Chapter 12
An Overview of Mining and the Environment in Western Australia

Charles Roche and Gavin Mudd

Abstract This chapter identifies and explores the common environmental effects of mining in Western Australia (WA). Utilising unique state-specific data, we examine site-specific factors with reference to metals, mine life cycle, cumulative impacts and temporal disturbance. Emerging trends are discussed with specific reference to WA including in relation to production, ore grades, waste, scale, socio-environmental issues and mine legacy impacts. Finally we explore the constraints on effective environmental management imposed by the WA approach to mining development and discuss challenges for the effective environmental management of mining.

Introduction

Since settlement the approach to managing the impacts of mining in Western Australia (WA) has changed, with a gradual adoption of environmental standards since the 1970s, following similar trends across Australia (see Mulligan 1996). More recently, Western Australians, like citizens in other jurisdictions throughout the world, are rethinking their attitude to mining and demanding a more thorough assessment and evaluation of the impacts, risks and benefits of the mining industry (Hobbs 2011; Brueckner and Mamun 2010; Nicol 2006). The environmental impacts of mining are, at one level, local, and site-specific—issues a typical Environmental Impact Statement (EIS) might focus on. A different view, however, sees environmental impacts as increasing, cumulative and driven by industry

---

C. Roche (✉)
Mineral Policy Institute, Perth, WA
e-mail: charles.roche@mpi.org.au

G. Mudd
Environmental Engineering, Monash University, Clayton, VIC Australia / Mineral Policy Institute, Perth, WA
e-mail: gavin.mudd@monash.edu

M. Brueckner et al. (eds.), *Resource Curse or Cure ?*, CSR, Sustainability, Ethics & Governance, DOI 10.1007/978-3-642-53873-5_12,

trends. The dominant development ideology affecting how the industry is viewed, assessed and described to some extent predetermines how we identify, regulate and resolve environmental impacts.

This chapter brings together these divergent ways of thinking about environmental impacts of mining. First, typical impacts are presented with reference to the stages of mining, spatial and cumulative impacts and the longevity of disturbance. Second, we offer an exploration of trends in mining, both physical and conceptual, that can shed light on likely future impacts and how the approach to managing environmental impacts in WA defines our focus and shapes our solutions.

Western Australia

WA is a mining state. From the early gold rushes near Coolgardie, to the more recent massive expansion of iron ore and gas, the state is dominated by mining: it influences finance, policy, politics and even our identity. The expansion of mining in WA is captured in the ore and waste tonnages (see Fig. 12.1), where the industrialisation and massive increase in the scale of activity in the 1960s and continuing strong growth since the 1990s can be seen. This increase in activity has been supported by government policies that have shaped the way society sees, interprets and manages the growing environmental impacts of mining.

Common Environmental Impacts of Mining

Environmental impacts can be assessed under, and divided into, a number of frameworks. The most common are direct and immediate impacts related to mining, such as land clearing, noise, dust, wildlife morbidity, tailings, water resources, land clearing, waste management, biodiversity and ecosystem changes, and air-water-soil pollution issues. Over time these have become the staple ingredients in environmental impact assessment (EIA) and regulation (see Chap. 11). More recently, with increasing demands on the state's water supply from mining, agriculture and domestic uses, the use and contamination of water has become increasingly important (see Chap. 14). Similarly, increasing local and global awareness of biodiversity loss has resulted in close examination of this aspect of mining, particularly under the *Environment Protection and Biodiversity Conservation Act 1999* (see Chap. 13).

In addition to direct and local impacts, there is a growing awareness of long-term risks and impacts from changed landscapes, pollution events, climate change and transport. For example, open-cut mines are often left as open voids and are rarely ever backfilled (eg. Nicol 2006; Mudd 2009), leading to cumulative impacts on the landscape which affect post-closure land use and ecosystems. With respect to climate change, future trends in rainfall patterns and temperature will affect the

