Department of Environment
and Resource Management

Scientific Monitoring Program

For The South East Queensland Horse Riding Trail Network

Toward Q2 Tomorrow's Queensland
Queensland Government

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Department of Environment and Resource Management

September 2010

#29524

Contents

Introduction

The South East Queensland Horse Riding Trail Network (HTN) includes more than 500 km of trails within 29 reserves between Gympie and the State's southern border. The HTN trails mainly occur in Forest Reserves (FR), but a few are in State forests and timber reserves. The reserves that host the HTN trails are being converted to national parks following the South East Queensland Forests Agreement (SEQFA) signed in 1999. The HTN trails link to a broader trail network that includes about 340 km of trails in Queensland's forest plantations and at least 470 km of trails on other tenures, including several other State forests.

Recent amendments to the *Nature Conservation Act 1992* (NCA) specify that the HTN trails must be reviewed by the Chief Executive and that the review should start as soon as possible and finish before 2026. The NCA also specifies that the review will be informed by an assessment undertaken by a Scientific Advisory Committee (SAC) of the impact of horse riding use on horse riding trails and adjacent areas. The SAC's assessment must be based on the results of monitoring and evaluation conducted over a period long enough to assess the likely impacts of horse riding use, and must take account of the cumulative impacts of horse riding and other activities conducted in the HTN trails and adjacent areas and vegetation communities.

The Queensland Government has committed to a detailed scientific monitoring program that will operate over a 20 year period with regular points of review, to monitor any potential impacts that result from horse riding on SEQFA lands. The monitoring program will be overseen by an independent SAC. The budget for the monitoring program is set at $150 000 per year and is not subject to increases to cover increasing costs over time.

The objective of the Horse Trails Scientific Monitoring Program (the monitoring program) is to monitor horse riding on the South East Queensland Horse Riding Trail Network through South East Queensland protected areas and identify any impacts of such use and recommend management actions to address such impacts.

This document outlines a plan to establish a monitoring and evaluation program to inform the SAC about impacts of the HTN network and its users on the State's interests, including both environmental and social values. It draws upon a literature review of horse riding impacts on protected areas undertaken by Dr Catherine Pickering (Pickering 2008), and follows a workshop at which possible monitoring targets, methods and systems were discussed by SAC members, Queensland Parks and Wildlife Service (QPWS) rangers, DERM officers and representatives of horse rider and conservation interest groups.

Scope of the monitoring program as specified in the Terms of Reference (ToR)

The Terms of Reference (ToR) document was prepared to provide guidance to the SAC and DERM on the objectives, function, design, structure, scope and outputs of the Horse Trails Scientific Monitoring Program.

Broadly speaking, potential impacts from horse riding and the HTN can be either primarily social (ToR 5.1, 5.8 and 5.9) or primarily biophysical (ToR 5.2–5.7). Social impacts first affect people’s perceptions or amenity, and biophysical impacts first affect infrastructure, native species, ecosystem functions, weeds or any one of many other environmental factors. Although this social–biophysical dichotomy is somewhat imperfect because of various feedbacks, it is arguably useful to broadly categorise and plan impact monitoring and assessment across the HTN.

Given the large extent of the HTN and the limited budget for the monitoring program, the strategy adopted for the first phase of the program is to target areas most at risk to degradation from horse riding and/ or other users. Therefore tracks with steep slopes on erodible soils are more likely to have erosion damage than level tracks. Similarly natural creek crossings are more at risk to damage from track users rather than concreted causeways. The areas with the highest level of use are obviously more at risk to physical damage and adverse social impacts than rarely used tracks.

Spatial and temporal patterns of use by horse riders and other users (ToR 5.1)

The spatial and temporal patterns of use of the HTN are fundamental data to underpin all social and biophysical monitoring. Ideally, use monitoring should provide information about the type of use, as well as its distribution in space and time. There are a variety of methods for collecting these data on the trails, most which have multiple users, and given the large expanse of the network some combination of methods will be applied.

The approach recommended here involves two key components:

1. Automated counting systems located on trails preferred for horse riding use
2. Observations of park managers.

Automated counting systems

The automated counting systems should ideally be capable of distinguishing horses, 4wd vehicles, trail bikes, mountain bikes and walkers. They should also record time of record, but need not record direction of travel. They should be located on trails preferred for horse riding use, and in each of the trail groups. It is important that the locations of these counting systems are not known; otherwise this may affect the behaviour of some users. There is a range of equipment ranging from infrared and magnetic counters to cameras that can be used for this purpose. The ideal configuration and types of equipment will require research and adaptive learning to provide reliable data. Independent observations are also required to validate the data produced by automatic recorders.

Automatic recorders have to be regularly serviced, ranging from every month for counters through to every week for cameras, and must be securely and generally cryptically located to prevent theft or vandalism. There may be a varying amount of laboratory time required to collect and process the information from these recorders, e.g. the images on cameras require human observation and analysis.

Locations at which counting systems could strategically be placed include:

1. Hills Road section of ‘Noosa trail No. 3’ in eastern Woondum FR
2. Harry Springs Break, central Tewantin FR
3. River Break near day-use area in southern section of Mapleton FR
4. Bottle and Glass Road, north-eastern Mapleton FR
5. Dog-link Break, central Bellthorpe FR
6. East Boundary Break, eastern Bellthorpe
7. Gold Creek Boundary break BFP
8. Reservoir Break, eastern BFP
9. northern end of Waterfall Creek Break, Numinbah FR
10. southern end of Neranwood Break, Numinbah FR.

Counter arrays or camera systems at these locations would be installed with substantial protective infrastructure and are envisaged as fixed locations at which monitoring will occur for a long enough period to gain a robust set of visitor usage data. A potential student program comparing the data from cameras, infrared data loggers and visitor counting may be able to be funded from the program.

Observations of park managers

Park managers and on-ground staff have been interviewed in 2008 to provide advice on their direct observations of track usage e.g. seeing people on the HTN, and indirect observations e.g. horse manure on tracks. This provides a baseline of usage before the major tenure conversion of forest reserves to national parks occurred. It is envisaged that these interviews will be repeated on a three yearly basis to indicate any perceived change in usage. Expert elicitation techniques for gathering and analysing these data will be employed to make best use of these qualitative data. The regular contact with rangers will also allow them to raise issues of concern which may help direct further research requirements.

Monitoring of social impacts

The nature and changes to perceptions, understandings, concerns and visitation experience of visitors to these protected areas with respect to horse riding within the designated SEQFA protected areas (ToR 5.9).

'On site' issues can be addressed through direct interviews of trail users and perhaps also park neighbours.

Key issues to be canvassed in the questionnaire for the initial on site interviews of social impacts should include:

- basic demographic data: origin/residence, age
- visit specific information: activity, size of group, route, destination, duration and frequency of such visits
- general expectations and motivations for visit
- perceptions of :
    - track condition
    - park condition
    - management performance, and
    - appropriateness of current use
- perceptions or experience of conflict with other users
- concerns or issues around use or management
- knowledge of allowed uses and change in tenure
- participation in other uses
- use of other recreational resources managed by QPWS
- attitudes and values.

A draft questionnaire is under development by DERM (see Appendix 1). This will be used as guidance for a consultant to develop a robust questionnaire and sampling strategy. It is likely that a pilot study will be funded initially and on the results and learnings from this pilot study that a final questionnaire and methodology for collecting the information will be finalised after discussion with the SAC. The surveys will be used to collect data on trail use by all trail users.

The nature and changes to perceptions, understandings and concerns of the wider community including stakeholders and other interest groups with respect to horse riding and its impacts in the designated SEQFA protected areas. (ToR 5.8)

Widening the scope of inquiry to a broader cross-section of the public of south-east Queensland may require a large phone/mail survey such as AC Nielsen surveys. These surveys are expensive and must be carefully devised. If the opportunity arises, an appropriate question or two could be included in broad public surveys conducted by DERM for other purposes.

However it is most likely that an independent specific survey will be required to measure and monitor opinion in the broader population of the appropriateness of horse riding and other activities on the use of trails in protected areas, and of the likelihood of impacts on natural or experiential values.

Monitoring of biophysical impacts

Initial assessment of biophysical impacts of horse riding and the HTN trails should focus primarily upon those biophysical attributes most likely to show some discernable response to horse riding use, particularly horse riding use as described by the code of practice for the horse trail network in South East Queensland (Pickering 2008).

Primary initial targets may include:

- water quality:
    - nutrients
    - turbidity
    - dissolved oxygen
- track condition:
    - erosion and erodiblity
    - compaction
    - informal trail development
- weeds:
    - numbers of species
    - relative dominance
    - penetration into, and impact upon surrounding vegetation

Many other types of biophysical impacts might be considered for study, but as a first step, assessment of the impacts listed above should provide a good foundation from which further studies, perhaps addressing more subtle or more localised issues, can be planned.

What level of assessment: Inventory, monitoring or experiments?

Pickering (2008) suggests that a mixture of inventory, monitoring and experimental methods are likely to be required for the HTN monitoring program. The merits and applications of these three assessment approaches are illustrated in figure 1 below. While a mixture of all three approaches would undoubtedly be the most informative, in the initial stages it is recommended that the focus should be upon establishing a well designed monitoring framework based on quantitative and repeatable assessments of the biophysical factors listed above. Limited experimental work is also recommended, primarily aimed at assessing highly dynamic or transient water-quality impacts.

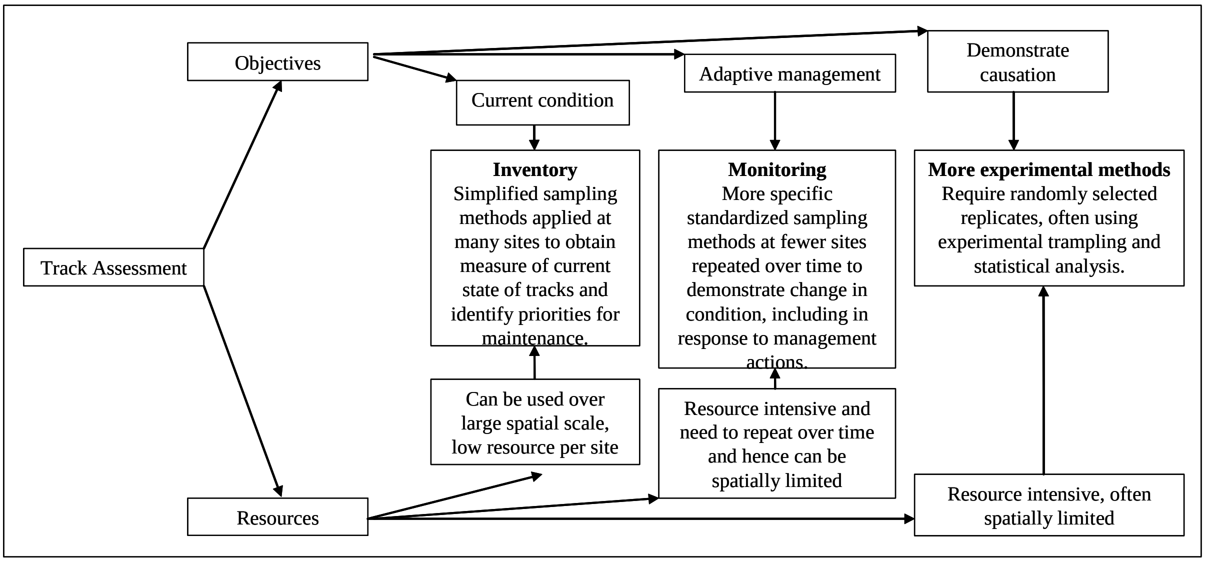


Figure 1. Diagrammatic representation of three levels of impact assessment recommended for the HTN trails by Pickering (2008) (from Pickering, 2008).

A basic inventory of the HTN trails, suitable to stratify site selection for monitoring, has been conducted using available spatial data and GIS analysis, and is presented in Appendix 2. It might be argued that a more detailed on-ground inventory would be valuable for the purposes of directing immediate management and infrastructure improvement. However, such an inventory is not recommended as part of the scientific monitoring program because it would add little to the ongoing day-to-day assessment and maintenance of the HTN trails by QPWS rangers. The expertise and experience of the rangers and their management responses to observed impacts, such as trail improvement or weed control, is a fundamental factor in the ultimate impact of horse riding and the HTN trails on the State's conservation assets. Therefore, the monitoring program should include periodic 'surveys' of ranger perceptions of horse riding impacts and associated issues.

However, the initial aim of the formal HTN monitoring program should be to provide quantitative data for consideration by the SAC, rather than qualitative inventory. Also, the potential for polarised public interest in the SAC's assessment means that the HTN trail monitoring program must avoid perceptions of subjectivity or bias as far as the budget and available expertise allow, which arguably also devalues investment in inventory-type data collection.

A key point about the SAC's role is that their assessment of a particular horse riding trail need not be based on measurement or monitoring of that specific trail, but may be based on appropriate information obtained from measuring or monitoring, and evaluating, other trails or parts of the trail with relevant characteristics. This suggests that the first priority for the monitoring program should be to provide general information about relationships between trail characteristics and their performance and sustainability as horse trails and as management trails more generally.

Another key point, upon which there was general agreement at the SAC workshop on monitoring issues held on the 2–3 July 2008, is that detecting any impacts from the HTN trails on the biophysical environment is complicated by a 'noisy background' of environmental variability and from necessary management activities such as trail maintenance, burning and weed control. Perhaps most importantly, attributing impacts to horse riding per se is seriously complicated by impacts from other park users.

