COMMUNITY EMPOWERMENT AND COOPERATION IN ENVIRONMENTAL MONITORING OF EXTRACTIVE SITES: PATHS TO A STATE-WIDE INTEGRATED SYSTEM

MARLOW, D.

In Queensland and elsewhere, there is a paucity of environmental data on abandoned extractive sites, and the public service agencies responsible for determining and monitoring the environmental conditions on these sites are inadequately resourced. There is also a paucity of publicly available environmental data on operational extractive sites (and little independent monitoring of these sites), and a lack of public trust in both the companies that conduct extractive operations and the government that oversees these operations. The requisite knowledge could be gained and much trust regained by empowering local communities and NGOs (Non-Government Organisations) to participate in joint community-industry-government environmental monitoring of extractive sites, where the results are uploaded to public-access online databases and reporting systems. The reward for the communities would be participation in the decision-making process on natural resource management issues - particularly issues relevant to extractive sites.

The environmental information relevant to decision-making on extractive sites is presently stored on multiple databases (some of which are multi-purpose databases), if it is stored at all. The value of the stored data is diminished, because it is difficult or impossible to assemble all the information required for optimal decision-making on any issue involving extractive sites. To gain important social benefits, the data needs to be integrated and made publicly available. However, if government and industry fail to heed legitimate community concerns regarding extractive sites and fail to involve communities in this joint endeavour, communities will still carry out environmental monitoring – but with the goal of gathering evidence in disputes with government and industry.

This paper defines an 'extractive site' as a 'mine site or oil/gas field'.

INTRODUCTION

PROBLEMS AND OPPORTUNITY

Governments find it increasingly difficult to adequately fund their environmental management and monitoring responsibilities, with resultant declines in governmental environmental monitoring (Buckland-Nicks, 2015; Garda, Castleden and Conrad, 2017; McKay and Johnson, 2017; Wells and Richardson, 2015). Communities have attempted to fill part of the gap with community-based environmental monitoring (CBEM) programs, but have found that the information they gather is often not used by decision-makers (Conrad and Hilchey, 2011; Murphy-Mills, 2015; Stepenuck and Green, 2015). In Australia and elsewhere, there is also a lack of public trust in the extractive industry and in government. Harvey and Bice (2014) observed that "Extractive companies are usually unpopular and generally mistrusted; there is no getting away from this". A recent study by Cameron and McAllister (2016) found that public trust in government was at its lowest since it was first measured in 1969. These problems could be largely overcome, if a cooperative partnership of government, industry, community and academia conducted data gathering on (and environmental monitoring of) extractive sites and uploaded the results to public-access online state-wide databases. This paper focuses mainly on the system of resource extraction in Queensland, but also has a wider Australian context.

THE EFFECT OF EXTRACTIVE OPERATIONS ON THE ENVIRONMENT

Extractive industries alter the environment as a consequence of their operations. The air, the soil, surface water and ground water can be contaminated, and aquifers can be over-used or depressurised. The extractive industries and the governments that approve and oversee their operations have a social obligation to reduce such environmental damage to a practicable minimum. Environments potentially adversely affected by extractive sites need to be adequately monitored, to identify and quantify any emerging environmental problems.

The monitoring needs to continue even after an extractive site has closed, because a contaminated site can leach contaminants into waterways, centuries after extractive operations have ended (Leblanc et al., 2000). Wind can blow contaminated dust from the tailings piles and waste heaps of abandoned mines into populated areas (Castillo et al., 2013; Taylor et al., 2014). The rapid development of coal seam gas (CSG) fields in Queensland has created a new monitoring imperative, because of possible interactions with usable aquifers. Aquifers and their ecosystems can't be rehabilitated, and any unforeseen consequences of CSG extraction on the Great Artesian Basin will take decades or centuries to work through the aquifers (Prosser, Wolf and Littleboy, 2011).

A LACK OF DATA, A LACK OF TRUST

THE PAUCITY OF INFORMATION ON ABANDONED SITES

The Queensland Floods Commission of Enquiry (QFCE) investigated the problems presented by abandoned mines in Queensland in a case study analysis of the contamination of Cave Creek by acid mine drainage (AMD) from the abandoned Mount Oxide copper mine site after rainfall events (QFCE, 2012). See FIG. 1. The QFCE made several cogent observations regarding the inadequacy of data collection at abandoned mines:

- It was not possible to determine the impact of the 2010/2011 floods on abandoned mines, or the resulting impact on the environment, because of the lack of monitoring and physical inspections, and information collected on those mines.
- Constraints on resources mean that the public service must prioritise the collection of information at what it knows to be high risk sites.
- To understand the hydrology of some sites, it is necessary to monitor conditions in wet and dry seasons over many years.
- Data collection is integral to appropriate management - contamination of Cave Creek might have been addressed earlier, had a systematic risk assessment and regular site inspection program been in place.
- The source of information on all known abandoned mines in Queensland is the Queensland Minerals Occurrence database, which was not specifically designed for use

FIG. 1. Contaminated creek near the abandoned Mount Oxide mine, the blue colour indicating the presence of copper precipitate in the sediment (Image source: Queensland Floods Commission Enquiry).

