PROGRAM 3

SUSTAINABLE WATER ALLOCATION

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Controlling Nonpoint Source Pollution

The purpose of this article is to introduce some of the characteristics of nonpoint source pollution and to explain how these characteristics give rise to problems for policy designers interested in its control. This article is the first in a series of three *Catchword* articles which will examine the nonpoint source pollution problem and review research work currently being undertaken by the CRC and its stakeholders. This first article reports on nonpoint source pollution and its current state in Australia, nonpoint source pollution characteristics, information problems, and issues in the design of policies for pollution control. Subsequent articles will examine the role of market-based incentives, particularly the design of tradable permit schemes, for controlling pollution from nonpoint sources in Australia.

State of Surface Water Pollution in Australia

Pollution from nonpoint or diffuse sources[1] has been identified as the leading cause of contamination in many of Australia's catchments and coastal ecosystems (see for example the National Land and Water Resources Audit 2001, Australia's State of the Environment 2001). Australia's National Pollutant Inventory (NPI) Summary Report of Third Year Data 2000-2001 suggests that, of the 23 water catchments assessed, nonpoint sources account for 65%-95% of nutrient emissions to inland waters, particularly in catchments dominated by non-urban land uses (NPI 2002, p.25). In 2003, the Australian Productivity Commission released a report identifying nonpoint pollution as the major contributor of sediment and nutrients to the Great Barrier Reef lagoon (PC 2003). Nutrients, primarily nitrogen and phosphorous, salinity (a measure of salt concentration) and turbidity (as a proxy for sediment concentration) have been identified as the major pollutants of concern (NLWRA 2001).

Characteristics of Nonpoint Source Pollution

Nonpoint source pollution, sometimes referred to as diffuse pollution, results from land runoff, precipitation, atmospheric deposition, drainage, or seepage. Nonpoint sources refer to broad, diffuse sources of activity that generate contaminants that are applied, spilled, leaked, leached, eroded, or dumped onto or into land or water (Dosi and Zeitouni 2000). Nonpoint source pollution is characterised by stochastic events, occurs over a range of scales (temporal and spatial) and because discharge is diffuse and driven by stochastic processes, cannot be easily quantified or measured.

Catchment or regional scale pollution problems will often involve numerous, small and spatially heterogeneous polluting agents including urban and agricultural sources. At such scales, it is considered difficult and/or costly to systematically monitor the individual production practices or production inputs of each agent that give rise to pollutants. Even if we could monitor each potential source, pollution events are typically driven by stochastic environmental processes such as climate. Similarly, it is difficult to infer the contributions of individual polluters by measuring ambient downstream water quality at a single point downstream since this too is affected by stochastic environmental processes and our knowledge about these processes (i.e. pollutant generation, transport and fate) is imperfect. Thus, not only are contributions from individual sources difficult to measure or observe, they cannot be accurately inferred from ambient monitoring of water quality either.

Interdependency exists between upstream sources and downstream concentrations and pollutants in these systems are not uniformly mixed. This occurs because water flow, and therefore contamination of surface waters in a catchment, typically occurs along a topographic gradient and pollutants are usually transported from upstream areas to downstream areas where impacts and damages occur. Unlike air pollution where pollutants may diffuse and uniformly mix with the receiving environment, nonpoint source pollution of surface waters is usually characterised by increasing pollutant concentrations at the bottom end of the catchment. Added to this are the time lags between when contaminants are produced and when environmental damages occur; this means that the damages associated with an individual agent are also difficult to establish.