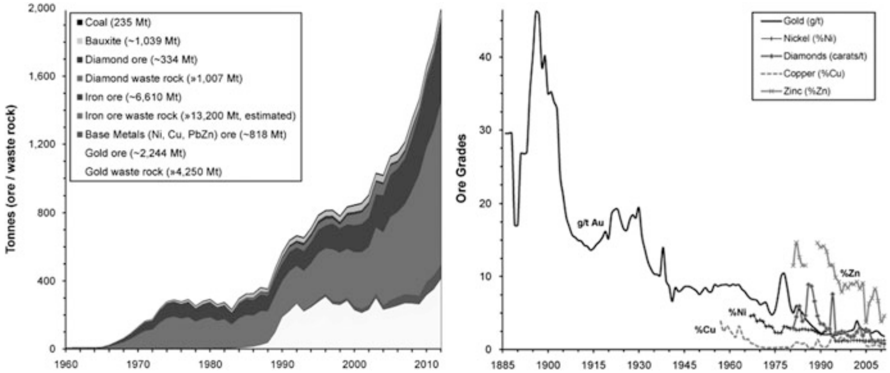

Fig. 12.1 Historical trends for some sectors of the Western Australian mining industry—ore and/or waste rock for coal, bauxite, diamonds, iron ore, base metals (Cu, Ni, Pb–Zn) and gold (cumulative tonnages in brackets) (*left*); ore grades for gold, nickel, copper, zinc and diamonds (*right*) (Notes: iron ore waste rock is assumed to be 2:1 with saleable ore due to lack of reported data; no consistent data available either for bauxite and coal; %Cu–%Zn shown from start of large-scale mines only)

hydrologic behaviour of different areas (eg. Holper 2007), leading to adaptive changes in biodiversity and ecosystems in combination with any changes due to mining.

When considering a specific mine, it is important to consider not only the local impacts in relation to environmental resilience and capacity, but also the long-term bioregional, environmental and social contexts. In other words, it is critical to think through cumulative impacts from all mines in a region (along with other activity, such as agriculture) as well as the long-term risks that mining brings such as erosion of, or seepage from, mine tailings and waste rock. There is a real need to move beyond scientific reductionism in the assessment process to a more holistic management of mining risks and impacts (Franks et al. 2013). Even without detailed or specific knowledge of impacts, the scale of mining in WA and the need for cumulative and regional assessments is evident in Fig. 1.1 (see Chap. 1), which clearly illustrates the extent of the industry in the Pilbara and the Goldfields.

While a detailed discussion of environmental impacts is beyond the brief of this chapter, common[1] impacts have been presented in Table 12.1, organised with reference to: (1) type, whether it is biological, physical or chemical; (2) the relative importance of the three stages of mining, exploration, extraction and post closure against these impacts; (3) spatial and cumulative impacts; and (4) estimated time scale at which impacts might be relevant.

---

[1] Specific or potential industry sectors such as uranium, rare earths, salt, mineral sands and others have additional/unique impacts (e.g. radiation exposure and radioactive waste).

Table 12.1 Common environmental impacts of mining

Stage of mining					
Exploration	Extraction	Post closure	Risks and impacts	Spatial and cumulative impacts	Time scale of disturbance (years)
***	***	**	*Introduction of fire, weeds and ferals*	Local-regional	<50
***	***	*	*Habitat loss and fragmentation*	Local-regional	<50–100s
–	***	***	*Permanent land alienation from open-cut and underground mines and dumps*	Local-regional-state	10,000s
*	***	***	*Land use changes, waste rocks dumps, tailings dams*	Local-regional	<500-1000s
*	*	***	*Inadequate remediation and rehabilitation*	Local-regional	<500–1,000s
*	***	**	*Groundwater and surface water abstraction and interactions*	Regional	<50–10,000s
*	**	**	*Sedimentation, changes in river and lake morphology*	Local-regional	<500–10,000s
*	***	**	*Modified surface water hydrology*	Local	<500–1,000s
*	***	*	*Greenhouse gases*	State-global	1,000s
*	***	***	**Contaminated groundwater and surface water**	Local-regional	<50–1,000s
*	***	***	**Acid and metalliferous drainage**	Local	<50–1,000s
*	***	*	**Release of contaminants from mining, processing and transport**	Local-regional	<50
*	***	**	**Air pollutants and fugitive emissions**	Local-regional	<500
**	**	**	Wildlife [incl. invertebrates and stygofauna] mortality from habitat change, injury, pollutants, exploration holes	Local-regional	<50–100s
*	***	**	Stress on and loss of biodiversity, ecosystem function/fragmentation	Local-regional	<500

*Minor, **Intermediate, ***Significant; texts in underline—biological, italic—physical, bold—chemical (with thanks to Frost and Mensik 1991; Spitz and Trudinger 2009; Bridge 2004)

Mineral Case Studies of West Australian Mining

The mining industry across WA has grown considerably in recent decades, especially in response to the iron ore, nickel and gold booms. These are outlined below with brief histories related to increasing environmental impacts and their increasingly cumulative spatial and temporal scale.