> in the management of abandoned mines. This database is not exhaustive. For some sites, the information is more than 40 years old. *Very few of the mines on the list have been individually inspected* (my italics). It would be useful for the Queensland Government to review the information held by all of its agencies *and seek information from the public* (my italics) to add to this database.

THE PAUCITY OF PUBLIC INFORMATION ON OPERATOR-CONTROLLED SITES

In Queensland, it is the site operator's responsibility to monitor the environmental conditions on and surrounding operating sites. The Queensland Department of Environment and Heritage Protection (2016 a; 2016 b) defines environmental monitoring for mine site rehabilitation as a company-controlled element, and ascertains whether site operators are complying with their approval conditions and other legal obligations by means of desk audits and site inspections. However, site operators are often not required to communicate monitoring data to government unless indicators exceed set limits. The Department of Science, Information Technology and Innovation (2017) does require some coal seam gas activities and coal mines to supply monitoring data on their water releases to the department to be checked against approval limits. This system of exception reporting of monitoring data and occasional government inspection, with little or no independent verification, is inherently flawed. Moreover, in Queensland, there is no public right of access to environmental monitoring data collected by site operators. When Taylor, Davies and Kristensen (2014) attempted to access data collected by Xstrata Mount Isa Mines under its environmental authority, a departmental director informed them that the department "cannot provide the mine's data to external sources without consent".

However, in New South Wales, Section 66(6) of the *Protection of the Environment Operations Act 1997* requires every holder of an environment protection licence (licensee) to make pollution monitoring data available to the public within fourteen days of obtaining the data. If the licensee maintains a website relating to the subject of the licence, the information must be displayed prominently for public consumption. Otherwise, a copy of any of the monitoring data related to pollution must be made available, at no cost, to any person who requests a copy of the data (New South Wales Parliamentary Counsel's Office, 2012).

A LACK OF COMMUNITY TRUST IN THE INDUSTRY AND GOVERNMENT

In a CSIRO survey of Australian attitudes towards mining, Moffatt, Zhang and Boughen (2014) found that the community lacked faith that governments could hold the mining industry accountable, or that legislation and regulation could be counted on to ensure that mining companies did the right thing. They also found a low level of community trust in the important actors in the mining industry in Australia, NGOs faring the best, followed by industry and the federal government, with state governments trusted the least.

The lack of public trust in government is borne out, elsewhere. Barclay et al. (2012) concluded that the unwillingness of successive state governments in New South Wales to commit additional funding to address the impacts of mining, combined with lack of trust in the state government more generally, and perceptions of a lack of local government capacity had led to heightened levels of community activism in that state. The Australia Institute's 'Greasing the Wheels' report (Aulby and Ogge, 2016) claimed that the mining industry had exerted undue influence over the Queensland and Commonwealth governments, and that this had created a "continuing malaise in public trust". It presented several case studies of mining projects gaining extraordinary access to government ministers and gaining extraordinary outcomes, including "legislative changes to remove environmental protections, federal and state government approval of projects despite serious environmental concerns, and even retrospective approval of illegal mining activities".

Gillespie et al. (2016), in a study of stakeholder trust in the Queensland CSG industry reported that external stakeholders perceived the trustworthiness of the Queensland CSG industry to be low and on par with the trustworthiness of the Queensland coal mining industry and the Queensland Government, and significantly less trustworthy than the Queensland agricultural industry. The head of one of the country's largest gas producers has warned that the nation's oil and gas industry "had lost the trust of the public" (Robins, 2017). The chief executive of the nation's peak farming body has claimed that "a deep community distrust of the sector is at the core

of state-based restrictions and moratoria on gas exploration and development", and has called on the gas industry to repair its public image if it wants a productive relationship with farmers (Australian Associated Press, 2017).

COMMUNITY CONFLICT WITH INDUSTRY AND GOVERNMENT – A TALE OF TWO COMMUNITIES

The increasing public cynicism regarding the current system of resource extraction has fuelled the growth of new activist opposition to that system, both regionally and nationally, imperilling both present and future extractive operations.

Higginbotham et al. (2010), in their study of coal-affected communities in the Upper Hunter Valley described how for twenty years, community concerns were largely ignored by authorities, residents and civil society groups who protested about air pollution and health risks were marginalised, mining industry groups sought to discredit residents' complaints, regional parliamentarians discounted residents' views, and government dependence on coal revenue from the Upper Hunter contributed to residents' scepticism. They argued that "environmental injustice and health inequity in the Upper Hunter has arisen because political economic interests outweigh concerns about long-term damage to the health of this relatively small and electorally insignificant rural population". However, they concluded that the balance of power was shifting as residents' pressure gained momentum and resonance in local government, green politics and mass media. The mounting community pressure led directly to a change in government policy – "In 2009 and 2010 there was a high level of community concern about the cumulative impact of coal mining on air quality in the Upper Hunter Region. The Upper Hunter Air Quality Monitoring Network was established in October 2010 to provide reliable, regional air quality monitoring data. By February 2012, fourteen monitoring sites were operational in strategic locations" (New South Wales Office of Environment and Heritage, 2015).

