Specific Nature Conservation Projects
2006/07 – 2011/12
Project Report

1. PROJECT TITLE:
Prevention, containment and eradication of *Phytophthora cinnamomi* infestations in the National Parks from the South Coast of Western Australia.

2. OBJECTIVE/GOAL:
To undertake a strategic approach to preventing the further spread of *P. cinnamomi* whilst containing/eradicating high priority infestations in the National Parks from the South Coast of Western Australia (WA), including the Fitzgerald River National Park (FRNP).

3. SUMMARY OF WORK UNDERTAKEN:
Since 2006 the *Biodiversity Conservation Initiatives - Saving our Species* and *Specific Nature Conservation Project*s within DEC have funded a series of projects managing the impact of *P. cinnamomi* in the native plant communities from the South Coast of WA. This has included four projects between 2006-2011 before they were consolidated into one single strategic project in 2011-2012 that incorporated a number of on-going activities and a number of other new activities (Table 1). All five projects aimed to advance *P. cinnamomi* management across the South Coast Region including the protection of the high priority FRNP. This report provides a combined summary these projects activities and the results of the monitoring conducted to date.

Table 1. *Biodiversity Conservation Initiatives - Saving our Species* and *Specific Nature Conservation Project*s managing *Phytophthora cinnamomi* in the native plant communities from the South Coast Region of Western Australia from 2006 to 2012.

ID	Duration	Title
PHA1	2006-2011	Last Stand at Bell Track - Saving the Fitzgerald River National Park (FRNP)
PH1	2006-2011	The development of novel phosphite application techniques to control *P. cinnamomi* within the Stirling Range and FRNP
PH2	2006-2010	Phosphite application onto Critically Endangered and Endangered Flora Populations and Threatened Ecological Communities within the Albany, Esperance, Busselton and Frankland Districts
PH5	2010-2011	*Phytophthora* interpretation and management at Pabelup Drive and across the FRNP
PH1	2011-2012	Prevention, containment and eradication of *P. cinnamomi* infestations in the National Parks from the South Coast of Western Australia

PHA1: Containment of the Bell Track Infestation, FRNP
The FRNP is an International Biosphere Reserve recognised for its high biodiversity with over 2000 plant species including many endemics, threatened ecological communities and rare fauna. This unique biodiversity is highly susceptible to the introduced plant pathogen, *P. cinnamomi.* Currently, the 330,000 ha of native plant communities within the FRNP is still largely free of the disease resulting in the National Park being one the State's highest priority areas for preventing any new introductions of the pathogen and reducing its rate of spread within existing disease centres.

Phytophthora cinnamomi was introduced to the FRNP in 1971 with the construction the unauthorized Bell Track (Figure 1). The disease caused by the pathogen at Bell Track varies from the scattered plant deaths within the northern area to highly destructive within the southern area. Currently the pathogen is located within an internally drained micro-catchment on the watershed between two major drainage systems, the Susetta/Fitzgerald Rivers and Copper Mine Creek (Figure 2). If the pathogen was to enter either of these drainage systems, large areas of the Park would inevitably become infested. In 2004 a Response Plan was prepared that identified possible strategies for a management plan aiming to contain *P. cinnamomi* within its current catchment. Prior to this, the infestation had been managed only through hygiene protocols, managed access and regular aerial phosphite treatment.

In 2006 the "Last Stand at Bell Track" project commenced with the formation of a project steering committee and the appointment of a project officer. The steering committee included Department of Environment and Conservation (DEC) staff from the local districts, South Coast Region, Nature Conservation Division and Science Division. The committee evaluated a number of strategies and control techniques, including those techniques being investigated by the Centre for *Phytophthora* Science and Management (CPSM) in an experimental-scale eradication trial within the native plant communities at Cape Riche near the FRNP.

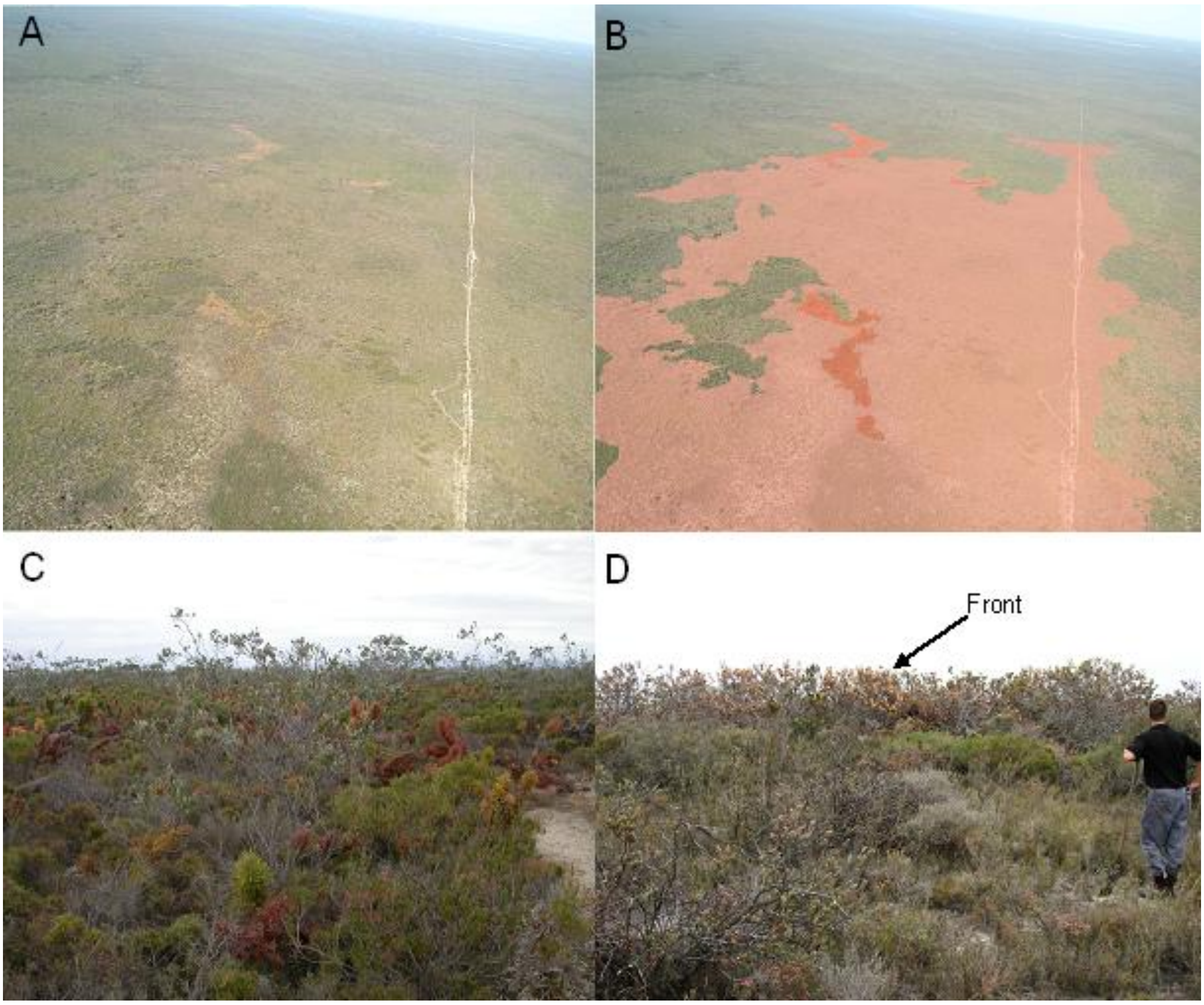

Figure 1. The construction of Bell Track within the Fitzgerald River National Park introduced *Phytophthora cinnamomi* in 1971 (A, B). The disease caused by the pathogen results in death of susceptible plant species and a significant loss the structure and biomass of the native plant communities at Bell Track. The impact within the Kwongan heath at the northern part of the infestation (C) and the Proteaceous dominated heath within the southern part with more highly defined distinct disease fronts (D).

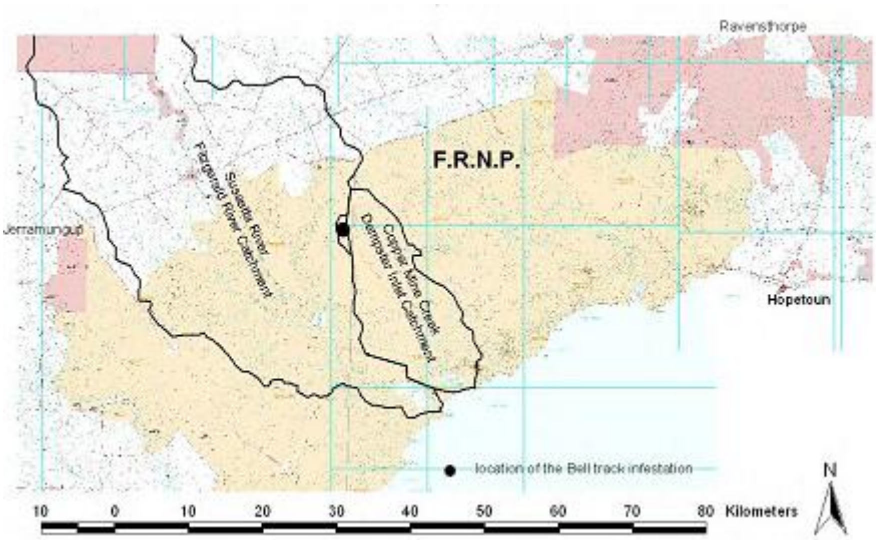

Figure 2. *Phytophthora cinnamomi* within the Bell Track located within an internally drained micro-catchment on the watershed between the Fitzgerald River Catchment and Copper Mine Creek Catchment.

The 'Last Stand at Bell Track'

The Bell Track containment project used a multi-disciplinary integrated management plan that applied common *Phytophthora* Dieback management tactics with novel technologies and new techniques. The plan consisted of five programs including: (i) planning and risk assessment; (ii) mapping the occurrence of the pathogen (iii) containment; (iv) impact reduction; and (v) monitoring and science-based investigations (Appendix 1).

Program 1: Planning and Risk Assessment

A quantitative risk assessment was conducted using Bayesian Belief Networks (BBN) to assess the risks associated with the project and the likely effectiveness of the different management strategies. The BBN model aimed to describe the 'cause and effect' relationships between the different management strategies and identified key threats to the project (Figure 3). The model allowed for the incorporation of empirical observations, system sub-models and expert opinion. The BBN model identified key information gaps that were included within the monitoring program allowing for the model to be further refined as new information became available. The BBN for the Bell Track project was developed during two workshops with participants that had significant technical expertise in *Phytophthora* management and/or catchment hydrology.

The risk assessment identified four threats that could result the pathogen spreading from the Bell Track catchment, including:

I. spread of the pathogen by hydrological discharge into adjacent catchments;
II. root-to-root spread of the pathogen;
III. animal vectoring; and
IV. human vectoring.

The BBN evaluated six different management strategies, namely:

I. strict application of hygiene protocols;
II. containment of the infestation with a perimeter fence;
III. containment of any hydrological discharge exiting the catchment after significant rainfall events;
IV. preventing the root-to-root spread of pathogen by combining root impervious barriers, soil fumigation and vegetation-free buffer zones installed at high risk locations;
V. phosphite application; and
VI. wildfire management including prescribed burning.

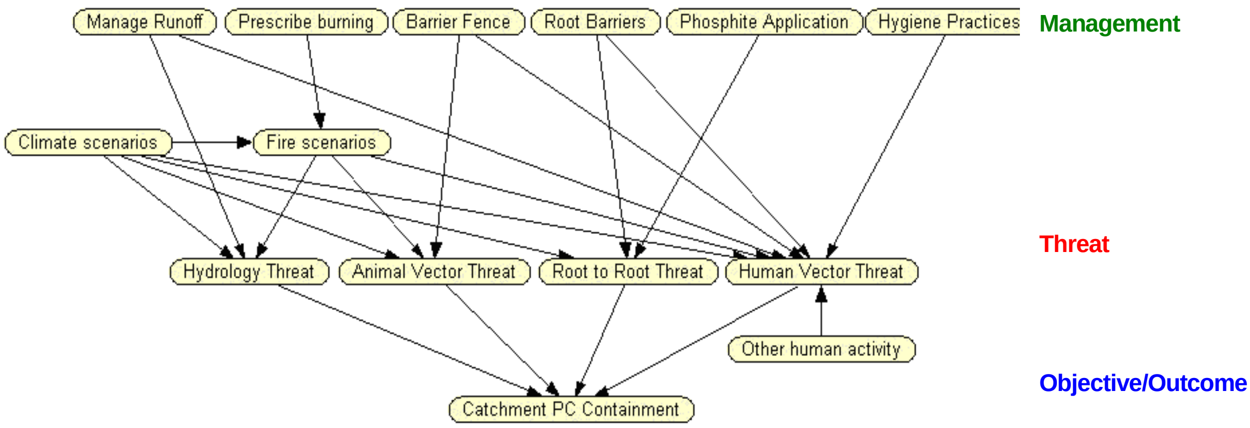

Figure 3. A Bayesian Belief Network model was used to elucidate interactions between the different management strategies, identified threats to the project goal and contributing factors.

The BBN model predicted that with no management of the Bell Track infestation there was a 32.5% likelihood of that the pathogen would still be contained within the catchment after 50 years (Figure 4). The model ranked the different management options from highest to lowest as follows: phosphite (17.3%); hygiene practices (9.2%); prescribe burning (2.2%); barrier fence (-1.4%); root barriers (-3.3%) and manage run-off (-5.4%). The model predicted that strict hygiene combined with phosphite treatment would be the most effective strategy (63%) (Figure 4). The management strategies with a negative effect were a result of the high risk of spreading the pathogen during their installation or as a consequence of altered hydrology. Human vectoring was identified as the greatest threat to the project highlighting the critical need to ensure that all activities conducted during the project applied the strict hygiene protocols.

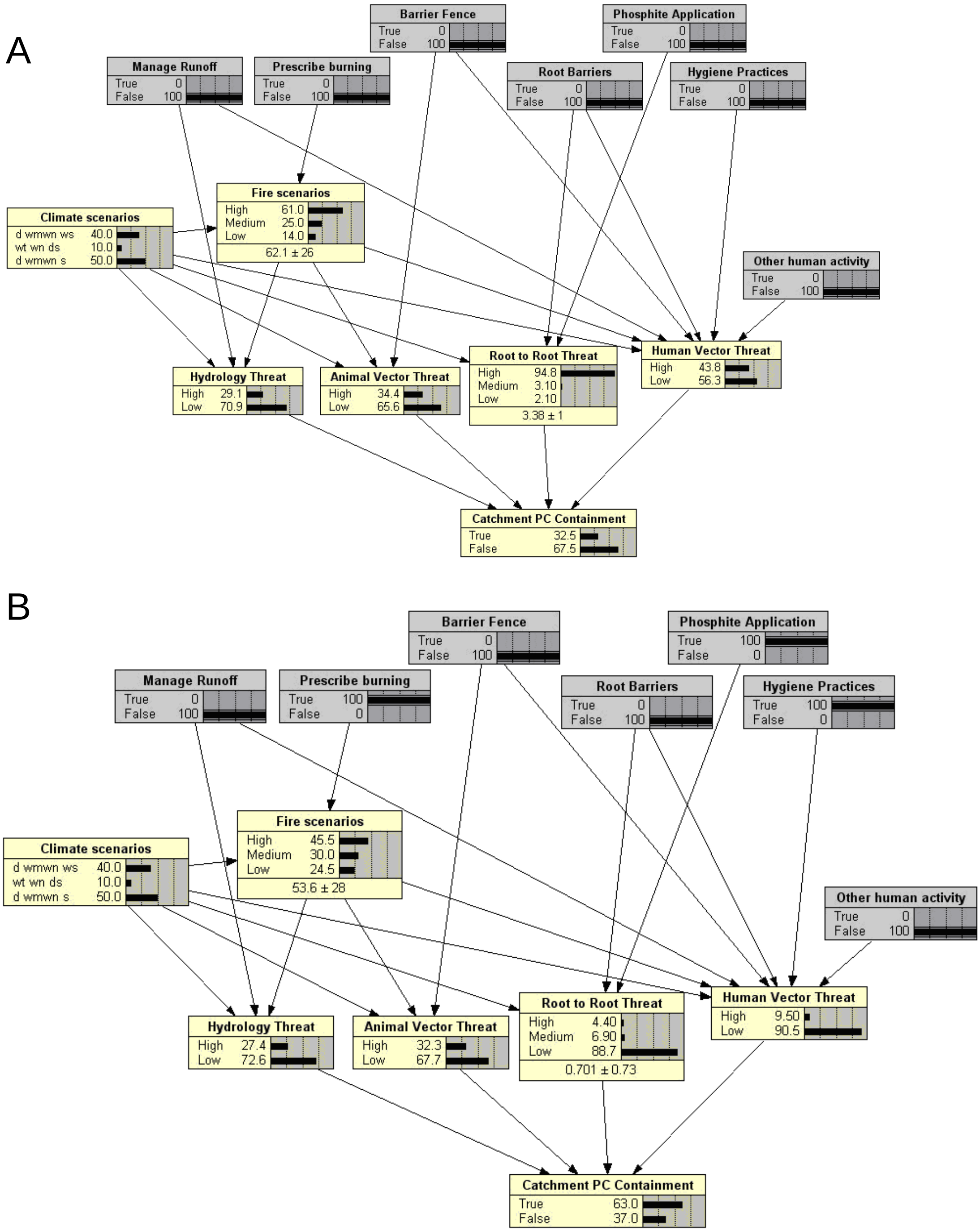

Figure 4. The Bayesian Belief Network model based on the 'do nothing' scenario gives a 32.5 % chance of *Phytophthora cinnamomi* being contained within the catchment after 50 years (A); the scenario that gave the highest probability (63 %) of containment included on-going phosphite application and implementation of strict hygiene (B).

Program 2: Mapping the Occurrence of the Pathogen

It was critical that the project was able to detect, map and monitor *P. cinnamomi* within the Bell Track catchment with the highest possible accuracy. At the commencement of the project aerial photographs (1:4,500) were captured for visual assessment by the Department's *Phytophthora* disease interpreters to identify the likely infestation boundary. The indicative boundary to the disease centre was then confirmed by a process of systematic on-ground visual interpretation of disease symptoms within the native vegetation. A comprehensive on-ground interpretation of the Bell Track catchment was conducted in 2005, 2006 and 2007 and 2009. Regular on-ground monitoring of the pathogen was also conducted at high risk locations across the catchment. Aerial helicopter survey's of the Bell Track and adjoining catchment's was conducted in 2007, 2009, 2010 and 2012.

In addition to traditional interpretation, Digital Multi-Spectral Imagery (DMSI) was used to determine disease occurrence and monitor disease centre expansion. DMSI was acquired in 2007, 2009, 2010 and 2011 covering a 500 ha area surrounding the Bell Track *P. cinnamomi* disease centre. The impact of infestation reduces plant community structure and biomass resulting in a lower Plant Cell Density (PCD). By comparing the PCD data from different years the pathogen occurrence could be determined. This has proven useful in monitoring disease centre expansion, surface water modelling and assessment of the efficacy of the different management strategies (Appendix 2).

Over 4000 soil and plant tissue samples were collected during the six years of the project. The results of these samples (pathogen present or absent) were used to confirm the mapping of pathogen or to ensure the absence of the pathogen prior to any major earth works e.g. the construction of the fence. Samples were tested for the presence of *Phytophthora* species using traditional baiting techniques and molecular identification providing high confidence data.

