailed information necessary to reduce pollution rather than a government agency seeking the detailed information required for a command and control approach to pollution (Carlin 1992, Ribaudo *et al.* 1999). Government agencies are not in the best position to have the optimal knowledge of possible process changes, input changes, behavioural changes or all available control technologies that could reduce pollution in varying circumstances.

It is something of a paradox, that policy to address externalities, a situation of market failure may involve market based instruments. The fact that agronomic management influence off farm impacts reveals that information held by private actors is vital to effective mitigation. Economically, the way to harness such interests for the common good, is to create a market for environmental goods or services. Precisely defining the broad parameters of capturing dry season flows and first flush rainfall events will require further consideration by biologists, agronomists and soil scientists. If such a task is possible finding of an appropriate institution to administer, monitor and enforce the operation of the created market remains the only constraint.

There is currently no agency with environmental tasking in a proximate location that could manage a regional mitigation scheme. There needs to be a responsible body to administer permits, maintain monitoring, and enforce penalties and fines. Because the aim of pollution control, monitoring during dry season irrigation times and in first flush rainfall events would be required and is more cost effective than continuous monitoring. Establishing a body with the appropriate technical skills and cultural sensitivity in a rural area would be extremely difficult. An alternative would be to consult a regional natural resource management body such as Burdekin River Integrated Floodplain Management Committee to manage the scheme given appropriate resources.

5.2.6.3 Wetland Banking

Bankable rights have been employed in the United States for wetland conservation goals. Wetland mitigation banking allows a developer to build on degraded wetlands in exchange for the protection of environmental features of a wetland located elsewhere (Edmonds *et al.* 1997). This approach requires extensive investigation of the values of the wetland to be developed and other options, to ensure that unique features of the area to be developed are considered. Seagrass beds do not coincide with private ownership in the same way that land based ecosystems do. That is wetlands can occur on 'private property' whilst the State Government owns the near shore marine environment. Also, given the distance from dugong habitat to the north and south, the Upstart Bay sanctuary may be important to retain connectivity, therefore banking could result in localised environmental outcomes that are unacceptable.

5.3.7 Summary of Policy Options

Mitigation Policy Option	**Constraint to achieving objective**
Direct regulation sets water quality targets and amount of fines for breaches	Requires intensive information on technologically feasible level of pollution control (having no incentive to reduce pollution below limit, the policy can result in more total pollution). Costly to monitor and enforce. Politically difficult to revise.
Planning controls (eg. Coastal Protection and Management Act 1995)	Monitoring and enforcement of implementation or effectiveness of mitigation not addressed.
Incentives and subsidies (eg. Grant for providing on-farm mitigation)	Payment usually tied to environmental quality outcomes Potential for other activities to affect seagrass health and distribution makes contractual specification of an environmental outcome unfeasible.
Information and extension	Given high costs involved in mitigation, not likely all farmers will voluntarily implement enough changes to achieve acceptable environmental outcomes.
Endorsed voluntary self regulation	Given high costs involved in mitigation, not likely all farmers will voluntarily implement enough changes to achieve acceptable environmental outcomes.
Market based instruments – tradeable permits	The difficulty of finding an agency with credibility in the region that could administer and enforce the scheme.

5.4 Conclusion

Identifying the feasible agricultural pollution mitigation alternatives most likely to afford protection to a nearby environmental resource allowed an exploration of policy responses, despite data limitations. Concepts such as ecological uncertainty and ecological sustainability are equity arguments which justify preventative management. Seeking to understand the nature if not the quantity of benefits and costs is a no regret approach to environmental management. Applicable policy options cover the full spectrum from command and control responses, information provision, incentives and market based instruments. Such options differ in the way of motivating individuals to act in society's best interest. Within the existing regulatory framework, planning tools have the potential to provide the basis for pollution mitigation action.

Property level planning processes could be used to extend technical assistance to landholders about farm level wastewater monitoring, retention devices, and even to require their installation. However, the ongoing incentive to capture potentially environmentally detrimental flows is not established thereby. Thus combining planning tools with market based incentives yeilds multiple benefits. The policy instrument most likely to align private interests with public interests is tradeable permits. The goal of such a scheme would be to capture dry season flows and to capture the first flush of high pollutant concentration runoff. The establishment of institutional support mechanisms such as administration of monitoring, fines and enforcement are unresolved, there is no agency currently positioned to synergistically assume these functions. If the irrigation development were to proceed, then an investigation of the social benefits of Upstart Bay Dugong Protection Area may assist in setting appropriate water quality parameters in the mitigation scheme. In chapter 6, how a combination of policy instruments could be applied to agricultural pollution more generally is discussed.