Gold

Gold has been a cornerstone of the WA mining industry for well over a century, beginning with the initial 1890s boom centering around Coolgardie–Kalgoorlie and its near neighbours, continuing in the 1930s Depression-era mini-rush and then the 1980s mega-boom which, since then, has produced more than double the gold mined in the previous century (data updated from Mudd 2007, 2009). The early years were dominated by prospectors and underground mines, sometimes using mercury or cyanide, but on a local scale. The 1980s saw the emergence of carbon-in-pulp (CIP) cyanide-based ore processing technology combined with a 10-fold increase in the price of gold—creating a giant boom which propelled gold to a dominant export commodity again. This latest boom, however, has seen large-scale mining development due to the lower ore grades which CIP can process, combined with cheap diesel and the rise of open-cut mining. Just as the production of gold has reached record levels, so too has the production of mine wastes and environmental impacts (Mudd 2007).

The various underground and small open-cut mines along the Golden Mile at Kalgoorlie were bought together under one project and converted to a super-sized open-cut mine in 1989—known as the SuperPit. At the site, 60–70 million tonnes (Mt) of rock are mined per year, of which 11–12 Mt of ore are processed with a grade of approximately 2.3 grams per tonne (g/t) gold. Since 1989, the SuperPit has produced some 460.6 tonnes of gold (~14.8 million ounces), 228 Mt of tailings and 1,257 Mt of waste rock (data updated from Mudd 2009). The pit creeps ever closer to the twin towns of Kalgoorlie–Boulder, and the local community has raised concerns over rock debris flying from blasting, seismic events causing damage to houses or infrastructure (e.g. associated with blasting of old underground mines), long-term rehabilitation, dust build-up in homes and rainwater tanks, tailings dam seepage impacts on the groundwater beneath and adjacent to the tailings dams, as well as sulfur dioxide (SO_2) emitted from the Gidji Roaster (which was moved 20 km north of town to minimise SO_2 impacts on the town) (see Cooke 2004). While the extent of these impacts and their significance can be debated, Kalgoorlie residents and visitors are confronted by a mountainous horizon of waste rock sitting behind the town. It is important to remember that such significant changes to the landscape—such as the ever deepening open-cut, waste rock dumps and tailings dams—will effectively be permanent structures (unless rehabilitation requirements change), forever altering the character of Kalgoorlie–Boulder. Over what time frame and spatial scale should the management of such changes be examined? Such a question has yet to be answered for the SuperPit.

Iron Ore

The iron ore industry continues to dominate WA's mining industry in terms of scale; by 2012 the export of iron ore from the Pilbara was Australia's biggest single export earner. Rapid development of iron ore mining from the early 1960s has not significantly depleted the Pilbara's still massive mineral resources which are extracted by the three big companies of Rio Tinto, BHP Billiton and, more recently, Fortescue Metals Group. A range of junior to mid-tier companies have also operated across the Pilbara and there are smaller projects in central, mid-west and southern WA.

The Pilbara iron ore industry now comprises three railway lines, dozens of open-cut mines intermeshed with national parks, small towns, pastoralism and other smaller industries such as tourism. In taking a more holistic approach, there were good strategic environmental grounds to allow the Rio Tinto and BHP Billiton mines to merge in the Pilbara, since this would have reduced the need for infrastructure duplication, joined together fractured mining leases, optimized energy costs, minimised land disturbance and potentially reduced the total environmental footprint from iron ore mining. Market concerns, however, precluded such a merger of giants and thus an opportunity to implement a more holistic approach to environmental planning across the Pilbara was missed.

Apart from the issues noted above, the amount of mine waste remains poorly documented in the Pilbara, since only saleable iron ore[2] is reported by Rio Tinto and BHP Billiton but not raw ore and the associated waste rock. Fortescue and other smaller miners report both ore processed and waste rock. How can we understand the long-term risks from waste rock and tailings in the absence of robust data?

In the Pilbara, projects have changed from mining the mountains above the plains to digging deeper open-cuts and many mines now operate below the water table—leading to changes in the nature of the waste rock. Below the water table, the shales, which occur with the iron ore, contain a small fraction of pyrite, or iron sulfide. When pyrite is exposed in the surface environment to water and oxygen it reacts to form sulfuric acid, which in turn dissolves salts and heavy metals—forming a toxic seepage known commonly as acid and metalliferous drainage (or acid mine drainage, also AMD). As such, AMD risks are a relatively recent but significant environmental development in the Pilbara as mining proceeds below the regional water table (see DRD 1999; ECS 2004).

---

[2] Saleable iron ore is raw iron ore that has been beneficiated or processed to remove impurities, increase iron grade or allow blending of different ore types.

At Mt Whaleback, AMD was first observed by BHP in 1995 and, given the highly reactive geochemical nature of the pyritic shales, it requires very active assessment and management. Porterfield et al. (2003) stated that at that time there were 200 Mt of acid-generating shales still to mine, while total waste rock for the mine life was estimated to be some 4,000 Mt. However a full account of waste rock has never been published for Mt Whaleback—let alone for all other sites in the Pilbara. There are identical pyritic shale AMD issues at Rio Tinto's Mt Tom Price iron ore mine in the Pilbara (Taylor and Pape 2007).

