MAKING INTEGRATIVE, CROSS-DISCIPLINARY RESEARCH HAPPEN: INITIAL LESSONS FROM THE UPPER HUNTER RIVER REHABILITATION INITIATIVE

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Abstract

This paper outlines the structure and initial findings of a cross-disciplinary research project that examines ecosystem responses to a major rehabilitation initiative involving riparian vegetation management and emplacement of engineered wood structures along the Upper Hunter River, NSW. Institutional arrangements are considered, outlining some of the challenges at the interface between scientific experimentation and practical implementation of river rehabilitation treatments. Primary lessons learnt to date relate to establishment and management of cross-disciplinary rehabilitation programs, concerns for educational structures and practice, and scientific and managerial responses to changing institutional arrangements.

Keywords

River rehabilitation, institutional arrangements, cross-disciplinary, geomorphology, aquatic ecology

Introduction

Rehabilitation of riparian and riverine ecosystems, or river landscapes, is a strategic environmental goal in Australia, and an international research priority. Rehabilitation and research are, or should be, interdependent activities, because any attempt to reconstruct a river landscape tests our knowledge of the structure and function of the system and our predictive capacity (Hobbs & Morton, 1999). Unfortunately most rehabilitation programs lack the capacity or knowledge to predict trajectories of responses to management initiatives, because they are based on inadequate models of the structure and function of the system (Cairns, 1990). Inadequacy arises because these systems are complex, where order may be emergent rather than predetermined, and previously unknown feedback loops and interactions make it difficult to predict ecosystem futures. This degree of complexity makes it difficult to set and meet rehabilitation goals and frame the research that underpins such initiatives.

Major investment of time, effort, resources and goodwill is required to establish an operational environment in which linkages between rehabilitation practice and research can be explored. Particular challenges are faced because of the shifting government regulatory environment in which these endeavours are developed and applied. This presents considerable difficulties in the creation and maintenance of collaborative work and funding arrangements. Changes in priorities and associated logistical constraints result in major concerns for tightly structured research programs (especially those relating to PhD projects), pushing the limits of what can be achieved through application of adaptive management principles to the limit!

This paper outlines the development of a cross-disciplinary project that examines biophysical responses to a major channel and riparian zone rehabilitation program along a 10 km reach of the upper Hunter River, NSW (Figure 1). The Upper Hunter River Rehabilitation Initiative (UHRRI) links research and monitoring with implementation of rehabilitation measures. The long term aim is to establish a diverse aquatic ecosystem that will be enhanced by the introduction of a range of engineered log structures and the creation of a largely indigenous riparian plant community. The initial stimulus for the project was provided by detailed experimental appraisals of river responses to emplacement of engineered log jams along the Williams River, a tributary of the Lower Hunter (Brooks *et al.* 2004).

The overarching philosophy of the UHRRI program emphasises interdisciplinary research that is integrative, historical, analytical, comparative and experimental at appropriate scales. It seeks understanding of the system at a range of scales across a range of disciplines. By adopting a multidisciplinary approach, the program aims to develop an integrated understanding of the biophysical processes currently driving the riverine ecosystem, and how manipulations of the system through rehabilitation initiatives will give rise to new systems that reflect complex, non-linear interactions among biophysical processes.

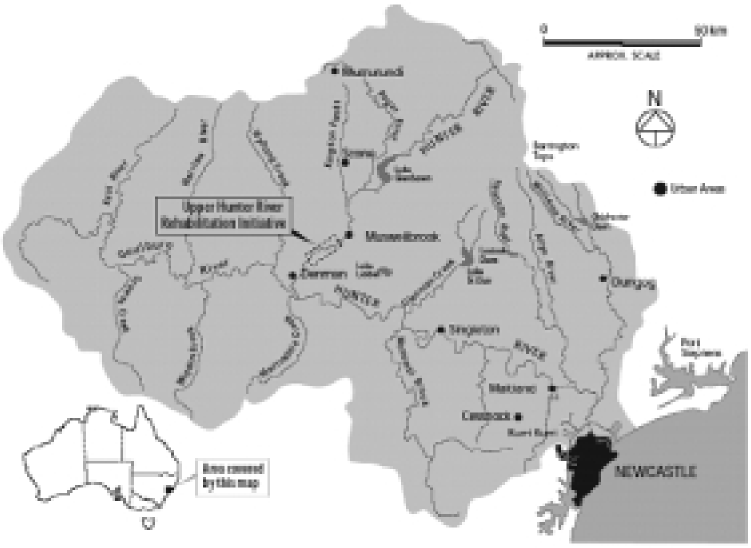

Figure 1 – Study area location

In specific terms, the project aims to:

1) understand biophysical process interactions in a highly disturbed river system;
2) test theories of directed ecosystem change;
3) understand catchment-scale drivers of reach-scale change;
4) predict interactions and feedbacks emerging from manipulating a complex system;
5) better understand the processes determining the success of riverine rehabilitation, providing enhanced degrees of understanding, predictability, control and efficiency in management; and,
6) provide a broader understanding of realistic outcomes that can be expected when rehabilitating highly degraded river systems.