Another coal-affected community in the Lower Hunter lost its battle. The residents of the small town of Bulga fought a very public, bitter, long-running (2009 to 2017) legal dispute with Warkworth Mining Limited and the NSW Government over the expansion of the Mount Thorley Warkworth open-cut coal mine through a 'permanent' conservation zone to the town's outskirts. There was support for the expansion from larger communities, remote from the environmental consequences, but who would benefit financially from the mine's expansion (Australian Broadcasting Corporation, 2015). After the residents' legal victories in the Land and Environment Court and the state Supreme Court over the government and the company, the government changed the law to ensure that a new application by the company would succeed. The mining company promptly reapplied and the expansion over the protected area was approved (Lock the Gate Alliance, 2016). The television networks and the press widely covered the dispute over the years, with the residents portrayed in a favourable light in a dispute framed as a 'David versus Goliath' struggle. Such acrimonious public disputes fuel community distrust in both governments and the extractive industry.

There is a valuable lesson to learn from the tale of these two disputes – 'United we stand; divided we fall'. A single small community is highly vulnerable to the resource extraction agendas of remote governments and powerful corporations. A network of communities is a much more formidable foe – or much-valued partner.

COMMUNITY-BASED ENVIRONMENTAL MONITORING

PRINCIPLES FOR SUCCESS

In the context of this paper, the point of community-based environmental monitoring is to improve the management of extractive sites, so the data gathered has to be used to further this goal – preferably to be used in resource management, rather than as legal evidence in disputes.

The monitoring needs to meet professional standards of scientific rigour. Harrison et al. (2013), in a study of volunteer-gathered data in the Waterwatch ACT catchment monitoring program, concluded that "the Waterwatch database provides a good quality baseline data set for monitoring water quality in the ACT" and "The quality of Waterwatch data provides an opportunity to extend site coverage to parts of the ACT that are not well sampled at the moment". These findings mirrored those of an earlier study by Nicholson, Ryan and Hodgkins (2002) on data collected by Waterwatch Victoria volunteers. Shelton (2013) concluded that volunteer citizen scientists could collect water quality data that was not significantly different from that gathered by professionals, but that

it was necessary to select ideal parameters and provide comprehensive training. Sharpe and Conrad (2006) warned that adequate accuracy and precision could be achieved only with sufficient resources, through the use of standardised protocols, and use of Quality Assurance / Quality Control procedures.

The monitoring needs to be compatible with current government and industry monitoring, so that the community data is integrated with the government and industry data. McKay and Johnson (2017) recommended the involvement of decision-makers early in the design process to provide vision to the program, define important environmental parameters for monitoring and decide on appropriate methods of measurement to ensure data relevance and compatibility.

The monitoring needs to be sustainable. There are many suggestions in the literature about how to avoid volunteer burnout (Buckland-Nicks, 2015; Dickinson et al., 2012; Murphy-Mills, 2015; Sharpe and Conrad, 2006; Weston and Conrad, 2015). However, the best solution is for the monitoring to be done by community groups whose passion and mission is to conserve the environment and who are part of a larger state or national structure. Landcare and Natural Resource Management (NRM) groups would be well-suited to this task.

THE BENEFITS OF MULTI-SECTOR PARTNERSHIPS

A complex geographically-dispersed issue like the environmental management of extractive sites would be most effectively addressed by a cooperative partnership between government, industry, academia and community, because all groups have a stake in the issue, and all have much to contribute.

A major consequence of such a partnership could be a rebuilding of public trust in government and the extractive industry. Communities would necessarily have closer relationships with the government and the industry. Site operators and government site managers would regard the maintenance of healthy community relationships as part of daily business. This transparency and cooperation could markedly decrease the level of community disputation with the industry and government.

Government would also benefit from the extension of government monitoring networks, cost savings, promotion of public participation to achieve government goals, and provision of an early warning system of ecological changes (Sharpe and Conrad, 2006). Industry would benefit from the improved communication and relationships with communities, thereby increasing cooperation for future development activities (Noble and Birk, 2011). Universities would benefit from working relationships with government and industry decision-makers, new opportunities for societally significant scientific papers and student theses, and valuable onsite experience for staff and students. Communities would benefit from their involvement in impact management and from discussing their environmental concerns directly with industry (Noble and Birk, 2011).

TWO VOICES FROM LOCAL COMMUNITIES - MONITORING VERSUS REHABILITATION

WOWAN/DULULU LANDCARE – DEE RIVER, QUEENSLAND

The Dee River forms part of the headwaters of the giant Fitzroy River catchment in Central Queensland. Periodically, AMD from the abandoned Mount Morgan copper-gold mine has heavily contaminated the river with heavy metals. Dululu and Wowan are two small towns, located about 40 km downstream from the mine. Wowan/Dululu Landcare is a group of mostly farmers, with great concerns for the environmental health of the river. Neal Johansen, president of the group, wrote:

"Generations of locals have been driving over the Dee River bridges and guessing what colour the water was going to be on that day. As we were seeing this on a daily basis all our lives, it seemed like the norm. A Landcare meeting held in 1996….was the start of a long and arduous campaign to bring the situation at the abandoned Mount Morgan mine to the attention of the public and politicians alike.