Program 3: Implement Containment Strategies

Preventing Water Associated Spread

As the pathogen can spread rapidly in free water, it was important to map the topography of the catchment and model possible overland flow during flood events that could lead to outbreaks of the pathogen. Detailed hydrological modelling of the catchment was conducted that identified sub-catchment boundaries and drainage connections throughout the Bell Track catchment (Figures 5). This allowed for a comparison of the current *P. cinnamomi* occurrence in relation to sub-catchment boundaries to determine areas where the pathogen is at greatest risk of spreading into an adjoining catchment. The model indicated that the pathogen was contained within two sub-catchments that were internally draining due to the presence of four large depressions or sumps within the southern area. It was calculated that these sumps that have adequate capacity to hold the runoff volume associated with large rainfall events. However, some minor water diversion and soil erosion measures were used along Bell Track and the fire breaks surrounding the infestation to ensure that these cleared areas did not lead to significant run-off.

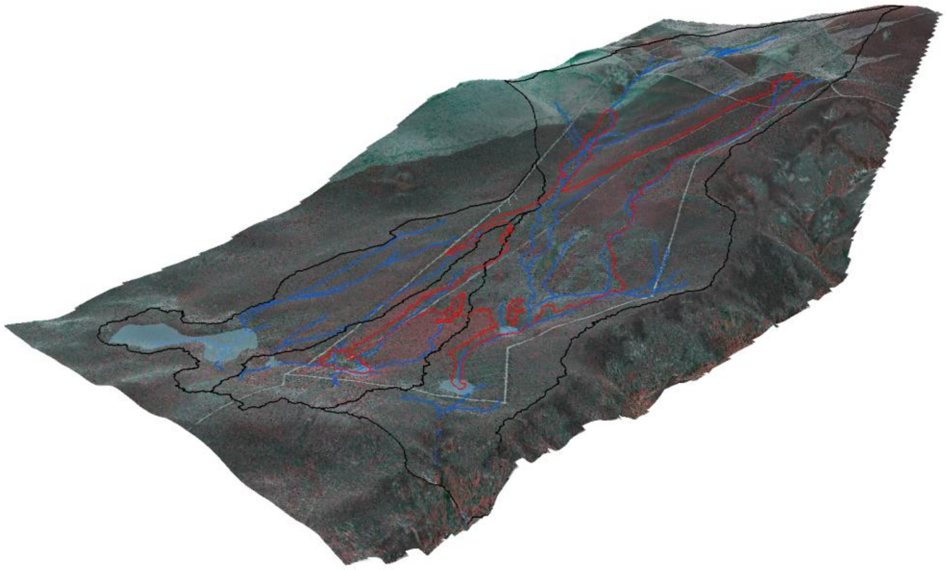

Figure 5: Three dimensional over view of the Bell Track catchment. Black lines denote catchment boundaries, blue lines streams, blue areas natural sumps and red lines boundary of the *Phytophthora cinnamomi* disease centre.

A fire management plan was implemented to prevent large areas of the catchment being burnt during wildfire. A large wildfire would have significant impacts on the hydrology of the catchment and would increase the risk of the pathogen spread within hydrological discharge following rainfall events. Wildfire within the catchment could also increase the risk of animal and human vectoring. The fire management plan included:

- the construction of a double fire break surrounding the fenced containment zone;
- a series of 50 m wide fuel reduction areas transecting the Bell Track catchment;
- water tanks were installed on-site to assist fire suppression; and
- 15 km of prescribed burning at strategic locations across the 1000 ha catchment.

Preventing Root-to-Root Spread

To contain the pathogen in its current sub-catchments, root-impervious membranes, herbicide treatment and vegetation-free buffer zones were installed at three high risk locations. These high risk areas were the 'elephant trunk' on the western boundary, the south-west corner and the south-east sump (Figure 6). The root-impervious membrane was a high-density polyethylene root barrier (1 m wide x 1 mm thick) buried to ca. 90 cm depth and located 2-5 m forward of, and parallel to the edge or 'front' of the disease centre. To determine an adequate size for the vegetation removal, the root system of a representative sample of vegetation was examined by air spading. The air spading indicted that plant roots of common overstorey species were highly connected and often did not extend beyond 8 m from the base of the tree. The effect of vegetation removal on soil moisture conditions was also investigated and it was found that vegetation removal led to significant increase in soil moisture (up to 400%). To maintain this break in root connectivity at the locations the root-impervious membranes were installed, Polyvinylchloride (PVC) irrigation (20 mm diameter) was installed in 200 m lengths underneath the membrane. The fumigant Metham Sodium was applied to this irrigation at 133g per m once a year during the winter months when adequate soil was present to promote sterilisation.

Preventing Animal & Human Vectoring

The risk of animal and human vectoring was managed by:

- a strict access and hygiene policy for all vehicle access to the Bell Track catchment within the Wilderness Zone requiring approval from the Conservation Commission of WA. Approved access was supervised by the Ranger in Charge of the National Park and was restricted dry soil conditions;
- regular checks of contractors to ensure compliance with the access conditions including appropriate application of hygiene;
- installation of access controls including track closures, secured gates, defined routes of access and the construction of a northern access track;
- installation and maintenance of a vehicle wash down facility;
- 'green bridges' constructed at a water gaining site in the south-west corner; and
- an animal control program within the containment zone to remove large macro-pods.

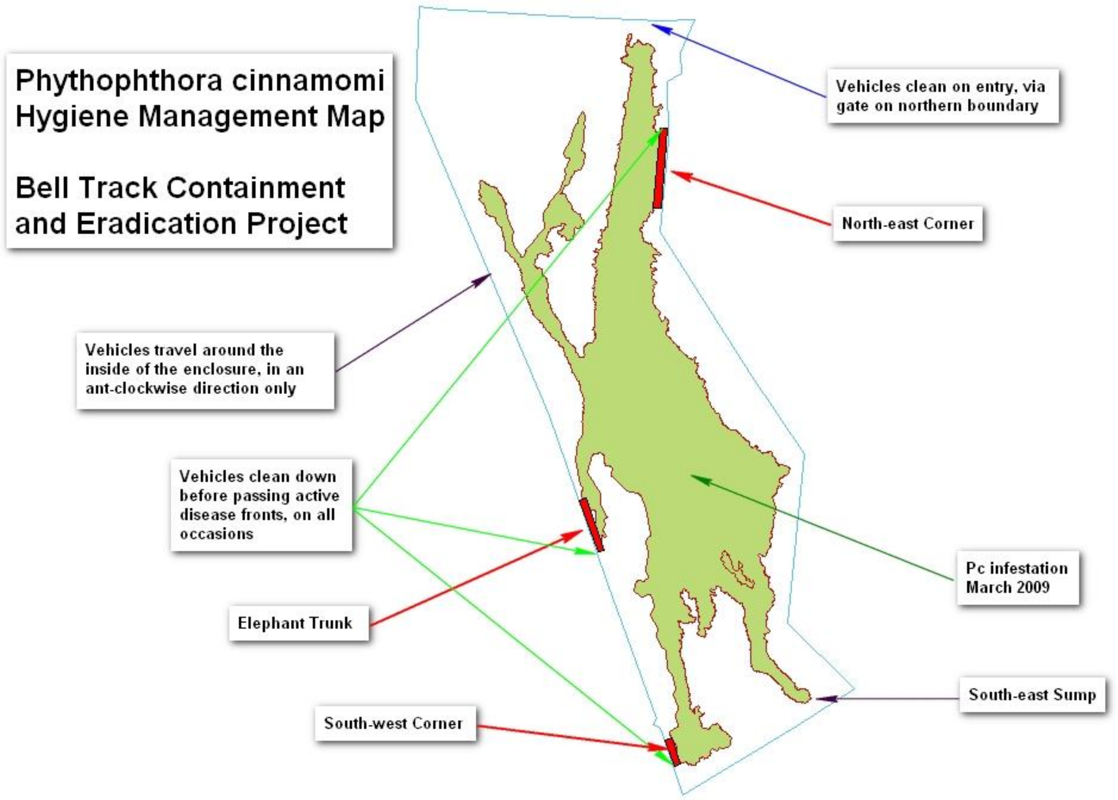

Figure 6. The map from the hygiene management plan prepared during the installation of extra containment controls at the elephant trunk' on the western boundary, south-west corner and south-east sump where there was considered a 'high risk' of pathogen spreading outside the fenced containment zone.

Program 4: Reduce Disease Impact

Phosphite has been regularly applied as an aerial low-volume spray at the Bell Track infestation since 1997 and this treatment was maintained during the project. The majority of phosphite treatment has been targeted low-volume aerial spraying as the cost of treating the entire infestation was cost prohibitive. This project also used on-ground low-volume foliar spraying and high intensity (30% active ingredient) phosphite application (HIPA). This additional treatment was applied in a 10 m wide buffer perpendicular to the advancing disease ‘front’ to act as a chemical barrier and prevent autonomous spread of the pathogen.

Strategic re-vegetation was conducted in 2008 in the south of the infested area. Here the impact of *P. cinnamomi* had resulted in significant loss of structure and biomass in the Proteaceous rich health. The re-vegetation aimed to rapidly re-establish mid and upper storey canopy cover, thereby reducing surface water flow and water stored within the soil profile. Five plant species were selected for the re-vegetation based on their resistance to *P. cinnamomi;* their growth form (i.e. plants were all small shrubs over 0.5 m tall); and their occurrence locally. These five species were *Acacia myrtifolia*, *Calothamnus quadrifidus, Eucalyptus pleurocarpa, Melaleuca nesophila* and a small number of *Hakea victoria*. Plant species were sourced from a nursery that had industry accreditation for good hygienic practices and a subsample was checked to ensure the stock was free from *Phytophthora*. The five species were planted at locations 20 m apart along east-west transects across ~ 20 ha area at the southern end of the infested area.

Figure 7. The Bell Track containment project combined access controls such as secure gates (A), fencing (B), signage (C) with strict hygiene (D, E) and intensive pathogen sampling (F).

Figure 8. The Bell Track containment project also used a number of novel control techniques to contain the pathogen including aerial phosphite treatment (A), root impervious membranes and geo-textile filtration systems (B), green bridges (C), fumigation with Metham Sodium (D), high intensity phosphite application (E) and revegetation of the infested area (F).

Program 5: Monitoring and Science-Based Investigations
A range of different scientific investigations and monitoring was conducted to inform management decisions and assess the effectiveness of the different management strategies. A comprehensive interpretation program monitored the pathogen occurrence across the Bell Track catchment and regular re-checks were conducted at high risk locations. Remote sensing using DMSI and aerial survey of the catchment using a helicopter were conducted over the duration of the project.

Hydrological Investigations
A series of hydrological investigations were conducted to provide insight into the hydrological characteristics of the catchment. As the pathogen can spread rapidly in free water, it was important to map the topography of the catchment and model possible overland flow during flood events that could lead to outbreaks of the pathogen in the containment area. Detailed hydrological modelling of the catchment was undertaken, including Light Detection and Ranging (LiDAR) aerial capture that consisted of both a high resolution digital elevation model (DEM) and 0.5 m contours. ArcGIS Spatial Analyst® was used to define sub-catchment boundaries and drainage connections throughout the Bell Track catchment (Appendix 3). This allowed for a comparison of the current *P. cinnamomi* occurrence in relation to sub-catchment boundaries to determine areas where the pathogen is at greatest risk of spreading into adjoining sub-catchments. The model indicated that the pathogen was contained within two sub-catchments that were considered to be internally draining due to the presence of four large depressions or sumps (Appendix 4). It was calculated that these sumps that have adequate capacity to hold the runoff volume associated with large rainfall events.

To validate that the sub-catchments were self draining and the large depressions (sumps) had adequate capacity, further modelling of rainfall events in the catchment was conducted using XP Storm®. This modelling exercise investigated: the hydrological analysis of surface flow rates and volumes based on peak flood rainfall events in the catchment to determine the magnitude and behaviour of water to be contained; and the identification of feasible surface water engineering options to divert and store water during peak flood events and prevent downstream catchment flow. The study examined theoretical average recurrent interval (ARI) rainfall events with frequency intervals of 50, 300, 500 and 1000 years. These ARI events were for single events with the duration of 36 hours. The model estimated that the sumps within the catchment would have sufficient capacity to hold any stream or overland flow during all such extreme rainfall events. The sumps contain a deep sand- soil profile capable of holding any run-off. Sump depth was checked using vehicle mounted drill rigs to describe the soil profile. It was determined that no substantial hydrological engineering was required for water collection if a 1 in 1000 year rainfall event occurred. However, some minor water diversion and soil erosion measures were used along Bell Track and the fire breaks surrounding the infestation to ensure that these cleared areas did not lead to significant run-off.

Epidemiological Investigations

As part of the PH1 project two different epidemiological field trials were established at three different National Parks on the South Coast of WA, Fitzgerald River (Bell Track), Gull Rock and Stirling Range National Parks. The first field trial investigated the spatial and temporal pathogen dynamics and the second trial investigated the spatial invasion patterns of *P. cinnamomi* within susceptible native plant communities. The knowledge gained during this research has been directly utilised during the 'Last Stand at Bell Track' project and other *Phytophthora* Dieback management initiatives being conducted by DEC. Some examples of the experimental questions included:

- What time of year should you sample to confirm the presence or absence of the pathogen?
- What time of year is it safe to conduct earthworks?
- How deep can the pathogen be isolated and as such how deep should root connectivity be disrupted to prevent root to root contact?
- How long can you sample a dead plant after death and still expect a good chance of isolation?
- Does the removal of vegetation at firebreaks increase soil moisture and thus the risk of spreading the pathogen on vehicles or footwear?
- How do climatic events change the epidemiology of the pathogen?
- How far is cryptic expression ahead of the disease front based on plant mortality so an appropriate hygiene buffer can be used during operations?

Some small scale investigations were also conducted at Bell Track including:

- a trial to determine if surviving susceptible plants within the infested area were disease escapes or actually resistant genotypes of susceptible species;
- the root structure of susceptible native plant species investigated by air spading; and
- monitoring soil moisture levels at the location of the vegetation free buffers and root impervious membranes on two occasions.

The epidemiological investigations also included two glasshouse experiments. The first investigated the conduciveness of the soils of the South Coast to infection by *P. cinnamomi*. This has produced empirical data that can be used to model pathogen spread and impact across the South Coast Region. Further, the data obtained could be used in risk assessments to prioritise areas and plant communities for management. The second glasshouse trial determined the susceptibility of *Banksia, Eucalyptus, Hakea and Grevillea* species to *P. cinnamomi*. The results of this study were used in an ARC Linkage Research project where DEC is an industry partner that is investigating the mechanisms of phosphite effectiveness and plant resistance to *P. cinnamomi*.

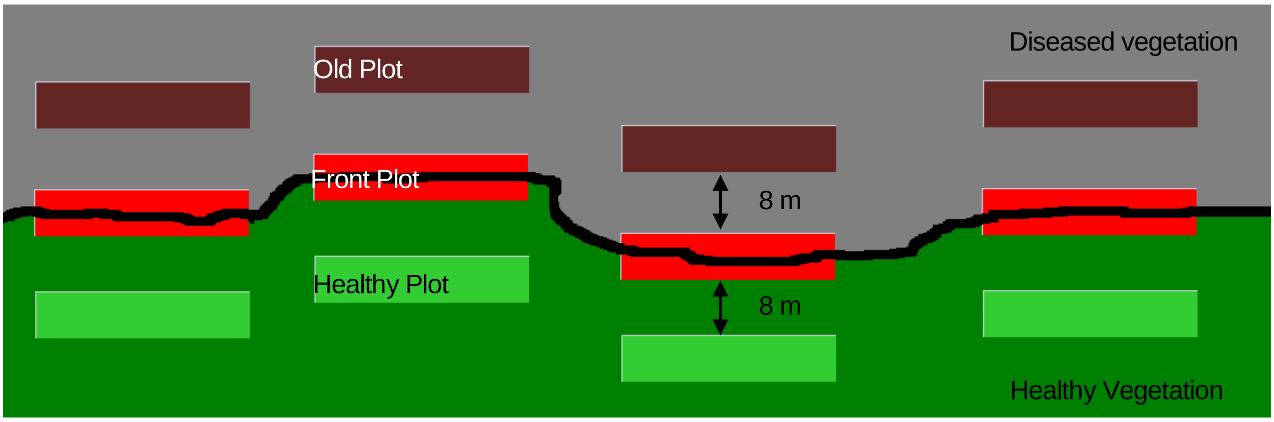

Figure 9. The layout of the epidemiology monitoring plots showing three plot types (old infested, 'front' or edge of disease centre and healthy). Four replicate plots were assessed at the disease centres within Fitzgerald River, Gull Rock and Stirling Range National Parks over an 18 month period.

Flora Monitoring

The flora and soils across the Bell Track catchment were mapped during this project. Floristic quadrants were also established in the different plant communities within the catchment to monitor disease impact.

Phosphite Treatment Monitoring

Long term monitoring plots and transects established in 1991 were monitored during the project to assess the efficacy of the aerial phosphite treatment. Furthermore DMSI was used to assess the effectiveness of the 20 ha of HIPA conducted within the southern half of the Bell Track infestation.

PH2: Phosphite application in Threatened Flora Populations and TECs across the south west of WA

Phosphite was applied by aerial spraying to Threatened Ecological Communities (TECs) and Threatened Flora as outlined in Table 2.

Table 2. This project funded aerial phosphite treatment in a number of threatened flora populations including critically endangered (CR) and vulnerable (VU) species and threatened ecological communities (TECs) and priority ecological communities (PECs) across the south-west of Western Australia.

Site	Target	Area
2007/08		
Stirling Range National Park	Montane Mallee Thicket TEC (6 occurrences): Wedge Hill Little Mondurup, Yungemere, Mt Success, Southwest Gog, Hosteller Hill	120 ha
	The only known occurrence of CR taxa *Daviesia pseudaphylla* at East Pillenorup Track	45 ha
Cape Le Grand National Park	*Lambertia echinata* ssp *echinata* CR (4 populations)	27 ha
Busselton	Shrublands on Southern Swan Coastal Plain Ironstones TEC (7 occurrences)	70 ha
Mt Lindesay	Little Lindesay Vegetation Complex TEC	15 ha
2008/09		
Stirling Range National Park	*Daviesia glossossema* (CR) at South Bluff and *Banksia anatona* (CR) at Ellen Track	13.8ha
	Montane thicket (CR) TEC, (6 occurrences: Bluff Knoll, East Bluff, Moongoongoonderup, Isongorup, Bakers Knob, Pyungoorup) Montane mallee thicket (EN) TEC: (7 occurrences): Wedge Hill, Little Mondurup, Yungemere, Mt Success, Southwest Gog, Hosteller Hills, Mt Hassell	284 ha
	The only known occurrence of CR taxa *Daviesia pseudaphylla* at East Pillenorup Track	45 ha
Millbrook Nature Reserve	CR *Banksia brownii*, Boulder Hill for *Andersonia pinaster* (VU) and at Bon Accord Rd PEC	15 ha
Cape Le Grand National Park	4 populations of *Lambertia echinata* ssp *echinata* CR	68.4 ha:
Busselton	Shrublands on Southern Swan Coastal Plain Ironstones (Busselton) TEC: (7 occurrences)	70 ha

PH5: Containment of the Pabelup Drive Infestation, FRNP

A new *P. cinnamomi* infestation was discovered near Pabelup Drive within the FRNP in April 2009 during aerial helicopter surveys funded by the SNCP program (Figure 10). SNCP and State NRM funds were used to implement a management plan to contain the Pabelup Drive infestation (Appendix 5). The project aimed to prevent the spread of the pathogen in surface water flows and root-to-root transmission between host plants, thereby protecting over 30,000 ha of healthy native vegetation down catchment. The infestation was associated with a fire break that had been used recently during the 2003, 2005 and 2008 wildfires that occurred within the Park. The 2003 and 2008 wildfires had been very intense due to a high fuel load within the local native plant communities and as a consequence there was very little vegetation biomass across the site (Figure 11). The loss of biomass within the native plant community decreased the probability of detecting the pathogen within soil sampling and consequently caused difficultly in accurately interpreting and mapping the occurrence of *P. cinnamomi* across the site. To provide the highest possible accuracy in mapping the pathogen a large number of soil/plant tissue samples were tested. The dramatic loss of vegetation also increased the risk of water associated spread due to run-off across the catchment. As a result the management plan made particular effort to prevent the water associated spread of *P. cinnamomi*.