As observed at mines across Australia and around the world, sulfide oxidation and AMD can last for decades to centuries or more (Taylor and Pape 2007; Mudd 2010a, 2011). AMD can contain concentrations of heavy metals tens of thousands of times higher than water quality guideline values for freshwater ecosystems, human health (recreation or drinking) or public infrastructure, meaning it is a very serious cumulative risk which needs detailed scrutiny—yet most of the data remains elusive and outside the public realm (Mudd 2009, 2010a).

Finally, the WA Environmental Protection Authority, in a very rare decision against development, did not approve the development of an expanded iron ore mine at Windarling, part of the Koolyanobbing project near Southern Cross, due to the high biodiversity values of the site. Yet this was simply overturned by the WA Government and the site has now been mined (see Nicol 2006). The Windarling case highlights the real conflicts between biodiversity protection and iron ore mining—a tension which is present across the iron ore sector.

Nickel

Western Australia's substantial nickel (Ni) reserves were ignored until the discovery at Kambalda in 1966, which set in motion the great nickel boom with deposits also discovered across central WA and elsewhere. There were essentially three types of deposits—small high grade Ni sulfides, large low grade Ni sulfides, and large low grade Ni laterite deposits. The 1960s–1970s were dominated by high grade mines around Kambalda and Kalgoorlie, while from the 1990s large low grade Ni sulfide and laterite projects were developed. Some of the concentrates are processed locally at the Kalgoorlie Ni smelter, with Ni further refined at Kwinana, while for Ni laterite projects they produce a refined Ni metal along with cobalt. Laterite projects are considerably more energy intensive than sulfide projects, and thereby also more carbon intensive (see Mudd 2010b).

About two-thirds of WA's Ni resources are in Ni laterites, such as Murrin Murrin, with most of the remaining Ni sulfides in low grade ores. Based on reported Ni resources, it is clear that the Ni sector can grow substantially over the next few decades if laterite deposits become fully developed (see Mudd and Mohr 2010) although there will be a growing energy and carbon intensity in the longer term due to this evolving ore mix. In the context of climate change, at the same time the world is trying to find ways to lower carbon footprints, WA's Ni industry will face the challenge of increasing energy intensity for Ni mining while trying to find low carbon energy sources. At present there is little evidence to suggest the Ni industry understands the full gravity of this challenge, let alone the broader mining sector (see Mudd 2010b).

Other increasingly important aspects are complex ore mineralogy (such as Ni laterites) and toxic impurities, with the best example being the failure of the Armstrong Ni mine near Kambalda at the height of the recent Ni boom (Giurco et al. 2009). The Armstrong deposit was never developed by Western Mining Corporation due to the high arsenic content and low iron to magnesium oxide ratio of the ore. Junior miner Titan Resources began open-cut mining in mid-2004, only to find that the ore exceeded agreed tolerances for sale to the Kambalda mill—and (then) WMC promptly rejected all Armstrong ore. The collapse of the project almost sent Titan Resources bankrupt—and the mine still remains in mothballs in 2013. The issue of toxic impurities in ores, such as arsenic or even minor asbestos in some ores, will only grow in importance with respect to environmental and occupational health and safety issues.

Trends in Mining

There are four key trends influencing the future of the WA mining industry and the management of its environmental impacts. Collectively, they present a future for WA where the scale of mining increases, ore–waste ratios decline, community expectations rise and negative environmental mining legacies continue to grow in number and scale. In short, managing impacts is going to be increasingly complex and challenging, demanding a fundamental change in their evaluation, regulation, monitoring and management.

Increasing Production and Resources in WA

Mining in Western Australia has been dominated by a select group of commodities, initially gold in central WA from the 1890s, followed by the rise of iron ore, nickel, and bauxite–alumina in the 1950s–1960s. Other commodities have also made important contributions, such as mineral sands, diamonds, coal and base metals. In general, there is ongoing success in expanding mineral resources at existing mines or making new discoveries (e.g. Tropicana gold or De Grussa copper deposits). A compilation of production and economic resource statistics given in Table 12.2 demonstrates WA's dominance in iron ore, diamonds, nickel, cobalt, gold, ilmenite, zircon and bauxite–alumina.