With these issues in mind, it is suggested that the monitoring program should initially aim to address three initial questions about biophysical impacts of the HTN trails.

1. How does water quality change where trails traverse steams?
2. How are characteristics of HTN trails (such as regional location, soil type/land zone, trail slope, trail construction, vegetation type and use), associated with the impacts from erosion or weeds?

3. In areas prone to degradation, does horse riding use, or associated infrastructure, affect track condition, weeds or water.

Answering questions 1 and 2 will provide the SAC with a quantitative assessment of variability in trail characteristics and environmental impacts across the HTN network, the relative strengths of any association between trail characteristics and environmental impacts, and a broad assessment of the cumulative effects of all users on the HTN trails.

Answering question 3 is an initial and pragmatic response to the requirement that the SAC's assessment pay particular attention to impacts brought about from horse riding use. The actual mechanics of addressing these questions will involve numerous more specific tests but the questions above provide sufficient framework for the first few years of inquiry.

Water quality in streams and water bodies (ToR5.6)

Water quality issues could be addressed in two main ways:

1. Long term water quality monitoring.

The Environmental Health and Monitoring Program (EHMP) has for the past 7 years been measuring the latent water quality of freshwater and estuarine waters in South East Queensland. There are 127 freshwater monitoring sites in South East Queensland which are recorded twice yearly using a standardised methodology. DERM Water Planning Ecology conducts the collection and analysis of the data. Attributes recorded include pH, conductivity, temperature, dissolved oxygen, nitrogen concentration, fish, aquatic macroinvertebrates, and ecosystem processes (EHMP 2008). This program provides baseline data with which to assess any water quality data collected for the HTN monitoring program.

Ideally water would be sampled and tested at every creek crossing on the HTN, with or without culverts, that have standing or flowing water both 50 m upstream and close to the crossing downstream. However given budget constraints and the confounding issues of multiple users of the horsetrails, it was decided that an event based assessment program would be the most efficient use of resources. If significant impact of horse riding was detected from these studies, then a wider water quality monitoring program may be required.

2. Event based assessment.

To quantify more dynamic and episodic impacts, experimental studies should be used to compare the passage of horses with those of other trail users, including motorcycles, mountain bikes and four wheel drives in terms of changes in turbidity, dissolved oxygen and other attributes. Both the amount and duration of impacts are important.

Potential suitable locations for this include:

- multiple natural crossings on Waterfall Creek Break crossings in Numinbah FR
- multiple natural crossings on Little Yabba Ck west of Charlie Moreland Park
- crossing on Branch Creek of Dog Link Break at Bellthorpe
- unhardened crossings on main loop in south section of Mapleton FR
- crossings on the western edge of Woondum FR.

Another event based approach is to target major horse riding events where a large number of horse crossings will be made over a single day or weekend. By recording water quality conditions before and after the event, some conclusions can be made on the impact of the horses on water quality. The significance of the effect can only be assessed by understanding the natural variability of the stream over time, so the monitoring must occur for a number of occasions before and after the event, and should be compared with nearby streams of the same hydrological characteristics that are not impacted by the horseriding event.

The Murrumba Endurance Ride was targeted to conduct a full Before, After, Control, Impact (BACI) designed study on the impact of this event on water quality. However after some exhaustive field and laboratory study, suitable unimpacted control streams of the same character as those to be crossed where unable to be found.

As this would compromise the scientific design, an experimental approach on private land was pursued. This would allow the control of the users on the trails/ tracks, and for any impacts to be firmly attributed to specific users. The details of the experimental design for this research are provided in Appendix 7.

The difficulty with all sites where the roads are used by multiple users is that the impact of one type of user, e.g. horses can not be readily isolated. Hence the decision was made to locate the measurements to private forested lands where the trail use could be controlled.

Changes in pattern and distribution of weeds (ToR 5.2)

Trail condition including soil stability and adjacent vegetation and communities (ToR 5.4)

Evidence of cause of changes to trail stability (ToR 5.5)

Sampling Design

The suggested approach is to measure indicators of impacts from weeds and erosion at random locations, stratified by a few key variables of interest within the most suitable parts of the HTN networks. There are many factors that might reasonably be expected to influence weed and erosion impacts around the HTN network. Some of the most obvious factors are:

1. use - type, frequency, timing
2. trail slope
3. trail surface - gravel or natural soil
4. trail construction - formed or simply scraped
5. soil characteristics
6. vegetation type
7. climatic variables, particularly rainfall
8. geographic location (e.g. trail groups described in Appendix 2).

Even this short list of factors suggests a highly complex sampling scenario, which is emphasised by the strong likelihood of interactions in the effects of many of these factors. A full factorial approach to sampling across each of the five 'trail group' blocks would be a massive undertaking, and not all combination of factors are present to be sampled in all trail groups, nor are all interactions likely to be equally interesting. Table 1 provides a summary of the key factors, the other factors that should be controlled or used to stratify sampling across each factor, and the trail groups or clusters within which the factors vary enough to support a study of their effect (based on the inventory presented in Appendix 2).

In addition to the measuring weeds and erosion, the impact of the track on the adjacent forest will be monitored. This will be done by permanently marking and recording a 50 x 10 square metre plot for vegetation structure and floristic attributes. The CORVEG methodology (Neldner *et al*. 2006) will be followed. For more explanation see Appendix 5. These data will also provide information on the any change in the structure and floristics over time after the change in tenure in these areas.

Survey-gap analysis

The survey-gap analysis tool (SGA) was developed by the New South Wales National Parks and Wildlife Service (1998) to assist in targeting biological survey sites for data poor areas. It does this by assessing how well biological survey sites capture regional biodiversity using regional environmental heterogeneity as a surrogate (or their 'complementarity') (Faith *et al*. 2004; Faith & Walker 1996a) and is an extension of environmental diversity (ED) complementarity (Faith *et al*. 2004; Faith & Walker 1996a; Faith & Walker 1996b). SGA reduces the variation in a set of expert nominated, remotely-derived environmental traits at any location to a statistic of environmental variation (p-median) which reduces with the selection of successive complementary sites (Funk *et al*. 2005). P-median calculates the distance from these candidate sites to selected survey sites (Faith & Walker 1996a). A selected site which would best improve the p-median is also likely to be the site which will add the greatest number of additional species (Faith & Walker 1996c). The environmental dissimilarity between pairs of sites is calculated via a simple linear model (Funk *et al*. 2005). SGAP utilises an iterative process whereby ED complementarity is recalculated after the selection of each successive biological survey site.

Survey-gap analysis (SGA) will be used in this study to stratify the location of weed monitoring plots across the South East Queensland Horse Trail Network which captures heterogeneity in eleven environmental variables which show a high degree of variability across the region and are likely to drive vegetation patterns. Of these 11 remotely-derived extrinsic variables, eight will be generated using the ANUCLIM climate modelling package (Houlder *et al*. 2000): (1) maximum temperature of the warmest period, (2) temperature annual range, (3) annual precipitation, (4) precipitation of the wettest quarter, (5) precipitation of the warmest quarter, (6) annual mean moisture index (7) lowest period moisture index and (8) mean moisture index of the coldest quarter. Two categorical grids, horsetrail slope and an index of broad vegetation group moisture requirements, will be converted for use by the SGA to a dissimilarity matrix. The Euclidean (geographical) distance between pairs of sites will also be considered. Initially, all variables will be given equal weighting in terms of their ability to influence plant distributions.

Table 1. Overview of factors and sampling considerations for study of association of HTN trail characters with weeds and erosion

Factor	Key levels	Key impacts	Where best studied	Notes regarding weediness	Notes regarding erosion
Use	type (horse, pedestrian, motorbike, mountain bike, 4wd), frequency (lots vs little), timing (wet vs dry, seasons)	erosion & weeds	Paired sites for type (listed elsewhere), but difficult to control for frequency. Frequency and timing probably best addressed primarily for horses and best done experimentally	Probably interacts with all other effects but difficult to identify how best to deal with such interactions	Key interacting/blocking factors - slope, trail surface, trail construction, land zone
Slope	will be a continuous variable for analysis but stratification will use classes e.g. low (<10%), moderate (10-32%) and steep (>32%)	erosion & weeds	Should be considered in all other studies	Key interacting/blocking factors—land zone, veg formation, trail construction	The main factor for studies of erosion. Key interacting/blocking factors—trail surface, land zone, use, trail construction
Trail surface	gravel vs. natural	erosion +/- weeds	Bellthorpe, Mapleton, Enoggera	Key interacting/blocking factors—veg formation and land zone	Key interacting/blocking factors - slope, use, land zone, trail construction
Trail construction (formed vs. unformed)	formed vs. unformed	erosion & weeds	Bellthorpe, Tamborine (predominantly horse), Imbil	Key interacting/blocking factors—veg formation and land zone	Key interacting/blocking factors - slope, use, trail surface, land zone
Land zone (surrogate for soil character)	mainly 3 (alluvium),11 (metamorphics) & 12 (granite), but 5 , 8 & 9-10 are also interesting	erosion & weeds	Bellthorpe, Tewantin-Woondum, Numinbah-Austinville, Beerburrum	Key interacting/blocking factors—veg formation, slope, trail construction	Key interacting/blocking factors - key interactions—slope, use, trail surface, trail construction
Vegetation formation	rainforest, wet euc, dry euc, non-remnant +/- swamp	weeds	Bellthorpe, Mapleton, Tewantin-Woondum	Key interacting/blocking factors—land zone	Key interacting/blocking factors—slope, use, trail surface, trail construction

Sampling protocol

The sampling protocol at each location will involve:

1. For weediness: define the 5 m section of trail centred on each randomly selected location; a permanent star picket will be placed 5 m either side of the trail edge; on both sides of the trail sample belt-transects of 5 contiguous quadrats 1 m deep (1 m x 1 m) from the trail edge1 out to 5 m, with additional 1 m x 1 m quadrats at 10, 15 and 20 m. In each quadrat record:
    - foliage projective cover of exotic perennial grasses, other exotic species, native perennial grasses and other native species
    - which exotic species are present
    - shrubs and regenerating trees present
    - woody debris and litter
    - for more detail see Appendix 5.
2. For erosion and trail condition: the star pickets used in 1. define the transect line. At each trail transect measure:
    - maximum trail width[1]
    - track surface features.
3. For vegetation structure and floristics: the star pickets used in 1. to define the end of the transect line will be used to mark the corner of the 50 m x 10 m CORVEG plot. For more detail see Appendix 5.

For erosion

Two methods were trialled to categorise the track surface:

- A track profile between permanent pegs on either side of the track was recorded using technical surveying equipment (Total Station). This gave an accurate surface of the track for its width, and measured cover and depth of indentations and erosion effects. This technique was trialled at Bellthorpe with a QPWS registered surveyor Thomas McDonald. It requires a high level of expertise and time to operate. It would also require the purchase of a Total Survey station (estimated cost of $25 000). Given these constraints, and the fact that the tracks are graded on a regular basis, a simpler method of erosion assessment was sort.
- An alternative less quantitative approach is to use contiguous 1 m^2 quadrats to determine the cover of stone/ gravel, bare earth, litter, manure, indentations/ erosion effects, roots, plant cover. The depth of the erosion effects below the general track surface will be measured and attributed to a source if possible, e.g. distinct markings of 4WD/ car, motor bike, mountain bike, horse, walker. The presence or absence of informal trails within 50 m, and the depth of the lowest point on the trail relative to the natural ground surface[2] will also be recorded for more detail see Appendix 5.

More general information to supplement and verify the GIS data used for sample stratification will also be recorded at each location sampled, including:

- trail slope
- terrain slope
- landform element
- vegetation formation
- trail surface
- trail construction.

As part of their routine management, rangers have the tracks graded and exercise weed control.

[1] trail edges might be defined, for instance, as the point at which ground layer vegetation cover is at least half that in the surrounding vegetation

Therefore monitoring sites will be periodically ‘re-set’ by grading or weed control. Data on trail maintenance, such as the timing and nature of the last maintenance treatment, should be available from QPWS’s Strategic Asset Management Database (SAMS). This database may also serve as a repository for photo monitoring or other data acquired by rangers in their day to day management and assessment of the HTN network.

Evidence of vectors of weed dispersal (ToR 5.3)

While there are a number of track users that are potential vectors for weeds, it should be possible to examine the type of weeds that horses may be transporting to the HTN. The main pathways could be on their hooves, on their hair and through their faeces. Horses will be examined for weed seeds on their body using techniques referenced in Pickering (2008), and glasshouse germination trials will be conducted on the faeces that horses leave on the trail. A project proposal has been developed and is provided in more detail in Appendix 6.

The presence of a seed on the animal or in its faeces does not necessarily mean that the weed species will survive and establish, particularly if horses are constrained to the HTN as specified in the Code of Conduct. Even if a weed does establish, it may have been introduced by other users of the track system, particularly motor vehicles. Therefore it is important to research the weed seeds that are carried onto the trails by all users.

Any evidence of impact of horse riding on the surrounding biotic environment and the cultural and natural resources of protected areas under the Nature Conservation Act 1992 (ToR5.7)

Monitoring track condition and weeds will allow assessment of the strength of association between risk of degradation and trail characteristics, including use. However, concluding causality is more complex than assessing association.