The management plan to contain the Pabelup infestation within its current sub-catchment (Figure 12, 13) included:

- detailed occurrence mapping though a systematic soil and plant sampling regime;
- fencing of the three discrete infestations to prevent animal vectoring using a solar powered farm style fence;
- detailed hydrological modelling of surface water flows across the catchment;
- bunding to manage surface water run-off surrounding the infested areas using a root impervious plastic membrane up to a height of 40 cm above ground level;
- installation of two alignments of geo-textile filtration systems to filter *P. cinnamomi* within surface water flows allowing for run-off from the infested area to exit into the drainage system to the west of the sub-catchment;
- herbicide treatment of the vegetation within the containment area to destroy any potential host plants that could harbour the pathogen;
- phosphite treatment of the containment area to reduce pathogen activity;
- localise fumigation using granular Metham Sodium at the location of the geo-textile filtration systems; and
- detailed monitoring of pathogen spread within and outside the containment area.

The SNCP program funded the interpretation, survey; implementation of some containment activities whilst undertaking priority prevention activities to prevent further spread of the pathogen across the FRNP. Specifically SNCP funded:

- interpretation and mapping the occurrence of the Pabelup infestation discovered in April 2009 including survey of the surrounding native vegetation;
- linear interpretation of 850 km of roads and tracks within the Park in 2009 with a resurvey of strategic roads in 2011;
- survey of the 30,000 ha of the Pabelup catchment for the presence of the pathogen;
- the discovery of another *P. cinnamomi* disease centre down catchment within Lake Pabelup lead to further interpretation and mapping of this Lake Pabelup infestation;
- two phosphite applications covering a 14 ha target surrounding Pabelup containment site;
- provision of district staff to assist with fencing of the Pabelup infestation;
- construction of a vehicle washdown facility at the Gairdner Ranger Station;
- construction of a ‘green bridge’ at the intersection of the Susetta River and the southern fire-line to reduce the risk of human vectoring within the FRNP;
- installed access controls including steel gates and bollards to close public access to the Fitzgerald Inlet Track; and
- contributed to the construction of a new washdown bay and depot upgrades at the Jacup Ranger Station.

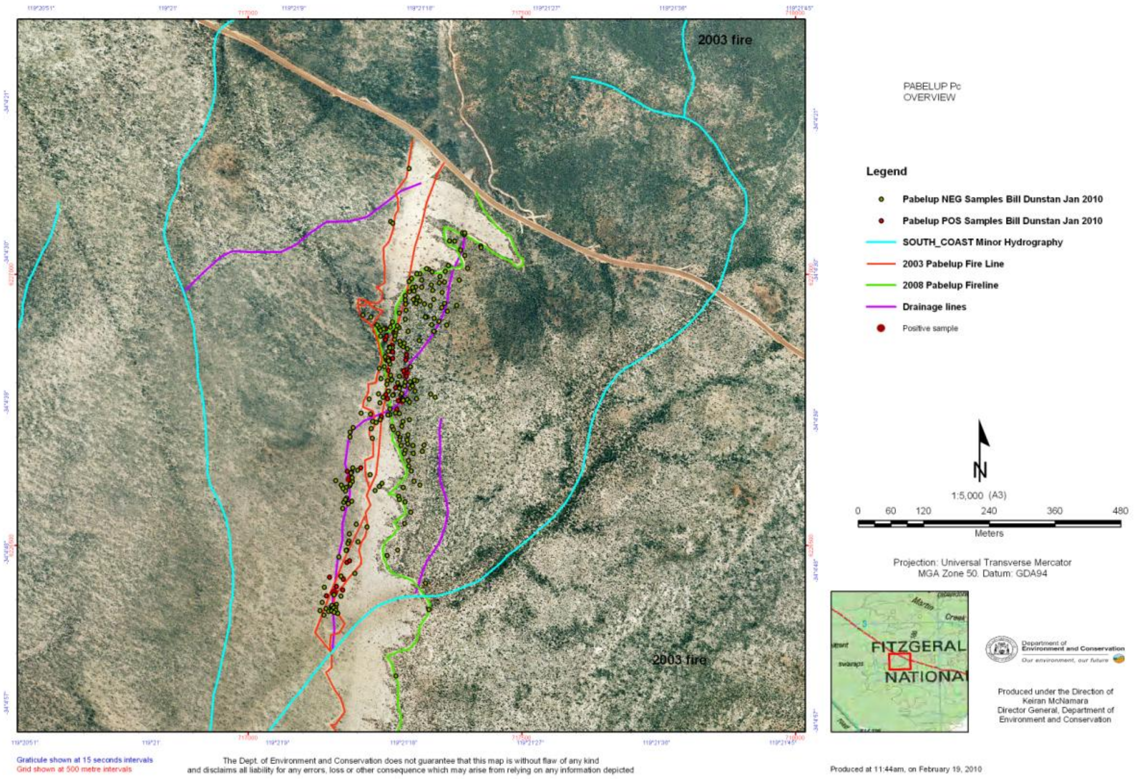

Figure 10. This project undertook a *Phytophthora cinnamomi* containment project near Pabelup Drive within the Fitzgerald River National Park.

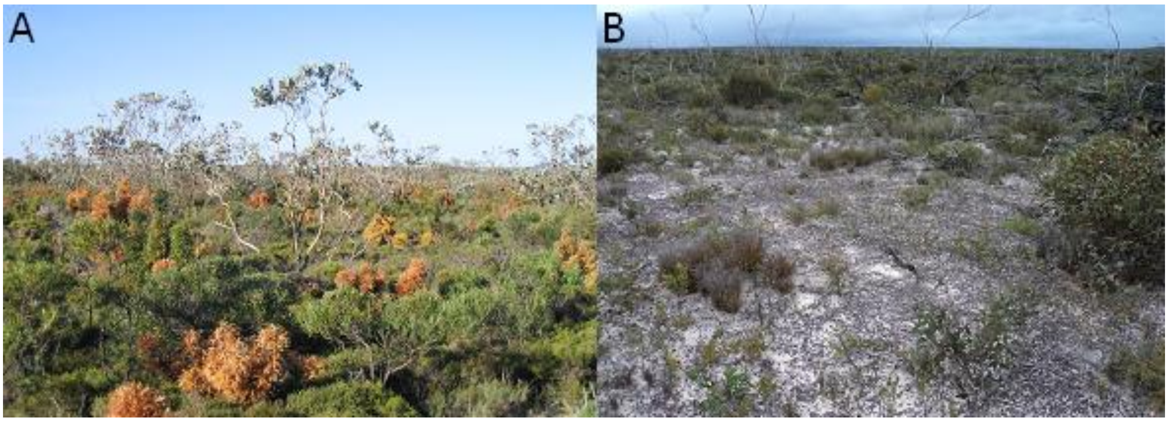

Figure 11. The Pabelup Drive infestation had been heavily burnt during recent wildfires. Some unburnt pockets of vegetation showed the impact of disease on susceptible plant species (A), however the majority of the vegetation was heavily burnt masking the disease expression of the pathogen (B).

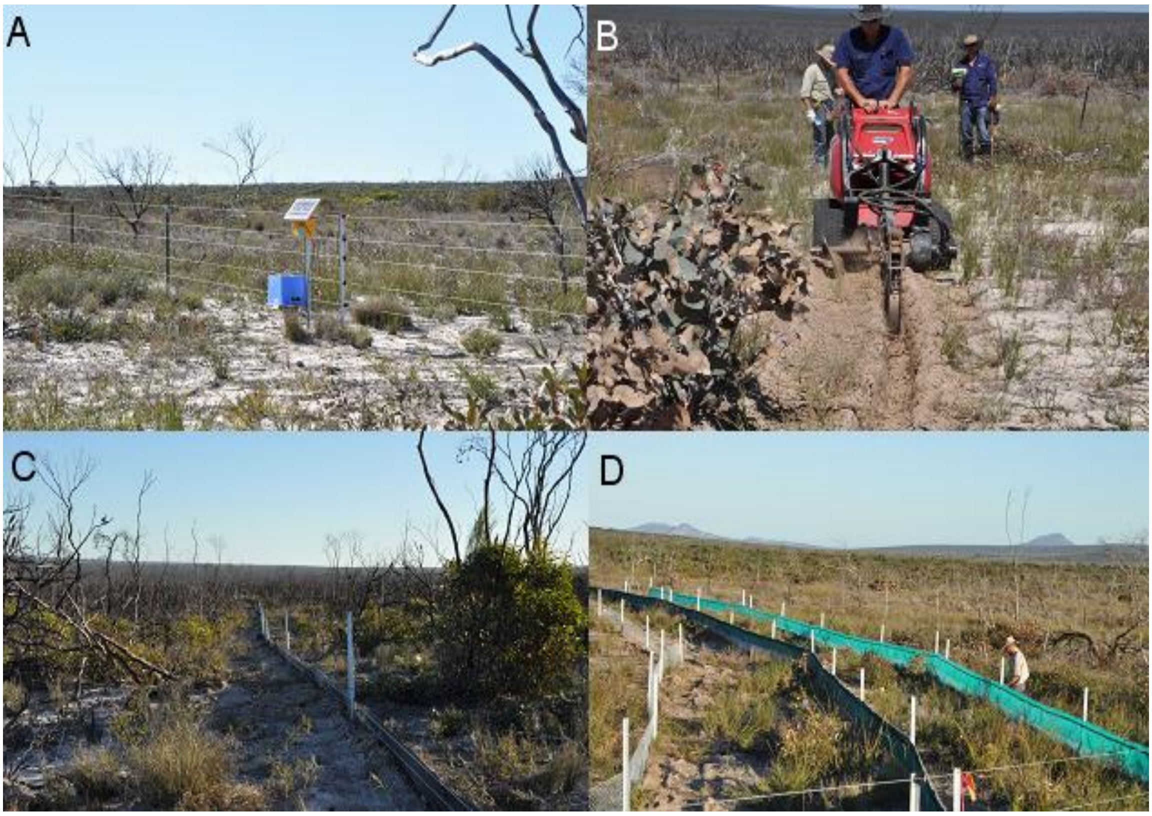

Figure 12. The containment project at the *Phytophthora cinnamomi* infestation near Pabelup Drive included the fencing of the infested areas (A), installation of root impervious membranes (B), bunding to control surface water flows (C) and geo-textile filtration systems (D).

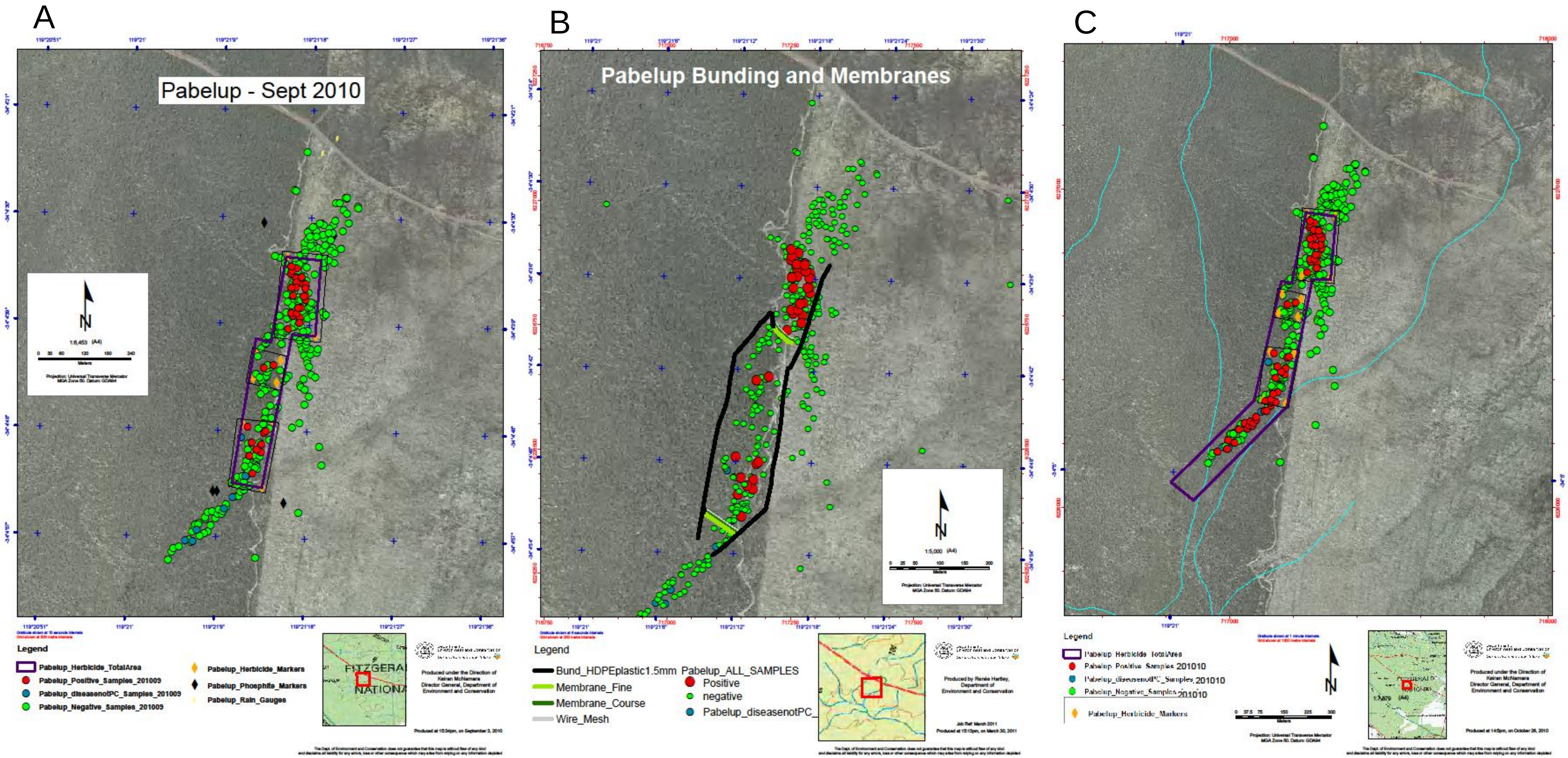

Figure 13. The Pabelup Drive infestation consisted of three disease centres. The three disease centres were fenced (A), contained within surface water bunding and geo-textile filtration systems (B) then combined with host destruction using aerial herbicide treatment (C).

Survey, Interpretation & Mapping of *Phytophthora* Dieback within the Fitzgerald River and Stokes National Parks

At the commencement of the containment project in 2006, the pathogen was only known from two locations within the FRNP: the Bell Track infestation and a small infestation at the Jacup Ranger Station. To ensure that the investment to contain the pathogen at Bell Track was not in vain, it was essential to conduct a rigorous survey of the National Park; including:

- broad helicopter surveys of the major river systems and landforms within the wilderness area;
- linear surveys of over 1000 km of tracks, trails and roads within the Park's boundaries and surveys in the road network surrounding the Park;
- assessment of local sand and gravel quarries;
- Park visitor and management facilities; and
- regular opportunistic sampling by field staff.

During the past year Stokes National Park (SNP) and areas of Proposed National Park to the east and west of SNP were also interpreted.

Preventing the Spread within Priority Protection Areas

This project upgraded hygiene facilities within the FRNP and SNP (Figure 14), including:

- the construction of a vehicle washdown bay at the Gairdner Ranger Station ;
- the construction of a vehicle washdown bay at the Jacup Ranger Station and resurfacing of the yard;
- the upgrade of the vehicle washdown bay in SNP; and
- the purchase of a high-pressure water cleaner for the Ravensthorpe depot.

During the past two years a number of access controls have been installed within the FRNP to reduce the risk of vehicles spreading *Phytophthora* Dieback (Figures 15, 16). Careful planning was undertaken in the positioning and design to reduce problems with illegal vehicle access and vandalism. Twelve gates and associated signage were installed as well as improvements made to existing infrastructure. High risk access tracks including Drummond Track and Fitzgerald Inlet Track were destroyed by soil ripping and earthworks to remove the existing tracks.

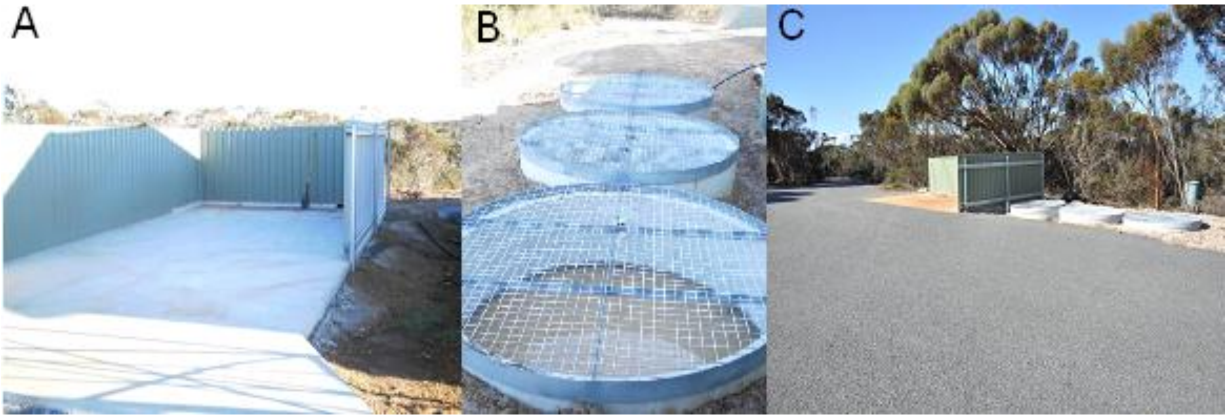

Figure 14. This project allowed for the installation of a vehicle washdown bay at the Gairdner Ranger Station and upgrades to the Jacup Ranger Station, both within the Fitzgerald River National Park.

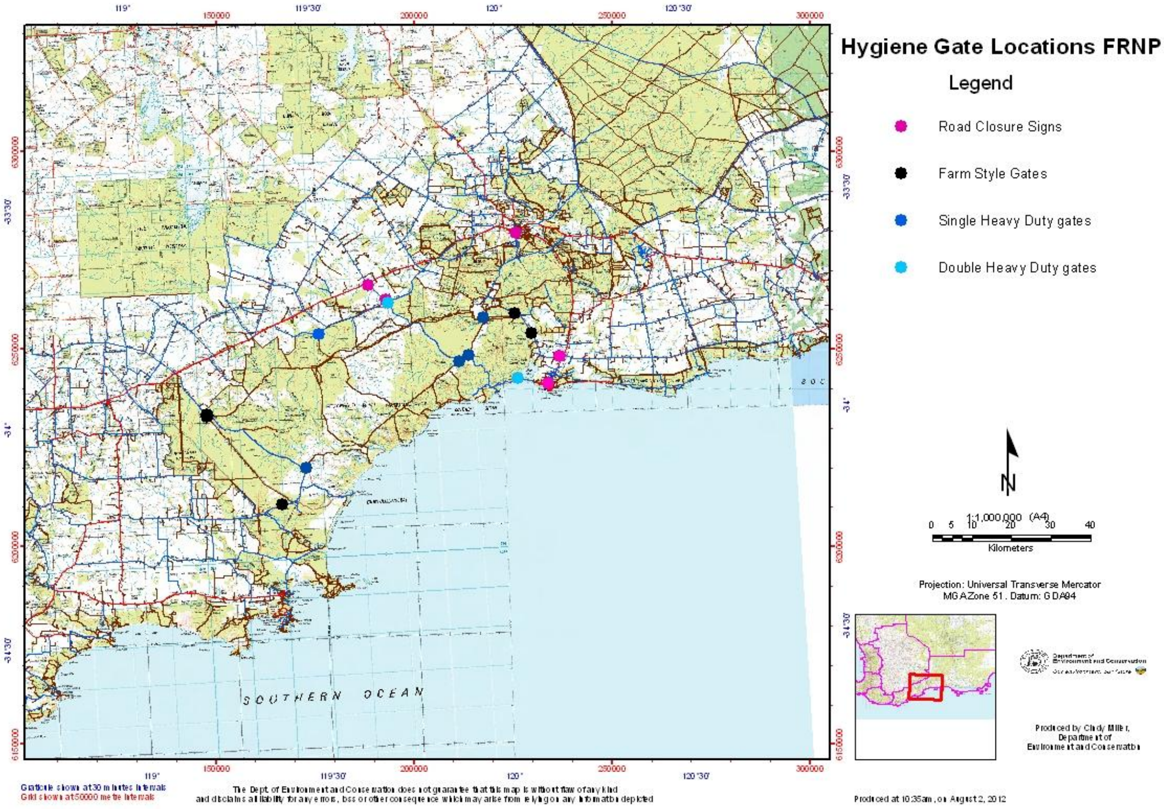

Figure 15. The locations of the access controls installed within the Fitzgerald River National Park during this project.