Table 12.2 The 2012 and cumulative production statistics plus economic mineral resources for WA

Mineral/ metal	Units	Cumulative production	% Australian production	2012 production	Economic resources	Years remaining[a]
Iron ore	Mt Fe ore conc.	6,610	92.95	476.2	96,234	202.1
Copper	kt Cu	1,735.6	7.23	179.3	8,841	49.3
Lead	kt Pb	909.0	2.27	8.7	10,923	1,255.5
Zinc	kt Zn	3,322.6	6.19	57.1	7,531	131.9
Gold	t Au	6,902.5	54.45	180.88	6,309	34.9
Silver	t Ag	2,584	2.8	128.5	8,876.8	69.1
Coal	Mt coal	235	<0.001	7.46	3,999.0	536.1
Bauxite	Mt bauxite	1,046	~59.6	45.08	4,533	100.6
Alumina	Mt alumina	302.1	67.90	12.81	~1,471	114.8
Diamonds	Mcarats	809.3	99.93	9.88	302.6	30.6
Ilmenite	Mt ilmenite conc.	42.62	~84.2	0.303	199.2	657.4
Rutile	kt rutile conc.	3.43	~24.6	~0.051	7.74	151.8
Zircon	Mt zircon conc.	12.20	~55.7	0.163	23.55	144.5
Manganese ore	Mt Mn ore conc.	12.04	11.56	0.700	~314[b]	448.6
Nickel	kt Ni	4,933.6	93.71	231.5	37,628.6	162.5
Cobalt	kt Co	72.0	81.43	5.88	1,666.1	283.4
Tin	kt Sn	~66.9	7.97	~0.3	~2.55	8.5

Cumulative production data updated from Mudd (2009); 2012 production data from DMP (2013a); economic mineral resources from MINEDEX reports on 5 May 2013 (DMP 2013b)

[a] Assuming 2012 constant production rates only; conc.—concentrate (i.e. saleable)

[b] Manganese ore only

Declining Ore Grade, Increasing Waste

Two related factors affecting mining in WA are declining ore grades (or quality) and increasing mine wastes. The available data, extracted and updated to 2012 from Mudd (2009), is shown in Fig. 12.1.

The long-term decline in ore grades is clearly evident—with gold being perhaps the most pronounced. Based on reported mineral resources across WA (see data from DMP 2013b), future declines in ore grades will be more gradual, and individual mining projects are more likely to face constraints such as impurities (e.g. arsenic in some Kambalda Ni ores, some high phosphorous iron ores in the Pilbara), mineralogy (e.g. disseminated Ni sulfide versus Ni laterites, or magnetite versus hematite for iron ore) or processing characteristics (e.g. fine grained ores) rather than ore grade alone.

The quantity of ore is generally that reported as processed and is close to covering 95 % or more of reported metal production. For waste rock, however, not all mines or companies report this data; gold is a minimum only, diamonds are actual, while iron ore assumes a 2:1 ratio from saleable ore (which is probably a significant underestimate). For nickel–copper–zinc (base metals), coal and bauxite there are no reported data (or only the rare year). The cumulative data are also given in Fig. 12.1, showing that in WA alone annual mine waste has now reached the order of 2 billion tonnes (Gt) per year—since 2000, cumulative mine waste to 2012 was some 16.4 Gt while the century to 2000 was only some 13.3 Gt. Given the missing data, these approximations are clearly an under-estimate.

What is clear is that the scale of mining in WA has changed with a four-fold increase in tonnages since the late 1980s - transforming the economy. Such an increase in scale, when combined with declining grades and increasing waste, has increased the social and environmental impacts of mining. Current regulatory systems, especially as they relate to administration and enforcement, have thus far failed to address industry-wide, regional or cumulative impacts and seem ill-prepared to respond to the challenges of a scaled-up industry. In an Australian context, the need for change to address increasing impacts and resource depletion is recognised by industry stakeholders. Prior et al. (2013) make a compelling case for reform to reduce impacts and leverage more value from the mining industry while diversifying to other sectors.

Society and the Environment

The change in attitudes to mining and related environmental and human impacts in Australia (Prior et al. 2013; Hobbs 2011; Brueckner and Mamun 2010; McColl 1980) is encapsulated in the 2006 Magellan lead incident. After less than 2 years of exporting from the Esperance Port, 9,500 bird deaths led to human, bird, soil, water and sediment testing for lead contamination. The subsequent inquiry by the Education and Health Standing Committee (2007: 14) found that the events were foreseeable, foreseen and very predictable:

> From the outset, clear advice was given about the danger of the Magellan product; the concerns about the transport route, and the risks of inadequate handling systems and environmental monitoring at the Port.