"DNR [Department of Natural Resources] controlled the mine site and seemed to think that any interference from Landcare was a direct challenge to their authority and this proved difficult to overcome. Fortunately, Corinne Unger was then appointed head of the DNR mine site and the whole situation then changed and they were receptive to the fact that there were environmental issues that needed to be addressed. Landcare worked with DNR to bring this awareness to the politicians. Landcare held monthly meetings, many of them attended by mine staff and we attended their meetings as well, and a solid and trusting relationship

was formed and stays strong to this day….. A severe shortage of government funding is preventing the mine from being rehabilitated and there is no funding in sight. We have been unsuccessful in achieving the big picture, or shaming the government to comply… ..I think that everyone involved has developed a passion to see the best possible outcome and we have developed a strong respect for each other. We have also been lucky to have the Fitzroy Basin Association [a regional NRM group], which has been supportive in many ways" (Johansen, 2017).

KURRI KURRI LANDCARE – LOWER HUNTER REGION, NEW SOUTH WALES

Page (2013) reported that a continuing flow of AMD from the Neath Colliery site had severely contaminated a tributary of Swamp Creek and quoted a government spokesperson as saying that the seven AMD sites in the Lower Hunter had been rated as low-to-medium risk and higher risk sites were given priority for remediation funding. She went on to quote an environmental and soil scientist as saying that the acid runoff was "very toxic" and "The only real way to treat it is impound the water in a dam and treat it with super-fine lime". The Kurri Kurri Landcare group spent eight years using hydrated lime to neutralise acidic water at the Neath colliery that flowed into Swamp Creek and ultimately the Hunter River. In 2007, the Department of Lands ordered the work to stop, claiming that the group was harming the environment, because sludge was smothering the creek bed (Australian Broadcasting Corporation, 2008). In 2014, with the creek at Neath again heavily contaminated, the group wanted to resume their rehabilitation work, but permission was denied (Kelly, 2014).

Col Maybury, president of the group, wrote: "I developed automated Slaked Lime feeders that, using variable speed screw feeders, fed lime into a pumped flow of the [Neath] AMD, mixing as it flowed through launders and neutralising the acid effectively at a cost of less than 10 cents per tonne of coal. The refuse is inert and suitable for landfill disposal. We were asked to go to Greta, where a large acid spring came up the coal skip tunnel and then flowed into Anvil Creek and the Hunter River. We made an automated small plant that mixed the lime and acid and so neutralised the AMD. The resultant mix was directed by pumps onto the natural grasses and produced exceptional growth, but it was too expensive for our meagre resources". (Maybury, 2017)

He went on to describe fractious relationships with local councillors, state politicians and the public service, as the group agitated for government action to remediate the Neath site and government support for the group's own remediation work.

These voices illustrate community problems with the present system. Continual monitoring of continuing environmental problems when nothing is done to remediate the problem is deeply dispiriting and frustrating. Landcare groups have a basic drive to rehabilitate damaged environments and when their efforts are criticised and opposed by government, they too become dispirited.

DISCUSSION

PATHS OF COMMUNITY INVOLVEMENT IN GATHERING DATA AND IMPROVING MANAGEMENT ON EXTRACTIVE SITES

1. Call on the monitoring expertise of independent environmental monitoring organisations to acquire the environmental evidence needed to force improvements in government and industry behaviour – the adversarial alternative to multi-sector partnerships.
2. Supplement an existing government environmental monitoring system in an area of poor coverage.
3. Participate in citizen science environmental monitoring initiatives.
4. Participate in regional partnerships of community, government and industry in environmental monitoring.
5. Participate in a state-wide partnership of community, government and industry.

A range of organisations and initiatives were reviewed, with a view to their possible applicability to these paths (See TABLE 1).

PATH 1: THE INDEPENDENT ENVIRONMENTAL MONITORING ORGANISATION

When extractive site operators and state governments are dismissive of or hostile to legitimate community concerns, adversarial situations arise and the opportunity to create community-industry-government partnerships to address environmental problems is lost. One avenue of recourse for adversely affected communities is to gather environmental evidence, in order to apply legal or media/political pressure to effect favourable changes in corporate and political

TABLE 1. A comparison of community-oriented environmental monitoring organisations and initiatives

Title and Location	**Scale, Impact, Path(s)**	**Participants**	**Purpose**	**Important features**
Earthworks 'Community Empowerment Project' (U.S.A.)	Nation air quality 1	Non-profit activist NGO, acting on requests from communities	Empower communities to record infrared video evidence of air pollution from oil and gas activities.	**Nation-wide coverage by a single expert unit.** Tool for community empowerment. Cost-effective.
Community Science Institute (U.S.A.)	State water quality 1	Non-profit NGO, recruiting and training community groups and acting on requests from home owners	Collect water quality data to evaluate risks to waterways and groundwater. Inform communities.	**Public access to data.** Fee-for-service sample analysis (non-profit). **Financial sustainability.**
Imperial County Community Air Monitoring Network (U.S.A.)	County air quality 2	Multi-sector (community groups, local state and federal agencies, universities)	Inform the public about air quality in real time. Identify air pollution hot spots and trends.	**Public access to data.** **Long-term sustainability.** **Low-cost sensors.** **Supplements regulatory sensor network.**
Rocky View County Groundwater Monitoring Network (Canada)	County groundwater quality 2	Semi-local (community members, county council, university)	Monitor water levels to assist with long-term planning and policy development regarding groundwater resource allocation.	**Public access to data.** **Low-cost system.** Methodology can be easily adopted.
Waterwatch (NSW, ACT, Victoria)	State surface water quality 3	Multi-sector (community groups, government agencies, universities, schools, landholders)	Monitor water quality for catchment management, education and awareness-raising.	**State-wide coverage.** **Public access to data.** Continued government financial support. Multiple applications.
HLW (South East Queensland)	State Region surface water quality, catchment loads, etc 4	Multi-sector (community groups, government departments, regional councils, universities, industry, utility companies)	Improve sustainable use of land and waterways. Monitor and report on catchment and estuarine health.	Region-wide coverage. Widespread data access. **Public report card.** Includes land and water. Continued government financial support. Multiple initiatives.
FPRH (Fitzroy River Basin, Bowen Basin, Queensland)	State Region surface water quality 4	Multi-sector (community groups, government departments, regional councils, universities, extractive and agriculture industries)	Develop and implement integrated waterway monitoring and reporting.	Region-wide coverage. **Public access to data.** **Public report card.** Extensive extractive sector involvement. Continued government financial support.