Figure 16. Some examples of the access controls installed within the Fitzgerald River National Park including track closures (A), access removal through ripping (B) and gates allowing managed access only (C, D).

PH1: Novel Control Techniques

In addition to the epidemiological investigations described above for the Bell Track infestation, a series of experiments were conducted into a range of novel control techniques, including:

- High Intensity Phosphite Application (HIPA) field trials;
- Fumigation using Ethanedinitrile; and
- the assessment of different boot cleaning procedures.

HIPA within the National Parks of South Coast WA

Two field trials into the use of HIPA were established in 2006 and intensively monitored until 2008. The trials were conducted at the same three *P. cinnamomi* disease centres as the epidemiology field trials, namely the Fitzgerald River (Bell Track), Gull Rock and Stirling Range National Parks. Phosphite is traditionally applied as an aerial spray, ground based spray or trunk injection. This project trailed stem application of 30 % phosphite (~100 x normal foliar spray rate) to treat large plant species in a 10 m wide strip perpendicular to the advancing disease front within the currently healthy vegetation (Figure 17). The premise was to increase the resistance of the treated plants to *P. cinnamomi* creating a chemical barrier to contain the pathogen. These field trials are now complete and the findings are being written into scientific journal article publications.

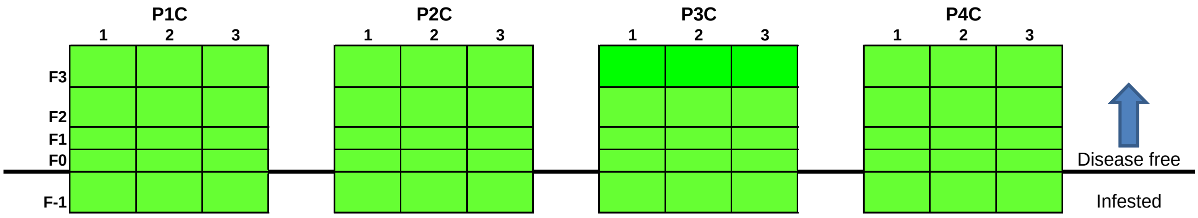

Figure 17. Eight monitoring quadrants were established along *Phytophthora cinnamomi* disease fronts caused at three South Coast National Parks to investigate the efficacy of High Intensity Phosphite Application to contain the pathogen.

HIPA within the Northern Jarrah forest

A field trial was established using HIPA to treat *Eucalyptus marginata* and *Banksia grandis* in a *P. cinnamomi* disease centre in the Jarrah forest east of Dwellingup. The trial investigated the efficacy of HIPA (10, 20, 30 and 40 % phosphite) stem application to trunk injection (5% phosphite) to reduce plant mortality. The concentration of phosphite within the leaves was determined using Gas Chromatography 10 days after treatment. Eighteen flora monitoring quadrants were established and have been monitored one year after treatment. Further monitoring will be conducted for at least another 4 years.

Fumigation using Ethanedinitrile

For a long time it was considered too difficult to eradicate the pathogen once it establishes in native plant communities and management concentrated on preventing the further. This project has demonstrated the potential for eradication through the use of fumigants such as ethanedinitrile (EDN) and Metham Sodium. This project tested the efficacy of EDN to sterilise soils infested with *P. cinnamomi* during *in vitro* laboratory trials as part of a BioGeneious Challenge project. A year 10 student, Joel Camkin, from Mater Dei College worked with scientists from DEC and Murdoch University to test EDN and develop experimental protocols that could be used in future field eradication trials (Figure 18). Joel was awarded 'Regional Finalist' for his project.

This project conducted two experiments.

1. The effect of EDN on the survival of *P. cinnamomi* on agar disks
2. The effect of EDN on the survival of *Phytophthora cinnamomi* in wood plugs in soil

Figure 18. Two *in vitro* trials investigated the efficacy of Ethanedinitrile to kill *Phytophthora cinnamomi* on agar discs (A) and within wood plugs in soil. The rates of fumigant were measured using Gas Chromatography (B) as part of a BioGeneious Challenge project (C) and the effect on the survival of the pathogen was determined (D).

Assessment of Boot Cleaning Procedures

An experiment was conducted that investigated the efficacy of different boot cleaning methods commonly used to prevent the spread of *P. cinnamomi*, including brushing, foot baths, 70% ethanol spray and the Phytofighter-1000 foot bath. Boots were contaminated with two *P. cinnamomi* isolates in colonised millet seed within two soil types, Bell Track south grey sand and Pabelup orange clay (Figure 19). Boots were dipped in wet soil slurry containing the colonised millet seed before being cleaning using 5 different methods: no treatment, 15 sec spray with 70% ethanol; 15 sec brushing with stiff brushes; 15 sec immersion into a footbath containing 70% ethanol; and the Phytofighter 1000 footbath.

Figure 19. An experiment was conducted during this project to investigate the efficacy of different boot cleaning methods to reduce the risk of Phytophthora Dieback spread.

Investigations into the Hygiene Effectiveness

Over the past year there were three studies completed into the application of different hygiene procedures including:

- an inventory of DEC hygiene infrastructure across the DEC districts and regions from the south-west of WA;
- an assessment of vehicle cleaning; and
- an assessment of hiker's compliance at a boot cleaning station at Sullivan Rock on the Bibbulmun Track.

Communication Outcomes

Since 2006 there has been over 44 press articles/radio interviews, 12 conference presentations, and two briefings to the Conservation Commission of WA and five DEC symposia profiling different aspects the SNCP *Phytophthora* Dieback projects.

4. KNOWLEDGE ACQUISITION/ADAPTIVE MANAGEMENT:

The implementation of these projects has allowed DEC to (I) build corporate knowledge by implementing world first plant pathogen control strategies and tactics in a remote location; (II) develop and utilise new skills and knowledge in *P. cinnamomi* management with the potential for wider community deployment; and (III) deploy techniques using an adaptive, multi-faceted experimental management approach. The knowledge gained during these projects has directly been utilised during the development of DECs *Phytophthora* Dieback policies, procedures, management plans and specific management projects. An excellent example of this the integration of new knowledge, skills and techniques into the *Phytophthora* Dieback management plan currently being developed for the FRNP. Furthermore, this new knowledge will have benefit for all land managers including local governments, natural resource management groups, private landholders and community conservation groups. Currently the DEC's Phytophthora management manuals, guidance statements, management procedures, website information and training courses are undergoing review. The results of this SNCP project will be incorporated into these documents to further improve DEC's *Phytophthora* Dieback management performance.

Specific areas of knowledge acquisition, skills gained and techniques developed during the SNCP *Phytophthora* Dieback projects including:

- up to date occurrence mapping data of *Phytophthora* species within native plant communities from the South Coast of WA;
- understanding the site specific epidemiology's of *P. cinnamomi* within native plant communities from the South Coast WA;
- optimising detection, diagnosis and mapping of *P. cinnamomi*;
- hydrological catchment characterisation and development of modelling approaches of determining future pathogen spread;
- new phosphite application techniques;
- fumigation techniques for the *in situ* and *ex situ* sterilisation of soil;
- the development of new containment and eradication techniques that have broad applicability;
- an inventory of DEC hygiene infrastructure across the south-west districts and regions; and
- an assessment of current DEC hygiene protocols.

Information and data sets pertaining to these SNCP *Phytophthora* Dieback projects have been recorded in a number of locations including:

- all electronic files from DEC staff members backed up onto external hard drives and DEC servers;
- significant reports and documents filed within the DEC corporate record system;
- interpretation and mapping data included with DEC GIS datasets;
- soil and plant sampling diagnostic results captured within the DEC Vegetation Health Service and Centre for Phytophthora Science and Management (CPSM Murdoch University) databases;
- phosphite treatment recorded within the DEC Phosphite database;
- the research findings have been published in peer reviewed scientific journal articles and other journal articles are currently under development. For example the Bell Track containment project has published in the New Zealand Journal of Forest Science; and
- the findings from this research have been presented a number of state, national and international scientific conferences, manager's forums and community workshops.

5. BIODIVERSITY OUTCOMES ACHIEVED SO FAR

The projects described within this report have protected over 350,000 ha of excellent condition native plant communities from the impacts of *P. cinnamomi* within the South-west of WA, an internationally recognised biodiversity hotspot. Specifically this project undertook prevention and containment activities within FRNP and SNP.

The phosphite application undertaken within these projects has ameliorated the threat posed by *P. cinnamomi* to:

- 2 Critically Endangered TECs and 1 Endangered TEC;
- 16 Critically Endangered taxa: *Andersonia axilliflora, Banksia anatona, Banksia montana, Daviesia glossossema, Leucopogon gnaphaloidies, Persoonia micranthera, Daviesia pseudaphylla*, *Lambertia fairallii, Banksia brownii, Latrobea colophona, Lambertia echinata* ssp *echinata, Lambertia echinata* ssp *occidentalis, Darwinia* sp *Williamson, Petrophile latericola, Gastrolobium papilio* and *Grevillea maccutcheonii*;
- 5 Endangered taxa: *Daviesia obovata, Darwinia wittwerorum, Darwinia* sp *Stirling Range, Banksia nivea* ssp *uliginosa, Grevillea elongatea;*
- 3 Vulnerable taxa: *Andersonia pinaster, Banksia squarrossa* ssp *argillaceae, Gastrolobium modestum;*
- 2 PECs; and
- > 20 Priority flora species.

6. MONITORING METHOD, RESULTS:

PHA1: Monitoring the Containment of the Bell Track Infestation

The “Last Stand at Bell Track” project aimed to contain *P. cinnamomi* within the 1000 ha Bell Track catchment by the integration of commonly used strategies and new control techniques. The majority of the Bell Track management strategies and other project related activities were implemented within the first three years. The project has since implemented its monitoring program, maintained the controls and added further controls at a number of high risk sites across the catchment. The monitoring program for the Bell Track containment project included a number of science based investigations that assessed the efficacy of the different controls and researched important knowledge gaps (Figure 20). This allowed for the validation of the models developed during the project and provided valuable data to inform management decisions.

The monitoring program included:

1. on-ground interpretation of the disease symptoms to:
    a. track the spread (disease centre expansion) of *P. cinnamomi* across the Bell Track catchment; and
    b. assess the effectiveness of the control techniques deployed at the three high risk locations;
2. remote sensing using DMSI to:
    a. monitor pathogen spread (disease centre expansion) within the Bell Track catchment;
    b. assess the effectiveness of the 20 ha of management scale HIPA;
    c. assess the effectiveness of the control techniques deployed at the three high risk locations;
    d. survey the native plant communities across the catchment for any suspect areas to sample during survey activities;
3. hydrological investigations to:
    a. describe the hydrological characteristics of the Bell Track catchment;
    b. model the response of the catchment hydrology after extreme rainfall events that could lead to pathogen outbreak;
4. epidemiological field trials to:
    a. investigate the spatial or temporal variation of the pathogen at Bell Track;
    b. monitor the weather conditions at Bell Track and their effect on pathogen activity or spread;
5. long term floristic monitoring of the autonomous spread of the pathogen, disease and the efficacy of the aerial phosphite treatment;
6. compliance with access and hygiene protocols for the project including an access register and checks of the hygiene management plans for specific activities.

Monitoring the Spread of the Pathogen

The occurrence of the pathogen across the catchment was comprehensively mapped in 2005, 2006, 2007 and 2009 (Figure 21). Re-checks of the disease boundary have been conducted at least once a year, most recently in February 2012. Between 2006 and 2009 the occurrence of the pathogen increased within Bell Track from 142.9 in 2006 to 184 ha (2007) and 212.8 ha in 2009 (Figure 22). This increase was a result of water associated spread in two locations and the interpretation of more area ‘infested’ in the north-east where disease interpretation was more cryptic. The two locations of significant pathogen spread included the poorly defined drainage zone of the western disease boundary and a well defined drainage line between two sumps in the south-east.

In 2006/07 there were a number of large rainfall events within the FRNP including a total of 113 mm of rainfall over 24 hrs in early January 2007. This large rainfall would have resulted in significant hydrological discharge across the catchment and it’s likely this caused the 500 m extension of the pathogen recorded in the south-east area. Within a few weeks of this rainfall, the pathogen was observed to cause a mass collapse of *Banksia baxteri* in a defined line ~ 10 - 30 m wide and the distance of the two sumps. Extra containment strategies have since been installed to address this high risk area.

All monitoring conducted to date indicates that the pathogen is still contained its current sub-catchments at Bell Track and more broadly within the Bell Track catchment.

Figure 20. The monitoring program for the 'Last Stand at Bell Track' containment project included hydrological investigations (A); epidemiological studies of the pathogen (B); recording weather conditions on site (C), air spading to describe the root architecture of susceptible species (D), flora monitoring (E) and intensive sampling of the pathogen (F).

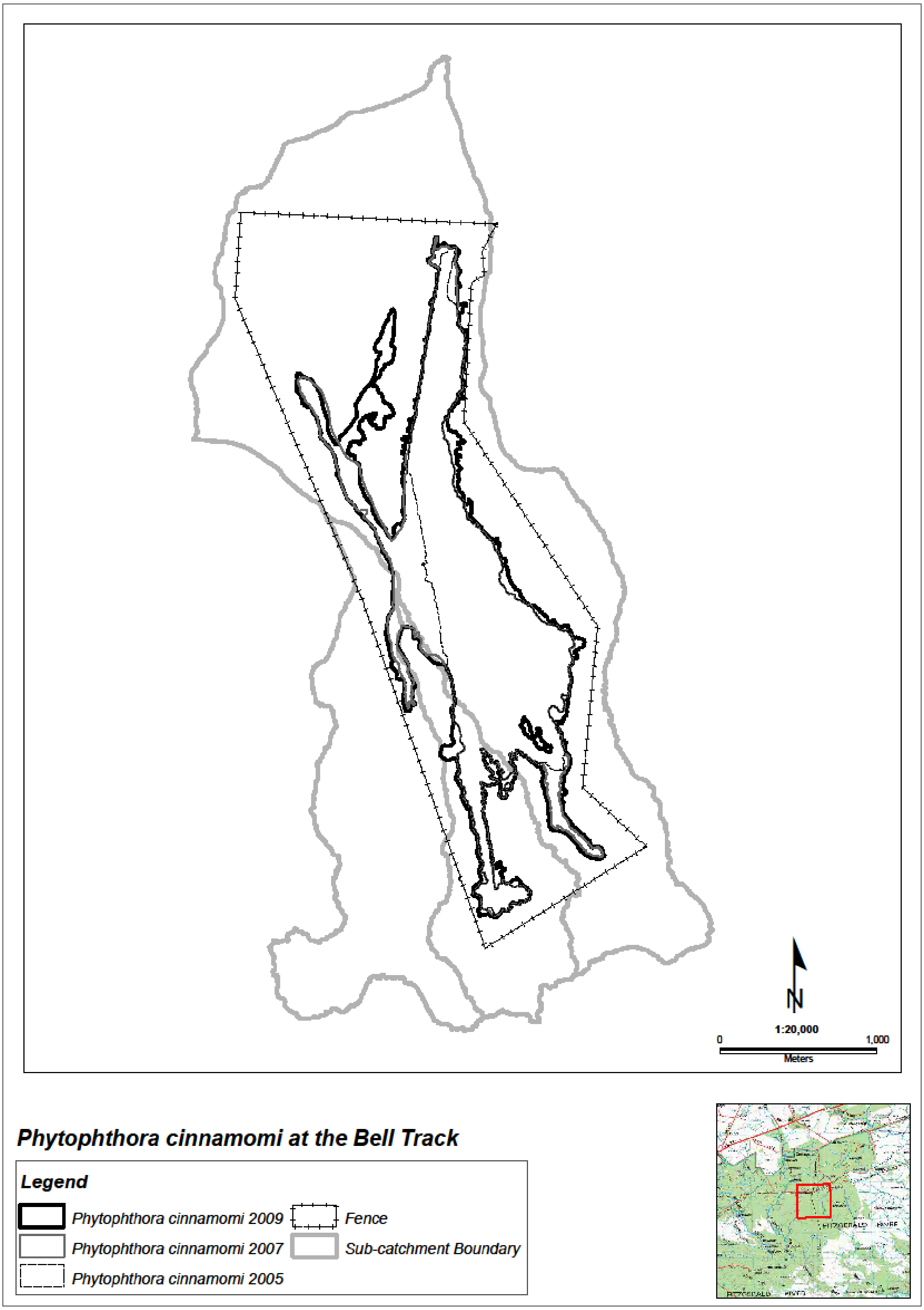

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Figure 21. The occurrence of *Phytophthora cinnamomi* within the Bell Track catchment in the Fitzgerald River National Park as interpreted in 2005, 2007 and 2009. The boundary of the infestation at the different times of assessment is shown in black and the sub-catchment boundaries are shown in grey. The checked line shows the position of the fence and fire breaks forming the containment zone surrounding the infested area.