Therefore specific effort should be made to directly measure the impact of horse riding use and associated infrastructure. For example, Pickering (2008) points to BACI studies as suitable tests of direct causation.

Such studies could be used to:

- assess impacts of large horse riding events (such as endurance trials) on trail condition, weeds (assessed before and three months after the event), and water quality (before, during and after the event) (see Appendix 3)
- test for a causal link between horse use and specific impacts or risks highlighted by the broader network sampling study.

Summary

Given the extensive network and the variety of users on the HTN, the monitoring program is targeted to areas which are suspected to be most prone to impact from horses and other users. Both social and biophysical impacts are to be investigated. Because of the inability to control many factors, both environmental and social, it is unlikely to be possible to assign the cause of impact to any particular type of track user, rather in most cases, the accumulative impact will be monitored. This will still provide important information for the management of the HTN in South East Queensland.

While the monitoring approach of the HTN will be continued, a suite of targeted experimental studies and direct observations of specific events will provide some opportunities to analyse the impact of horse use on specific attributes, e.g. water quality and erosion. Pilot studies have been applied to small areas to ground truth and fine tune the methodology and the learnings will be applied before the monitoring is implemented over the whole HTN. Various aspects of the monitoring program will be staged at appropriate intervals to make best use of the limited resources. Where possible, partnerships or extensions to existing programs will be developed to provide efficient use of resources.

References

EHMP (2008). Ecosystem Health monitoring Program 2007-08 annual Technical Report. Moreton Bay Waterways and catchments Partnership, Brisbane. www.ehmp.org

Faith, D. P., Ferrier, S. & Walker, P. A. (2004) The ED strategy: how species-level surrogates indicate general biodiversity patterns through an 'environmental diversity' perspective, *Journal of Biogeography*, 31, 1207-1217.

Faith, D. P. & Walker, P. A. (1996a) Environmental diversity: on the best-possible use of surrogate data for assessing the relative biodiversity of sets of areas, *Biodiversity and Conservation*, 5, 399-415.

Faith, D. P. & Walker, P. A. (1996b) Integrating conservation and development: incorporating vulnerability into biodiversity-assessment of areas, *Biodiversity and Conservation*, 5, 417-429.

Faith, D. P. & Walker, P. A. (1996c) How do indicator groups provide information about the relative biodiversity of different sets of areas?: on hotspots, complementarity and pattern-based approaches, *Biodiversity Letters*, 3, 18-25.

Funk, V. A., Richardson, K, S. & Ferrier, S. (2005) Survey-gap analysis in expeditionary research: where do we go from here? *Biological Journal of the Linnean Society*, 85, 549-567.

Houlder, D., Hutchinson, M.F., Nix, H.A. & McMahon, J.P. (2000) *Anuclim 5.1*. Centre for Resource and Environmental Studies: The Australian National University, Canberra.

Neldner, V.J., Wilson, B.A., Thompson, E.J. and Dillewaard H.A. (2005) *Methodology for Survey And Mapping of Regional Ecosystems and Vegetation Communities in Queensland*. Version 3.1. Queensland Herbarium, Environmental Protection Agency, Brisbane. http://www.derm.qld.gov.au/publications?id=1418

NSW National Parks and Wildlife Service (1998*) Vertebrate fauna survey: NSW comprehensive regional assessment project report,* NSW NPWS, Sydney.

Pickering, C.M. (2008). Literature Review of Horse Riding Impacts on Protected Areas and a Guide to the Development of an Assessment Program. Environmental Protection Agency: Brisbane http://www.derm.qld.gov.au/register/p02813aa.pdf

APPENDIX 1—Draft Issues for forest trails survey

(to be conducted at entry/exit areas)

Note: The actual wording of questionnaires and mechanisms of collecting information need to be devised by experts before implementation

- age (in broad classes), gender
- postcode of your normal place of residence
- how many times have you visited this reserve
- when did you last visit
- what did you do (or usually do) while visiting this area (i.e. walking, horse riding, mountain biking, swimming, trail bike riding, 4WD)
- how many people were in your group
- which trails did you use
- are you aware that horses are allowed to use these trials
- did you know that horses where allowed to use these trails before coming here
- what was the source of information you used about the trials
- how many horses have you seen using the trials on this visit
- have you seen any horses using the trials on previous visits

What is you level of agreement (Strongly disagree to strongly agree) for the following statements:

- the trails are in good condition
- the reserve is in good condition
- park management is adequate
- the presence of horses on the trails reduces my enjoyment of the trail
- the presence of horses on the trails is OK provided they slow down for walkers and other users
- horses should not be allowed any where in conservation reserves
- horses should be allowed in conservation reserves provided they are confined to certain defined trails
- I will not return to this trial because it is available for use by horses
- horse riding is more damaging to trails than mountain bikes
- horse riding is more damaging to trails than 4WDs
- horse riding is more damaging to trails than motorised trail bikes

Any other comments?

Issues for broader South East Queensland type survey (AC Neilsen or equivalent)

- Did you know that horse riding is allowed on a number of forest trials in South East Queensland conservation reserves
- What is your level of agreement (Strongly disagree to strongly agree) for the following statements:
- Horses should not be allowed anywhere in conservation reserves.
- I am likely to go horse riding on trials in conservation reserves in South East Queensland.

APPENDIX 2—A biophysical overview of South East Queensland Horse Riding Trail Network

For the purpose of summarising information for this overview, the HTN is subdivided into five 'trail groups' (Map 1). The trail groups include trails outside reserves but associated with the HTN, and were delineated based primarily on proximity and connectivity. For finer scale descriptions, within trail groups, trails in adjacent and connected reserves have been assigned to so-called 'trail clusters'. Basic statistics for the trail groups and trail clusters, including the reserves traversed, are provided in Table 1, and the trail clusters within each trail group are shown in Maps 2 to 11.

The data presented here is from a desktop analysis using GIS and various digital data on the trails and their biophysical context. It is intended as a broad background to the biophysical environment traversed by the horse-riding trail network.

The HTN trails span a broad range of environments. Average annual rainfall ranges from about 1000 mm up to around 2000 mm, and altitude varies from near sea-level up to around 700 m (Table A1).

The HTN trails are all used for access by reserve managers, and for other purposes, and the nature of their construction and maintenance is not uniform (Table A2). Most trails are dozed or graded tracks that incorporate water management features such as whoa-boys and drains. Trails are typically graded or bladed every few years. Some trails run along more thoroughly 'formed' roads, including some bitumen sections, while others are simply 'slashed' fire-breaks on otherwise unmodified soil surfaces. Such variability in construction, and the potential for management to modify trail construction in response to any observed degradation, clearly complicates assessment of impacts from horse riding on the trail network. However, while variation in trail construction may prove to be the single most important determinant of impacts from a given level of horse-riding use, there are many other factors that vary across the trail network.

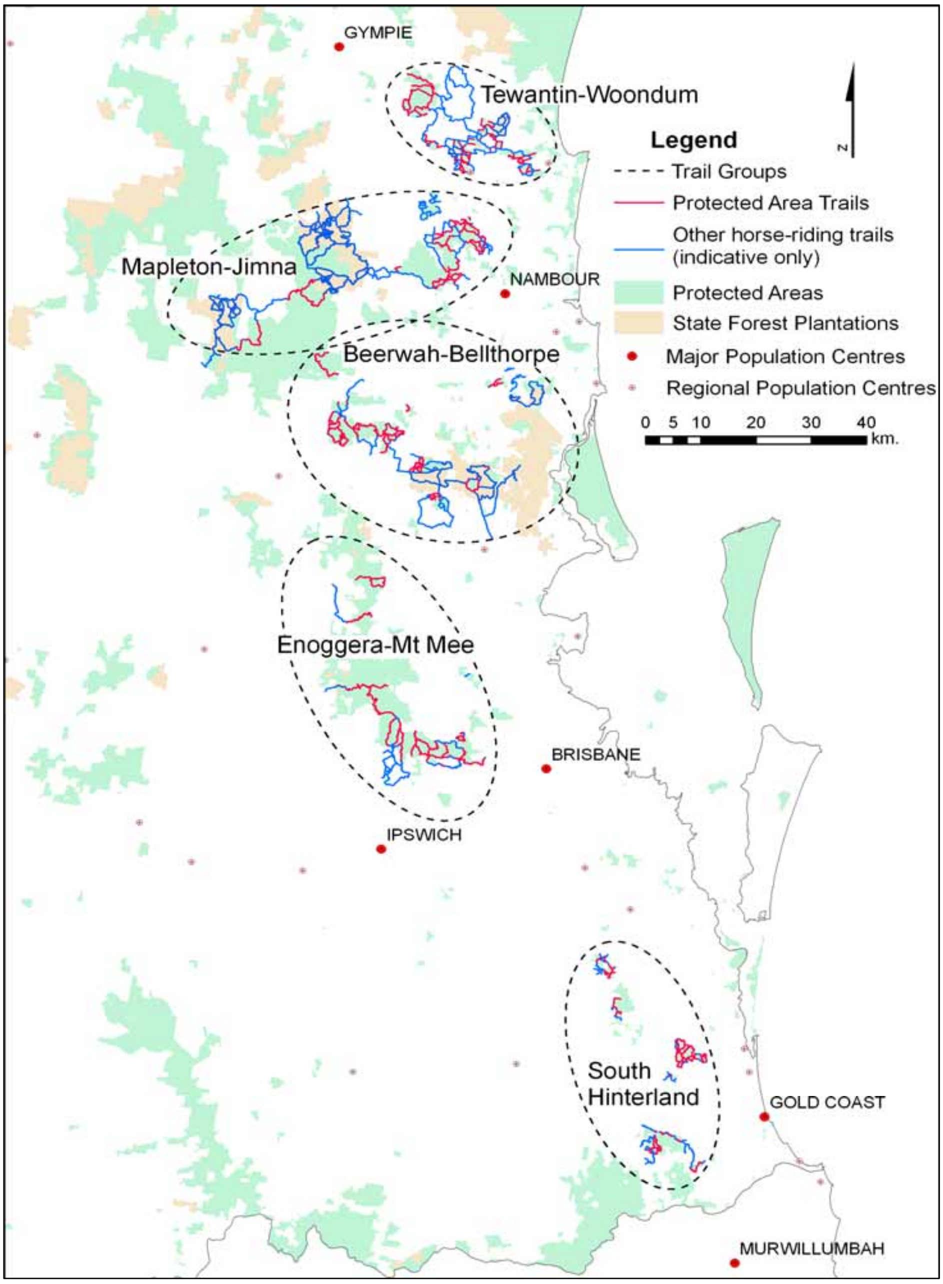
As well as management, most of the HTN trails are used by the public for other purposes. Some are public roads carrying all kinds of vehicles; some are regularly used by walkers, mountain bikers and even four-wheel drive enthusiasts; and many are also subject to substantial unauthorised use. Mountain bikes are sometimes ridden on trails where they are not permitted, but anecdotal evidence strongly suggests that the most damaging use of the HTN trails involves unauthorised access with motorised trail-bikes. There is insufficient information to adequately assess the extent and impact of other users of the HTN trails and there is also too little data on horse use along the HTN network and associated trails. Gathering such data will be an important initial and ongoing task for monitoring.

The HTN trails traverse a variety of distinct geologies and a diverse array of regional ecosystems (Table A3). The predominant vegetation is eucalypt forest and woodlands, but this varies from classic 'wet sclerophyll' forests, often with well developed rainforest mid-strata, through to quite heathy dry eucalypt woodlands.

The primary geology traversed by the HTN trails is metamorphic rock (land zone 11), although some trail clusters, particularly Mapleton and Bellthorpe, traverse substantial areas of granite geology. Most trail clusters also traverse alluvial landforms (Table A3). The most variable geology occurs in the Tewantin-Yurol-Ringtail trail cluster.

The "Biodiversity Status" of the Regional Ecosystems the HTN trails intersect reflects the extent of clearing and other degradation to which each ecosystem has been subjected. Most of the HTN trails traverse 'not of concern' REs, and few 'endangered' REs are encountered along the trail network (Table A3). However, the Tewantin-Yurol-Ringtail cluster in the Tewantin-Woondum trail group provides an important exception to this general observation, where substantial areas of endangered regional ecosystems are traversed.

The HTN trails mostly have gentle to moderate slopes but some trail groups such as the Enoggera-Mt Mee group include many with steep or very steep slopes (Table A4). Trails rarely exceed 50 per cent slope. The slope of the surrounding terrain is generally considerable steeper than that of the trail's path, with moderate to steep terrain quite common. Landform varies from predominantly undulating in some areas (e.g. Tewantin), to predominantly hilly in many others (e.g. D'Aguilar).



Map 1. Map of South East Queensland's Horse Riding Trail Network showing the five trail groups used to summarise information in this overview.

Table A1. Basic statistics on trail length, altitude and rainfall for the South East Queensland Horse Riding Trail Network and other associated trails. Numbers are averages with ranges in parenthesis.