The foreseeable and thereby avoidable nature of the contamination eroded public confidence in the industry and the ability of the government to regulate it. While the strong findings in the inquiry and the government response may have satisfied some concerns, subsequent pollution scares when exporting through Fremantle reinforced negative public perceptions of the industry and its regulators (EPA 2011; WA Government 2007; Parliamentary Committee 2007).

The lack of a coherent policy and adequate regulatory system at both a federal and state level results in poor environmental stewardship and creates uncertainty for the resource industry, which has troubled the sector over many decades (Frost and Mensik 1991). Ad-hoc decisions, or specific negotiated agreements, tend to be obscure, giving little guidance for future projects and increasing social concerns. Similarly, international (Whitmore 2004) and local analysis (Brueckner and

Mamun 2010) of industry codes and practices have demonstrated significant problems as well as practical and theoretical concerns with the domination of industry in voluntary industry processes.

Internationally, the increasing importance of traditionally 'non-core' social and environmental issues for the mining industry demonstrates how far the industry has come and the new challenges it faces. Of the ten business risks facing mines and metals in 2012–2013, three are socio-environmental factors, namely sharing the benefits, fraud and corruption, and maintaining a social license to operate. While fraud is less of a problem in WA than in some developing countries, there is no doubt that sections of the community are arguing for more benefits and expecting less impacts (Ernst and Young 2012).

In some ways the developmentalism of WA has hidden or slowed the pace of change that has been increasingly promoted and accepted in other regions. McMahon and Van der Veen (2009), respectively a World Bank mining specialist and mining consultant, describe four strategic drivers/phases of the mining industry: in phase 1 profits were the primary driver; then in phase 2 environmental pressures commenced in the 1960s; followed by phase 3, sustainable development, social and cultural issues; and finally into the current fourth phase whereby mining, in addition to earlier drivers, has to contribute as an 'engine of growth' for local and regional economies. Perhaps the question for WA should be: do we have the systems in place to ensure that the state develops its economy from this 'engine' or are we merely the purveyors of commodities? Alternatively, what is the return for the loss of natural resources and ongoing environmental impacts?

Mining Legacies

The WA Department of Mines used to compile detailed statistics on mining infrastructure across the state—as shown in Table 12.3. Although this information is very useful, it is no longer being collated and synthesized. In addition, although the cumulative area of mined land which has been rehabilitated was included in this assessment, the data alone do not allow any assessment of the success of rehabilitation. That is, have issues such as wind erosion, water seepage and biodiversity or ecosystem recovery been addressed in an acceptable manner? At some former mines in WA, despite some rehabilitation works being undertaken following mine closure, ongoing pollution risks and problems can remain. For example, the 1980s copper–zinc mine at Teutonic Bore, north of Kalgoorlie, was generating acid mine drainage only a decade after closure (see Johnston and Murray 1997), and the tailings dam from the old Gidgee gold mine was allowing substantial wind erosion events causing major dust nuisance problems to adjacent pastoral properties (MPI 2013).

Given the enormous scale of modern mine wastes and infrastructure—and the fact that it continues to grow exponentially (see Fig. 12.1)—closer attention must be given to the potential for mining legacies to develop, whereby old mines, even if

Table 12.3 Extent of rehabilitation of mine sites in Western Australia (ha)

	2003			Cumulative total to 31 Dec 2003		
Activity	Disturbed by mining	Preliminary rehabilitation	Revegetation	Disturbed by mining	Preliminary rehabilitation	Revegetation
Borefields and pipelines	9	4	6	1,930	415	85
Camp site	8	3	2	1,366	394	304
Exploration	57	15	6	4,980	1,513	836
Mine infrastructure	395	182	166	51,171	5,263	4,037
Open-cuts	655	285	109	35,678	8,815	6,105
Tailings dams/evaporation dams	271	319	278	33,693	2,753	2,117
Waste rock dumps/heap leach piles	632	695	828	36,222	17,799	11,639
Total	2,027	1,503	1,395	165,040	36,952	25,123

Data courtesy of WA Department of Industry and Resources (WADoIR) (Email—J Gregory, 9 March 2004) rehabilitated, can lead to ongoing environmental pollution and/or public safety impacts.

Managing Landscape and Development

While mining's impacts on the environment can be understood as discrete biological, physical and chemical effects, their cumulative nature and industry trends combine to present WA with growing, interrelated and complex environment and industry management challenges. These existing and future challenges are a direct result of, and will be determined by, WA's management response, either directly by government actions or by other actors responding to government policies, processes, legislation and regulation. This places the ideology of developmentalism (see Chap. 2), that has dominated Western Australia's approach to mining development since the 1950s, at the forefront of determining the state's response to environmental impacts.