Nonpoint Information Problems

The inherent characteristics of nonpoint source pollution give rise to information problems for policy designers. Braden and Segerson (1993) classified these nonpoint information problems as:

[1] *Nonpoint source pollution, of diffuse pollution, refers to broad, diffuse sources of activity that generate contaminants that are applied, spilled, leaked, leached, eroded, or dumped onto or into land or water (Dosi and Zeitouni 2000). Nonpoint sources are characterized by stochastic events, occur over a range of scales (temporal and spatial) and because discharge is diffuse, cannot be directly or easily quantified.*

1) Problems of natural variation

   a) Temporal variability

   b) Spatial variability

2) Problems of monitoring and measurement

3) Inability to observe individual emissions

4) Inability to observe individual inputs/practices

5) Inability to infer individual emissions from ambient concentrations

Spatial variation includes differences due to climate and landscape heterogeneity and includes variability associated with rainfall, evapotranspiration, runoff, soils, land use, physical location of management practices and the fate of contaminants in the environment. Temporal variability includes uncertainty due to rainfall frequency, abatement technology, hydrological variability, production factors (e.g. timing of management practices) and the assimilative capacity of the environment.

Inability to observe individual emissions implies moral hazard characterised by hidden actions (Braden and Segerson 1993). Since water quality can be considered a public good, moral hazard gives rise to another issue for policy design termed the 'free rider effect'[2]. The free rider problem, characteristic of public goods, occurs when one polluter derives benefits from the increased abatement undertaken by other polluting firms without actually reducing pollution itself. Since contributions are unobservable and subject to stochastic processes, the public good nature of water means that benefits are nonexclusive (i.e. nonexcludability applies) and indivisible; the free rider has no incentive to reduce their level of pollution (Tietenberg 2000). This moral hazard problem ultimately gives rise to increased discharges and higher environmental damages.

Just as it is not practical to observe individual emissions, it is also difficult to monitor and target agents based on production inputs, and technologies used by multiple polluting agents are also unobservable. Production and abatement technologies (eg. land management practices) define a firm's 'type' (Tomasi *et al.* 1994). For example, in an agricultural catchment, different soil types, hydrological characteristics and topographic factors give rise to differences in the kinds of crops that could be grown and therefore also differences in farming practices and technologies ('types'). As the number of polluting firms increases, so also does the problem for the policy designer in obtaining information about each firm's specific 'type' or for firms to know about the 'types' of other firms (Tomasi *et al.* 1994). This unobservability of firm's type is a form of information asymmetry characterised by hidden information and is termed adverse selection (Taylor *et al.* 2001; Tomasi *et al.* 1994).

Inability to infer individual emissions from ambient concentrations refers to the fact that it is not possible to attribute ambient pollution to any one firm since environmental damages are not separable across firms (Braden and Segerson 1993; Shortle and Abler 1997). Thus, the contribution of one firm is not only inseparable from that of another firm, but depending on their location within the catchment, the total contribution of that firm to ambient pollution levels could actually depend on the contributions of other firms as well as stochastic environmental processes. The inability to infer individual emissions from ambient pollution levels is also an example of moral hazard characterised by both hidden actions and natural variation (Segerson 1988; Xepapadeas 1991).

Policy Design Issues

Nonpoint pollution's characteristics and its associated information problems give rise to some important considerations for policy design. Horan and Shortle (2001) categorised these considerations as policy targeting problems, namely:

1. Who to target?

2. What to target?

3. How to target?

Who to target?

The answer to this policy targeting question may at first seem obvious, however nonpoint information problems give rise to uncertainty about who to target. For example, it may appear that an obvious choice is to target the individual firms responsible for creating the nonpoint externality and thereby managing externality contributions through a 'polluter pays' system (Shortle and Horan 2001). However the unobservability of emissions, the inability to infer individual contributions from ambient water quality concentrations, and a large number of small, diffuse, and heterogeneous contributors gives rise to moral hazard about which firms are responsible for nonpoint pollution and the degree of individual responsibility (Shortle and Horan 2001).

An alternative approach to targeting the producers of pollution is to target the beneficiaries of pollution

[2] *"When goods exhibit both consumptive indivisibility and nonexcludability properties, some consumers may enjoy the of the goods purchased by others without paying anything themselves." (Tietenberg 2000, p.71)*

NEW TOOLKIT SOFTWARE

CatchmentSIM

CatchmentSIM is a freely available stand-alone 3D-GIS application specifically tailored to hydrology based applications. It can be thought of as a collection of topographic and hydrologic analysis algorithms that have been purpose built for the process of hydrologic analysis and included in a Windows based user-friendly GIS environment.