Trail Group (see map 1)	Trail cluster (see maps 2 to 11)	Reserves traversed	Network Trails (km)	Other trails (indicative only) (km)	HTN trail altitude (m)	HTN trail annual rainfall (mm) (BIOCLIM estimate)
Tewantin-Woondum	Tewantin-Yurol-Ringtail	Ringtail SF, Tewantin FR 1, Tewantin FR 3, Tuchekoi FR, Yurol SF	68.5	97	78 (3-194)	1594 (1398-1746)
	Woondum	Woondum FR 1	40.8	0.8	278 (77-487)	1432 (1307-1526)
	Woondum-Tewantin Connect			53.9		
	Total		109.3	151.7		
Mapleton-Jimna	Imbil	Imbil FR 1, Imbil SF, Kenilworth SF	19.1	176.2	466 (149-603)	1235 (1136-1351)
	Jimna	Conondale FR 2, Jimna SF	13.1	83	608 (518-684)	1159 (1065-1244)
	Mapleton	Mapleton FR	83.1	51.9	247 (27-441)	1698 (1361-1796)
	West Cooroy	West Cooroy SF		27.1		
	Total		115.3	338.2		
Beerwah-Bellthorpe	Beerburrum	Beerburrum East SF, Beerburrum FR 1, Beerburrum West SF	30.2	130.5	100 (30-140)	1425 (1342-1560)
	Beerwah-Mooloolah	Beerwah FR, Beerwah SF		25.1		

	Bellthorpe	Bellthorpe FR 1, Bellthorpe FR 2	81	26.3	376 (139-638)	1484 (1156-1776)
	Conondale South	Conondale FR 2	12.2	0.1	548 (368-638)	1414 (1288-1506)
	Mooloolah	Mooloolah FR	4.7	1	119 (40-210)	1842 (1787-1880)
	Others			14.5		
	Total		128.3	197.6		
Enoggera-Mt Mee	D'Aguilar	D'Aguilar FR	8	9.9	411 (180-594)	1302 (1076-1419)
	Enoggera	Enoggera FR, Mount Glorious FR	51.1	16.9	284 (88-510)	1221 (1085-1480)
	Mt Glorious	D'Aguilar FR, D'Aguilar SF, Mount Glorious FR	48	42.4	395 (96-709)	1281 (999-1565)
	Mt Mee	Mount Mee FR	12.8	0.1	266 (116-442)	1242 (1093-1387)
	Others			1.3		
	Total		119.9	70.6		
South Hinterland	Clagiraba	Clagiraba FR	1.2	5.1	147 (81-178)	1332 (1296-1354)
	Nerang	Nerang FR, Nerang SF	40.2	3.7	116 (15-228)	1380 (1308-1454)

Numinbah-Austinville	Austinville FR 2, Numinbah FR	21.6	29.2	211 (89-391)	1617 (1354-1977)
Tamborine	Tamborine FR	7.2	2.5	114 (48-263)	1152 (1121-1238)
Wickham-Plunkett	Plunkett Conservation Park, Wickham FR, Wickham Timber Reserve	12.7	10.9	75 (35-199)	1141 (1104-1192)
Total		82.9	51.4		

Table A2. Data on trail construction and surface characteristics across the HTN network. Figures are kilometres of trail, with percentage of such trails having slopes >10% indicated in parenthesis. Based on QPWS data.

Trail group	Trail cluster	Formed sealed1	Formed gravel	Formed natural	Unformed gravel	Unformed natural	Unclassified
Tewantin-Woondum	Tewantin-Yurol-Ringtail	8.3 (5.2%)	0.1 (0%)	0.1 (0%)		55.5 (4.8%)	6.4 (4.4%)
	Woondum		3.6 (25.4%)	0 (0%)	1.5 (34.1%)	38 (19.4%)	
Mapleton-Jimna	Imbil		0.5 (33.5%)	10.4 (37%)		8.5 (30.9%)	
	Jimna		1.2 (11.5%)	1.5 (22.1%)		10.5 (19.1%)	
	Mapleton	0.1 (63.4%)	16.2 (16.1%)	0.9 (10%)	6.4 (24.7%)	61.9 (22.5%)	0.3 (43.7%)
Beerwah-Bellthorpe	Beerburrum		0 (0%)	15.7 (0.5%)		13.3 (7.5%)	1.9 (0%)
	Bellthorpe	0.6 (56.5%)	15.8 (25%)	6.6 (19.7%)	10.6 (36.5%)	49 (42.7%)	
	Conondale South		2.5 (34.5%)	10 (26.7%)		0.1 (17.9%)	
	Mooloolah	0.2 (2.3%)				4.6 (28%)	
Enoggera-Mt Mee	D'Aguilar		7.7 (60.7%)			1.6 (66.6%)	
	Enoggera	0.5 (33.5%)	41.3 (31.7%)		7.4 (35.4%)	2.9 (34%)	
	Mt Glorious	0.2 (39.6%)	38 (42.2%)		0.1 (48.6%)	10.5 (38.9%)	
	Mt Mee		2 (38.7%)			11 (53.4%)	
South Hinterland	Clagiraba			1.1 (20%)			0.2 (82.7%)
	Nerang	0.4 (17.3%)		10.1 (24.5%)		34.1 (34%)	
	Numinbah-Austinville	0.4 (0%)		0.2 (28.8%)		22.4 (43.3%)	
	Tamborine		4.2 (39.1%)		0.1 (44.2%)	3.1 (9%)	
	Wickham-Plunkett					13 (22.3%)	

1trail sections on sealed roads are generally beside rather than on the road and typically are unformed with natural surfaces.

Table A3. Biodiversity status of Regional Ecosystems traversed by the South East Queensland Horse Riding Trail Network. All figures are kilometres of trial length. For biodiversity status, figures in parenthesis indicate the length of trail along which a higher status is 'subdominant'.

		Vegetation formation					Land zone							Biodiversity Status		
Trail group	Trail cluster	Non remnant	Dry eucalypt	Wet eucalypt	Rainforest	Swamp	2	3	5	8	9-10	11	12	Endangered	Of-concern	Not of concern
Tewantin-Woondum	Tewantin-Yurol-Ringtail	12.9	20.6	36.5	0.1	0.3	0.4	4.7	14	2.8	37.6	7.6	3.3	14.7	22.6 (3.2)	20.4 (7)
	Woondum	1.4	7.2	31.1	3.3	0		0.6	0	1.8		6.5	34.1	0.1	2.8 (0.6)	38.7 (4.7)
Mapleton-Jimna	Imbil	0.7	15.9	0.5	2	0.2		0.3				17.7	1.5		3.2 (0.2)	15.6 (0.1)
	Jimna	0.1	13.1	0	0	0						13.2				13.1
	Mapleton	3.5	7.2	72.5	2.7	0		1.9				0	84	0.2	10.3 (0.4)	71.9
Beerwah-Bellthorpe	Beerburrum	7.9	6	17	0	0		0.4	8.8		3.5		18.2	1.3	1.2	20.5
	Bellthorpe	0.9	25	46.1	7.6	3.1		9.2				31.6	41.8		15.9	65.8 (8.9)
	Conondale South	0.9	0	10.9	0.8	0				3		5.4	4.1		3.2	8.4
	Mooloolah	0.2	3.2	0.7	0.7	0					4.8			0.7	0	3.9
Enoggera-Mt Mee	D'Aguilar	0.2	5.3	0	3.8	0						9.3				9.1
	Enoggera	0.1	50.6	0	1.4	0						52.1				52 (6.3)

	Mt Glorious	1.8	45.4	0	1.6	0						48.8				47 (11.4)
	Mt Mee	0.1	12.9	0	0	0						13				12.9
South Hinterland	Clagiraba	0.5	0.8	0	0	0						1.3				0.8
	Nerang	1.1	43.4	0	0	0.1		0.1				44.5				43.5
	Numinbah-Austinville	0.6	16.7	5.4	0.1	0.1		0.4		0.4		16.9	5.2		1.1	21.2 (2.5)
	Tamborine	0.1	7.1	0	0	0.2		0.2			6.4	0.6	0.2		0.4	7
	Wickham-Plunkett	3.8	9.1	0	0	0.1		0.3			5.6	7.1			0.1	9.1
	TOTAL	**36.8**	**289.5**	**220.7**	**24.1**	**4.1**	**0.4**	**18.1**	**22.8**	**8.0**	**57.9**	**275.6**	**192.4**	**17**	**60.8**	**460.9**

Table A4. Trail and surrounding terrain slope and relief data for HTN trails. Figures are percentages of trail length.

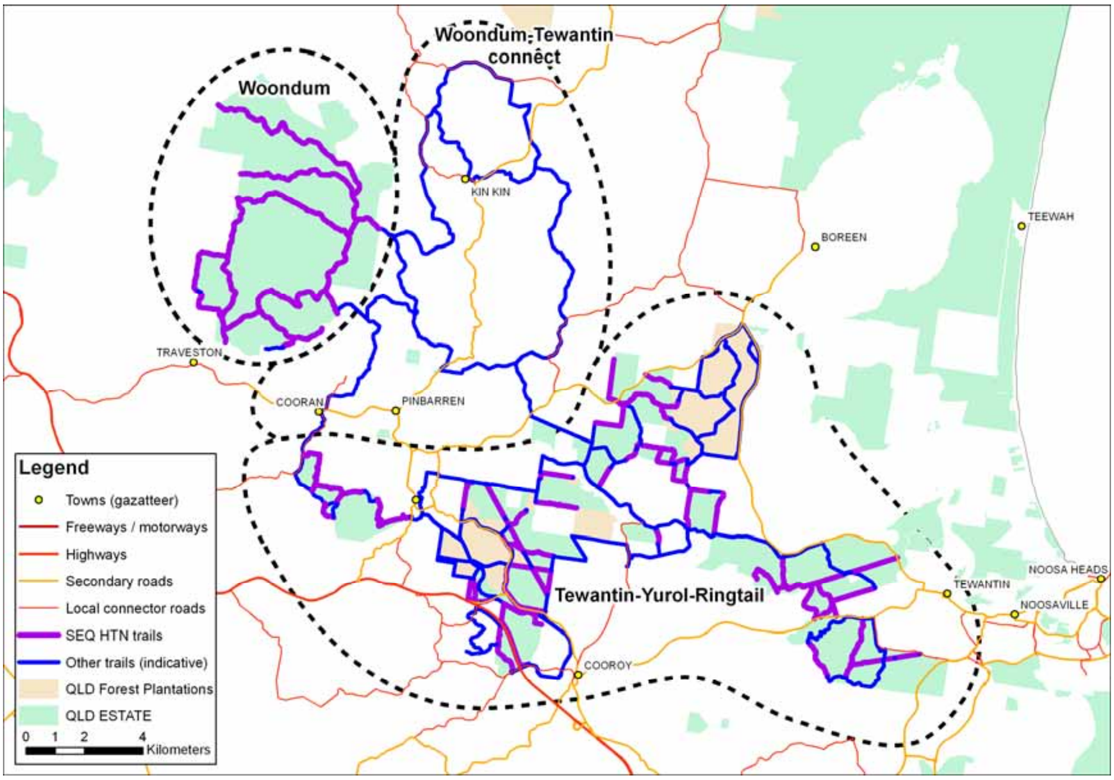
		Path slope						Terrain slope						Terrain relief (200m radius)			
Trail group	Trail cluster	Level (<1%)	Very gentle (1-3%)	Gentle (3-10%)	Moderate (10-32%)	Steep (32-56%)	Very steep (56-100%)	Level (<1%)	Very gentle (1-3%)	Gentle (3-10%)	Moderate (10-32%)	Steep (32-56%)	Very steep (56-100%)	Plain (<9 m)	Rises (9-30 m)	Low hills (30-90 m)	Hills (90-300 m)
Tewantin-Woondum	Tewantin-Yurol-Ringtail	33.6	46.3	15.2	4.8			15.5	50.9	20.8	12.6	0.3		44.1	35.7	18.7	1.5
	Woondum	17.2	35.8	27.2	18.7	1.1		2.9	27.3	28.3	31.6	9.4	0.6	4.9	28.2	48.4	18.4
Mapleton-Jimna	Imbil	7.8	28.5	29.2	32.5	1.9		1.3	13.0	28.5	50.6	5.4	1.3		6.4	72.3	21.3
	Jimna	13.5	33.2	34.9	18.4			3.0	26.9	36.1	33.9				12.5	87.5	
	Mapleton	14.3	33.3	30.6	21.2	0.6		2.7	24.6	32.4	36.6	3.6	0.2	1.1	26.7	63.8	8.3
Beerwah-Bellthorpe	Beerburrum	38.3	45.2	13.0	3.4			14.9	51.7	20.9	10.9	1.6		43.9	37.9	18.2	
	Bellthorpe	6.1	24.9	32.0	34.0	3.0		0.6	9.9	25.0	47.9	15.4	1.2	0.8	6.0	57.7	35.4
	Conondale South	11.6	30.1	29.9	27.1	1.3		1.8	18.7	26.5	45.1	7.4	0.4		5.6	83.9	10.5
	Mooloolah	9.1	34.7	28.9	27.3			1.1	21.3	27.7	47.1	2.9			19.5	77.6	2.9
Enoggera-	D'Aguilar	2.7	12.3	22.4	52.1	10.3	0.3		2.1	4.1	41.3	47.2	5.3		1.6	10.7	87.7