Institutional Arrangements: The Structure and Funding

The UHRRI was developed with three interdependent components, focussing on revegetation, reintroduction of wood and research. From the outset, it was intended that funding would be obtained on an opportunistic basis, with UHRRI as the umbrella under which all activities would take place. An Executive Committee was established between the Hunter Catchment Management Trust (HCMT, now the Hunter & Central Rivers Catchment Management Authority, HCRCMA), the Department of Land & Water Conservation (DLWC, now the Department of Infrastructure, Planning and Natural Resources, DIPNR) and Macquarie University. Funding was obtained to employ a Project Manager for one year to develop the project and obtain funding for its continuance. This culminated in the award of an Australian Research Council – Linkage Grant for 2003–2007.

The ARC Linkage Project comprises a team of scientists from three Universities and four industry partners, Bengalla Coal Mine (BCM), Mt Arthur Coal (MAC), Macquarie Generation (MacGen) and DIPNR. A cash commitment for five years was gained from each partner. The Grant employs the Project Manager and a Research Officer, and funds 5 PhD scholarships. BCM and MAC zoned off 8–10 km of their combined river frontage specifically for this study, and provided assistance with planting and weed control, provision of logs for reintroduction of wood, and access to GIS applications and data. The revegetation and reintroduction of wood is funded through the Natural

Heritage Trust. Major in-kind support has been provided by NSW Department of Lands (the river gangs), the mines, HCMT and DIPNR for implementation of revegetation and reintroduction of wood, topographic survey, scientific support (design, data analysis), administration support for the Project Manager, and access to long term hydrological and cross-section data sets.

Due to its continuing evolution, and changes in government structure, the present format of UHRRI is a joint venture funded by the ARC, DIPNR, Department of Lands, Hunter & Central Rivers CMA, NSW Fisheries (DPI), Macquarie Generation, Mt Arthur Coal and Bengalla Mine, and incorporates researchers from Griffith University, University of New England, Macquarie University and the Australian Museum. A 5-year program of revegetation and reintroduction of wood commenced in late 2003 and the first stage of wood reintroduction commenced in June 2004. Science Advisory and Stakeholder subcommittees operate as part of the UHRRI framework. Extensive support from Green Corps teams has facilitated the completion of several components of the project.

Overview of the study reach

The study area, located 5 km south-west of Muswellbrook (Figure 1), is characterised by relief of ~100 m with a valley floor width of 1–2 km. The 10 km study reach comprises a meandering gravel bed river (sinuosity ≈ 1.3) with an upstream catchment area of 4220 km^2. The reach has been subject to extensive planform adjustment and channel expansion in historical times, transforming a passive meandering channel to a system that is locally prone to active lateral adjustment. Extensive river training works have been conducted in this reach over the last 40 years, but at the commencement of this project the river could generally be characterised as stable. The riparian vegetation community is now dominated by willows and exotic herbaceous species.

Although theoretical rehabilitation models suggest that rehabilitation efforts should concentrate on the upper, less disturbed parts of catchments before attempts are made on downstream reaches (e.g. Rutherfurd *et al.* 1999), selection of the UHRRI reach reflects pragmatic concerns to place river rehabilitation in context of human and ecological needs. The following attributes contributed to reach selection:

- the reach is typical of areas where previous (and likely future) river works were focused;
- the reach is representative of many lowland river conditions;
- the reach was previously desnagged, limiting current availability of woody habitat;
- the pool-riffle morphology of the low flow channel represents a ‘typical’ focus for investigations of ecosystem processes along rivers (though considerable variation in pool-riffle spacing is evident in this system);
- the study area is adjacent to a population centre, increasing the prospects of attracting community support for ongoing rehabilitation efforts and maintenance;
- riparian landholders were very supportive of this experimental initiative, and provided substantial funds to the project.