Chapter 6

Water Quality and The Great Barrier Reef

6.1 Introduction

In Chapters 2 to 5 how the characteristics of potential agricultural production and the ecology of a nearby environmental resource influence pollution mitigation policy options is outlined. Agricultural pollution mitigation policy for a dugong sanctuary focuses on issues relevant to wider land use impacts on the Great Barrier Reef Marine Park. Based on a case study built on best available information this chapter draws some insights for policy to address externalities at a larger scale.

Policy makers need to be careful that policies intended to result in less pollution do not have unitended consequences. One of the key impediments to the implementation of policy options outlined in Chapter 5 arises because of the consideration of only new potential contributions to water, where nearby existing production operates without similar constraints. Mitigation policy imposition on a subset of producers (potential new producers) raises the prospect of relative inequity and competitive disadvantage. The wider scope for contributions of water borne pollutants (from both new and existing producers) into the Reef requires a holistic abatement approach avoiding such disincentives to abate.

Water quality decline in the Great Barrier Reef lagoon (the Reef) has recently attracted attention from the Commonwealth and Queensland governments, resulting in the formation of a Joint Taskforce. The Joint Taskforce called on the Productivity Commission to outline water borne pollution abatement policy options *inter alia* (Productivity Commission 2002). The Productivity Commission report into water quality management in the Reef outlined the economic characteristics of declining water quality in the Reef, existing policy approaches, and how a policy analysis of options might be framed (Productivity Commission 2002, 2003). The framework introduced in the report involves prioritising pollutants, evaluating likely effectiveness and cost of policy options, and examining the institutional arrangements necessary for successful implementation.

This chapter firstly explores agricultural pollution mitigation policy in the context of Reef water quality pollution mitigation and management. Secondly provides further perspectives on the policy discussion in the Productivity Commission report with insights gained from the case study allowing a more searching analysis to be performed of regional solutions. Policy options are analysed on the basis of their ability to cope with information asymmetry, their ability to motivate individuals to act in the public interest and their ability to cope with site variability. A combination of instruments, voluntary, market based and regulatory in nature employed immediately would assist in meeting Reef water quality objectives in a timely manner. Finally this chapter explores issues in the implementation of abatement policy options for the Great Barrier Reef lagoon. Catchment wide case studies selected with community capacity in mind would highlight implementation issues for all Reef catchments cost effectively. Effective implementation of mitigation policies requires determination of the socially optimal level of protection.

6.2 Water Quality in the Great Barrier Reef Lagoon

The existing policy response to pollution control focuses on point source contributors to water quality entering the Reef with the main economic instruments being used for pollution control following the regulatory approach involving licensing and permits and planning procedures for development approvals. The Queensland Environmental Protection Agency does not currently have a mandate to control diffuse source discharges (Productivity Commission 2003).

> "There would appear to be significant scope for re-examining the current ERA (environmentally relevant activity) list to include other activities responsible for diffuse source discharges, and to ensure that the level of regulation and control was consistent with the level of threat posed by each activity. Further, there may be more equitable and cost-effective approaches than the current system of controls" (Productivity Commission 2003, p 52).

The regulatory approach is ill suited to controlling diffuse pollution because of the limited information held by policy makers on abatement costs (Productivity Commission 2003). Individual polluter abatement costs are required for a first best policy. The specificity of agricultural production activity over geographically dispersed areas implies that the marginal cost of alternative mitigation strategies will vary and it is not likely individuals would reveal those costs to policy makers (Productivity Commission 2003). The fact that damage costs for the same quantity of pollutant differs across individual polluters can be harnessed by policy. However, the information asymmetry problem considerably constrains the ability of a state authority to institute regulatory pollution control from diffuse sources.

Diffuse sources of pollution (non-point source as opposed to point source) particularly from agricultural activities, are considered the predominant source of water borne pollutants in catchments draining into the Great Barrier Reef (Productivity Commission 2003). Since diffuse pollution is technically unmeasurable (at present) the threat posed by agricultural activities is indeterminate[1]. Policy responses to an indeterminate potential threat to high (but unknown) value natural assets must be based on the nature of the threat. The threat from diffuse pollution is both chronic and irregular, driven by flood events. However, pollution pathways are not uniform across and within different land uses and regions. Such variation will affect the risk between regions and within a region. The costs and benefits of particular abatement options can thus vary at the property scale, influenced by proximity to watercourses, soil type and topography etc.