Mt Mee	Enoggera	9.9	29.2	28.5	31.5	0.9		1.5	13.7	26.7	48.1	9.8	0.3		0.9	75.7	23.4
	Mt Glorious	6.9	21.5	29.7	37.7	4.0	0.1	0.1	5.6	18.3	49.7	24.0	2.3		0.6	41.8	57.6
	Mt Mee	4.8	20.4	23.4	45.3	6.1		0.0	4.5	13.7	53.7	27.9	0.2		3.6	48.1	48.3
South Hinterland	Clagiraba	6.6	29.6	33.5	22.1	6.2	2.1	1.8	1.9	13.6	70.0	10.6	2.1		0.5	86.3	13.2
	Nerang	8.8	27.8	32.1	29.7	1.6		1.5	14.5	31.7	48.1	4.2		0.7	8.8	78.6	12.0
	Numinbah-Austinville	9.1	26.6	22.8	37.8	3.8		0.6	9.9	22.7	52.3	14.2	0.3		8.1	56.2	35.7
	Tamborine	11.1	34.3	27.4	26.9	0.2		0.3	16.9	21.5	58.5	2.9		0.6	25.6	73.8	
	Wickham-Plunkett	13.2	32.9	31.9	19.0	3.0		1.5	17.6	37.9	35.6	7.4		0.1	36.7	52.2	11.0

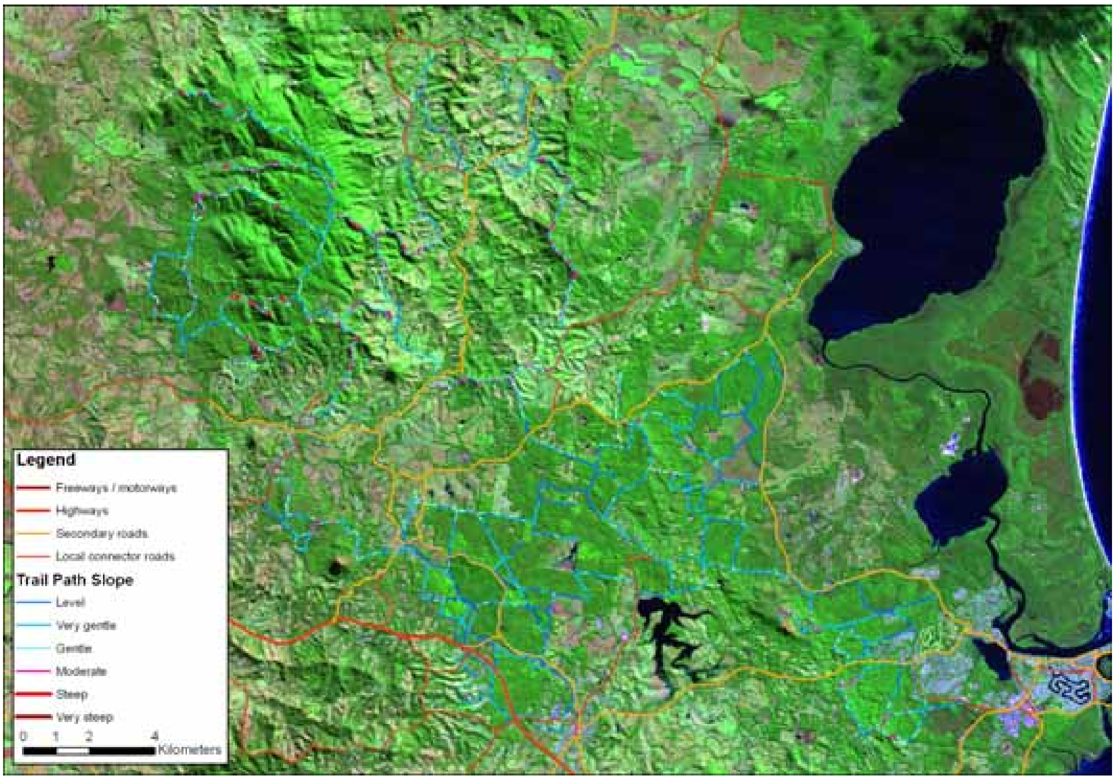
Table A5. Density of drainage across the horse-riding trail network and associated trails on other tenures. Estimates based on GIS analysis using 1:100k scale 'drainage' data.

		Estimated average number of 'spots' per km close to drainage (% trail length <5 m from drains in parenthesis)		Estimated number of relatively substantial waterways crossed per km.	
Trail Group	Trail Cluster	HTN Trails	Other trails (indicative only)	HTN Trails	Other trails (indicative only)
Tewantin-Woondum	Tewantin-Yurol-Ringtail	1 (1.3)	1.2 (1.7)		0.02
	Woondum	0.3 (0.4)	0 (0)		
	Woondum-Tewantin Connect	-	0.9 (1.4)		0.09
Mapleton-Jimna	Imbil	0.7 (1.4)	1.2 (2.2)		0.02
	Jimna	0.4 (0.8)	1.6 (3.2)	0.2	0.05
	Mapleton	0.6 (1)	1 (1.1)	0.02	0.06
	West Cooroy	-	1 (1.7)		
Beerwah-Bellthorpe	Beerburrum	1.2 (1.6)	0.9 (1.1)	0.03	0.04
	Beerwah-Mooloolah	-	0.8 (1.1)		
	Bellthorpe	0.7 (1.4)	1.2 (1.6)	0.02	0.08
	Conondale South	0.1 (0.1)	0 (0)		
	Mooloolah	0.2 (0.3)	0 (0)		
	Others	-	1.7 (1.9)		0.3
Enoggera-Mt Mee	D'Aguilar	0.4 (0.5)	1.7 (4.2)	0.25	0.9
	Enoggera	0.2 (0.7)	0.2 (0.4)	0.02	0.3
	Mt Glorious	0.3 (0.5)	1.2 (2.2)	0.2	0.4

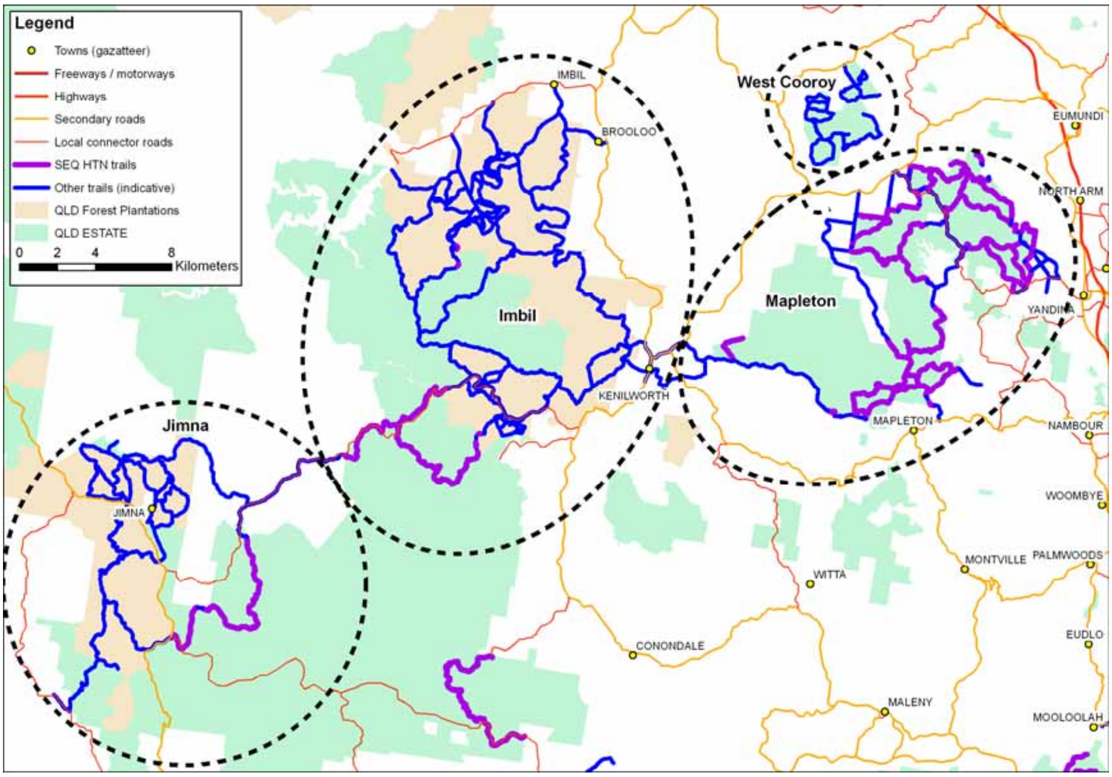
	Mt Mee	0.7 (1.9)	0 (0)	0.2	
	Others	-	0 (0)		
South Hinterland	Clagiraba	0.8 (1.3)	2.5 (5.2)		0.8
	Nerang	0.3 (0.4)	0.5 (0.6)	0.05	0.3
	Numinbah-Austinville	1.1 (2.6)	1.4 (1.7)	0.6	0.1
	Tamborine	1.1 (2.2)	0 (0)		
	Wickham-Plunkett	1.2 (1.4)	0.6 (0.7)		



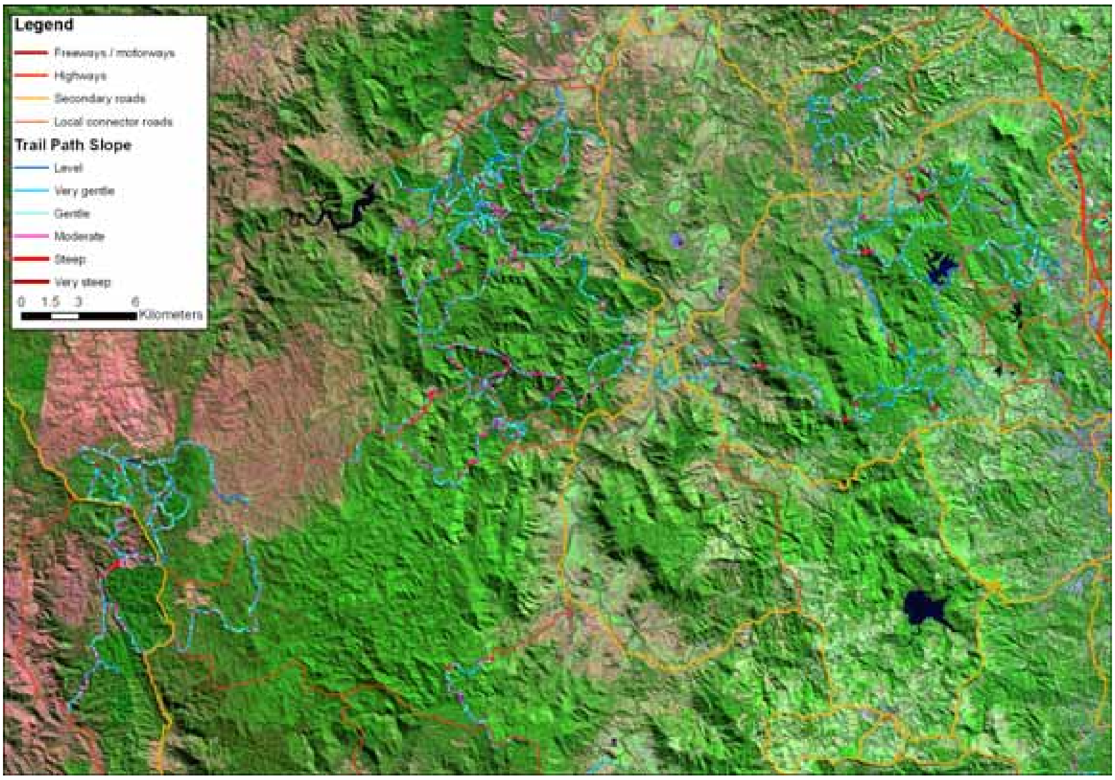
Map 2. HTN and other trails, and trail clusters in the Tewantin-Woondum trail group.



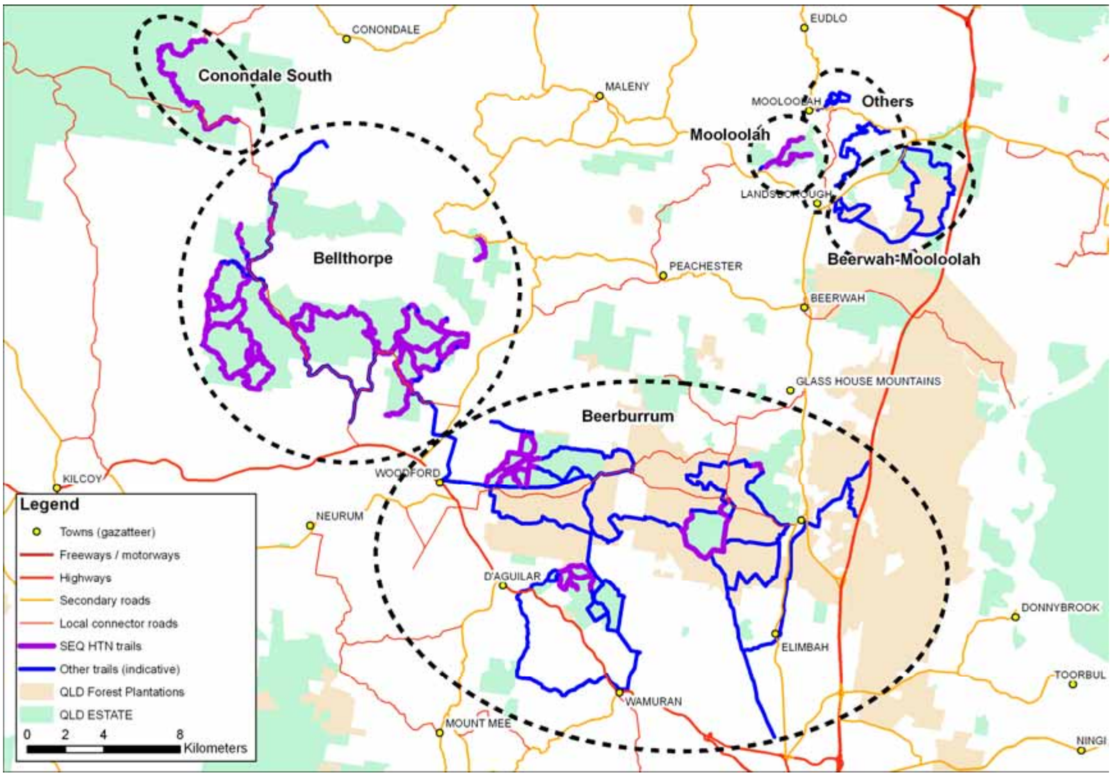
Map 3. Landsat map showing slope classes across the Tewantin-Woondum trail group.