behaviour. A variation of this scenario is one where communities fear present or future environmental damage from developing industries (such as gas fields) in areas where there is inadequate or no relevant publicly-available environmental monitoring data. These communities may want to monitor the present situation and create environmental baselines to prove industry culpability in the future. In these situations, a concerned community needs to call on the services of an independent environmental organisation – preferably a non-profit community-oriented NGO. Two organisations in TABLE 1 are applicable to the Australian situation and Path 1.

Earthworks (n.d.) solicits communities adversely impacted by extractive operations to tell their stories and offers possible avenues of assistance – one of which is the Community Empowerment Project, where a community can request Earthworks to supply a thermographer, equipped with a sophisticated infrared camera, to record infrared video evidence of air pollution from oil and gas activities. It may be possible to fund a similar service in Australia on a non-profit fee-for-service basis. The closest Australian equivalent of Earthworks is probably the Mineral Policy Institute (n.d.), but it is not well-funded. An alliance of conservation organisations and private donors might be able to provide seed funding or supplementary support. This concept is worth pursuing, because a single expert unit would have nation-wide coverage.

The Community Science Institute operates a state-certified water quality testing laboratory. It recruits, trains, and provides technical support for community groups to conduct long-term baseline stream monitoring. Its surface water and groundwater monitoring results are stored on public-access online data archives, so that the public and municipal and county governments can better understand and manage water resources in their jurisdictions. This non-profit NGO is financially self-supporting – testing is on a fee-for-service basis and volunteer groups are encouraged to seek funding from local sources, such as their local government authority (Penningroth et al., 2013). There appears to be no reason why this model could not be successfully adapted to the Australian situation.

There is a third possibility that could be pursued – adding a limited environmental monitoring/analysis capability to Landcare or the Natural Resource Management (NRM) state coordinating bodies. The nation-wide Landcare movement is made up of more than 5,400 volunteer local groups, who "safeguard, rebuild, regenerate, and sustainably manage the natural environment" (Landcare Australia, n.d.). The Natural Resource Management initiative is also nation-wide, with each state having a coordinating body for the regional NRMs within the state. For example, the NRM Regions Queensland (n.d.) "focuses on the state-wide delivery of regional natural resource management outcomes, in partnership with industry, community and government" and the Fitzroy Basin Association (n.d.), a regional Queensland NRM, lists its mission as "empower our region with the resources, knowledge and skills to maintain our natural assets for future generations".

Given a mandate and secure ongoing funding, the regional NRM bodies could assemble the necessary capabilities at the community level. The function would still require a state-level or national champion, but the capability itself could lie with the NRM state coordinating body, to be made available to regional NRMs on request.

PATH 2: SUPPLEMENTING GOVERNMENTAL ENVIRONMENTAL MONITORING

When a government environmental monitoring system has inadequate coverage in an area where communities have significant environmental concerns, communities may see advantage in participating in a parallel monitoring system. The parallel system would be designed either to feed monitoring data into the governmental system, or to keep the local communities informed of the local situation. Two organisations in TABLE 1 are applicable to the Australian situation and Path 2.

The Imperial County Community Air Monitoring Network is designed to fill the need for more detailed data on particulate matter in an area that often exceeds air quality standards. The five monitoring stations in the regulatory network were too few in number and not designed for community application. The community owned and operated network now produces real time data from 40 low-cost sensors. While initially funded by a federal environmental health research grant, the system is designed so that the community would have the resources, knowledge, and capacity to sustain it (English et al., 2017). This concept could work in Australia, in some circumstances. Queensland's Department

of Environment and Heritage Protection (n.d.) allows public access to hourly air quality data from its network of 29 monitoring stations. However, there has been recent controversy about what was claimed to be large gaps in the network in the central Queensland coal fields, with the government having no plans to extend its network there and the communities not having any access to mining company monitoring data (Lodge, 2016).

If extractive sector monitoring data were real-time integrated with the government monitoring data in a public-access real-time reporting system, coverage would be much improved at little cost. Such an arrangement should be regarded as part of an extractive site operator's 'social licence to operate'. However, if this essential reform is to be indefinitely delayed, low-cost community-owned-and-operated monitoring systems (preferably compatible with the relevant government monitoring system) may be required to satisfy community needs.