The site variability of diffuse source pollution makes the targeting of instruments a key strategy to enhance effectiveness. One option is to determine policies on a case-by-case basis (Productivity Commission 2003). The operational costs of such a policy would be high and likely to invoke reactive responses. Therefore, a more strategic response is needed. The holistic policy approach indicates preferable options will be capable of incorporating site-specific factors (or combinations of options). The Commission employed a qualitative analytical approach due to time constraints and information requirements. The nature of the diffuse pollution policy problem of water quality on the Reef indicates that successful instruments are likely to:

1. Deal with information asymmetry,

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[1] Modelling of nonpoint source pollution has been used in various situations to establish a reference point in some situations. However the variability of soil properties and ecological processes along Queensland's east coast would prove problematic for such an approach.

2. Create incentives for individuals to act in the public interest, and
3. Cope with site variability.

6.3 Policy Options

The objective of abatement policy for diffuse sources is to achieve the goal of reducing water-borne sediment, nutrient and pesticides entering the Great Barrier Reef lagoon at least cost (Productivity Commission 2003). The report uses two examples to illustrate the qualitative analytical approach, soil erosion from grazing and fertiliser and chemicals from cropping. The Productivity Commission assessed three abatement options as having high probabilities of success to address unsustainable land use practices in the application of fertilisers and chemicals. In brief the three options were; nutrient sensitive zone management, auctions and compulsory industry best management practices. The Commission assessed each option against the following criteria; information requirements, feasibility, cost, flexibility, distribution of costs and benefits and the likelihood of achieving desired change in land use. The three options are described below and evaluated in the context of their ability to cope with information asymmetry, their ability to motivate individuals to act in the public interest and their ability to cope with site variability.

6.3.1 Nutrient Sensitive Zones

This instrument applies to those parts of the landscape that have the highest capacity to result in water-borne pollution, being declared nutrient sensitive zones (Productivity Commission 2003). To apply agricultural inputs in areas so zoned would require an approved nutrient management plan. This approach would require an agency to have the capacity and ability to assess an appropriate nutrient management plan on each property so designated. This information is location specific with management of application, timing and placement implicated. The costs of this approach then would be high to cover establishment of nutrient management plans and funding to ensure compliance. The Commission deemed this option to have a high likelihood of achieving desired change in land use as it focuses regulatory effort, prioritising enforcement effort. This approach was supported by the Science Panel (Intergovernmental Steering Committee 2003).

Given that most intensive cropping in Queensland relevant to water quality on the Reef occupies coastal catchments, the extent of nutrient sensitive zones is not likely to be small. Most farms have a drainage system, whether relying on natural contours and watercourses or man-made drains. Thus most farms have the potential to deliver nutrients to the aquatic environment, which may lead to water quality decline in the Reef lagoon. How deeming these vast areas sensitive zones and requiring a management plan might lead to an effective or cost effective outcome is not clear. The variability of geophysical characteristics within a catchment increases information asymmetry. This abatement option also fails to align private incentives with better environmental outcomes. Therefore this option does not meet the three elements which may indicate successful mitigation outcomes.

6.3.2 Auctions

Using auctions to address nutrients and chemicals in runoff from diffuse sources would involve land users specifying at what cost they would be willing to undertake practices which would result in improved water quality (Productivity Commission 2003). In such a scheme the hazards particular to an area can be set as the priority. Land users then choose how they might meet environmental objectives competitively, bidding to enter into a contract which specifies monitoring and compliance mechanisms. Auctioning funds for pollution mitigation practices could be interpreted as reinforcing the existing distribution of property rights. In this way such auctions would not be consistent with the polluter pays principle.

The costs of the program would include establishing the auction system, monitoring costs and administration costs (Productivity Commission 2003). The informational requirements are low for the government, landholders take the initiative to become informed of the scheme’s requirements in an effort to submit a successful bid. Some extension or technical assistance might be required in this regard. The tender process could encourage land users to increase awareness of their practices and if successful obtain a monetary incentive to implement it.