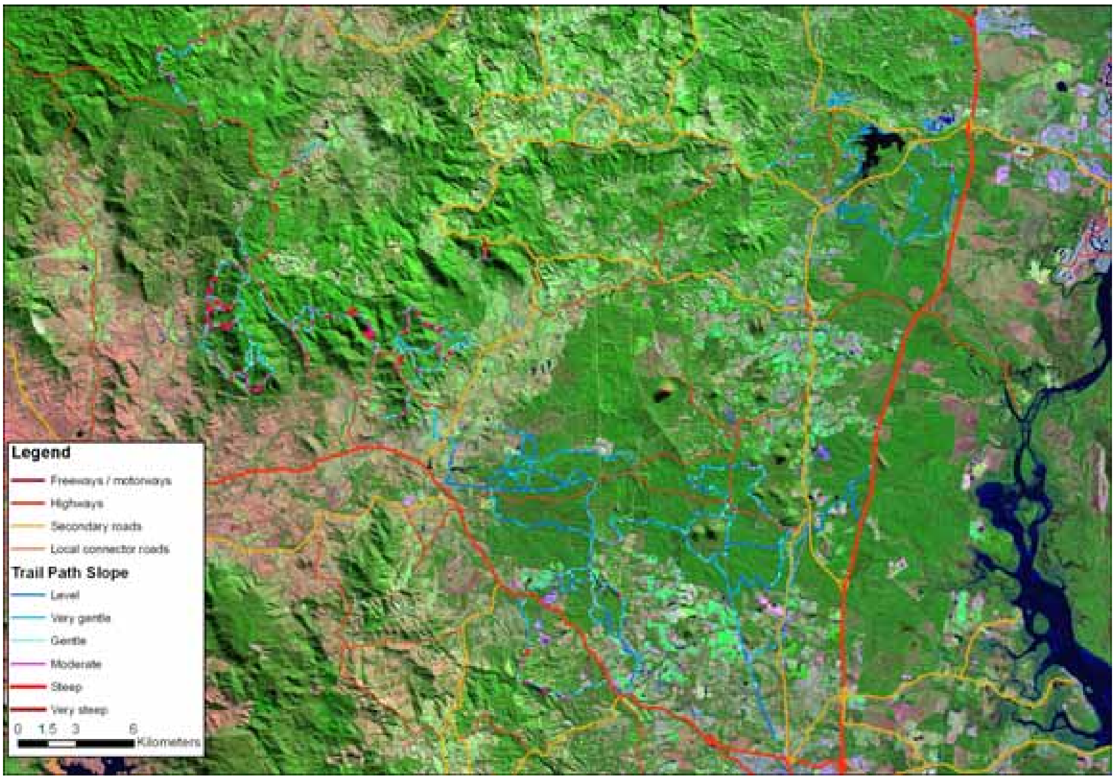
Map 4. HTN and other trails, and trail clusters, in the Mapleton trail group.



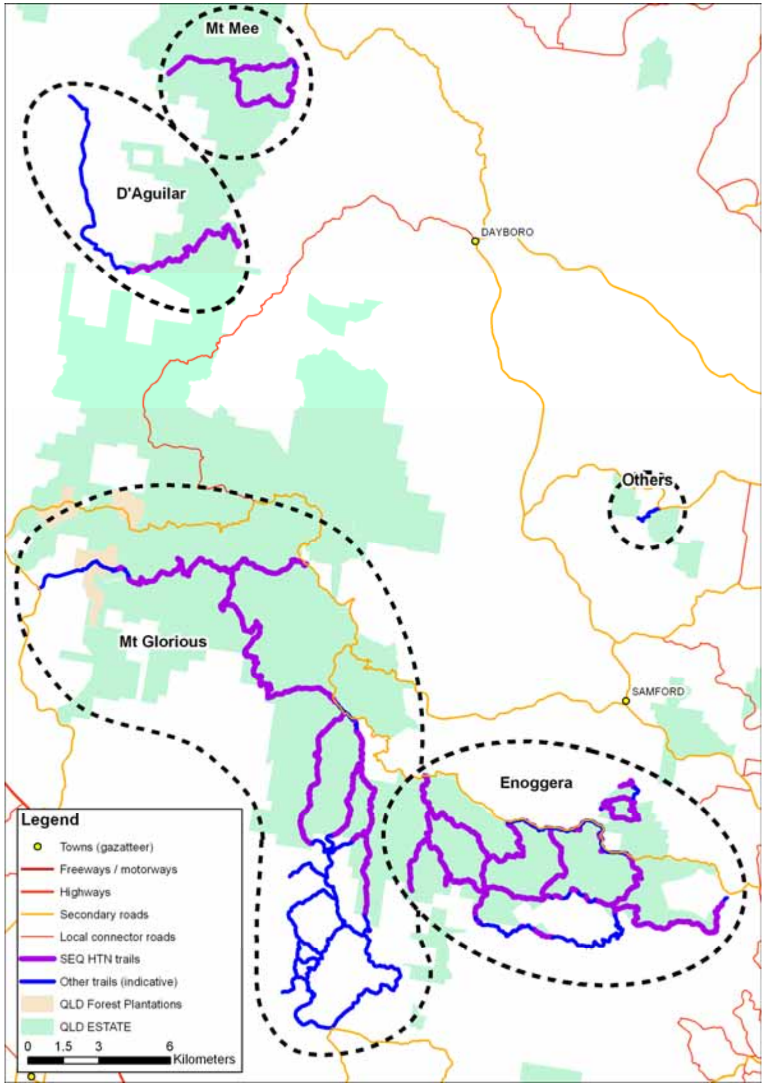
Map 5. Landsat map showing slope classes across the Mapleton trail group.



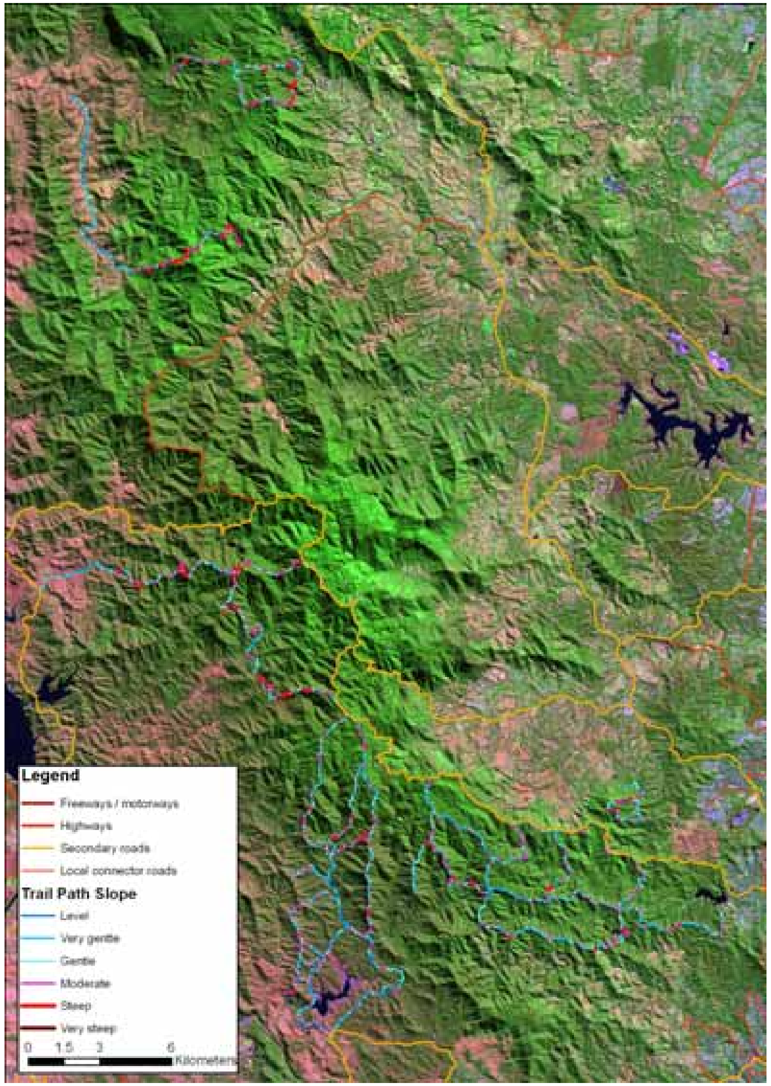
Map 6. HTN and other trails, and trail clusters in the Beerwah-Bellthorpe trail group.



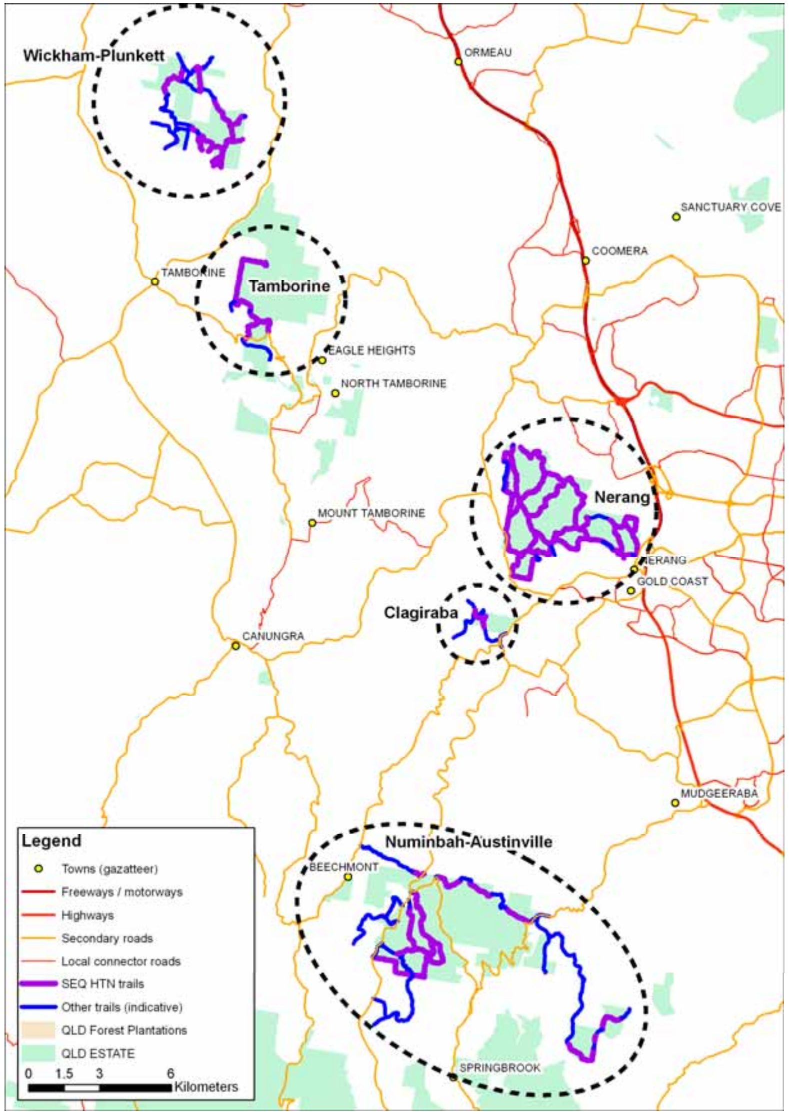
Map 7. Landsat map showing slope classes across the Beerwah-Bellthorpe trail group.