As detailed in Harman and Head (1982) WA has a history of large-scale government investment in, and intervention on behalf of, the mining industry starting with the Mundaring to Kalgoorlie pipeline, expanding with the development of the Kwinana industrial area and continuing with gas projects at Barrow Island, the Burrup Peninsula and the now abandoned gas hub proposed at James Price Point. According to Pick et al. (2008) the 'facilitation' role of the government is well enshrined in policy in the Pilbara and represents a neoliberal approach to development.

Whether this results from increasingly shared political ideologies, dominant autocratic and unquestioning development–centered leadership under a succession of premiers (Bolton 1982; see also Chap. 2) or is a result of WA being a 'client state' of transnational corporations (TNC) (Crough and Wheelwright 1982: 98) the result is the same: an almost unquestioning support for mining/processing megaprojects as the preferred development path for WA and a strong alignment of government and TNC interests. The consequence for the environment is the domination of the state's development role over its responsibilities to protect and manage the environment.

The ability of societies to question or even understand the extent to which developmentalism has affected attitudes to planning for development in WA is affected by the state's development history and dominant ideologies. Trigger (1997) identifies thought patterns where a 'hole in the ground' is seen as moral progress, the Australian landscape is only complete after development, and the natural environment becomes 'overburden' or 'waste'. The result is a world view where, in Trigger's words (1997: 176) "resource development is understood so routinely to have moral priority that alternate ways of viewing the land appear esoteric, impractical and without cultural foundation".

While this subjugation of the environment to development needs could be seen as just a phase in WA's history, it could also be a dominant theme that is set to continue under current and subsequent governments (see Chap. 2). Regardless, achieving the conceptual change that would allow, or indeed, promote a more balanced approach to what are seen as competing priorities is at the heart of an effective response to mining's environmental impacts. This could prove difficult given the influence of the mining industry and TNCs over the development agenda in WA and the dominance of developmentalism as an ideology across politics and, indeed, society.

Conclusion

For several decades now, the mining industry, government and society have worked to identify and manage the impact of the mining industry on the environment in WA. While our knowledge of specific impacts has increased it has also become apparent that impacts are interrelated, cumulative and long-lasting. As shown above, the increasing scale of production, long-term impacts and increasing waste now combine to present an ever-increasing problem at a time when society is questioning both the industry's influence over, and impact on, the state of WA. Similarly, as mining legacies grow in number and scale, it is vital that a national or state-based system is empowered and funded to reduce and ameliorate the ongoing environmental impacts from abandoned sites.

The impacts and trends are the challenges that the mining industry and its regulators must overcome if we are to balance environmental management with industry. While advances in science and practice will assist in reducing impacts, it is also clear that cumulative current impacts and future trends demand a change in conceptual thinking. A new approach is required, one that will support the introduction of holistic management of the impact on the environment within a socio-ecological context and ensure that all Western Australians, current and future, benefit from WA's natural resources.

References

Bolton G (1982) From Cinderella to Charles Court: the making of a state of excitement. In: Harman E, Head B (eds) State, capital and resources in the north and west of Australia. UWA Press, Perth, pp 27–42

Bridge G (2004) Contested terrain: mining and the environment. Annu Rev Environ Resour 29:205–259

Brueckner M, Mamun MA (2010) Living downwind from corporate social responsibility: a community perspective on corporate practice. Bus Ethics 19(4):326–348

Cooke A (2004) Review of environmental and public safety impacts of mining in the Kalgoorlie area. Legislative Assembly, Western Australian Parliament, Tabled Paper 2147 (January 2004) Perth

Crough GJ, Wheelwright EL (1982) Australia the client state: a case study of the mineral industry. In: Harman E, Head B (eds) State, capital and resources in the north and west of Australia. UWA Press, Perth, pp 75–102

Department of Mines and Petroleum (2013a) Resources data files—quantity and value 2012. http://www.dmp.wa.gov.au. Accessed 5 May 2013

Department of Mines and Petroleum (2013b) Mines and mineral deposits (MINEDEX)—online database: report 12. minedexext.dmp.wa.gov.au. Accessed 5 May 2013

Department of Resources Development (1999) Mining below the water table in the Pilbara. An information paper coordinated by the Pilbara iron ore environmental committee, Department of Resources Development (DRD), Perth, August 1999

Economics Consulting Service (2004) Water and the Western Australian minerals and energy industry: certainty of supply for future growth. Reported prepared by economics consulting services (ECS) for the chamber of minerals and energy of Western Australia, Perth, July 2004

Education and Health Standing Committee (2007) Inquiry into the cause and extent of lead pollution in the Esperance area. Published by the Legislative Assembly, Parliament of Western Australia, Perth, September 2007