The ability of this policy option to incorporate site specific aspects whilst introducing an incentive for land holders to reveal their costs thereby revealing private information and aligning private interests with environmental outcomes indicates its key role as part of an abatement policy mix. Careful implementation and application to high priority areas could yield least cost outcomes. The voluntary nature of participation in the auction process reveals that environmental outcomes are not guaranteed indicating that this policy option is best employed in combination with other instruments.

6.3.3 Compulsory Industry Implemented Best Management Practices

The Commission describes the informational requirements of sugar mills contractually enforcing adoption of best management practices as moderate (2003, p 219). However the specification of best management practices on similar soils in a mill area can involve vagaries due to combinations of other factors. This is demonstrated in the grower documentation of best management practices in the Johnstone River Catchment (Stewart 2000). Whilst growers need to sell their cane and have little scope to find an alternative buyer if their assigned mill refuses supply based on environmental non-compliance, suggesting that miller private interests align with the public interest in environmental outcomes sufficiently to impose change on growers is unrealistic and impractical. Mills need cane to crush to produce sugar and earn revenue.

The Commission used the example of the sugar industry's response to potential and actual acid sulphate soils in New South Wales as evidence that a policy facilitating industry implementation of abatement options is feasible (Productivity Commission 2003). The Commission in this instance overlooked the dissimilarity of environmental issues to be addressed. In the nonpoint Reef water quality case, effects are unable to be measured (although may be estimated) at the property level and ameliorations / alterations to existing practices are not easily prescribed. Abatement of cane production to reduce acid production (potential or actual) has clear linkages to an environmental duty of care. The local industry fully supported the move to implement environmental management to avoid State intervention. The absence of these factors in Reef water quality decreases the applicability to nonpoint source pollution. Imposed guidelines may be able to account for farm level variability but fail to create incentives for individuals to act in societies interest.

6.4 Implementing Abatement Options

Noting policy options the Productivity Commission then outlines general guidelines for implementation. Drawing on an emerging theme in environmental and natural resource economics, the report proposes devolution of implementing instruments to regional bodies (Productivity Commission 2003). Local organisations are suggested as being best placed to implement options due to local knowledge. Local organisations implementing instruments taps the strength of close knit communities to address some of the communication challenges of isolated communities. If local organisations are to implement options, resources and some decision making power must be devolved (Productivity Commission 2003).

The Productivity Commission report considers the economic aspects of such a process. They agree that the Commonwealth Government's role may involve provision of information to parties such as regional natural resource management bodies. They suggest that the Queensland Government's role could include establishing the broad framework for the arrangements, including additional devolution of responsibilities to regional bodies. Importantly, they note there should be mechanisms to ensure local actions are consistent with catchment, state and national objectives, with avenues for monitoring and reviews (Productivity Commission 2003).

The Science Panel (Intergovernmental Steering Committee 2003) highlighted the current state of regional natural resource management organisations in Queensland as suffering from burnout and fatigue from under resourced project management. They recommended that government agencies through the National Action Plan for Salinity and Water Quality and Natural Heritage Trust (2) should jointly provide financial, technical and project management assistance. Furthermore that the future development of water quality targets and risk classification must include community input and would best be achieved through existing regional structures using specific local water quality data. Such recommendations are based on the assumption that targets need to be developed with those who will be expected to make the changes to achieve them.

End-of-catchment objectives and targets need to be translated to upstream reaches and associated properties, so that there are measurable targets at the point where land use change can be observed and measured and consequent changes in water quality measured over a shorted time period than end of catchment targets. Dawson (2002) argues that community and industry acceptance will require a clear justification of the level of benefit derived. Determination of the socially optimal level of protection for each catchment yet applicable to the scale of the Reef is an area for further investigation.

The Commonwealth and Queensland Government summary statement of the Science Panels report documents that technical, institutional and social mechanisms for improving water quality in the Reef catchment and reducing contaminated runoff to the Reef should be trialled and demonstrated with a suitable level of support in key catchments. Appropriately selected catchment wide case studies could highlight implementation issues for all Reef catchments cost effectively. Investigating the process of devolving the development and implementation of policy options at the regional level incorporating community preferences for preservation and conservation is critical for achieving policy objectives at least social cost.

6.5 Features of Policy Implementation

Amongst the Commissions' general guidelines for implementation it discusses sequencing a suite of instruments using direct regulation as a last line of defence after other efforts have been introduced (Productivity Commission 2003). However, sequencing the implementation of different abatement options is not consistent with their assertion that the decline in water quality entering the Reef lagoon poses a significant threat to the natural, economic and social values of the Reef (Productivity Commission 2002). Particularly as the intergovernmental agreement states that the first stage in the protection of the Reef is stabilising and reversing the decline in water quality entering the Reef lagoon as soon as practicable (Intergovernmental Steering Committee 2003).