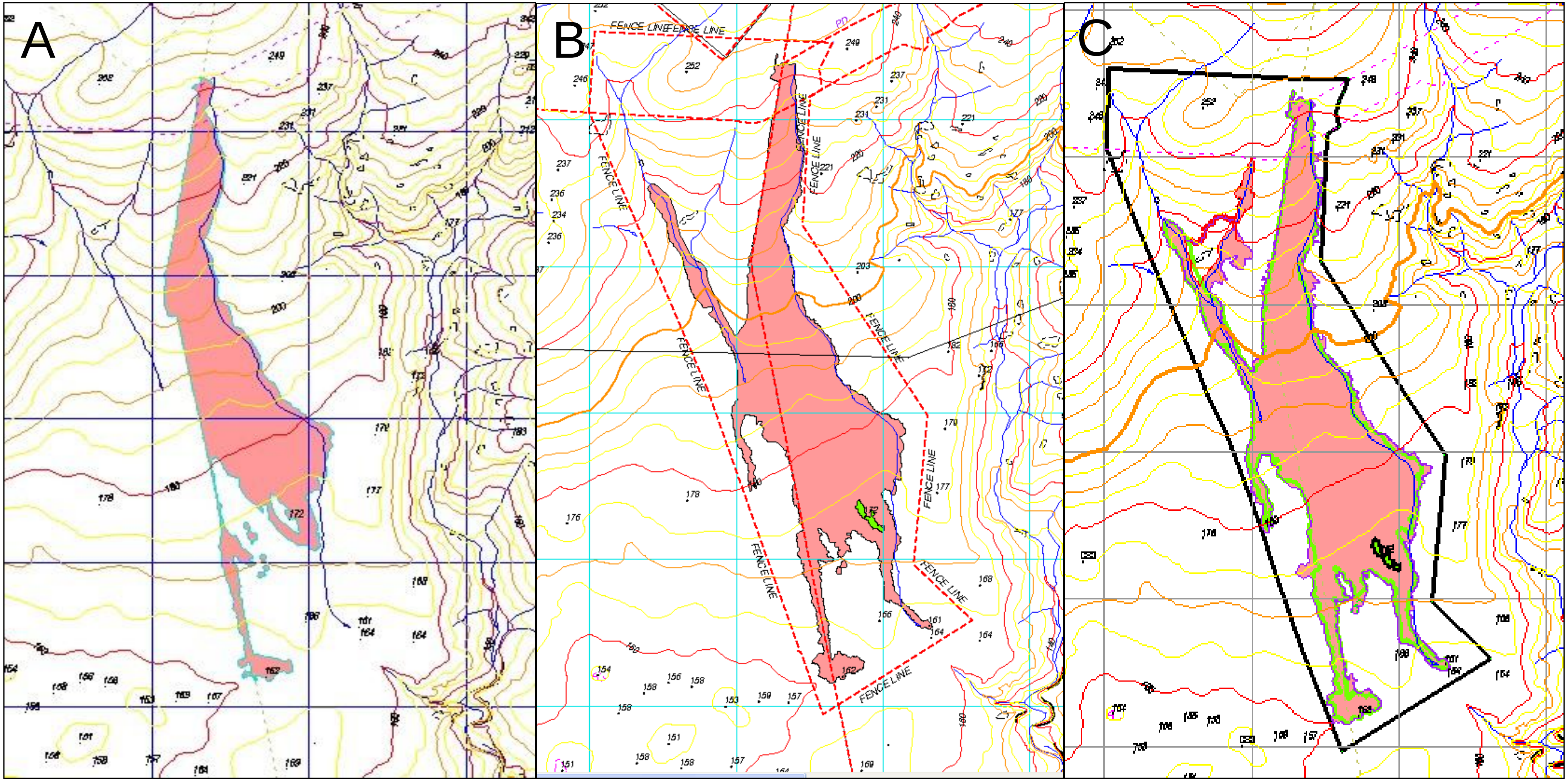


Figure 22. The mapped occurrence of *Phytophthora cinnamomi* in 2006 (A), 2007 (B) and 2009 (C) within the Bell Track catchment, Fitzgerald River National Park.

Hydrological Investigations

As the pathogen can spread rapidly in free water, it was important to map the topography of the catchment and model possible overland flow during flood events that could lead to outbreaks of the pathogen. Detailed hydrological modelling of the catchment was undertaken, including Light Detection and Ranging (LiDAR) aerial capture that consisted of both a high resolution digital elevation model (DEM) and 0.5 m contours. The modelling identified sub-catchment boundaries and drainage connections throughout the Bell Track catchment (Appendix 2 and 3). This allowed for a comparison of the current *P. cinnamomi* occurrence in relation to sub-catchment boundaries to determine areas where the pathogen is at greatest risk of spreading into an adjoining catchment. The model indicated that the pathogen was contained within two sub-catchments that were considered to be internally draining due to the presence of four large depressions or sumps. It was calculated that these sumps that have adequate capacity to hold the runoff volume associated with large rainfall events.

To validate that the sub-catchments were self draining and the large depressions or sumps had adequate capacity, further modelling of rainfall events in the catchment was conducted. This modelling exercise investigated: the hydrological analysis of surface flow rates and volumes based on peak flood rainfall events in the catchment to determine the magnitude and behaviour of water to be contained; and the identification of feasible surface water engineering options to divert and store water during peak flood events and prevent downstream catchment flow. The study examined theoretical average recurrent interval (ARI) rainfall events with frequency intervals of 50, 300, 500 and 1000 years. These ARI events were for single events over of 36 hours. The model confirmed that the sumps would have sufficient capacity to hold any stream or overland flow during all such extreme rainfall events. The sumps contain a deep sand-soil profile capable of holding any run-off. Sump depth was checked using vehicle mounted drill rigs to describe the soil profile. It was determined that no substantial hydrological engineering was required for water collection if a 1 in 1000 year rainfall event occurred (Appendix 4). However, some minor water diversion and soil erosion measures were used along Bell Track and the fire breaks surrounding the infestation to ensure that these cleared areas did not lead to significant run-off.

Epidemiological Investigations

The temporal and spatial soil inoculum dynamics of *P. cinnamomi* from disease centres within the FRNP, Gull Rock (GRNP) and Stirling Range National Parks (SRNP) from the South Coast of WA was determined through soil baiting. The behavior of the pathogen in terms of isolation frequency, spatial inoculum distribution and the seasonality of isolation frequency were determined over a 15 month monitoring period at each disease centre.

The isolation frequency of *P. cinnamomi* from the soil samples demonstrated significant spatial and temporal variation between and within all three disease centres (Appendix 6 and 7). The frequency of isolation and seasonal pattern for the pathogen from the random soil samples was similar for the GRNP/SRNP disease centres. However, the isolation frequency was distinctly lower at the FRNP disease centre with less seasonal variation. The isolation frequency at the FRNP/GRNP disease centres was higher at the front/old plots and the pathogen was isolated most frequently from shallow soils. There was no difference in the frequency of isolation between the front/old plots or the two soil depths within the SRNP disease centre.

The isolation frequency of the pathogen from the targeted soil samples was highest for soil collected from the base of *Lambertia inermis* var. *inermis* (90 %), then *B. coccinea* (87.5 %), *B. attenuata* (83.3 %), *B. baxteri* (80 %), *Xanthorrhoea platyphylla* (80 %) and lowest for *Banksia falcata* (56.6 %) (Table 3). The probability of detecting

P. cinnamomi from random soil samples was highest at SRNP (46 %), intermediate at GRNP (32%) and lowest at the FRNP (27 %). The probability of detecting *P. cinnamomi* from targeted soil samples was highest at GRNP (82 %), intermediate at SRNP (73 %) and lowest at FRNP (61 %). It was evident that *P. cinnamomi* infestation leads to changes in soil moisture, soil temperature, plant species biomass and structure within all three disease centres. However, there were only weak correlations of the measured environmental factors (rainfall, air and soil temperature) and the isolation frequency of the pathogen.

The pattern of inoculum occurrence found in *P. cinnamomi* disease centres was influenced by creation of dynamic spatiotemporal niche refuges favourable to the pathogen through ecosystem engineering by host and pathogen under the influence of local environment conditions. By understanding the epidemiological behaviour of the pathogen within different plant communities, soil types, topography and climate the management of *P. cinnamomi* can then be tailored for different sites significantly increasing the probability of management success.

The second epidemiological field trial investigated the invasion of healthy native vegetation by *P. cinnamomi*. The data collected has been useful in determining: that the pathogen moves randomly at an overall average or 1-2 m per year; the pathogen can be detected 3-6 months before disease expression is observed in susceptible plants; and the majority of highly susceptible species are killed within 12 months of the pathogen arriving within a 2 x 2 m quadrant.

Table 3. Probability of isolation of *Phytophthora cinnamomi* from the soil samples collected from random samples at two depths and samples at two depths targeted to soil around the collar of susceptible host in disease centres in three national parks.

National Park	Random			Targeted		
Fitzgerald River	Depth (cm)	Front	Old	Host	Depth (cm)	Probability of isolation
	10-20	34	4.85	*Banksia baxteri*	10-20	53.3
	40-60	25.7	9.01		40-60	60
	Mean	29.8	6.93		Mean	56.7
				Lambertia inermis	10-20	57.5
					40-60	74.2
					Mean	65.8
Gull Rock	10-20	35.1	19.6	*B. attenuata*	10-20	80.5
	40-60	37.5	21.4		40-60	79.5
	Mean	36.3	20.5		Mean	80
				B. coccinea	10-20	90.7
					40-60	77.1
					Mean	83.9
Stirling Range	10-20	37.5	54.8	*B. falcata*	10-20	53.3
	40-60	43.7	43.7		30-40	60
	Mean	40.6	49.3		Mean	56.7
				Xanthorrhoea platyphylla	10-20	76.7
					30-40	83.3
					Mean	80

Are surviving susceptible plant species in infested sites disease escapes?

During spring 2008 over 60 *B. coccinea* plants were underbark inoculated with *P. cinnamomi* at the Bell Track infestation. The aim of the experiment was to determine if the surviving *B. coccinea*, a highly susceptible plant species, within the infested area are disease escapes or have a greater level of genetic resistance. A range of responses were observed with some anecdotal evidence that a greater proportion of plants within the infested area have some tolerance of the pathogen. Further statistical analysis is required to elucidate the nature of any significant relationships. It is hoped that the results will identify *B. coccinea* plants that have a higher level of resistance that could be used in a breeding trial to develop resistant genotypes that could be used in the restoration of infested sites.

The conduciveness of soils from the South Coast of WA to infection by P. cinnamomi

A comprehensive glasshouse trial has been completed into the conduciveness of ten different soil types from the South Coast to infection by *P. cinnamomi* during summer 2007/08 (Figure 23). This trial demonstrated that different soil types can lead to different rates to death and different maximum levels of mortality. In summary the different soils can be described as high, medium or low impact. The data obtained will be useful in conducting risk assessments to prioritise areas for management, model disease spread and predict disease impact.

The susceptibility of Banksia*,* Hakea*,* Grevellia *and* Eucalyptus *species to* P. cinnamomi

The study showed that all *Grevillea* species tested and *H. orthorrhyncha* were resistant to *P. cinnamomi* (Figure 24). Further, *E. marginata* and *H. prostrata* were determined to be moderately resistant and all *Banksia* species were susceptible.

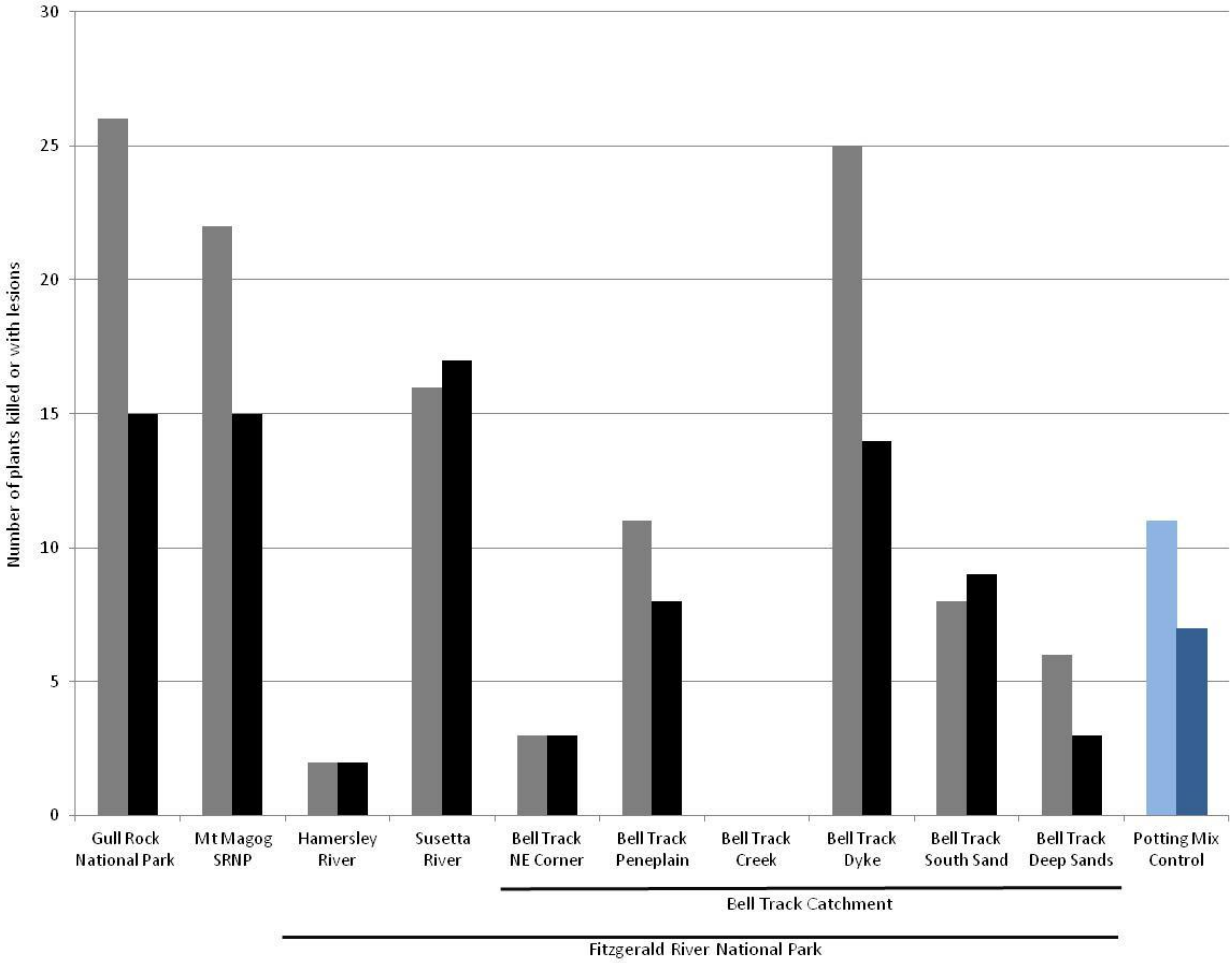


Figure 23. The conducivess of different soils to *Phytophhtora cinnamomi* infection from soils collected within the Bell Track catchment, Fitzgerald River, Gull Rock and Stirling Range National Parks.

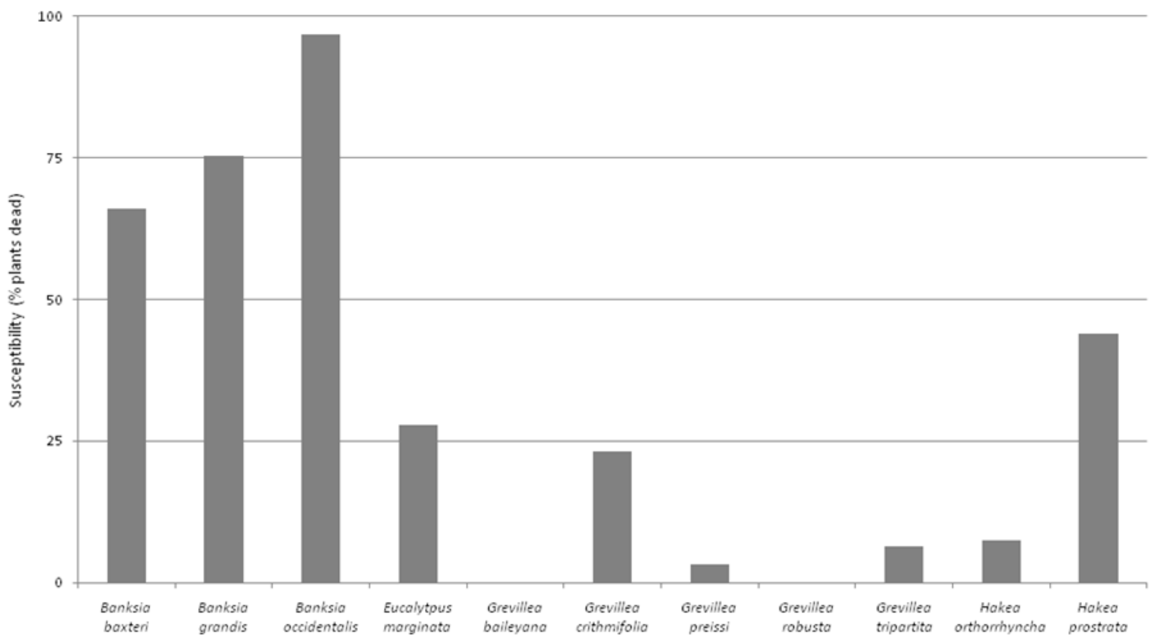


Figure 24. The percentage of *Banksia, Eucalyptus, Grevillea* and *Hakea* species killed when inoculated with *Phytophthora cinnamomi*.

Phosphite Treatment Monitoring
Monitoring of aerial phosphite treatment within the Bell Track infestation has shown the fungicide treatment to significantly reduce mortality in common species such as *B. baxteri* and *L. inermis* (Figure 25). Phosphite also has the added benefit of retarding disease centre expansion where transmission is largely due to root to root transmission.

DMSI was also used to monitor the spread of *P. cinnamomi* within the Bell Track catchment and evaluate the different containment strategies. The technique was very valuable in monitoring the 20 ha of HIPA used within the management plan to prevent root-to-root transmission of the pathogen (Figure 26). Further details of the use of HIPA for monitoring at Bell Track is described within the following report: Dunne, C. (2009). Digital Multispectral Imagery for determining the occurrence of *Phytophthora cinnamomi* at the Bell Track infestation, FRNP. Draft Report. Department of Environment and Conservation, Perth, Western Australia.

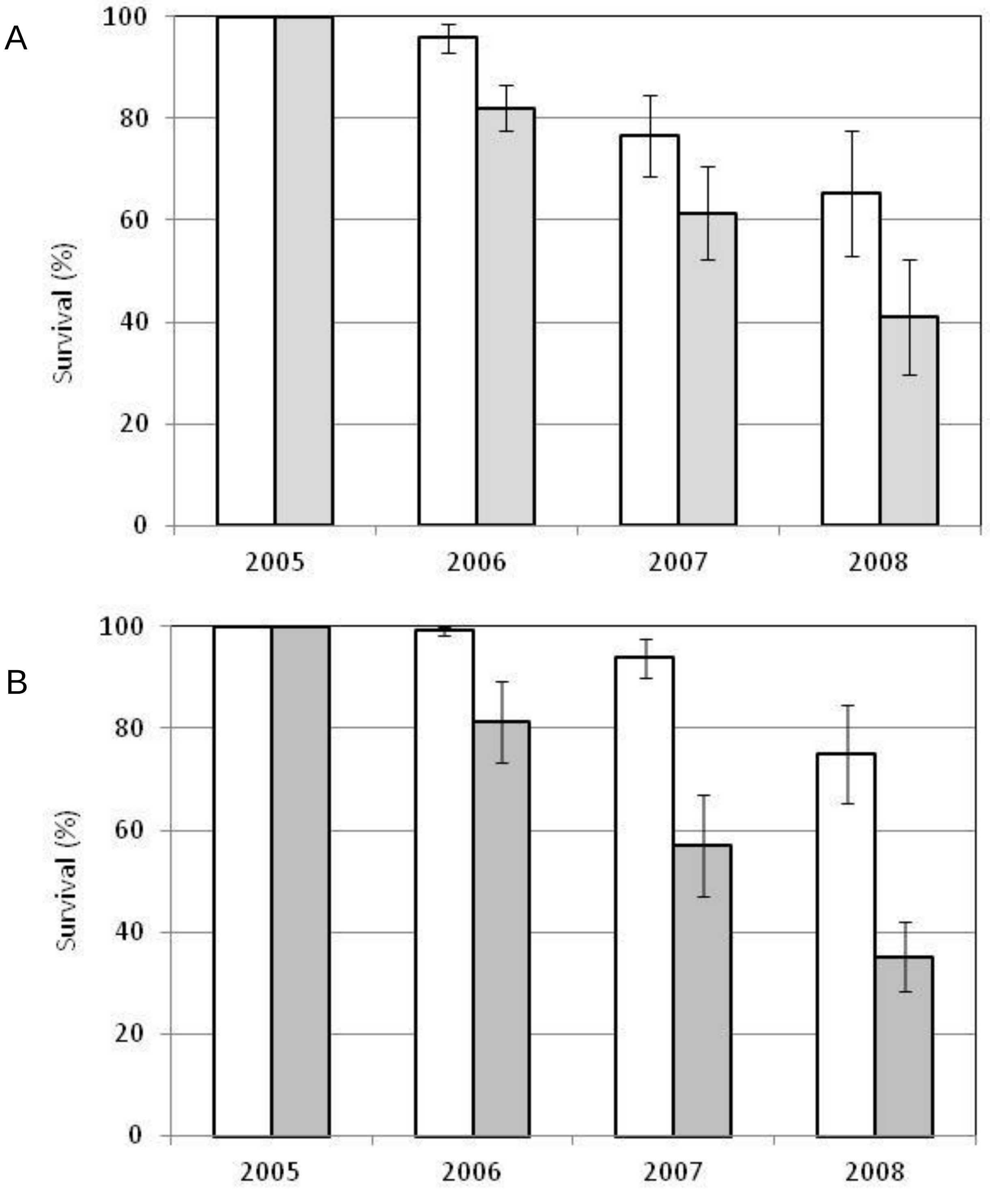


Figure 25. The efficacy of aerial phosphite treatment at Bell Track showing a reduction in mortality of *Banksia baxteri* (A) and *Lambertia inermis* (B).