Environmental Protection Authority (2011) Report 1415 Magellan lead carbonate project, Wiluna—to facilitate the export of containerised lead from the Port of Fremantle, change to environmental conditions. EPA, Perth, October 2011

Ernst and Young (2012) Business risks facing mining and metals 2012–13. http://www.ey.com. Accessed 5 May 2013

Franks DM, Brereton D, Moran CJ (2013) Managing the cumulative impact of coal mining on regional communities and environments in Australia. Impact Assess Proj Apprais 28(4):229–312

Frost F, Mensik S (1991) Balancing minerals development and environmental protection. Long Range Plann 24(4):58–73, http://www.sciencedirect.com/science/article/pii/002463019190007B

Giurco D, Prior T, Mudd GM, Mason L, Behrisch J (2009) Peak minerals in Australia: a review of changing impacts and benefits. Prepared for CSIRO minerals down under flagship. Institute for Sustainable Futures, University of Technology, Sydney and Department of Civil Engineering—Monash University, Melbourne, March 2010

WA Government (2007) Response to standing committee in relation to the cause and extent of lead pollution in the Esperance Area 2007, Perth

Harman E, Head B (eds) (1982) State, capital and resources in the north and west of Australia. UWA Press, Perth

Hobbs E (2011) Performing wilderness, performing difference: schismogenesis in a mining dispute. Ethnos J Anthropol 76(1):109–129

Holper P (ed) (2007) Climate change in Australia—technical report 2007. CSIRO and Bureau of Meteorology, Canberra, ACT

Johnston J, Murray G (eds) (1997) Managing sulphidic mine wastes and acid drainage, Best practice environmental management in mining series. Environment Australia, Canberra

McColl DD (1980) The mining industry and the natural environment. Resour Policy 6(2):153–165

McMahon G, van der Veen P (2009) Strategic drivers of the mining industry: from enclave production to integrated development. World Bank, Washington, DC

Mineral Policy Institute (2013) Mining legacies—Gidgee gold mine. Mining legacies project. http://www.mininglegacies.org. Accessed 5 May 2013

Mudd GM (2007) Gold mining in Australia: linking historical trends and environmental and resource sustainability. Environ Sci Policy 10(7–8):629–644

Mudd GM (2009) The sustainability of mining in Australia: key production trends and their environmental implications for the future. Department of Civil Engineering, Monash University and Mineral Policy Institute, Melbourne, Revised April 2009

Mudd GM (2010a) The environmental sustainability of mining in Australia: key mega-trends and looming constraints. Resour Policy 35(2):98–115

Mudd GM (2010b) Global trends and environmental issues in nickel mining: sulfides versus laterites. Ore Geol Rev 38(1–2):9–26

Mudd GM (2011) Paste and thickened tailings—friend against acid and metalliferous drainage? Paper presented at the 14th international seminar on paste and thickened tailings (Paste 2011), Perth

Mudd GM, Mohr S (2010) Mineral resources and production in the Goldfields–Esperance region: projecting future scenarios. Report prepared by Monash University for the Goldfields Esperance Development Commission, Melbourne

Mulligan D (1996) Environmental management in the Australian minerals and energy industries: principles and practices. UNSW Press and Australian Minerals and Energy Environment Foundation (AMEEF), Sydney

Nicol T (2006) WA's mining boom: where does it leave the environment? Ecos Magazine 133 (Oct–Nov):12–13

Parliamentary Committee (2007) Inquiry into the cause and extent of lead pollution in the Esperance area. Report No. 8. Education and Health Standing Committee, Perth

Pick D, Dayaram K, Butler B (2008) Neo-liberalism, risk and regional development in Western Australia: the case of the Pilbara. Int J Sociol Soc Policy 28(11/12):516–527

Porterfield DC, Miller S, Waters P (2003) A strategy for managing acid rock drainage in arid climates—The Mt Whaleback story. In: Farrell T, Taylor G (eds) Proceedings of the sixth international conference on acid rock drainage. AusIMM, Cairns, pp 143–146

Prior T, Daly J, Mason L, Giurco D (2013) Resourcing the future: using foresight in resource governance. Geoforum 44:316–328

Spitz K, Trudinger J (2009) Mining and the environment, from ore to metal. Taylor and Francis Group, London

Taylor J, Pape S (eds) (2007) Managing acid and metalliferous drainage. Leading practice sustainable development program for the mining industry. Commonwealth Department of Industry, Tourism and Resources, Canberra, February 2007

Trigger DS (1997) Mining, landscape and the culture of development in Australia. Cult Geogr 4:161–180

Whitmore A (2004) The Emperor's new clothes: sustainable mining? Jnl Clnr Prod 14(3–4):309–314