Outline of the research program

Using the principles outlined by Carpenter (1998) as a guideline, the UHRRI research program comprises four steps. The first step entailed generation of the multi-disciplinary team, ensuring participation by practitioners from all pertinent disciplines. The UHRRI research team currently comprises three fluvial geomorphologists, a terrestrial geomorphologist, a plant ecologist, a landscape ecologist, three fish ecologists, a malacologist/statistician, a hyporheic ecologist, an aquatic ecologist and two entomologists. However, the program is still developing, and it currently lacks capacity in areas such as systems modelling, terrestrial fauna ecology, soil science, hydrology and social science.

The second step is to systematically integrate current understanding of system structure and function through the development of conceptual ecosystem models. Through this process, the research targets key patterns and processes at appropriate scales, and at the interfaces between disciplines. Gaps in knowledge have been identified. In the UHRRI research process, further work is required to ensure that conceptual models can be applied at appropriate spatial or temporal scales in a truly cross-disciplinary manner. A systems modeller may be required to assist in this process.

The third step is to use the models to make predictions and generate testable hypotheses. This multidisciplinary team process generates predictions and hypotheses on the basis of observation, common sense, collective expertise and experience, conceptual models, and simulation predictions. In reality, the disciplinary specialists involved in UHRRI have driven the generation of hypotheses. In the future it is hoped that this will be a more collaborative process, building on the system knowledge that has now been developed.

The fourth step is to do the research, generate findings, contemplate implications, and develop the next generation of research questions. Given that our manipulations of the system are likely to have an immediate effect as well as long-term (slow developing) consequences, the models and long term studies will provide the information crucial to interpreting the results of the experiments and to using these results to predict ecosystem change, thereby enhancing development of theory.

In its present structure, years 1–3 of the UHRRI research program focus on the biophysical interactions at a catchment and reach scale, while years 4–5 will focus on the validation and refinement of the models through an extensive biomonitoring program. Various components of the research are outlined below.

Catchment-scale geomorphic research

Research co-ordinated by Dr Kirstie Fryirs has examined the spatial organisation of river types in the upper catchment, and interpretation of their structure, function and evolution (Spencer *et al.* 2004). Appraisal of physical linkages in terms of sediment flux, catchment hydrology and vegetation patterns guides insights into the changing nature, rate and impacts of ecosystem inputs and drivers along the study reach, examining factors that constrain what can realistically be achieved in rehabilitation terms (see Fryirs & Brierley, this volume). This catchment-scale biophysical template provides a basis to determine where in the catchment similar patterns and processes occur, and where similar treatments can be undertaken.

Reach-scale geomorphic research

Research completed by James Lander as part of an MSc(Hons) thesis has examined the character and behaviour of low, moderate and high lateral expansion zones within the study reach (see Figure 2). High lateral expansion zones, in which macrochannel width has increased by up to 400%, are coincident with areas where the channel was most sinuous and where confinement was less of a control at the time of European settlement. Channel segments that have undergone intermediate expansion still retain their pre-European planform. In the high and medium lateral expansion zones, the entrenched channel has a stepped morphology consisting of point and lateral bars, lateral and point benches, erosional ledges and large-scale re-alignment features formed in the last 150 years. Riffle zones occur adjacent to elevated bars and benches. Low expansion segments have incised marginally and expanded very little. These zones are dominated by long pools (up to 1 km in length), the morphology of which is ‘forced’ by outcrops of bedrock and terrace material along the bed and banks.

Channelisation activities in high lateral expansion zones has resulted in expansive surfaces of open gravels, the prevailing packing arrangement, sediment mix, hydraulic interactions and biophysical interactions of which differ markedly from those observed along low lateral expansion zones. Hydraulic interactions with these gravels present a different suite of biophysical and biotic interactions to those that characterised the system prior to European settlement. These findings have major implications for studies of vegetation distribution, hyporheic zone processes and nutrient fluxes (see Wolfenden *et al.* this volume).