The Rocky View County Groundwater Monitoring Network is a simple low-cost system where community volunteers measure the water level in their wells and enter the data through a web-based data portal, which allows the public to view and download the data. It was intended as an experiment to develop a cost-effective new approach to studying groundwater resources in Alberta, using a university-municipality partnership involving community members (Little, Hayashi and Liang, 2016). This process of landholder and community augmentation of groundwater databases has particular applicability to the CSG fields in Queensland. In their study of CSG water contaminants in Queensland, Navi et al. (2015) expressed concern that there was little monitoring of the chemicals of health significance in CSG water and there appeared to be no centralised monitoring of CSG water. They concluded that a consolidated database of CSG water samples, discharges, uses and contamination incidents was required for both industry compliance and sound environmental management.

In Queensland, the Department of Natural Resources and Mines maintains an online public-access groundwater database, which stores registered water bore data (water level and flow rate) from private water bores and Queensland government groundwater investigation and monitoring bores (Queensland Government, n.d.). It would be highly beneficial to expand the groundwater network, particularly in the CSG fields. Landholders whose groundwater might be adversely affected by extractive operations and communities exposed to CSG waters would have an environmental incentive to become involved. The online station data should include all relevant data, including any measurements of salinity and total dissolved solids, and any chemical analyses (fluoride, iron, aluminium, boron, mercury, lead and benzene). Extractive industry operators also need to contribute (or be required to contribute) their monitoring data to the present public-access groundwater database.

PATH 3: CITIZEN SCIENCE ENVIRONMENTAL MONITORING INITIATIVES

Community groups who see advantage in monitoring the environmental health of extractive sites could sometimes 'piggy-back' on existing compatible, multi-purpose citizen science environmental monitoring initiatives.

One organisation in TABLE 1 fulfils the requirements for Path 3.Waterwatch (n.d.) engages communities in monitoring and protecting the health of local waterways in New South Wales, Victoria and the ACT. Waterwatch volunteers are trained in the use of standard equipment and standard data collection methods that are suitable for non-professional and professional data gatherers. The parameters measured and the method of measurement are similar (but not identical) in all three jurisdictions – see TABLE 2. TABLE 2 demonstrates that the Waterwatch monitoring program is suitable for monitoring extractive sites. The FPRH column describes a monitoring program that was designed for extractive sites. Comparison of that column with the Waterwatch columns shows high similarity in the physical-chemical indicator group, both measure phosphorus/phosphate levels, and many Waterwatch and FPRH sites measure nitrogen/nitrate levels. Participants in New South Wales conduct monthly water quality testing and optional seasonal surveys of aquatic macroinvertebrates (senior sites only) to understand and monitor the health of their rivers and to provide quality assured data. This system is appropriate for extractive sites. Extractive site monitoring at times involves testing for one or more toxicants (such as copper), which is not done in Waterwatch. Consequently, testing for toxicants would require independent analysis.

One scenario might play out as follows: a community group in a mining region of New South Wales or Victoria believes that it is in the

TABLE 2. Publicly available data on physical, chemical and biological water quality parameters

Indicator/ Parameter	Unit	HLW *	FPRH **	WW Vic	WW NSW	WW ACT
PHYSICAL-CHEMICAL						
Air Temperature Water Temperature Temperature Range	°C °C	X √ (max) √	X X X	√ √ X	√ √ X	X √ X
pH (acidity)	pH unit	√	√	√	√	√
Electrical conductivity	µS/cm	√	√	√	√	√
Turbidity (water clarity)	NTU	X	√	√	√	√
Sulfate	.	X	√	X	X	X
NUTRIENTS						
Available Phosphate Reactive Phosphorus Total Phosphorus	mg/L mg/L P mg/L	X X X	X √ √	X √ X	+ X X	X X √
Dissolved Oxygen Dissolved Oxygen Dissolved Oxygen Range	mg/L %sat	√ (min) X √	X X X	- - -	+ + X	√ √ X
Nitrates Total Nitrogen Oxidised Nitrogen	mg/L . .	X X X	X √ √	-	X	√
TOXICANTS						
Arsenic to Zinc	score	X	√(0 to 16)	X	X	X
ECOLOGY						
Macro-invertebrates Bug Numbers Species Bugs		√ √ √	√ √ √	X X X	X - # - #	X - # - #
Fish		√ √ √	X	X	X	X
Ecosystem processes		√ √	X	X	X	X

NOTES

The toxicant parameters measured would vary with the resource type, and with the studies being done.

* HLW data is widely available, but not automatically publicly available.

** The value associated with each parameter is a score out of 100. A subset of these parameters may be measured at any particular monitoring site.

√ Yes (the number of these symbols in a cell equals the number of parameters measured)

X No + Senior sites only - Some sites only

\# Separate from Water Quality Surveys; the species counted varies; used to rate stream quality.

community's interest to monitor AMD discharge from an extractive site into a local waterway; the aim is to inform the community and the government regarding the scale of the problem; the group needs help (with training, testing kits, laboratory analyses, online public access to the data gathered; the group joins the Waterwatch network. Waterwatch gains dedicated volunteers and the group becomes part of a wide network of like-minded groups. The group conducts its monitoring at the high 'data collection' standard (rather than 'awareness raising' or 'educational') and the information gathered by the group is therefore uploaded to the Waterwatch public-access online database for use in catchment management. Environmental advocacy groups would also be able to access this extractive site data and use it to campaign for remediation work on those extractive sites.