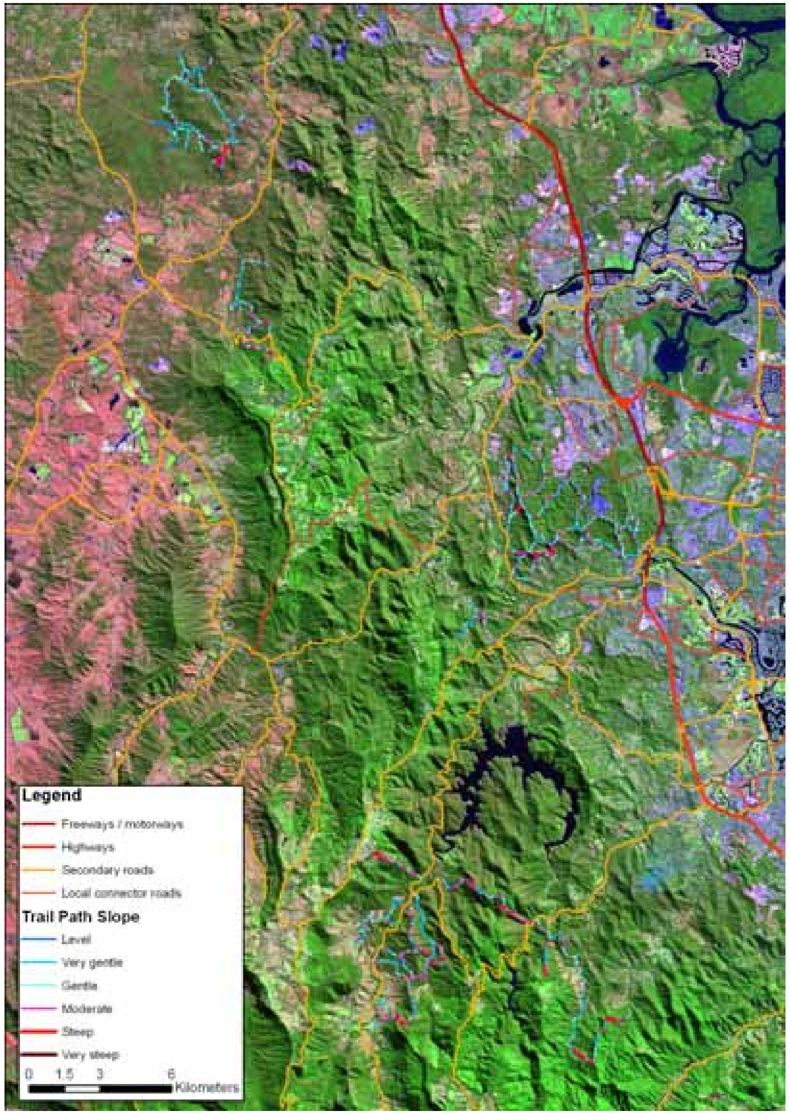
Map 8. HTN and other trails, and trail clusters in the Enoggera-Mt Mee trail group.



Map 9. Landsat map showing slope classes across the Enoggera-Mt Mee trail group.



Map 8. HTN and other trails, and trail clusters in the South Hinterland trail group.



Map 9. Landsat map showing slope classes across the South Hinterland trail group

APPENDIX 3—Monitoring of impact of single high intensity use events

This sampling would occur immediately before and after a high intensity horse riding events, e.g. the Lake Manchester or Murrumba Downs endurance rides. Observers would also be present during the running of the event.

The biophysical attributes recorded would include the track condition, water quality and presence of weeds before and after the event.

- Tracks would be measured for erosion of the surface of the track..
- Track width would be measured for evidence of expansion of the track width.
- The route would be surveyed for the development of informal trails.
- The amount of horse dung would also be quantified.
- A weed survey would be conducted prior to the event, and three months after the event (provided adequate rain was received) to sample for changed weed diversity or cover.

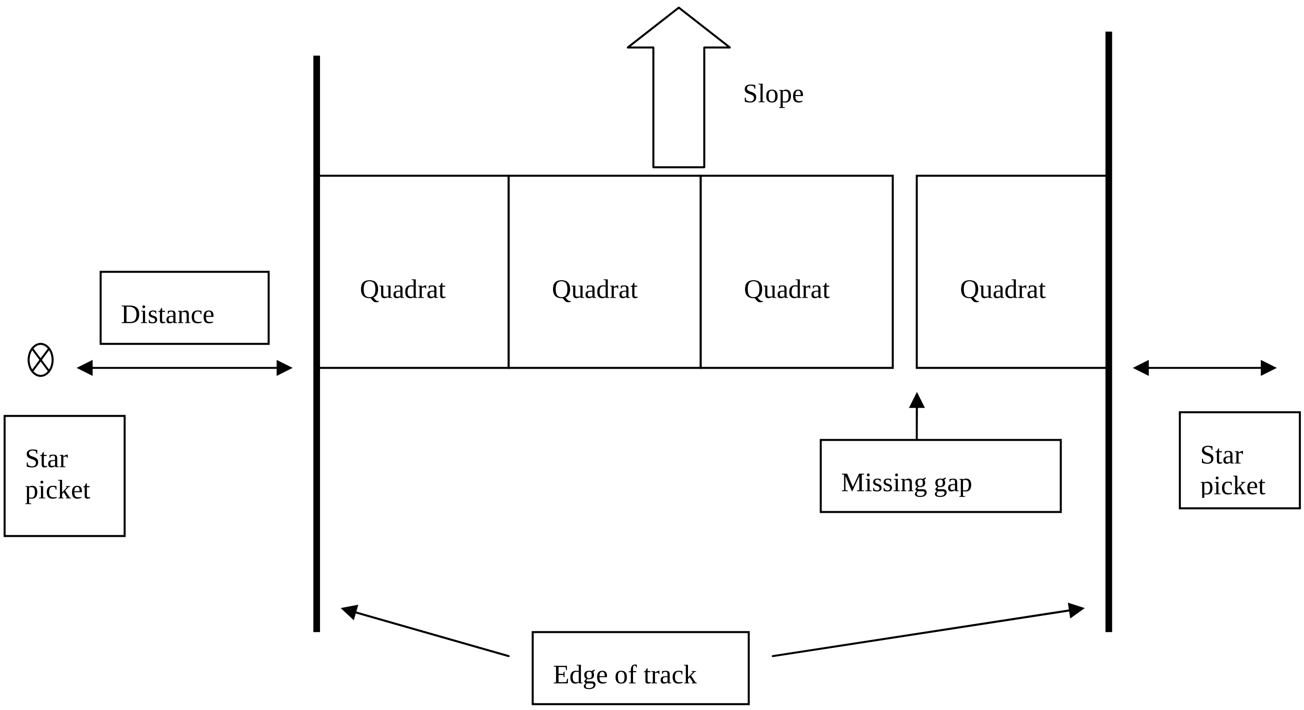
APPENDIX 4—Detailed sampling protocol for measuring erosion on tracks

The sampling protocol at each location is:

1. Locate position of site. Go to GPS coordinates predetermined in the laboratory to sample a combination of layers (slope, substrate, RE, etc).
2. Consider safety (visibility on the track, etc) before locating permanent star pickets.
3. A permanent star picket is hammed in between 2 m and 5 m from the edge of the track on either side of the road.
4. Date, recorders, site number, location, slope of track and GPS position of star pickets are recorded.
5. A measuring tape is run across the track between the two star pickets.
6. The distance from the star picket to the edge of the track is measured.
7. The first $1m^2$ quadrat is placed along the edge of track with a perpendicular side running along the tape and the quadrat placed on the downside of the tape.
8. Within each quadrat the following data are recorded, based on visual estimates;

- % of quadrat covered with litter
- % of quadrat covered with coarse woody debris (CWD) including living roots
- % of quadrat covered with rocks or stones
- % of quadrat covered with living vegetation
- % of quadrat covered with manure (specify if native or horse)
- % of quadrat covered with bare earth (sum of the these six categories is 100%)
- number of complete horse prints in quadrat
- erosion area as a percentage of quadrat
- depth of erosion in centimetres
- evidence and type of wheeled tread marks – Motor vehicle, motor bike, bicycle

9. Photographs are taken of each quadrat.
10. The second quadrat is placed contiguously with the first moving along the measuring tape, and the same recordings within quadrat are recorded. A third quadrat may then placed contiguously with the second, and recordings make. The final quadrat is to be located with one side along the edge of the track on the far side. In many cases that may mean a gap in the quadrats as the track width is frequently not a multiple of whole metres. The size of the gap is noted, but it is important that complete $1m^2$ quadrats are recorded and that the last quadrat is aligned along the edge of the track.
11. The distance from the edge of track to the other star picket is also recorded.



Definitions

Edge of track = defined as the interface where some living vegetation meets bare road surface. Frequently there is a marked change in slope, either a drop or a ridge, and the edge is a linear feature running the length of the track.

Coarse Woody Debris (CWD*)*= coarse woody debris or dead timber on the ground >10 cm diameter. For this study includes expose living roots >10 cm diameter.

Erosion area = % of quadrat area that is below the level of an assumed flat 1 m² quadrat.

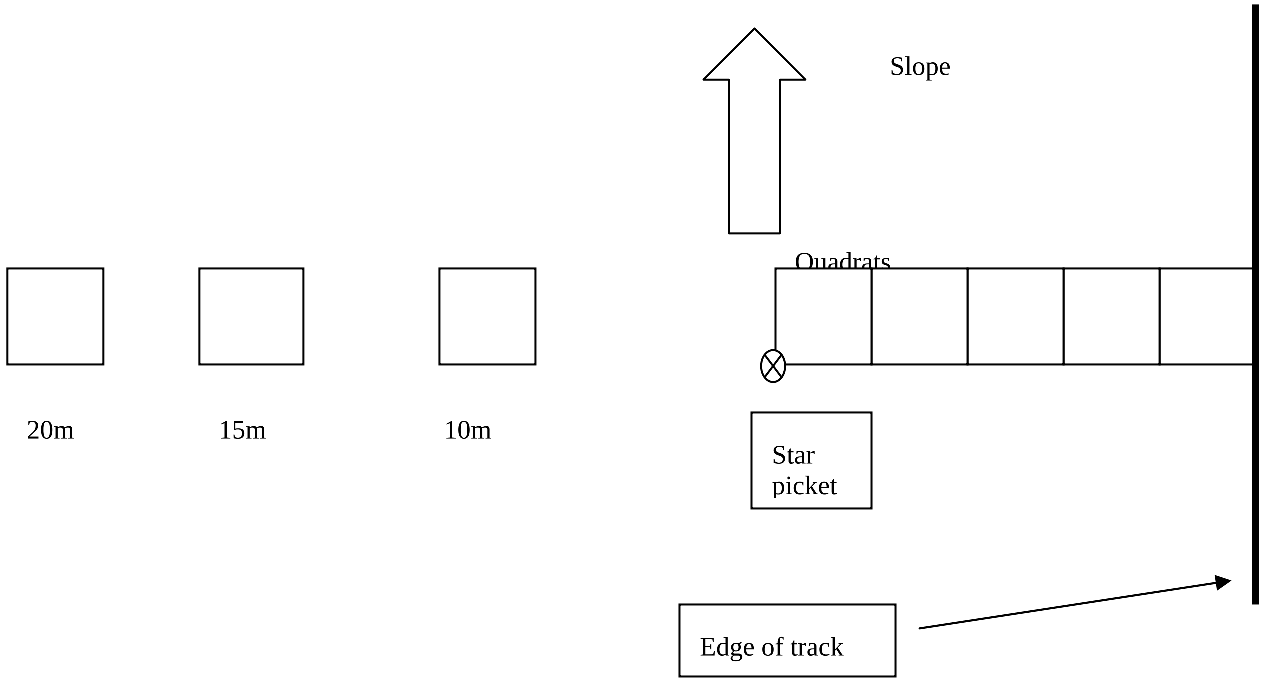
Erosion depth = is measured as the depth below an assumed level surface at the downslope part of the quadrat.

Count = number of complete horse hoof prints in quadrat. Fractions of complete hoof prints can be added. If cattle prints are present they are counted as separate horse hoofs.

APPENDIX 5—Detailed sampling protocol for measuring ground vegetation beside tracks

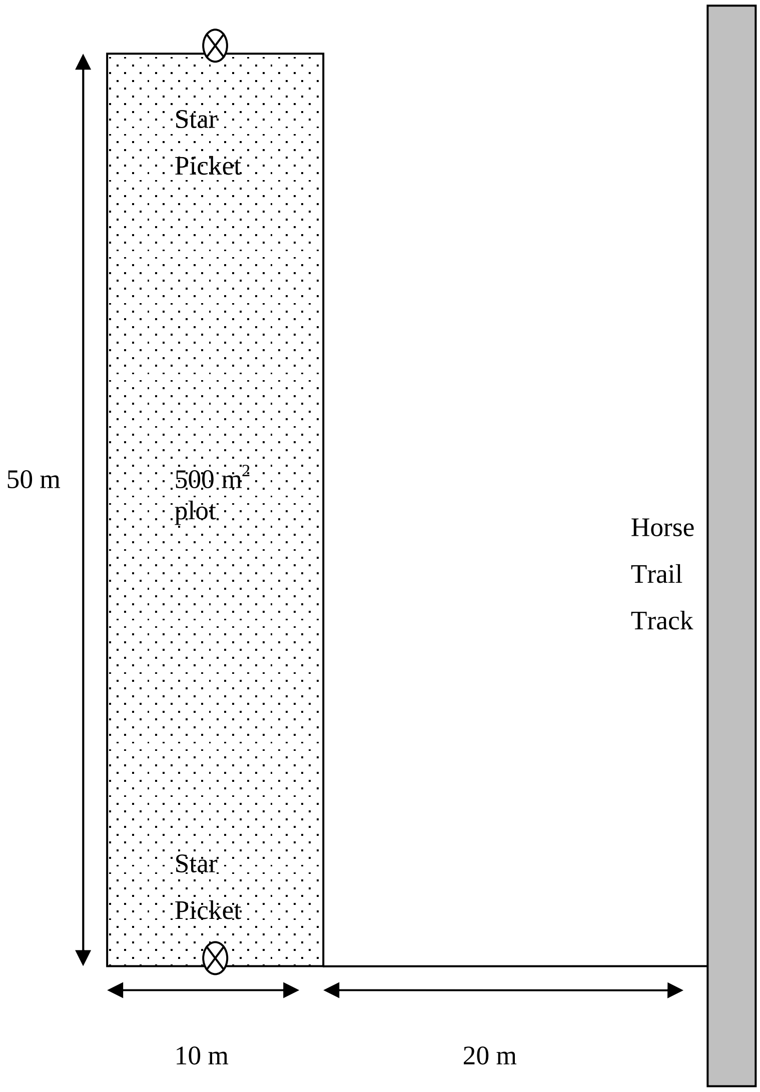
The sampling protocol at each location is:

1. The same star pickets from the erosion measurements are used to define the vegetation transects.
2. A measuring tape is run at a tangent from the edge of the road, touching the star picket and runs out for 25 m..
3. The terrain that the transect follows is sketched out on the proforma.
4. Five contiguous 1 m² quadrats are sampled from the edge of the track out to 5 m, a quadrat is then placed at 10 m, 15 m and 20 m. Quadrats are always located downslope of the measuring tape.
5. Within each quadrat, the projective foliage cover (PFC) of living biomass, litter, rocks, coarse woody debris and bare soil are recorded. These percentages will total 100%.
6. The living plants are assigned an individual PFC based on species. Shrubs and regenerating trees present are given PFC for the quadrat and their height.
7. At the 25 m mark the dominant tree species and structural formation is recorded to enable the vegetation to assigned to a regional ecosystem.
8. The procedure is repeated on the other side of the road.