The Commission's acknowledgement that a suite of instruments could be used to collectively address environmental objectives, implies that any one particular policy instrument is unlikely be the most cost-effective in all circumstances (2003). This notion was proposed by the CRC for Sustainable Sugar Production (Mallawaarachchi *et al.* 2002). In most cases it will probably be more cost effective to use several instruments simultaneously, corresponding to the variability in practices governments need to target, regionally and possible even across properties, as well as over time. Appropriate abatement options should also have an in-built mechanism for updating to cope with intertemporal variability (Productivity Commission 2003). Targeting of instruments can be guided by resource information using new Geographic Information Systems (GIS) tools (Mallawaarachchi *et al.* 2002).

Employing a suite of economic instruments may be useful for a number of purposes, potentially reducing the implementation – outcome lag. For example, the Productivity Commission acknowledged the utility of property level planning as a framework for multiple land use changes (Productivity Commission 2003). Property plans detailing practices might be an effective requirement for submission of a tender for an auction. Also, property plans could be required under planning legislation, resulting in agricultural producers detailing approved management practices. Thus, requiring plans could have dual roles, where landholders could use their property plan to tender for funding to change practices and also demonstrate an environmental duty of care.

Regulatory options may have some part to play in addressing diffuse source pollution. Regulatory options dealing with nonpoint source pollution were not exhaustively explored in the Commissions (2003) report. The *Queensland Environmental Protection Act 1994* requires individuals and companies to act with due care for the environmental impacts, the so-called duty of care. The Queensland Environmental Protection Agency administers enforcement guidelines to determine and investigate instances of actual or potential environmental harm. The evolution of Industry Codes of Practice afford individuals protection if they act within the bounds of specified practices. By requiring independently audited compliance reports environmental outcomes could be enhanced. This would require changes to current legislation and funding of administration and enforcement.

The full range of economic policy instruments to address a significant threat to an environmental resource should be employed in a timely manner. To this end, sequencing instrument implementation risks Reef water quality whereas establishing a suite of instruments recognises the nature of the threat. Appropriate instruments will likely include a regulatory component signifying the urgency and magnitude of the response to reduce the threat to Reef health.

6.6 Political Processes

> "For, in the translation of the insights of economists on such matters as externalities … to the practical policies that governments implement, we leave the realm of science and return to the realm of politics" (Parkin 1999, p. 5).

Many social decisions are made neither in markets nor by marketlike benefit-cost criteria, but through legal and political institutions (Page 1997). The Productivity Commission's economic assessment was marginalised in the Reef Water Quality Protection Plan (Queensland Government 2003), not covered in the economic incentives strategy and only referred to in passing in point seven of eight in the natural resource management strategy, with further discussion relegated to Appendix 1. Politics affects the process in many ways that can block outcomes that would result in higher levels of economic welfare (Hahn 2000). Which instruments end up as part of government policy to address diffuse pollution in the Great Barrier Reef only time will tell.

6.7 Conclusion

Economic instruments to address agricultural pollution in an expansion area may encourage more production in existing agricultural areas without consideration of externalities. Therefore, a holistic policy approach is well placed to avoid inequitable outcomes. The Memorandum of Understanding between the Commonwealth Government and the Government of the State of Queensland on cooperation to protect the Great Barrier Reef from land-sourced pollutants (Intergovernmental Steering Committee 2003) symbolises the magnitude of the policy response required to improve water quality entering the Reef. The coordination necessitated by the scale of the response indicates a piecemeal approach is unlikely to be efficient. In practice it will probably be a combination of policy options capable of addressing situation specific characteristics that yields the most cost effective environmental outcome. Policy options that inherently synergistically align incentives and reveal private information resulting in desired environmental outcomes must feature as part of the abatement policy mix.

Market based instruments have desirable features for pollution mitigation policy, creating incentives for private actors that align activity with social goals. In the case study tradeable permits could offer an effective way of internalising environmental effects, for Reef water quality management auctions might best address off-site impacts.

The suite of appropriate instruments should also include regulatory options to address the immediate nature of the threat.