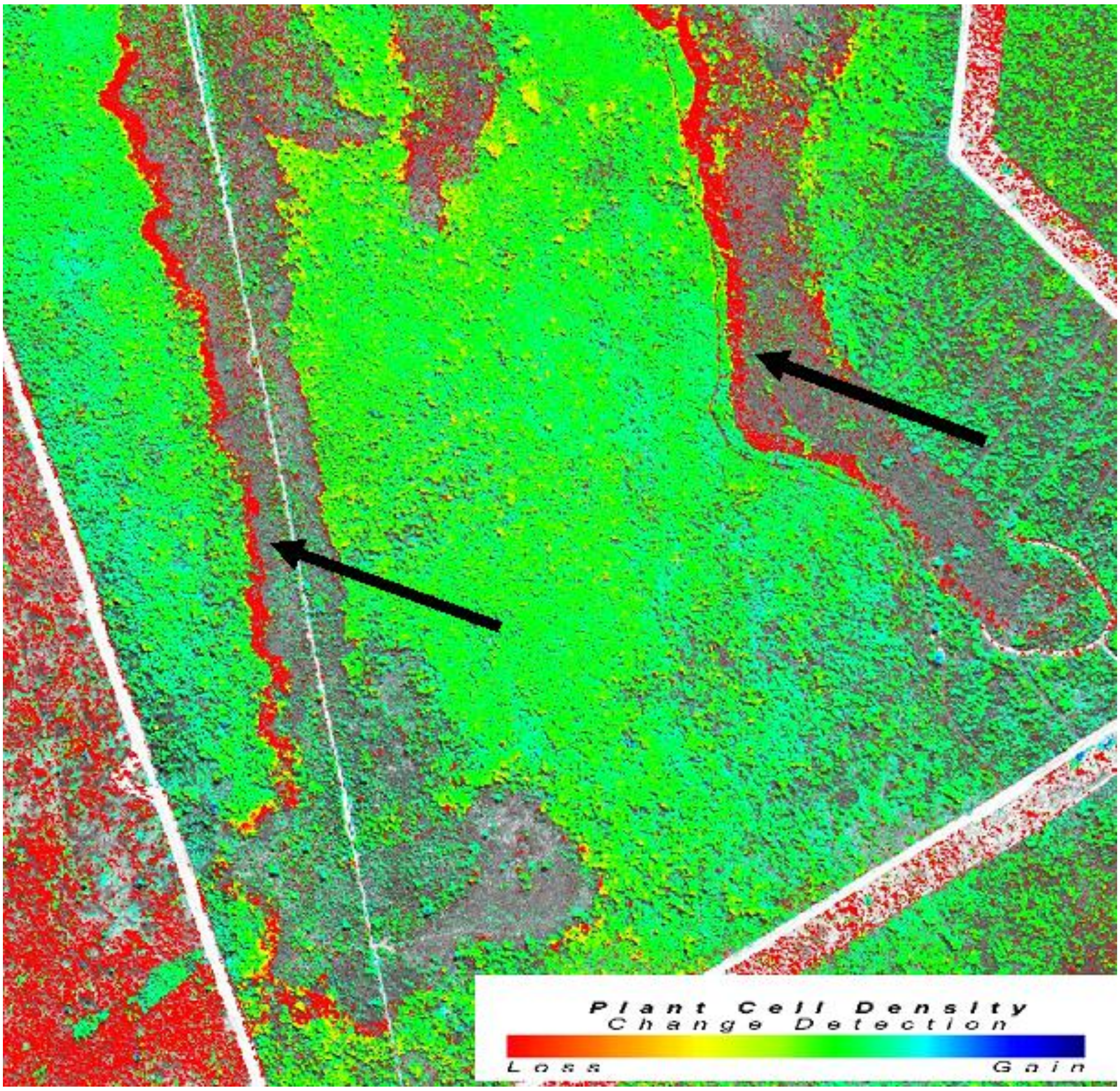


Figure 26. The change in plant cell density as an indicator of canopy cover at the Bell Track catchment indicating the Phytotoxicity that resulted in the 10 m treatment zone along the disease front after high intensity 30 % phosphite application.

PH2: Phosphite application in Threatened Flora Populations and TECs across the south west of WA
To monitor the aerial phosphite treatment conducted as part of the PH2 project the following was conducted:

- disease fronts have been pegged or captured using GPS to determine the 'rate of spread at Wedge Hill, Little Mondurup, Yungemere, Southwest Gog, Mt Success within the Stirling Range National Park (SRNP);
- Individuals of *Lambertia echinata* ssp *echinata* have been tagged for monitoring;
- Individuals of *Dryandra ferruginea* ssp *pumila* have been tagged for monitoring at Hosteller Hills (SRNP);
- Individuals at 4 occurrences of the Busselton Southern Ironstone TEC have been tagged including Williamson Rd (*Banksia nivea subsp. uliginosa; Lambertia echinata subsp. occidentalis; Banksia meisneri subsp. ascendens*), Gale Rd (*Banksia nivea subsp. uliginosa),* Smith Road and Tutunup Road (*Banksia squarrosa* subsp*. argillaceae*).

The SRNP monitoring showed good disease control at Wedge Hill east, Yungemere East and Southwest Gog with little upslope or cross-slope movement of disease fronts at these targets. Monitoring of quadrants for *Daviesia pseudaphylla* CR shows 45.5% survival of plants in sprayed quadrants compared with 24% for control/non-sprayed quadrants. Monitoring results indicate enhanced or stabilized population survival following phosphite treatment. A more complete account of the monitoring is detailed within the annual reports on the DECs aerial phosphite program.

PH 5: Containment of the Pabelup Drive Infestation, FRNP
Monitoring conducted to date has demonstrated that the pathogen is currently contained within the known infested Pabelup sub-catchment. In November 2010 two new *Phytophthora cinnamomi* infestations were discovered 2.5 km down catchment near Lake Pabelup. These infestations were found during on-ground surveillance and it's likely that these two new infestations are linked along a drainage line with the original Pabelup Drive infestation. It is unclear if they constitute one large infestation or a series of discrete infestations

that when combined total over 70 ha in size. Surveillance activities undertaken after the discovery of the original Pabelup Drive infestation, including ground based survey of the fire lines and aerial survey by helicopter, failed to find these new sites. This in part was due to the large buffer of healthy native vegetation between the original infestation and these new sites.

The origin of these new infestations and age is unknown. Initial laboratory testing of the isolates from the different sites suggest they are related. Given the significant size of the Lake Pabelup infestation it is likely that they have been present for some time (estimated to be at least 5-10 years old). It is our current estimate that the Lake Pabelup disease centre is the original infestation and that infestation found in April 2009 are possibly the result of human vectored spread due to the use of the containment fire lines during previous bushfire suppression. It is possible that the entire catchment from the Pabelup Drive infestation to Lake Pabelup to the south-east could be considered infested. As a result of the discovery the Pabelup management project focussed on containing the pathogen rather than eradication. Further monitoring of pathogen occurrence and the maintenance of the hydrological engineering controls will be undertaken over future years. If a suitable fumigation application method can be devised for this site there is the future possibility to attempting to eradicate the pathogen.

Interpretation, survey and mapping of *Phytophthora* Dieback within the Fitzgerald River and Stokes National Parks

A comprehensive interpretation program that included aerial helicopter surveys were conducted across the Bell Track catchment, adjoining drainage systems and across the Park in 2007, 2009, 2010 and 2012. This monitoring identified further six *P. cinnamomi* infestations over the six years of the project, namely the Susetta River (2007); Pabelup Drive (2009), Pabelup Lake (2010), Drummond Track (2012), old Ongerup Road (2012) and Doubtful Islands/Gordon Inlet Roads (2012) disease centres (Figure 27). Laboratory testing of the isolates from the different disease centres showed that these are not related to a break out of the pathogen from the Bell Track catchment, rather they are new introductions into the FRNP. The likely vectors for these other infestations include the use of infested basic raw materials, road construction, wildfire suppression and illegal vehicle access. The discovery of these new infestations highlights the often imperfect knowledge of the disease status of any area and the difficulties in accurately mapping the 330,000 ha of native plant communities within the FRNP. It is safe to assume that without the extra survey effort that was undertaken during this project, many of these new infestations would still be unknown.

The interpretation conducted at Stokes National Park during 2011/12 found that the park was free from *P. cinnamomi*. However, three samples taken in Reserve 27888, one from Reserve 26885 and one sample from Lake Shaster Nature Reserve all returned positive results for *P. cinnamomi*.

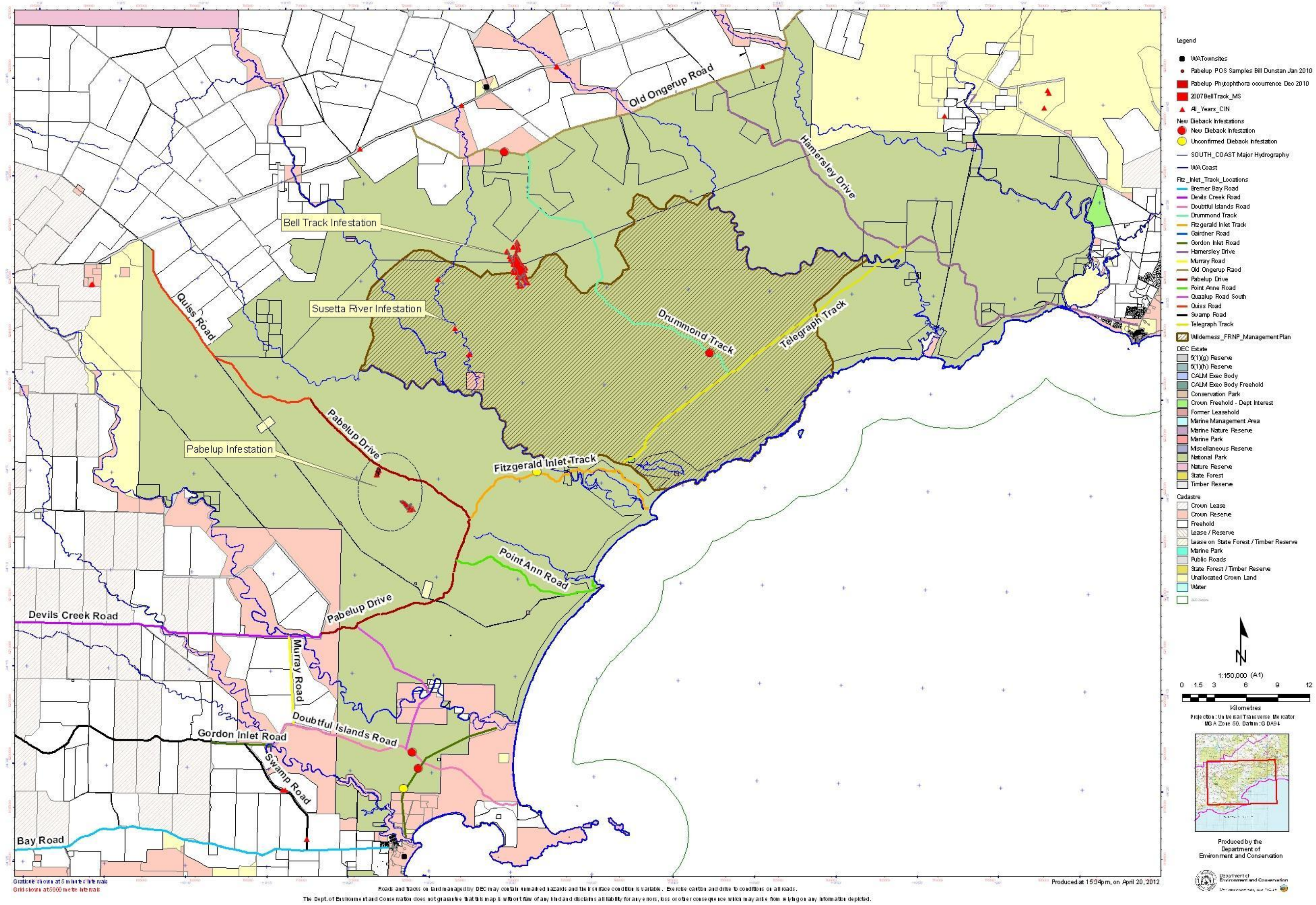


Figure 27. The known occurrence of *Phytophthora cinnamomi* within the Fitzgerald River National Park as of June 2012.

PH 1: Novel Control Techniques:

High Intensity Phosphite Application (HIPA) Field Trials

The two HIPA trials conducted within the native plant communities with the FRNP, GRNP and SRNP showed that HIPA treatment reduces mortality rates in targeted species, reduces *P. cinnamomi* soil inoculum in treated areas but has only a minor effect of reducing the rate of disease centre expansion (Appendix 8 and 9). The effectiveness of the treatment is affected by the epidemiology of the pathogen, soil type, geology, native plant community species composition and environmental factors. Furthermore the treatment works best in native plant communities on deep sands as the main transmission is considered root-to-root. Significant phytotoxicity was observed in the weeks to months post treatment. However, by 12 months post treatment most plant species had recovered from this phytotoxicity (Figure 28). These findings indicate the potential of HIPA as an effective containment technique and will be published in the coming years. The results of these trials were presented at the International *Phytophthora* conference in New Zealand in 2010 and will be published within scientific journals over the coming years.

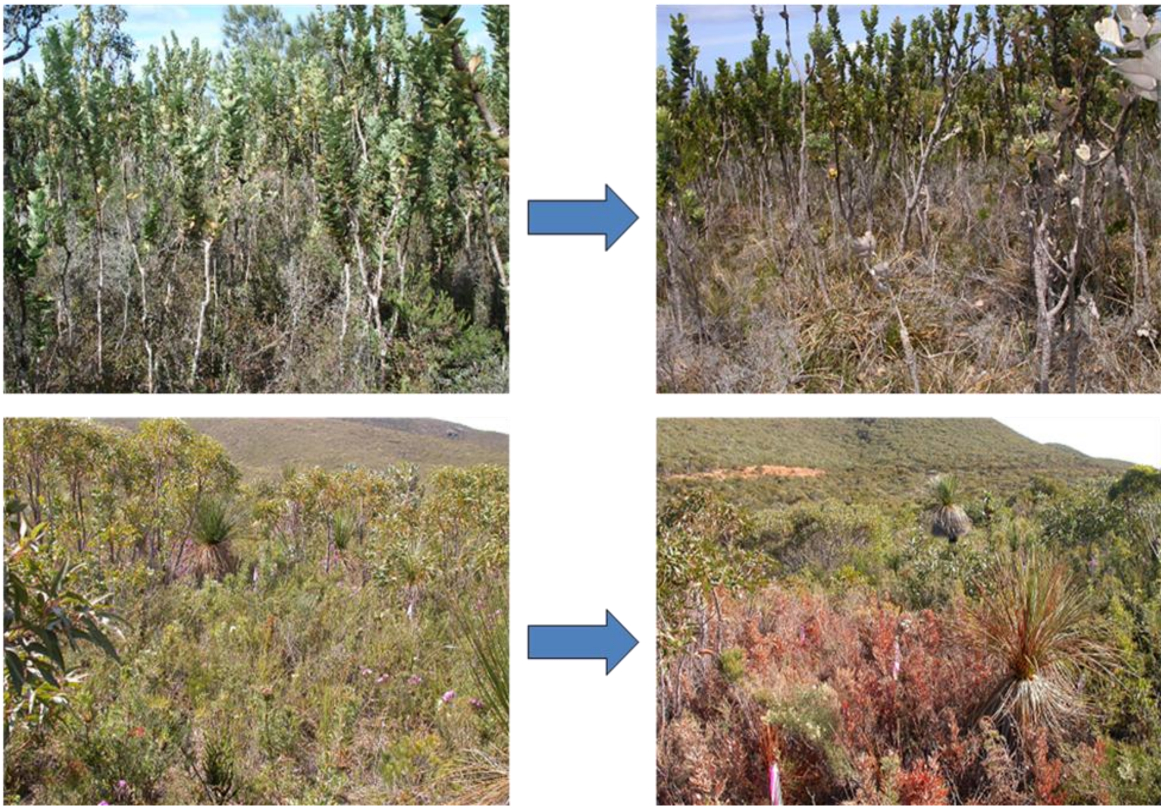


Figure 28. The high intensity phosphite application caused phytotoxicity within the treated areas, however most plant species had recovered fully within 12 months of treatment.

High Intensity Phosphite Application within the Northern Jarrah forest

The HIPA field trial that treated *Eucalyptus marginata* and *Banksia grandis* in a *P. cinnamomi* disease centre within the Jarrah forest showed that injection resulted in much higher phosphite tissues levels concentration within the treated plants than all HIPA treatments (Figure 29). HIPA worked best in *Banksia grandis* with reasonable levels of phosphite recorded within the plant tissue. In contrast, HIPA was mostly ineffective with only small amounts of the phosphite applied being detected with plant tissue. Further monitoring of plant mortality over the next few years will identify if the different treatments were successful in achieving control of the disease caused by *P. cinnamomi*.

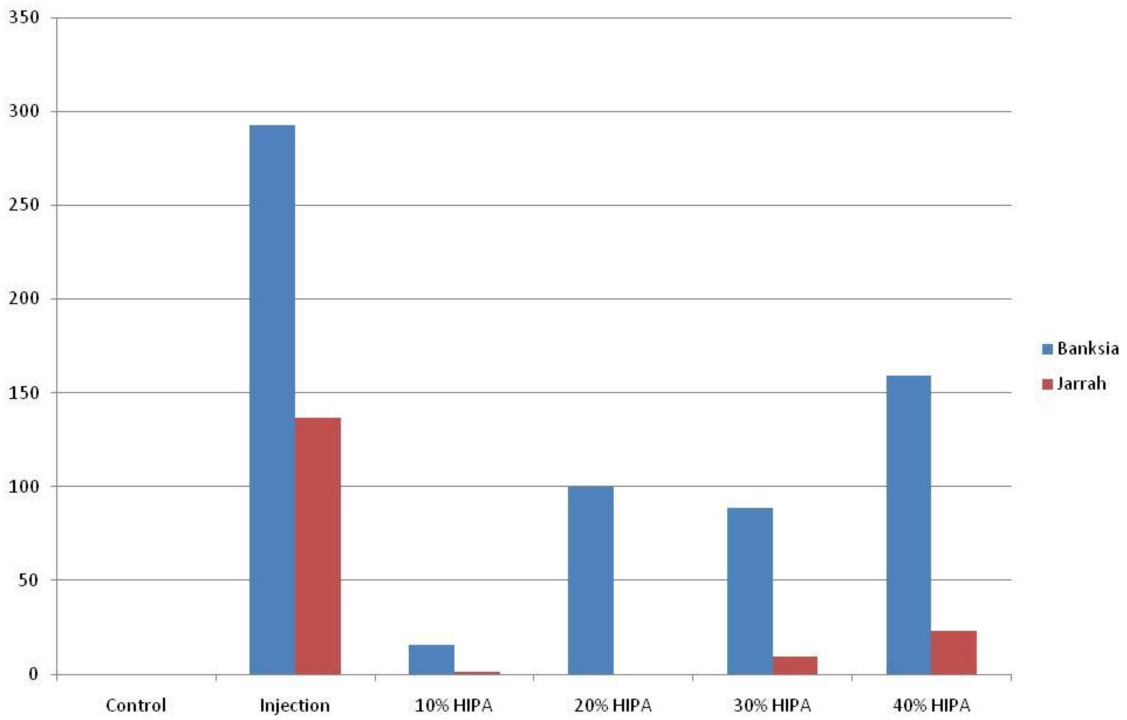


Figure 29. Phosphite tissue concentrations (mg/kg) from the high intensity phosphite application trial that compared traditional injection (5%) with four rates of HIPA in *Eucalyptus marginata* and *Banksia grandis*.