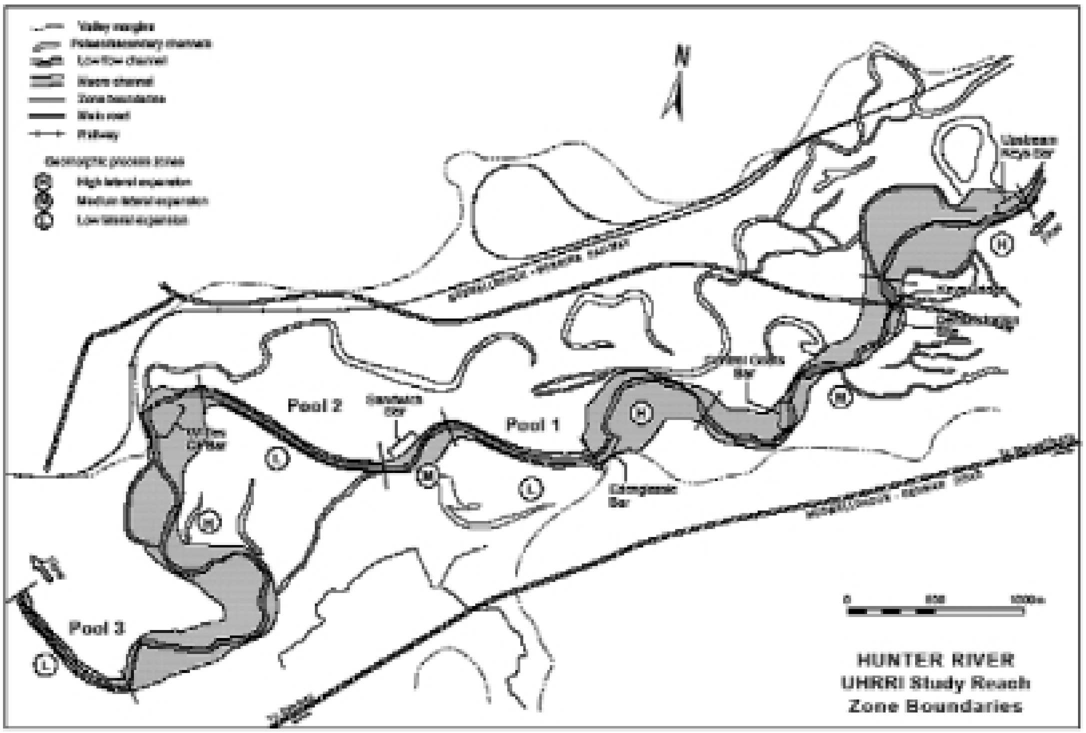

Figure 2 Study reach map

Geo-ecological research in the study reach

Various sub-models have been developed to characterise the interdependence of patterns and processes in the study reach. Most research is conducted by PhD students under the interdisciplinary supervision of the Chief Investigators. Integration is achieved through continual feedback, shared field time and a series of intensive workshops. The key research areas addressed by the PhD students are outlined below.

- *Vegetation dynamics in relation to geomorphic processes and structures* (Garreth Kyle, Macquarie University). This project aims to understand the relationships between the characteristics of geomorphic units (texture, nutrients, pH, water retention capacity and frequency of inundation) and both vegetation composition and plant traits at the reach- and catchment-scales. This will enable prediction of exotic and native plant responses to rehabilitation efforts and future riverine dynamics.
- *Riverine organic matter budgets and their relationship with riparian vegetation and flow* (Ben Wolfenden, UNE). This research aims to investigate riverine organic matter cycling (sources, transfers and sinks) and mechanisms of organic matter cycling and their contribution to ecosystem function. These organic matter cycles will be modelled using a geomorphic and hydrological template.
- *Fish distribution prior to, and after introduction of engineered structural woody habitat (SWH) into riffles and pools, the composition of fish assemblages associated with SWH in pools, and the behaviour of fish utilising SWH* (Tim Howell, Griffith University). This approach will combine conceptual models and predictive statements describing the expected responses of each fish species to the SWH in riffles and pools, collection of quantitative data on fish assemblages and analysis of the movements of fish.
- *Hyporheic zone patterns and processes and their relationship with surface water processes and geomorphology* (Sarah Mika, UNE). Specific research foci include the role of hyporheic zones in contributing to surface nutrient dynamics, the influence of woody debris reintroductions on interactions between bed topography, flow and hyporheic exchange, and the response of surface macroinvertebrates to reintroduction of wood.
- *Relationship between wood re-introduction, morphological adjustment, and sedimentological attributes of bars* (Jo Hoyle, Macquarie University). The effect of re-establishing wood in the channel on geomorphic structure

and function will be predicted, placing particular emphasis on bed material organisation in this supply-limited system. Changes in the bed topography will be quantified by comparing successive bed surveys with the baseline data taken immediately following engineered log structure construction. Changes in bed material sizes will be measured for all major geomorphic units. An ALS survey will be used to enhance modelling procedures (see Cohen *et al.* this volume).