PATH 4: REGIONAL ENVIRONMENTAL MONITORING PARTNERSHIPS

Community groups who see advantage in monitoring the water quality of streams immediately downstream of extractive sites could participate in the professional monitoring program of a regional environmental monitoring partnership – if their region has one. Any new requirement to monitor extractive sites would create an additional workload, only if additional monitoring sites had to be established, or additional visits were required. The cost of incorporating this capability into an existing compatible general-purpose system would be modest, compared to that of creating a new parallel organisation.

Two organisations in TABLE 1 fulfil the requirements for Path 4 - Healthy Land and Water (HLW) and the Fitzroy Partnership for River Health (FPRH). Healthy Land and Water (n.d.) operates multiple monitoring programs over land and water, pursues multiple initiatives and offers multiple services within the region, while the Fitzroy Partnership for River Health (n.d.) focuses on water quality issues. Extractive industry activities are not a major issue in South-East Queensland catchments, but are a major issue in the Fitzroy Basin - fifteen mining and oil/gas companies operating in the basin contribute freshwater monitoring data to the Fitzroy Basin Report Card (FBRC).

The Report Card system is the preferred mechanism to summarise the state of environmental health of an ecosystem, or convey the significance of monitoring results to the public (see TABLE 3 for a comparison of report card systems). Extractive sites are point sources of pollution, and so the measurements taken at a single monitoring station can be highly significant. In addition, extractive sites sometimes require monitoring of additional indicators (the toxicants). The HLW Report Card system applies to entire waterways and is not designed to report on pollution from point sources such as extractive sites. The FPRH initiative was designed in partnership with the extractive operators in the region and the FBRC reflects this. The FPRH provides public access to the monitoring results of individual stations and this should be standard practice for all regional monitoring partnerships. However, FPRH monitoring station data have de-identified Site IDs to conform to the partnership's data sharing restrictions. This restriction needs to be lifted. The Queensland Government now provides the public with timely and free access to relevant data from many of their resource databases, and other jurisdictions require this of extractive operators, as well.

While both partnerships have gaps in their freshwater monitoring network, neither makes any use of community groups to fill the gaps. In South East Queensland, all freshwater monitoring is carried out by scientists from the Queensland Government's Department of Science, Information Technology and Innovation. In central Queensland, there are two parallel monitoring and reporting systems. In the 'professional system', partner organisations upload their monitoring data for the purpose of informing the FBRC. The community-based monitoring system is an educational and awareness-raising tool. The two systems have a degree of commonality in parameters measured, but there are inconsistencies in terminology and units. Importantly, community monitoring results are not included in the FBRC because the FPRH believes that the community-sourced data lacks the required scientific rigour and consistency (Sader, 2016). This under-estimation of community capabilities is a flaw in both monitoring systems, and should be rectified. Community-collected monitoring results can conform to high standards of scientific rigour, if effort is put into making it so (see 'Principles for success').

PATH 5: A PROPOSED STATE-WIDE INTEGRATED ENVIRONMENTAL MONITORING INITIATIVE

This paper proposes an ambitious partnership of communities, NGOs, government, extractive industry, academia and learned societies to progressively create a Queensland-wide extractive site information system. There would be multiple steps in the process.

TABLE 3. Report card grading/scoring system – freshwater component

Report Card System	Reporting Areas	Reporting Area Components	Component Indicators	Station Indicators
HLW	18 catchments • Grade • Benefits	Physical/chemical Pollutant loads Riparian Ecosystem processes Fish Invertebrates • Score	No reporting on individual indicators (such as pH or dissolved oxygen)	No reporting on individual stations (needed for point-source pollution sources)
FPRH	11 catchments • Score • Grade (+ Fitzroy Basin Grade)	Physical-Chemical Nutrients Toxicants Ecology • Score and Grade	4 Physical-Chemical 4 Nutrients 0 to 26 Toxicants 0 to 3 Ecology • Score and Grade	4 Physical-Chemical 4 Nutrients 0 to 26 Toxicants 0 to 3 Ecology • Score and Grade
Waterwatch ACT	96 reaches in 5catchment areas of 1 catchment • Grade	Component indicators are not combined into evaluated groups	4 Physical-Chemical 2 Nutrients 2 Ecology • Grade	Monitoring results on individual stations are available elsewhere.

NOTES

Waterworks benefits rating: 1 star (minimum benefits) to5 stars (maximum benefits)

Environmental Condition Grade: F (Fail or Degraded), D (Poor), C (Fair), B (Good), A (Excellent)

Score: 0.0 to 1.00 (HLW) or 0 to 100 (FPRH)

Reporting Areas:
HLW The 3 marine zones have different monitoring parameters.
FPRH The Fitzroy River Estuary and marine zones have different monitoring parameters.