Fumigation using Ethanedinitrile

Ethanedinitrile (EDN) has so far been proven to be an efficient fumigant for the eradication of *P. cinnamomi*. This study found that when *P. cinnamomi* is exposed to the EDN at the concentrations above 1mg/L on agar and 40 mg/L on wood plugs it achieves a 100% kill rate (Appendix 10 and 11). There were some differences observed in the two soil types with the Pabelup soils needing slightly higher rates of EDN. Ethanedinitrile appears to have greater effects on wet soils, although it is still effective in the drier soil. There was also some slight variability between the different isolates, with DP51 being the most sensitive and DP55 the most resistant, particularly in when tested on *P. cinnamomi* colonised agar plugs.

Hygiene Investigations

Assessment of Different Boot Cleaning Methods

The study found that physical scrubbing or the use of the Phytofighter 1000 footbath are the most effective methods of cleaning boots; the use of a pressurized spray unit containing 70% ethanol alone is highly ineffective in preventing the spread of the pathogen (Figure 30). In summary there was a 25% recovery of the pathogen for all 5 boot cleaning methods, the Pabelup clay soil was the most conducive to spread with a 50% recovery of the pathogen, the Bell Track sand was non-conducive to pathogen spread and some boot designs posed a greater risk to spread than others due to differences in tread design.

Vehicle Inspections

The inspection of vehicles from the South Coast Region and Science Division vehicle compound at Kensington (Figure 31) found that:

- 15 % vehicles were inadequately cleaned;
- 30 % vehicles had light covering over large areas;
- 5 % of soils from vehicles had *Phytophthora* recovered during baiting of the collected material; and
- approximately 25 % had weed or other plant pathogens present the collected material.

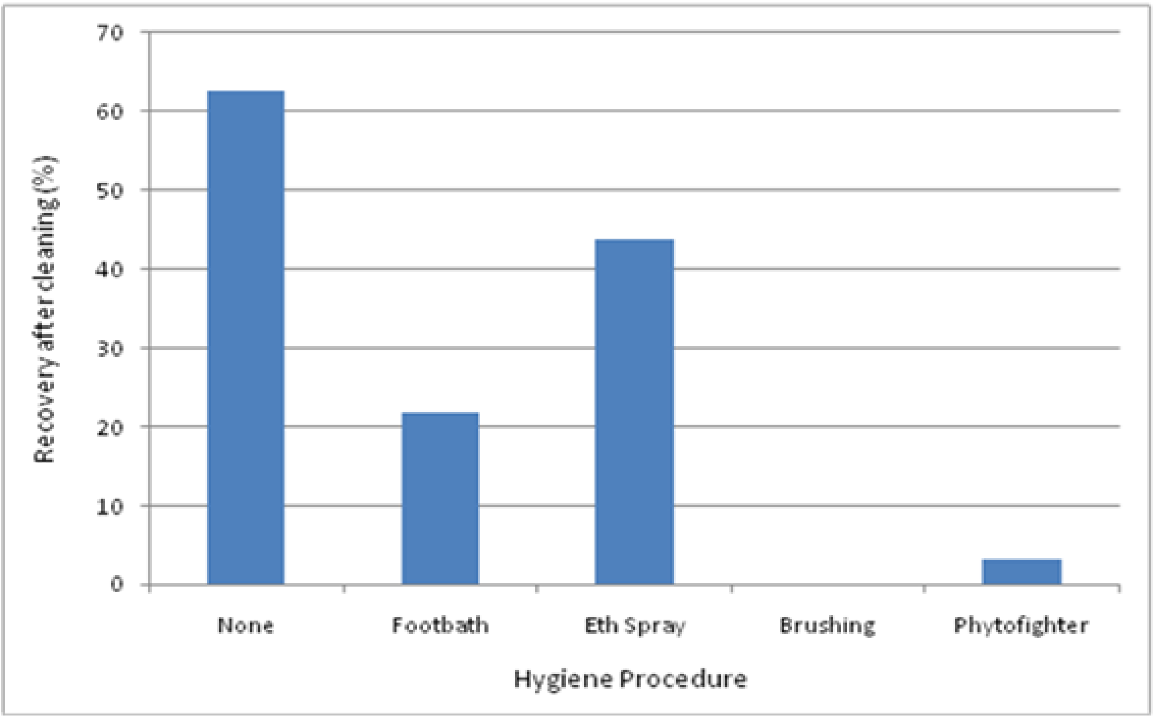


Figure 30. Hygiene trials investigating the effectiveness of different boot cleaning methods found brushing and the Phytofighter 1000 to be the most effective, footbaths partially effective and the use of 70% ethanol spray ineffective.

Figure 31. Vehicle inspections found that an inconsistent and inadequate application of hygiene protocols within the South Coast Region and Science Division vehicle compound at Kensington.

Hygiene Compliance by Hikers on the Bibbulmun Track

Motion sensor cameras were installed in early 2012 at the Sullivan Rock boot cleaning station on the Bibbulmun Track (Figure 32). In summary the monitoring found that 77% of people stopped to look at the station; 23% of people used the station to clean their footwear; and only 15% of people made a good effort at cleaning their shoes.

Figure 32. The boot cleaning station at Sullivan Rock on the Bibbulmun Track was monitored using surveillance cameras to assess the usage patterns of Hikers during January 2012.

Hygiene Infrastructure Audit

An audit of hygiene infrastructure was undertaken during 2011/12 and is included as an attachment to this report. Overall it found that there are inadequate facilities within many DEC managed sites, plus a number of facilities were being poorly maintained (Figure 33). The data collected will be used to develop a GIS layer to promote the use of these hygiene facilities.

Figure 33. The 2011/12 audit of DEC hygiene infrastructure including footbaths and vehicle washdown facilities found many to be in poor condition (A) or poorly maintained (B).

7. RECURRENT FUNDING:

The project outcomes achieved over the past 6 years will be maintained through the South Coast Region recurrent funding. External grants will be pursued to continue further development of novel control techniques and attempts to contain/eradicate *P. cinnamomi* infestations within priority protection areas.

8. FUNDING ADDITIONAL TO RECURRENT BUDGET DURING 12/13:

None required.

9. STRATEGIC CONTEXT
This project aligns with DEC Corporate Priority 3, 5, 12, NC KRA 2 and 3 and sub-outputs NC 2B, NC 2I, NC 3I, NC 3L and PVS 5F (DEC 2006; "Department and Service Priorities"). This project aligns with the key strategic goal G2: Understand the threats to biodiversity and develop evidence based management options to ameliorate threats within the "Strategic Plan for Biodiversity Conservation Research 2008-2017".

The project is also consistent with:

- Policy Statement No 3. (2010) *Phytophthora cinnamomi* and disease caused by it in native vegetation managed by the Department;
- the Nature Conservation Service Priorities 2010-2011;
- the Nature Conservation Service South Coast Region Plan 2009-2014;
- the "Stirling Range and Porongurup National Parks Management Plan 1999-2009;
- the "Response Plan for the Management of the *Phytophthora cinnamomi* infestation at Bell Track, Fitzgerald River National Park"; and
- the "Fitzgerald River National Park Management Plan 1991-2001".

10. PROJECT EXPENDITURE

Year	Title	Expenditure
2006-2011	PHA1: Last Stand at Bell Track. Saving the Fitzgerald River National Park 2006-2011 PH1: The development of novel phosphite application techniques to control *Phytophthora cinnamomi* within the Stirling Range and Fitzgerald River National Parks 2006-2011 PH2: Phosphite Application onto Critically Endangered and Endangered Flora Populations and Threatened Ecological Communities within the Albany, Esperance, Busselton and Frankland Districts 2006-2010 PH5: Phytophthora interpretation and management at Pabelup Drive and across the Fitzgerald River National Park 2010-2011	$2,295,620
2011-2012	Prevention, containment and eradication of *Phytophthora cinnamomi* infestations in the National Parks of the South Coast of Western Australia	$264,949
TOTAL		$2,560,569

11. COMMENT/DISCUSSION
The overall goal of these five projects described within this report was to protect the highly susceptible native plant communities from the impact of *P. cinnamomi*, in particular the FRNP. Unfortunately the number of known disease centres actually increased within the FRNP from 2 to 6 since 2006. However, most of these were probably already present in 2006 and if it wasn't for the extra surveys' conducted in these projects, they would still be undetected. In many ways this highlights the difficulties in *Phytophthora* Dieback management, especially the common scenario where there is always a lag in detecting new disease centres in landscapes as large as the FRNP (330,000 ha). It's important to note that there is no evidence that the origin of these new disease centres is related to the projects' sites or activities.

In the context of the goal of containing Bell Track and Pabelup Drive, these project were highly successful with all monitoring to date demonstrating successful containment. This is no small achievement and is a world first in management of *P. cinnamomi* in native ecosystems. Furthermore the projects have developed a number of new tools, new techniques and management strategies that have broad application in a range of soil borne disease applications. A number of these new approaches are already being applied to other priority protection areas and have greatly assisted in the successful eradication of a disease centre in Cape Arid National Park. Again this is a world first as eradication of *P. cinnamomi* has never been successfully achieved in any natural ecosystems. The capacity and technical expertise developed during this project makes DEC an international leader in *Phytophthora* Dieback management. This gained capacity and technical expertise is currently being applied in the development of the FRNP *P. cinnamomi* management plan and a State NRM project aiming to protect the top 100 priority protection areas across the south-west of WA. Furthermore this project has leveraged significant further investment (over $4.5 million) in *Phytophthora* Dieback management including management of the pathogen within the FRNP.

Maintenance and monitoring of the project sites will continue for a number of years to assess the effectiveness of the different management strategies. Where appropriate research findings will be incorporated into journal articles, management guidelines, policy documents and the training of DEC staff.

It's appropriate to acknowledge the efforts of staff involved in conception and implementation of these projects, in particular Malcolm Grant, Maria Lee and a number of South Coast Region and Science Division staff.

11. ENDORSEMENT

[signature] _Project Officer_ 20/9/12

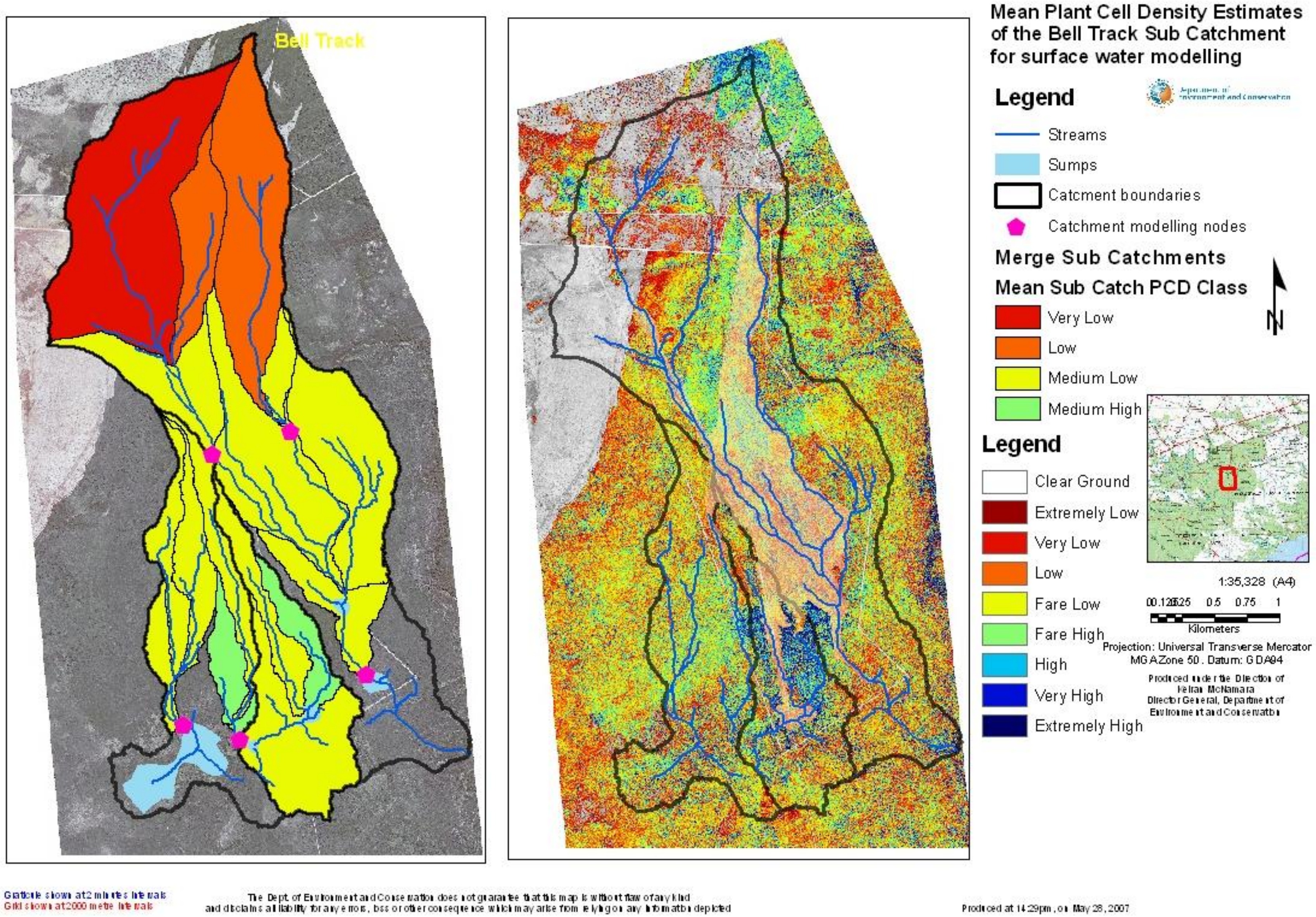
[signature] _Project Supervisor_ 12/9/12

[signature] _Branch/Regional/District Manager_ 12/09/2012

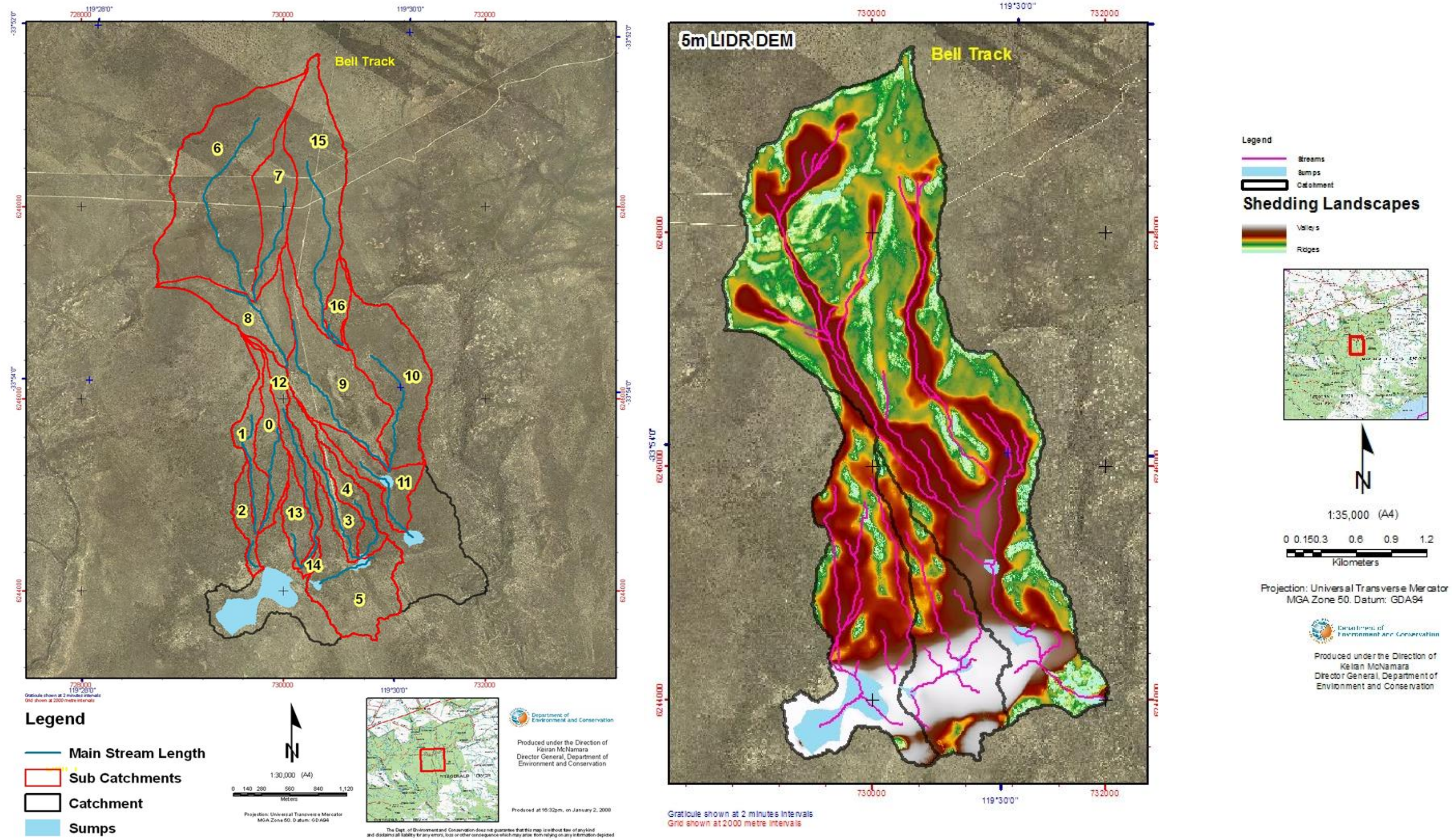
Appendix 1. The management plan for the containment of *Phytophthora cinnamomi* within the Bell Track catchment, Fitzgerald River National Park (FRNP).