The implementation of nonpoint source abatement policy will require resources. Natural resource management bodies although well placed to facilitate community involvement, lack administration capacity and funding. In devolved implementation, the government's role is to supply technical data such as the economic value of marginal changes, requisite for efficient instrument design. Using model catchments to explore lagoon wide abatement policy approaches will help to identify the extent of technical information required in each catchment and desirable institutional features and resources required. Finding ways to lever community capacity to implement policy options such as auctions and ensure desired environmental outcomes through adopting some 'tougher' regulatory options remains the challenge.

Chapter 7

Summary and Conclusions

7.1 The Context of This Study

Policies to mitigate pollution externalities are controversial as they impose costs to polluters in the short run. Those whose activities are under potential scrutiny do not always welcome research examining pollution mitigation policy options. The Australian sugar industry, however, has maintained a proactive stance on many environmental issues. Its location adjacent to the Great Barrier Reef Marine Park and relative proximity to major population centres along the east coast of Queensland makes industry activities more available to social scrutiny. Therefore, marine protected areas close to cane production areas was recognised as of particular interest for investigation.

7.1.1 An Overview of the Study

As an intensive land use, sugar cane growing has attracted community concern over water quality changes and perceived downstream effects. The sugar industry provides many economic and social benefits to the Queensland economy in terms of employment and production of a commodity. The Great Barrier Reef and other marine environments also provide economic and social benefits from tourism, fishing and recreational pursuits. Land use activity upstream of a marine protected area may alter the natural setting and impose costs on individuals and society that are not offset by commensurate increases in benefits. The economic causes of market failure were identified in Chapter 2.

Agricultural activities adjacent to near-shore marine protected areas have the potential to jointly produce agricultural goods and environmental externalities. The nature of relevant benefits and costs is also a source of conflict in natural resource management. The public good characteristics of environmental resources and the social costs of externalities linked to natural resource exploitation warrant government involvement in natural resource management. One policy response to such pollution problems is mitigation to manage effects on marine protected areas. Agricultural pollution mitigation policy options to protect the downstream environment can help to reduce the social costs.

Policy consideration of the joint production of an agricultural good and environmental externality implicates both existing and new activity. The case study was concerned with impacts occurring at the interface of agricultural production and the environmental resource for a new activity. In Chapter 3 the process used to select the case study area was outlined and key features of the case study area germane to discussion of agricultural pollution mitigation policy presented. Potential supply to Molongle Block in the Burdekin River Irrigation Area (in North Queensland) would allow new cane production in close proximity to the near shore marine environment in Upstart Bay. Thus, irrigated area expansion may result in artificial inputs associated with maintaining production exceeding crop requirements and soil absorption capabilities leading to degradation of the downstream environment. Seagrass meadows are sensitive to pollutants carried by water, particularly combinations of pollutants and may also be affected by altered timing and magnitude of flows. Defining the key features of the case study established the foundation for investigating feasible mitigation alternatives.

The specific characteristics of Molongle Block and Upstart Bay Dugong Protection Area given likely production techniques were highlighted in Chapter 4. Biogeochemical attributes are of particular interest in mitigating the effects of irrigated intensive cropping. The nature of the crop, soils, irrigation method and the ecology of the downstream environment lead to identification of feasible pollution mitigation alternatives including constructed wetlands and retention ponds.

The study theoretically examined using constructed wetlands to treat drainage waters or retention ponds to control the timing of pollution. Use of constructed wetlands for treatment of irrigated area drainage would employ biochemical processes to mitigate pollutants but transformation and capture of all nutrients on a long-term basis is uncertain. In fact constructed wetlands can act as sources of pollutants at times. One response to increase the certainty of environmental protection is to increase the size of the wetland. Using retention ponds to mitigate irrigated area impacts involves aiming to contain high pollutant concentration flows. With appropriate drainage design subsequent flows could be diverted. This option therefore is likely to be at lower cost. Retention ponds could feasibly be employed at the farm or sub-regional level in the Molongle Block.

Implementing retention ponds at the farm scale would allow individuals to carry out mitigation. However, there would be no inherent incentive to mitigate. Policy instruments differ in the way of motivating individuals to act in society's best interest. The interrelationships between site specific factors and management practices give landholders intimate knowledge of the likely results of specific practices. Landholders are likely to be best positioned to ascertain least cost management practices. Policy instruments need to accommodate variability and address information asymmetry. Possible policy options cover the full spectrum from command and control responses, information provision, incentives and market-based instruments. Chapter 5 qualitatively compared the likely effectiveness of economic policy options for intervention against the criteria of aligning private and public interests, accommodating variability and addressing information asymmetry. Quantitative comparison was constrained by the potential production area having limited geochemical and production data in accessible format and uncertainty about the ecological effects of mitigation.