Sampling protocol for measuring forest structure and species composition

This sampling protocol records a number of structural attributes (height, foliage cover and stem density) for each of the woody strata present in the forest. The basal area of the trees present in the 500 m² plot is also recorded using callipers or girthing tapes. For the ground layer the height and projective foliage cover of the species present is recorded from five quadrats and averaged for the plot. The methodology is provided in detail in Neldner et al. (2006).



APPENDIX 6—Evidence of vectors of weed dispersal in SEQ Horse Trail Network

Introduction

The South East Queensland Horse Riding Trail Network consists of 547 km of trails that provide a range of outstanding horse riding opportunities in Noosa, Mapleton-Kenilworth, Caboolture-Bellthorpe, Western Brisbane and the Gold Coast. This trail network has strategic connections to about 340 km of other trails in forest plantations managed by Forestry Plantations Queensland (FPQ) and over 470 km of trails on other lands mainly managed by local governments. The trail network in State lands is mainly located in Forest Reserves, with few in State Forests and Timber Reserves that are managed by the Queensland Parks and Wildlife Service (QPWS) division of the Department of Environment and Resource Management (DERM). The reserves that host the trail network are being converted to national parks following the South East Queensland Forests Agreement (SEQFA) signed in 1999. However horse riding is not permitted on national parks under the Nature Conservation Act 1992. Hence the major challenge to finalising the transfer of SEQFA lands has been to balance horse riding access with the management principles of protected areas.

Recent amendments to the *Nature Conservation Act 1992* (NCA) specify that the horse trail network must be reviewed by the Chief Executive and that the review should start as soon as possible and finish before 2026. The NCA also specifies that the review will be informed by an assessment undertaken by an independent Scientific Advisory Committee (SAC). The SAC's assessment of impact of horse riding on the trail network and adjacent areas must be based on monitoring and evaluation conducted over a period long enough to assess the likely impacts of horse riding use, and must take account of the cumulative impacts of horse riding and other activities conducted in the horse trail network.

The problem

Weeds are a major management issue for protected areas in Australia (See references by Pickering 2008). Over 192 significant weeds occur or have the potential to occur in South East Queensland (Thorp and Wilson 2008). Hence users of horse trail network are potential vectors of weed dispersal. These include vehicles, bicycles, motorbikes, walkers, horses and horse riders. Horse riding therefore poses a risk for the introduction of weed species along the horse trails in South East Queensland.

For example of the 14 significant grass weeds for south eastern Queensland (Thorp and Wilson 2008), all can be dispersed by seed, all can be found in pastures and many also occur on road verges. Hence they have the potential to appear in horse feed and dung. Several of them could also be spread on the fur of horses, on riders or on riding equipment. For example, Mossman River grass (Cenchrus echinatus) has burrs that attach to fur, African lovegrass (Eragrostis curvula) has seed that can be dispersed on the mud of cars and in animal fur, olive hymenachne (Hymenachne amplexicaulis), a weed of national significance, can be dispersed in stock feed, fountain grass (Pennisetum setaceum) can be dispersed on clothing, giant Parramatta grass (Sporobolus fertilis) and giant rat's tail grass (Sporobolus pyramidalis) have seed that can become attached to machinery, and seed that can attach to fur and hair, while grader grass (Themeda quadrivalvis) can be dispersed by animals, mud and on graders (hence the common name) (Thorp and Wilson 2008 and references there in).

Current practices designed to minimise the impacts of horse riding on multi-use trails in designated State forests, forest reserves and protected areas in Queensland are contained in a Code of conduct for recreational horse riding that is implemented by Queensland Parks and Wildlife Service. To avoid spreading of weeds, the Code requires the riders to:

Provide weed-free, good quality, processed feed to horses at least 48 hours prior to entering a forest reserve or protected area; and

Ensure that horses' coats, hooves, equipment and floats are clean and free of seeds before park visits.

Adherence to the horse riding code should reduce the risk of introducing seeds and reduce damage to vegetation that may favour the establishment of weeds.

Objective

The purpose of this project is to establish the extent to which horse riding within the Southeast Queensland horse trail network poses a risk for the introduction of weed species. An assessment on the extent of weed introduction by vehicle and bike wheels as well as on walker's shoes could also be conducted to establish relative risk from different users.

Methodology

To assess the relative risk of weed spread by horses, assessment of the seed load on horses (hooves, hair, coat, equipment), in feed, and in manure would help quantify the risk of long and short term dispersal of weeds from riding in parks. Horses could be examined for weed seeds on their body using techniques referenced in Pickering (2008), and glasshouse germination trials could be conducted on the dung that horses leave on the trail. Seeds from vehicle and bike wheels and walker's shoes and clothing could be determined using glasshouse germination trials as well.

The devised methodology should attempt to address contingency issues. For example, the presence of a seed on the animal or in its dung does not necessarily mean that the weed species will survive and establish, particularly if horses are constrained to the trail network as specified in the Code of Conduct. The relationship between weed seeds detected on vectors coming into the National Park and weeds detected along horsetrails needs to be investigated. It would be beneficial if the potential vectors of seeds that may establish on the trail network or adjacent areas can be identified.

Deliverables

Key milestones:

1. Detailed methodology for the study
2. Draft results
3. Final report

References

Pickering, C.M. (2008). Literature Review of Horse Riding Impacts on Protected Areas and a Guide to the Development of an Assessment Program. Environmental Protection Agency: Brisbane. http://www.epa.qld.gov.au/publications?id=2813

Thorp, J.R., Wilson, M (2008). Weeds Australia. Online document at URL: www.weeds.org.au

APPENDIX 7—Assessing stream health impacts from horse riding and 4WD vehicles in South East Queensland

Introduction

The South East Queensland Horse Riding Trail Network was developed to facilitate horse riding access to a number of former State forests in South East Queensland that have or will be transferred to National Parks under the South East Queensland Forests Agreement (SEQFA). The trail network consists of 547 kilometres of trails and is located on lands that are managed by the Queensland Parks and Wildlife Service (QPWS) division of the Department of Environment and Resource Management (DERM).

Biophysical targets considered to be most likely to show discernable response to horse riding use on the trail include: stream health; elements of track condition; and weeds. Other users of these trails include 4WD vehicles. This proposal focuses on horse riding impacts on stream health, and their relative impact compared with 4WD vehicles. The P-S-R framework was used to conceptualise and design the monitoring of this proposal as outlined by the whole-of-government Integrated Waterways Management Framework. Primary focus of the initial assessment is at the Stressor level, although we may also collect Ecological Response data for later consideration. A Griffith University honours student will be working with us on the development and implementation of this project.

It was decided that initial monitoring should employ a BACI type design, focusing on a worst case scenario of horse trail impacts. If impacts are detected the significance of these impacts can be assessed and monitored in following years. Risk to stream health is considered greatest when riding tracks pass through unculverted, flowing streams so the worst case scenario is considered as an intensive event, i.e. many horses in an area over a short period of time passing through unculverted flowing streams. This trial will simulate a horse event by coordinating a number of horses to pass through test stream crossings. 4WD impact will be from vehicles driving through stream crossings. If impact to stream health cannot be detected from a controlled experimental design simulating a single intensive horse even then it is unlikely that low intensity events or usage will be detectable. A comparison will be made between horse and 4WD impact on the stream health. If nothing is detected future investigation to these impacts will be deemed unnecessary, however if an impact is detected future investigations will be focused on the distance of impact downstream.

The design proposed is therefore a BACI design comparing change in upstream-downstream site differences at two unculverted crossings with intense horse impact, against two control crossings without significant horse impact. Control sites should have comparable ecological attributes to that of the impact sites including substrate type, flow, and local weather patterns. A minimum of two test and two control sites will be assessed. Each site comprises samples both upstream and downstream of a stream crossing.

Stressors of horse impact were assessed for their viability at an expert qualitative risk assessment which ranked stream health stressors with their relative risk (see table 1).

Indicators of these stressors were assessed for their applicability to the study (see table 2).

Table 1: Workshop qualitative risk assessment for horse impact stressors on stream health

Stressor	Likelihood	L conf	Consequence	C conf	Risk	Risk conf	worst case circumstance
Nutrients Direct	5	2	4	3	20	6	non-flowing
Deposited sediment	5	3	4	2	20	6	non-flowing
Physical dist rip/banks	5	3	4	2	20	6	wet ground
Physical dist bed	5	3	4	2	20	6	none
Changed light regime	5	2	3	2	15	4	non-flowing
Bacteria	5	3	3	1	15	3	non-flowing
Nutrients resuspension	5	3	2	2	10	6	non-flowing
Nutrients via transferred sediments	4	3	2	3	8	9	non-flowing
Weeds aquatic	2	2	4	3	8	6	
Physical dist waves	4	2	2	2	8	4	
Weeds riparian	3	1	2	2	6	2	
Horse drugs	3	1	2	1	6	1	
Litter	2	3	1	2	2	6	
Consequence is worst case (e.g. not flowing water)							
Scales are local and short-term							

Table 2: Potential Indicators to be measured include:

Indicator	Sensitivity	Specificity	Practicality	$	Relevance	Collection
Scats counting (in or near stream, solid or not)	Y	Y	H	Low	H	field
Littoral veg (ref Erosion study): cover, change.	Y	Y	H	Low	H	field
Pugging.	Y	Y	H	Low	H	field
Light penetration.	Y	Y	L	Low	H	field
Turbidity.	Y	Y	H	Low	H	field
Algal biomass, Chl-a: substrate &/or water column.	Y	Y	H	M	H	lab
Sediment traps.	Y	Y	M	M (2 visits)	H	lab
Ash-free dry weight of biofilms (dirt).	Y	Y	M	M-	H	lab
Ratio of carbon to ash-free dry weight of biofilms (C/dirt).	Y	Y	M	M-	H	lab
Algal biomass on cobbles/other substrate.	Y	Y	H	M	H	lab
Pootering (suck up insects): coarse taxonomy, abundance/biomass.	Y	Y	H	M	H	lab
Macroinvertebrates - sensitive spp loss.	Y	Y	M (destructive?)	M	H	lab
Macroinvertebrate composition.	Y	Y	M (destructive?)	M	H	lab
Macroinvertebrate functional groups / composition.	Y	Y	M (destructive?)	M	H	lab
Fcol/sterols (QHealth).	Y	Y	H	M	H	qhss

The design must be scientifically defensible, so consideration of meaningful effect sizes and power to detect an impact are essential. Due to budget considerations this will be reflected by fewer indicators monitored, but with higher sample repetitions, increasing the potential to detect an impact.

Methods

Indicators of high risk stressors will be sampled at multiple time points at control and test sites. At least three samples should be taken before and two after the event. One of the post samples will be taken immediately after the event.

Potential Indicators to be sampled:

1. Nutrients Direct

- Nutrient concentrations don't tell us much. Rapid turnover, because taken up by algae. Turbidity gave a better representation of impact. Spot samples not effective.
- Response can be a better indicator for direct nutrients
- Direct Measures: Sterols (faecal tracer); faecal count – (issue of endurance horse events with diarrhoea)
- Ecological Response measurements: Algal biomass; Chl-a (substrate or water column); algal species composition; artificial substrates – accumulation/species composition.

2. Deposited sediments

- Direct measure: Sediment traps
- Eco response: macroinvertebrate functional groups/composition; Ash free dry weight of biofilms.

3. Physical dist rip/banks

- Direct measure: Pugging extent
- Ecological response: pootering

4. Physical dist bed

- Direct measures: As for ecol response of nutrients direct
- Ecol response: macroinvertebrate abundance / composition

5. Changed light regime

- Direct Measures: Turbidity with turbidity meter. Light penetration (sensitive to urine colour) – is water deep enough for probe?
- Difficult due to residence time of changes

6. Bacteria

- Direct Measures: FCol (QHealth)
- Ecol Response: Macroinvertebrates – sensitive spp loss.