Lessons to date

Framing scientific practice in light of changing administrative (institutional) arrangements

Perhaps the greatest challenge faced in this project has been the orchestration of financial support, experienced and skilled personnel, and on-the-ground logistics associated with the practicalities of implementation of river rehabilitation treatments with the timeframe, rigours and sampling design requirements of scientific practice. Various structural impediments that were challenging at the outset have approached the very limits of workable outcomes because of institutional restructuring. Thankfully, pre-treatment data have been collected. However, more time would surely have helped in gaining cross-disciplinary insights into system behaviour, enhancing individual and collective awareness. Ultimately, the experimental design must adequately address concerns from all disciplinary perspectives, such that meaningful inter-relationships can be appraised at pertinent spatial and temporal scales.

Maintaining focus on bigger-picture, longer-term goals

Typically, the research process emphasises short-term goals constructed around the timeframe allocated for completion of research degrees. In cross-disciplinary projects that appraise system adjustments to river rehabilitation adjustments, a longer-term perspective is required. As a consequence of this dilemma, funding arrangements constrain the types of questions that can be asked. In addition, little research kudos is gained from long-term monitoring of biophysical phenomena. However, these pre-treatment data are a vital consideration in the assessment of treatment responses. Provision of these types of data previously constituted a mandated role of government departments or agencies. Progressive erosion of these services presents significant limitations for a suite of research and management applications.

Gaps in knowledge or available skills are inevitable. Consolidation of information into a coherent package, and its progressive enhancement, is vital. This provides a sound platform to work from, thereby 'grounding' the research and its management. In such endeavours, careful thought must be given to information management and related communication strategies. For example, sufficient time must be dedicated to baseline mapping through use of Geographic Information Systems tied to accurate field survey data.

In structuring the over-arching goals of the research program and the aims of each individual PhD project, due regard must be given to development of back-up plans. Adjustments are inevitable. It is too easy to deviate from core activities in the pursuit of enticing short-term goals or opportunities. However, increased breadth may equate to lesser depth of enquiry, and undue expansion of original goals may be unhealthy unless it is appropriately resourced and readily managed within existing structures. Lessons from this project indicate that it is imperative to get the foundation blocks right first, and only then add further initiatives as they are determined (or come to hand).

Lessons about educational structure and practice

Several lessons have been learnt about the variable pace of research developments in differing components of a project, and constraints that this places on the capacity to bring various threads together. Progress in the project is undoubtedly framed, to some extent, by the pace of progress of PhD students. While general objectives must be shared across the group and its various components, specific hypotheses can continue to be successfully addressed within the confines of disciplinary profiles (and their attendant expectations in terms of approach, statistical rigour, examination or publication process, etc). Inevitably, the structure within which we operate tends to restrain project design into neat compartments that enable completion of PhD theses. Existing educational structures constrain cross-disciplinary work because of the specific requirements of department (discipline) expectations for a given research product. Perhaps a new model is required for management of PhD students – one that transcends disciplinary and institutional boundaries. The traditional approach to graduate training entails a student-mentor process. In modern multidisciplinary research it "takes a whole village to train a graduate student" (Carpenter, 1998). A multi-mentored approach rewards students for their contributions to teams. In the UHRRI project, each PhD candidate has a core supervisor from their discipline plus another supervisor or supervisors from other disciplines that have a key interaction with the study topic. PhD students are also intimately involved in the four research meetings held per year, including administration and discussion of the different research components as well as the greater program. Each PhD student is also required to assist the other students with their fieldwork. Inevitably, the iterative process of sharing perspectives is time consuming. The key consideration here is the long-term personal (and societal) benefits that emerge – not short-term success measured solely in terms of PhD completions. Ultimately, enhancement of cross-disciplinary skills will provide the vision and leadership capacity that is required for future research developments. Hopefully this will lead eventually to enriched, more sophisticated and increasingly flexible educational structures.

Institutional/organisational lessons

In this research program, scientific insights go hand in hand with practical application of river rehabilitation techniques. Unfortunately, many institutional constraints severely limit the nature and timing of what can be achieved, as we are 'forced' to work within imposed funding arrangements. Such a scenario prevailed in the revegetation components of the UHRRI, where a total of 63,000 long-stemmed tubestock were purchased. These comprised 18 species that were native to the Hunter River riparian communities, based on information provided by Travis Peake of the HCMT. Species were allocated to one of five communities on the basis of landform and inundation frequency. The timing of planting was dictated by the funding schedule of NHT and the Green Corps, who undertook the planting.