CatchmentSIM is designed for use by anyone interested in automated catchment delineation and parameterisation from GIS data. However, the software is primarily focused on automated setup of run-files for flood and stormwater hydrograph models.

For further information visit www.toolkit.net.au/catchmentsim

control. This approach too is complicated by nonpoint information problems including unknown and spatially variable damages, time lags between contamination and damages, and the inability to identify all potential beneficiaries.

Alternatively, policies may target polluters indirectly. For example, if fertiliser was identified as a major polluting input it is possible (and potentially feasible) for the policy to target a few larger fertiliser manufacturers rather than multiple, unobservable and heterogeneous farm sources. However the targeting of a potentially law-abiding manufacturer also raises equity and political considerations

What to target?

The question of what to target is concerned with what aspect of nonpoint pollution production should be regulated, that is, which base to target. The term 'base' describes the target that is to be regulated or leveraged by the policy instrument to create an incentive for the firm to undertake abatement. It has been suggested that preferred bases should be more or less correlated with environmental conditions, easily enforceable at minimal cost, and targetable in time and space (Braden and Segerson 1993).

The question of which base to target arises because nonpoint characteristics and information problems prevent the use of traditional bases such as actual discharges, production inputs or practices, and ambient concentrations. The existing literature contains policy designs which have targeted:

- production inputs which give rise to pollution e.g. irrigation water use, fertilisers,
- production (land management) practices (types) e.g. crop management and tillage practices,
- emissions proxies - a measure of the performance of a management practice in reducing contaminant production
- modelled or estimated discharges - an estimate of actual emissions, and,
- ambient water quality concentrations

While the potential of these bases has been demonstrated in the literature, nonpoint information problems impose obstacles to their efficient and practical application. Such obstacles include establishing liability, enforcement and transferability of property rights, monitoring at reasonable cost, and that the information requirements associated with implementing an efficient or cost-effective policy design are often significant and onerous.

How to target?

Considering who to target and what base to target, regulators need also consider the question of policy instrument choice. Policy instruments for pollution control can be categorised into two major groups (Russell and Powell 1999):

- Regulatory instruments or 'command and control', and,
- Incentive instruments or economic or market-based incentives (MBIs).

Regulatory instruments

Regulatory instruments, sometimes referred to as command-and-control instruments, refer to instruments that specify a standard or metric to which polluters must comply and include such mechanisms as product prohibitions, technology-based discharge standards, quotas on emissions and disclosure of private information about polluting activities (Russell and Powell 1999). Regulatory instruments typically prescribe either a performance-based standard such as an emissions level, which firms must achieve, or a technology-based standard by which all firms must operate. Technology-based standards include restrictions on the use of certain types of inputs which give rise to pollution or by mandating the use of certain pollution-reducing (abatement) technologies (Baumol and Oates 1988). Performance standards set a uniform control target which all polluting firms must meet, however there is some flexibility as to how this goal is met (Stavins 2003).

Incentive instruments

Incentives include a range of instruments such as tradable permits, pollution charges or taxes, liability provisions, subsidies and schemes based on education and suasion (Russell and Powell 1999). Market-based instruments (MBIs) differ from command and control approaches in that they offer the polluter a financial incentive to undertake abatement. This incentive may come in the form of a direct price incentive as in the form of a tax or subsidy, or indirectly through liability law provisions. Incentives may not necessarily be driven by price. Other incentive policies include approaches such as education, extension and moral suasion. However, evidence suggests that these latter methods have only limited success when used in isolation from other approaches such as MBIs or regulation (Horan and Shortle 2001).

Unlike regulatory approaches which encourage behaviour through explicit directives regarding pollution control levels or methods, market-based instruments provide inducements, usually in the form of price

incentives and market signals, for firms to reduce pollution discharges (Stavins 2003). Examples of MBIs include taxes or subsidies, tradable emissions permits, deposit-refund systems, liability provisions and information programs such a public revelation about pollution of information disclosure (Russell and Powell 1999; Shortle and Horan 2001; Stavins 2003).