1. Standardise as far as practicable the environmental monitoring indicators, testing/sampling equipment, protocols and analysis laboratories for extractive sites.
2. Identify and prioritise gaps of knowledge on extractive sites – areas of particular community concern and areas where contamination could cause long-term damage would have a higher priority.
3. Gain extractive industry agreement to mutual sharing of data from monitoring stations – this could be a legislated requirement, but the industry would benefit greatly in public regard, if it announced this change of policy as an industry initiative.
4. Significantly increase community participation in environmental data gathering on (and monitoring of) extractive sites to professional data collection standard – especially in the priority areas.
5. Significantly expand the environmental monitoring networks, partly by means of new low-cost sensors and innovative but proven application of Information and Communication Technologies (ICT) – especially in the priority areas.
6. Upload all relevant monitoring data (community, government, industry) to appropriate groundwater, surface water and air pollution databases and the Queensland Minerals Occurrence database (or its successor) – these databases may be either state-wide or regional.
7. Create a public-access easy-to-use online extractive site inter-database data extraction and enquiry system that would constitute a virtual Queensland Extractive Site Information System.

The benefits of this approach could include greatly increased knowledge on extractive sites, greatly increased access to that knowledge, significantly improved decision-making as the 'Big Picture' emerges, increased cost-effectiveness of data gathering and monitoring, value-adding both to new data and data already gathered, focus on areas previously neglected because lack of knowledge creates lack of awareness, increased community participation in decision-making, improved relations and increased trust between the public, the extractive industry and government (with resulting declines in damaging disputes), and a greater role for universities and learned societies in improving the social fabric of Queensland.

As far as possible, this initiative would value-add to existing general-purpose environmental monitoring programs. The same monitoring groups would largely measure the same indicators with the same measuring equipment as previously (perhaps with some changes in station location), but with the added benefit of adding to the knowledge on extractive sites. This would be far cheaper, far easier to achieve and much preferable to creating and maintaining an entirely new system, with its accompanying bureaucracy and replication of functions.

There are obstacles to overcome if this proposal is pursued. A problem inherent in successful regional initiatives is that government, business and society focus attention on these regions and other regions are potentially neglected. Their very success may also delay the creation of a state-wide system, with perceived problems in integrating disparate monitoring systems and reduced urgency to create the larger system. A high degree of monitoring standardisation across regional systems is highly desirable, but standardisation need not be total - some indicators may be important in one region but not in another, or important at one station but not another. In some regions, extractive operations may not figure prominently and so only the few extractive site monitoring stations need to comply with the standardisation requirements. For example, consider TABLE 2, where it is apparent that there is a low degree of monitoring standardisation between HLW and FPRH – and the HLW sites are monitored only once a year. Because of its wide-ranging brief and limited budget, HLW concentrates on areas that require action (such as riparian zones and wetlands). It also uses catchment predictive modelling (where rainfall patterns are used to predict pollution loads in waterways) to compensate for its limited freshwater modelling. However, extractive activities are not a major source of pollution in these waterways and so only a very few monitoring stations would need to comply with any state-wide extractive site monitoring regime.

A problem inherent in embedding monitoring/reporting systems for extractive sites inside general purpose monitoring/reporting systems (such as those of HLW and FPRH) is being able to easily extract that information and link it to other relevant data held elsewhere, so that all relevant extractive site data is made available. A partnership of not-for-profit scientific organisations (such as the emerging Queensland Science Network, in Queensland) may be an appropriate custodian for this task, because the collection and dissemination of scientific knowledge is one of major functions of scientific organisations (Royal Society of Queensland, 2016). The relevant government agencies would be responsible for in-house work on their database systems.

Funding for the initiative (additional monitoring, software and hardware upgrades, management) could be raised from a small increase in the royalty on the output from operating extractive sites. Such a funding model is appropriate, because economic theory would indicate that the cost of remediating an operation should be a charge against production (i.e., the extractive industry). Funding for community-based monitoring and seed funding for community information systems could be channelled through the budget allocations for the NRM bodies. These bodies are professional and ongoing bodies that already conduct commercial services, are already agents for spending state monies, have appropriate governance arrangements in place, are already active in environmental monitoring across their regions, and are also capable of coordinating volunteer activity. Many of the volunteer groups would almost certainly be Landcare groups, which have a long-term commitment to environmental issues.

THE NEXT STEP FORWARD

There are multiple reforms that can and should be made to increase the publicly-accessible knowledge base of environmental information on extractive sites and rebuild lost public trust in government and the extractive industry. Several have been discussed

in this paper. What is needed is some mechanism whereby progress can be made on a model to achieve these reforms. Because mineral and oil/gas extraction is basically a state and territory responsibility, much of this needs to be done at a state or territory level. In Queensland, this might be achieved by the state government, the NRM Regions Queensland (representing the 14 regional NRM bodies in Queensland), the Queensland Science Network and one or more industry representatives getting together to develop a model to implement a suite of reforms.

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AUTHOR PROFILE

The author began his career as a milling metallurgist with Mount Isa Mines at Mount Isa, before returning to the University of Queensland to complete his M.Sc. He then worked on Hamersley Iron's financial modelling system, before returning to Brisbane to work for MIM Holdings as a Technical Computer Analyst. He later worked in the Queensland Public Service, holding the position of Principal Research Adviser at his retirement. He has lately involved himself in investigating the benefits to be derived from the involvement of communities and professional organisations in what he regards as the increasingly important issue of site rehabilitation.