No funding was provided for the establishment or maintenance of planted tubestock, such as watering. Unfortunately, due to drought conditions in 2003/2004 when planting occurred, very high rates of mortality were experienced (80% of 1289 plants in study plots, and estimated 50–98% overall). Hare grazing also contributed to significant mortality. Follow-up studies have been initiated to examine (1) the effects of substrate texture and landscape position on mortality, (2) the effects of herbivore repellant on grazing and mortality, and (3) the effects of weed mats, tree guards and shading by willows on growth and mortality.

The key lesson learnt is that core funding, rather than opportunistic funding through various grant schemes, is essential for proper management of rehabilitation projects. The tight time schedule and piecemeal nature of granting bodies is not conducive to successful planning and management. Rehabilitation projects require adequate funding for planning, implementation, monitoring and follow-up. Goals must be ambitious, but clearly achievable.

Large-scale cross-disciplinary and industry-associated projects require a large investment in time, way beyond a normal research project, reflecting the critical importance of partners and stakeholders, and associated contributions as measured by their input into project design and operation, funding arrangements, and maintenance of in-kind support. Of critical importance to UHRRI has been the role played by Fiona Marshall (DIPNR) and Peter Ainsworth (HCMT) in the development and practical application of the program. Inputs from Green Corps teams, River Gangs, surveying crews, etc have been absolutely vital. The time required to sustain these arrangements has been substantial. In hindsight, support would have been sought for a full-time UHRRI manager and a full-time research manager.

Maintain group dynamics through effective communication

Self-evidently, managing a multidisciplinary research program requires ongoing discussion and intellectual commitment, preferably face to face rather than remotely. Many meetings are required initially, to develop the ground rules and establish suitable lines of communication. A tight structure is required for meetings. Specific group tasks need to be identified early in the planning process, targeting some issues which engage everyone. Our experience indicates that it is too easy to withdraw to our host institutions and associated roles and responsibilities. While it may present additional challenges, cross-disciplinary research undoubtedly generates extra opportunities for fun and enhanced learning, and will ultimately be the cornerstone of genuine advances in ecosystem science and management.

Conclusions

Implementation of integrative, fully-costed and strategic river rehabilitation projects is required if economic and social benefits of major environmental programs are to be realistically appraised, and associated benefits are to be maximised. The pathway to future success lies in more coherent collaboration between researchers, industry and community groups. Cross-disciplinary and cross-institutional co-ordination of projects is likely to become an increasingly important part of environmental management. Orchestration of these activities may be hampered by ongoing change management processes, especially when they entail restructuring of departments and organisations, and associated adjustments to roles and responsibilities. Our effectiveness in working through these adjustments is determined primarily by strategic decision-making by the project management team, emplacement of an appropriate governance structure, implementation of a sound program for communication, appropriate documentation through all steps of management processes, and a lot of hard work!

The design and implementation of UHRRI and the directly linked ARC Project will enhance prospects for development of more cost effective river rehabilitation programmes that can directly target key management and societal priorities. Practical advice garnered from this exciting initiative to date includes:

- Keep goals simple, ensuring that they are achievable. Underpromise and overdeliver!
- Apply adaptive management principles to continually revisit goals in light of scientific, funding, institutional or other adjustments. Maintain flexibility so that opportunities can be grasped, but NEVER lose sight of bigger-picture, long-term goals.
- Ensure that everyone's role in the project is clearly defined, on paper and in practice. Appointment of a dedicated project/research manager is fundamental to the success of this kind of initiative.
- Continually remind all participants that the overall project is far bigger than any individual's input. Generate a collective sense of responsibility, maintaining a common (and clear) sense of purpose.
- Seek funding arrangements that over-ride structural and administrative changes in institutional organisations. Never take anything for granted.
- Put sufficient time into project organisation, remembering that this is a collective responsibility.
- Carefully structure the research program so that PhD projects fit elegantly into the over-arching goals, placing due emphasis on issues of spatial and temporal scale.
- Ensure that the purpose of each meeting is clearly stated and maintain focus. Distribute minutes promptly, ensuring that any divergence of opinion is addressed quickly. Never underestimate the importance of sharing information, while maintaining due regard for intellectual property rights. Regular newsletters are extremely important (if read and used effectively).
- Maintain a harmonious relationship among all participants, remembering that debate is healthy!

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