Considering environmental externalities at the design phase of irrigation areas would allow the use of output control devices such as wastewater drainage points to measure individual contributions. Information on marginal contributions to pollution loads and the effect on an ecosystem of pollution accumulation would make mitigation policy design efficient. However, evidence of marginal changes in environmental goods is unlikely to be available given the variability inherent in natural systems. Even if it is not possible to identify the extent of environmental diseconomies associated with marginal pollutant contributions, instituting mechanisms to share the costs of mitigation may be desirable to avoid the high potential costs of a do-nothing outcome.

A regional retention pond scheme would involve designing a pond to serve a number of farms. The design necessarily involves estimation of the volume of runoff able to be stored in the facility. This would serve as the cap on wastewater. Each farm therefore could be allocated a runoff volume. The producer then faces a choice, to mitigate and not use his allocation. If the producer wants to sell the allocation, they must satisfy criteria such as the reduction in pollution is permanent and enforceable. Thus the discharge permits can be transferred.

Introducing pollution mitigation policy in one part of a catchment whilst nearby agricultural producers do not undertake such actions could be a path of less political resistance. However a whole of catchment approach such as that proposed by the Science Panel (Intergovernmental Steering Committee 2003) and Productivity Commission (2003) to address water quality in the Great Barrier Reef lagoon offers a more coherent approach.

Addressing water quality decline in the Great Barrier Reef lagoon involves a range of complexities for pollution mitigation policy such as examining the range of threats to ecosystem health and prioritising threats. In the case study output control devices enable measurement of pollutants, however the diffuse nature of the effects of existing agricultural pursuits does not yield easily to measurement.

In Chapter 6 the insights gained from the case study are used to explore diffuse agricultural pollution abatement options identified by the Productivity Commission (2003). The Commission identified three options as having a high probability of success to address unsustainable land use practices in the application of fertilisers and chemicals. Chapter 6 outlines why one of these options, auctions, is more likely to be successful. Auctions have the potential to allow for site specific variation and overcome information asymmetry. Using auctions to address nutrients and chemicals in runoff from diffuse sources would involve land users specifying at what cost they would be willing to undertake practices which would result in improved water quality. However, auctioning funds to pay for improved water quality breaches the polluter pays principle. A suite of policy options including economic instruments will be required to adequately address the complexities of the agricultural pollution problem.

The Productivity Commission discussed how policy options could be implemented. Designing policies for river catchments is information intensive and involves interest groups. Devolving implementation of policy options to natural resource management bodies raises the prospect of strategic action, decreasing the likelihood of the lowest net social cost outcome.

7.2 Future Research Directions

If Governments support expansion of agricultural production then an investigation of the social benefits of Upstart Bay Dugong Protection Area would assist in setting appropriate water quality parameters for mitigation policy. This would involve ascertaining non-use values through some non-market valuation approach. Whilst some non-market valuation approaches are yet to gain popular support in Australia, the theoretical basis of such approaches is well established. A suitable technique is choice modelling, which presents complex alternatives in order to estimate potential improvements in utility through stated preferences.

Policy to address diffuse agricultural pollution requires information pertaining to the socially optimal level of protection for each catchment. Rather than trying to determine the magnitude of benefits for each catchment separately there may be scope to investigate the level of benefits by catchment. Exploring how identifying such values may be indicative of similar values in other situations is called benefit transfer in stated preference surveys. Benefit transfer issues in choice modelling have been investigated by Morrison et al. (2002), Rolfe et al. (2002), Morrison et al. (1998) and Morrison and Bennet (2000) among others. Designing surveys to address the issues of water quality management for the Reef is necessary for efficient policy and an interesting prospect, potentially contributing to knowledge of benefit transfer issues.

7.3 Conclusions

This policy analysis identified policy options and explored the relative efficiency of those options in a case study. The case study involved private benefits and social costs of environmental goods and services that are not traded in markets. The different spheres of value of private benefits and social costs often result in under-provision of environmental goods. Transboundary effects of land use activity on a marine protected area may impose costs on individuals and society that are not offset by commensurate increases in benefits. The joint production of an agricultural good and environmental externalities offers a potential policy problem where it may be beneficial to seek ways to minimise the potential for adjacent uses to diminish the value of preserved natural resources.