Regulation or incentives?

While MBIs can be at least as cost-effective as a regulatory instruments, the conditions for this are shown to be highly restrictive (Baumol and Oates 1988; Griffin and Bromley 1982). A range of different incentive instruments which take advantage of the differences in the production characteristics of firms, particularly marginal costs of abatement, have been shown to be more cost effective than a uniform regulatory approach which treats all polluting firms the same way (Baumol and Oates 1988; Cropper and Oates 1992). Baumol and Oates (1988) demonstrated that in the presence of imperfect information about firms, including lack of information about individual emissions and their control costs, MBIs will generally achieve environmental targets at a lower cost than command-and-control approaches. It has been shown that where the costs of abatement differ widely among polluting sources or firms, incentive instruments are likely to deliver greater benefits, relative to regulatory instruments. As such, market-based instruments or incentives are expected to be more cost effective than regulatory approaches when information problems and heterogeneity amongst sources exist. Since these are characteristics of pollution from nonpoint sources, it is possible that market-based instruments offered important advantages as policy instruments in nonpoint pollution control.

Conclusion

This article has provided an overview of the characteristics of nonpoint source pollution and explained the reasons why these characteristics give rise to difficulties for pollution control policy designers. These characteristics and associated nonpoint information problems may help to explain public policy's lack of progress in systematically addressing nonpoint pollution problems and why nonpoint pollution of surface and groundwater remains a pervasive environmental problem in Australia.

The CRC's Catchment Modelling Toolkit aims to provide a range of data and modelling tools which will allow users to predict and analyse many of the catchment biophysical processes which are important in the generation, transport and fate of nonpoint contaminants. Projects such as the "Toolkit" are fundamental in to improving our understanding of, and ability to predict nonpoint pollution dynamics. With such information and prediction tools at their disposal, policy designers will be better equipped to design policies which are able to successfully target and control nonpoint source pollution.

Regulatory instruments and incentives based on moral suasion and education are the most common policy approaches to nonpoint pollution control in Australia, with market-based instruments having received very little attention until recently. The next article in this series on policies for controlling nonpoint source pollution will examine the role of MBIs and their use in Australia, with an emphasis on the role of tradable emissions permit schemes (markets).

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PROGRAM 4

URBAN STORMWATER QUALITY

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Report by Tony Wong and Tim Fletcher

Some brief notes on the application of MUSIC

Rainwater/stormwater harvesting

Since its first release in 2002, MUSIC is now widely adopted in Australian practice for developing stormwater management strategies. Stormwater quality management has been the primary focus of the majority of these applications. However, there have been some applications where harvesting of stormwater at the building and precinct scales have been investigated as an integrated strategy, since the "diversion" of stormwater for use as an alternative source of water implicitly reduces the pollutant loads that are discharged to receiving waters. Using the pond module is the most common approach to modelling rainwater or stormwater harvesting with the volume of the permanent pool being set equal to the storage capacity of the tank and the extended storage being set to reflect the provision of on-site detention volume for flood control. If the model is used exclusively to determine stormwater harvesting performance, the choice of time step is only marginally relevant and it is common to adopt a daily time step (especially if the "catchment area" is 100% impervious) as most water demand can only be represented as mean daily demand.

A common approach to defining the degree to which potable (mains) water is substituted by harvested rainwater is by simply comparing the volume of inflows and outflows from the catchment (roof area) with the difference being the amount that has been reused. Users need to be cautious when adopting this approach for the following reasons:-

(i) Users quite often need to "factor up" (by a factor of 10 or 100) the catchment area (roof area) and the corresponding demand when examining stormwater harvesting and reuse owing to the units used in accounting for catchment runoff volume (ML/yr to two decimal places). MUSIC Version 3 will increase this to four decimal places so that water harvesting at individual allotment scale can be simulated without the need to adjust catchment areas and demand;

(ii) Evaporative losses in the storage could account for a significant percentage of the difference in inflow and outflow of the system - this generally only applies to storage systems exposed to evaporation potential, while in most cases, the user should