Dugong Protection Areas recognise seagrass meadows as having unique attributes, and are socially valuable by implication. Water quality is a key determinant of the health of seagrass ecosystems. Water transported pollutants can affect species composition, density and location of seagrass in near shore marine environments. Agricultural activities are likely to impinge on water quality. To identify effective mitigation alternatives, information on the potential impact pathways of potential agricultural pollution is needed. The case study of the Molongle Block and the Upstart Bay Dugong Protection Area indicates that identifying feasible mitigation alternatives is the first step to manage downstream effects. Site specific characteristics such as biological and geochemical features lead to different pollutant pathways and influence successful mitigation. Based on the characteristics of potential sugar cane production in Molongle Block, likely solutions would prevent the introduction of dry season flows, and contain increased herbicide, nutrient and sediment pollutants in first flush events.

Constructing artificial wetlands is one way to mitigate potential externalities. However, the nature of wetland treatment of pollution, harnessing natural processes to use nutrients and trap herbicides, does not consistently lower pollutant concentrations due to high flow influxes from storm events and uncertain residence times. This would be ecologically significant for treating first flush events. Management of wetlands to treat agricultural pollution is therefore likely to be relatively costly. Constructing retention ponds is another way to mitigate externalities from potential irrigation area extension for cane production. Retention ponds aim to control the timing of pollutants, offering the ability to reducing the concentration of pollutants. This method arguably has the potential to reduce environmental impacts at lower cost.

Many policy instruments could promote the use of retention ponds to mitigate pollutants. The characteristics of different policy options include the way of motivating individuals and ability to allow for various practices to fulfil the objective. For example command and control instruments define pollutant concentration limits based upon technologically feasible abatement. Such regulation however fails to provide incentives for private actors to exceed pollution mitigation targets; instead it provides a disincentive for failure to reach set targets. Command and control instruments also fail to adequately cope with variation in site characteristics. The fundamental problem with prescriptive approaches is the prohibitive cost of monitoring pollutants across vast geographical areas.

Within the existing regulatory framework, planning tools have the potential to provide the basis for successful pollution mitigation policy. Property level planning processes may be used to extend technical assistance to landholders about farm level wastewater monitoring, retention devices, and even to require their installation. Establishing retention ponds allows for a mitigation scheme at either the farm or regional level. An ongoing incentive to capture potentially environmentally detrimental flows could be established in a regional retention pond scheme with transferable discharge permits.

A regional retention pond scheme could allow for the design of a system of tradeable permits, aligning private interests with public interests. The goal of a system of tradeable permits in such a scheme would be to capture dry season flows and to capture the first flush of high pollutant concentration runoff. The establishment of institutional support mechanisms such as administration of monitoring, fines and enforcement are unresolved as there is no agency currently synergistically positioned that could assume these functions.

Preventative management offers a viable policy response to address potential irreversibility and sustainable resource use, particularly in the presence of ecological uncertainty and data limitations. Considering environmental externalities when designing the irrigation areas allows for the measurement and containment of individual contributions, avoiding non-point source complexities. Whilst addressing agricultural pollution mitigation as a point source problem, mitigation policy for a dugong sanctuary considers issues relevant to diffuse source impacts on the Great Barrier Reef Marine Park.

The Productivity Commission outlined water borne pollution abatement policy options for diffuse sources on the Reef (2003). Due to the scale of the water quality problem for the Great Barrier Reef lagoon, it will probably be a combination of policy options capable of addressing situation specific characteristics that yields the most cost effective environmental outcome. Policy options that inherently create incentives to reveal private information, synergistically align private and social interests, and allow for site variability will likely result in desired environmental outcomes should feature as part of the abatement policy mix. The suite of appropriate instruments should include regulatory options to address the immediate nature of the threat.

The implementation of nonpoint source abatement policy will require significant resources. Natural resource management bodies, although well placed to facilitate community involvement, lack adequate administration capactiy and resources. Using model catchments to explore lagoon wide abatement policy approaches will help to identify the extent of technical information required in each catchment and desirable institutional features and resources required. Even in devolved implementation, the government's role is to supply technical data such as the economic value of marginal changes, requisite for efficient instrument design. Further investigation of these values is a pressing need. The realities of the political process of abatement policy implementation to address declining water quality in the Great Barrier Reef lagoon may not heed the lessons to be learned from an economic analysis of policy options.

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