Strategy	Activity
Program 1: Planning and Risk Assessment	
Information Gathering	Disease records for FRNP collated including interpretation data and management history of Bell Track infestation. Engaged other agencies, industry and research organisations with previous experience in catchment hydrology and/or *Phytophthora* Dieback management.
Operational Planning	Prioritised the strategies and control techniques for implementation. Developed operational plans including hygiene management plans.
Risk Assessment	A quantitative risk assessment using a Bayesian Belief Network model predicted the effectiveness of the proposed management strategies and identified the risks to the project.
Establish Site Management Protocols	Staff and contractors were required to adhere to strict entry conditions and undertake training in *Phytophthora* Dieback hygiene. Hygiene management plans were developed to identify access and hygiene controls including gates, fencing, track upgrades, defined access routes, location of hygiene management points and operational signage.
Project Communication	The project actively engaged key stakeholders involved in *Phytophthora* Dieback management in the FRNP. The project also sought broad input and guidance from consultants, academics and other land managers throughout the project. Approximately 25 communication opportunities including newspaper articles, television news, radio interviews, internal DEC publications, external publications, scientific publications, workshop and conference presentations.
Program 2: Mapping the Occurrence of the Pathogen	
High Confidence Detection & Mapping of the Pathogen	Aerial and on-ground interpretation of the pathogen conducted in 2007 & 2009 supported by a comprehensive and systematic sampling effort throughout the project. All on-site activities that posed significant risk to moving infested soil were required to undertake soil sampling immediately prior to earthworks being conducted to provide evidence of pathogen freedom.
Program 3: Implement Containment Strategies	
Establish Containment Zone	Construction of a perimeter fence 12 km in circumference to contain the *P. cinnamomi* disease centre including buffers. Construction of 8 m wide vegetation-free zone adjacent to the perimeter fence. Installation of secure access gates, bollards and operational signage.
Implement Access & Hygiene Procedures	Installed and maintained hygiene clean down site at the northern access route into the containment zone for vehicles and equipment. Upgraded vehicle wash-down facility at local district depot in Ravensthorpe. Monitor compliance with hygiene and access conditions applied to entry into the Bell Track catchment.
Implement Containment Techniques	Hydrological engineering controls installed to prevent water-associated spread of the pathogen including: • improvements to drainage and surface water management across the site; • 'green bridges' were installed both sides of the fence at the moisture gaining site near the south-west corner; • installation of geo-textile filtration systems along the western and south-western border of the containment zone; and • a wildfire management plan for the Bell Track catchment including fire breaks, fuel reduction zones, installation of fire suppression infrastructure and 15 km perimeter prescribed burning. To prevent the root-to-root transmission of the pathogen at high risk locations a series of techniques were combined including: • herbicide treatment using Glyphosate to create buffer of dead vegetation ahead of the disease front; • installation of 5 km of root-impervious membranes to ~1 m deep into the soil profile to cut root connectivity; • Metham Sodium fumigation at the location of the root-impervious membranes delivered through a 3.5 km subterranean irrigation system. Removal of large macro-pods within the containment zone to reduce the risk of animal vectoring.
Program 4: Reduce Disease Impact	
Phosphite Treatment	Fungicide treatment with Phosphite by aerial application (375 ha total target) and on-ground foliar spraying/high-intensity stem application (20 ha) to reduce the spread and impact of the pathogen.

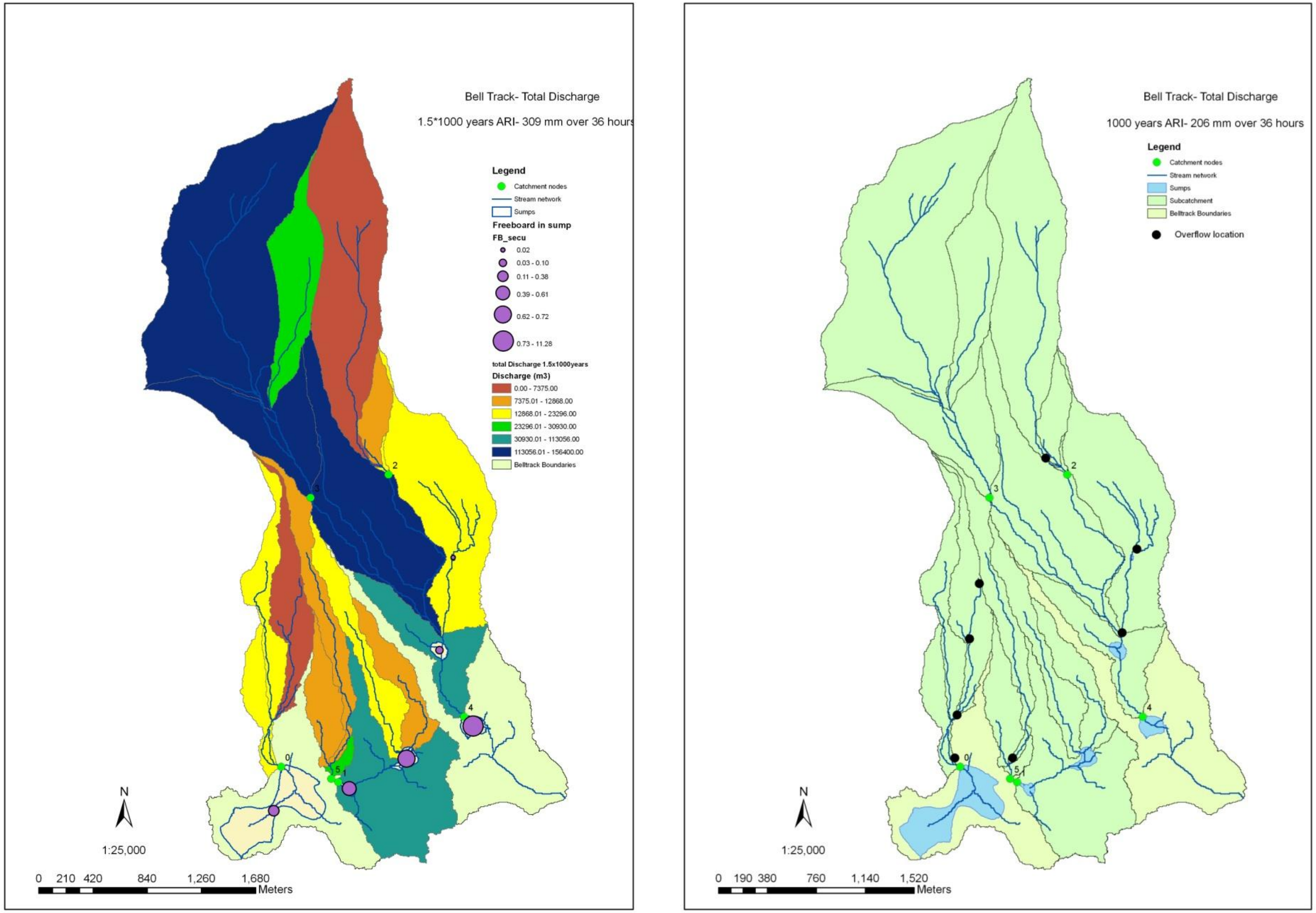
Revegetation	Re-vegetation of 20 ha of highly degraded vegetation within the *P. cinnamomi* disease centre with resistant plant species.
Program 5: Monitoring and Science Based Investigations	
Monitoring the Spread of the Pathogen	A comprehensive interpretation program monitored the pathogen occurrence across the Bell Track catchment and regular re-checks were conducted at high risk locations. Digital Multi-Spectral Imagery (DMSI) capture and analysis of the Bell Track catchment was conducted in 2007, 2009, 2010 and 2011. Aerial surveillance of the Bell Track and adjoining catchments using a helicopter was conducted in 2007, 2009, 2010 and 2012.
Hydrological Investigations	Detailed hydrological modelling of the catchment was undertaken, including LiDAR aerial capture that consisted of both a high resolution digital elevation model and 0.5 m contours. Hydrological characteristics of the Bell Track catchment to identify sub-catchment boundaries, drainage connections and high risk locations. Detailed hydrological modelling of catchment during extreme rainfall events to assess the capacity of the catchment to contain hydrological discharge. Monitoring of three weather stations across the catchment.
Epidemiological Investigations	As part of the project PH1 a number of field trials and investigations were conducted within the Bell Track catchment. This included long-term quadrants established across the disease centre to monitor any spatial and temporal variation in the epidemiology of the pathogen. Two glasshouse trials were also conducted to provide insight into the behaviour of the pathogen within the FRNP.
Flora Monitoring	The native plant communities and soils within the Bell Track catchment were mapped. Floristic monitoring quadrants were established in the different plant communities within the Bell Track catchment.
Phosphite Treatment Monitoring	Monitored the 20 ha of high intensity (30 %) phosphite application using DMSI. Long term transects established in 1991 within the phosphite treatment zone and within an untreated area were monitored throughout this project.



Appendix 2. The hydrological modelling of the Bell Track catchment integrated soil and vegetation mapping along with Digital Multi-Spectral Imagery to assess the risk of hydrological discharge carrying the pathogen into adjacent catchments.



Appendix 3. The sub-catchment boundaries, drainage connections and sumps within the catchment as determined through hydrological modelling of the Bell Track catchment (A) the shedding landscapes within the catchment based on the digital elevation model (B).

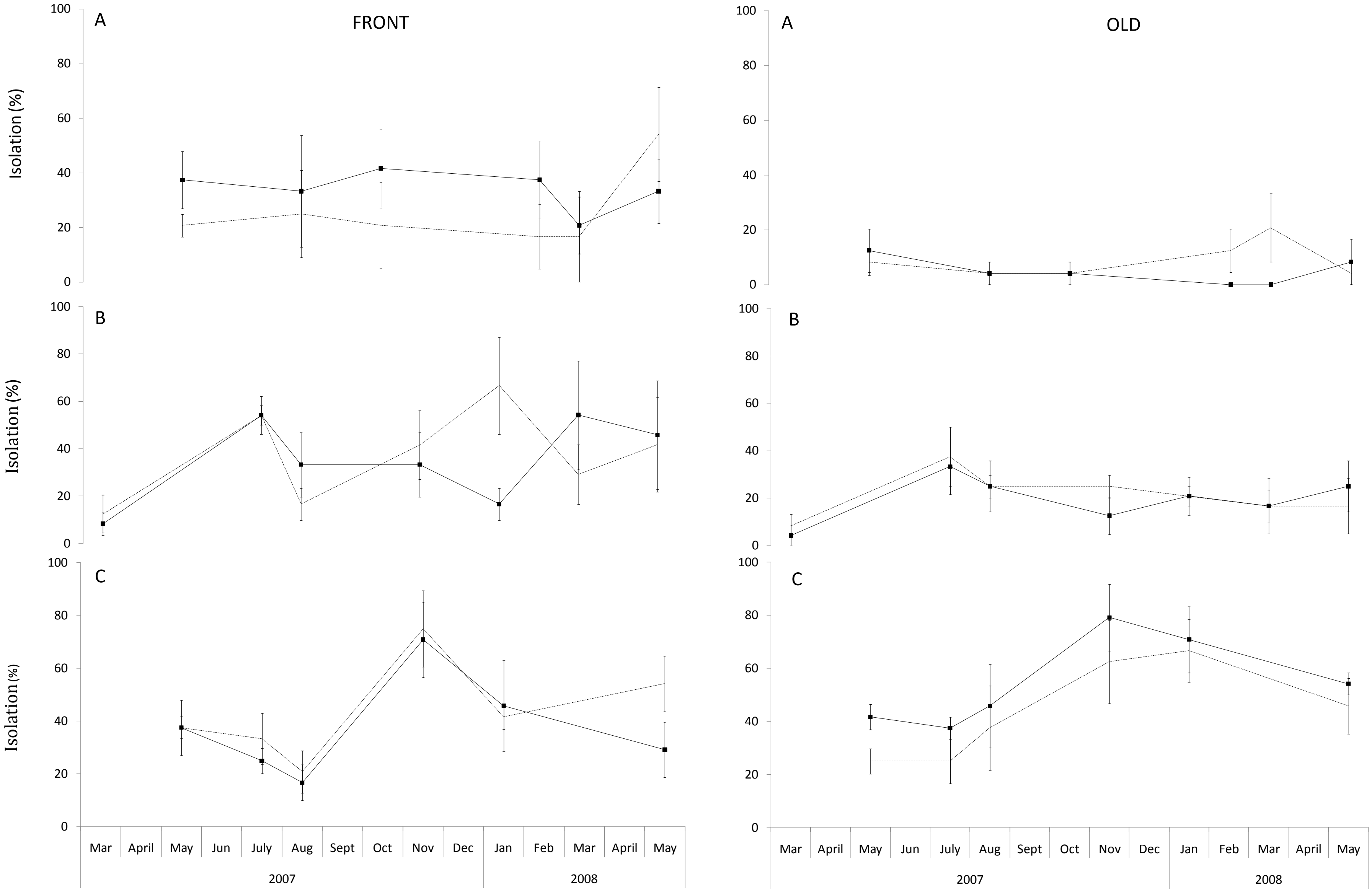


Appendix 4. The hydrological modeling of the Bell Track catchment concluded that no substantial hydrological engineering was required for water collection if a 1 in 1000 year rainfall event occurred within the *Phytophthora cinnamomi* infested catchment.

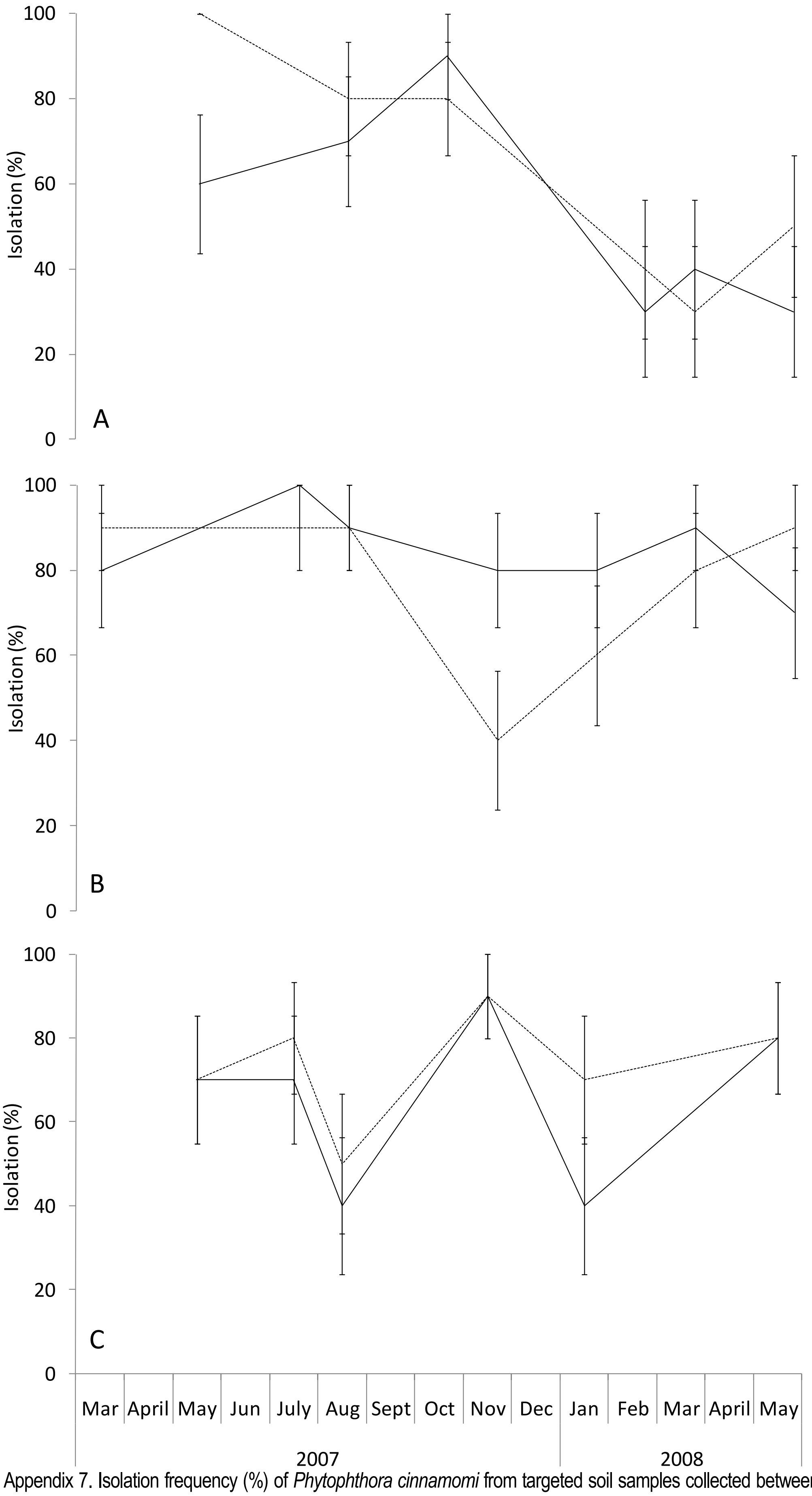
Appendix 5. The management plan for the containment of *Phytophthora cinnamomi* within the Pabelup catchment, Fitzgerald River National Park (FRNP).

Strategy	Activity
Program 1: Planning and Risk Assessment	
Management Plan	Development of a management plan to prevent: (I) the autonomous spread of the pathogen in surface and subsurface water flows; (I) the root-to-root transmission of the pathogen between host plants; (II) animal vectoring within the containment zone; and (III) human vectoring including the risk posed by all on-ground activities relating to this project.
Risk Assessment	A quantitative risk assessment using Bayesian Belief Networks developed a conceptual framework that predicted the outcomes of the proposed controls and interaction of these with key threats to successful containment.
Access & Hygiene Procedures	Hygiene management plans and other planning tools identified the access and hygiene controls required on-site, including: • management access only into the Pabelup containment zone; and • defined access routes, location of hygiene management points and operational signage. All on-site activities that posed significant risk to moving infested soil were required to undertake soil sampling immediately prior to earthworks being conducted as evidence of pathogen freedom.
Project Communication	Key stakeholders including the Conservation Commission of Western Australia were briefed on the project.
Training & Awareness	All staff and contractors were required to adhere to strict entry conditions and undertake training in *Phytophthora* Dieback hygiene.
Program 2: Mapping the Occurrence of the Pathogen	
High Confidence Detection & Mapping of the Pathogen	Comprehensive sampling and interpretation program undertaken to accurately map the occurrence of the pathogen and track disease centre expansion over time. Over 500 soil samples were collected during the project. A broad scale survey was conducted across the catchment including a linear interpretation of nearby fire lines, tracks, roads and drainage areas. This included use of remote sensing to detect changes in plant cell density using Landsat imagery.
Program 3: Implement Containment Strategies	
Establish Containment Zone	Construction of 3 containment zones with solar powered electric fences to reduce the risk of animal and human vectoring.
Implement Access & Hygiene Procedures	Maintain access conditions and ensure compliance with hygiene protocols. Implementation of hygiene management plans for all work conducted on site including the installation of semi-permanent hygiene points.
Implement Containment Techniques	Hydrological engineering controls installed to prevent water-associated spread of the pathogen, including: • bunding installed to manage surface water run-off across the catchment; • the installation of geo-textile filtration systems; and • soil fumigation with granular Metham Sodium within trenches at the geo-textile alignments. The hydrological engineering controls had two aims: (i) contain the infested water within the infested site allowing for filtration of inoculum before the water exits at the bottom of the sub-catchment; and (ii) divert clean water from entering the infested area thereby reducing the hydraulic pressures that could result in pathogen being spread into the incised drainage system at the bottom of the sub-catchment. The final design of the bunding structures and filtration structures using geo-textiles are given in Figure 12. The root-to-root spread of the pathogen was managed by: • herbicide treatment of the entire containment area using Glyphosate to decrease the density of host plants and reduce pathogen activity; and • the installation of root impervious membranes in associated with the installed bunding. Fungicide treatment using Phosphite through aerial application of 14 ha of the Pabelup catchment. Phosphite treatment aimed to prevent disease centre expansion via root-to-root spread, decrease pathogen activity and reduce the impact of the disease within the infested area.
Program 4: Monitoring and Science Based Investigations	
Monitoring the Spread of the Pathogen	A comprehensive interpretation program monitored the pathogen occurrence across the Pabelup catchment and regular re-checks were conducted at high risk locations. Aerial surveillance of the Pabelup and surrounding catchments using a helicopter was conducted in 2010 and 2012.
Hydrological Investigations	Detailed hydrological modelling of the catchment was undertaken, including LiDAR capture that consisted of both a high resolution digital elevation model and 0.5 m contours. Detailed hydrological modelling of the Pabelup catchment using similar techniques to those applied within the Bell Track containment project. This allowed for a comparison of the current *P. cinnamomi* occurrence in relation to catchment

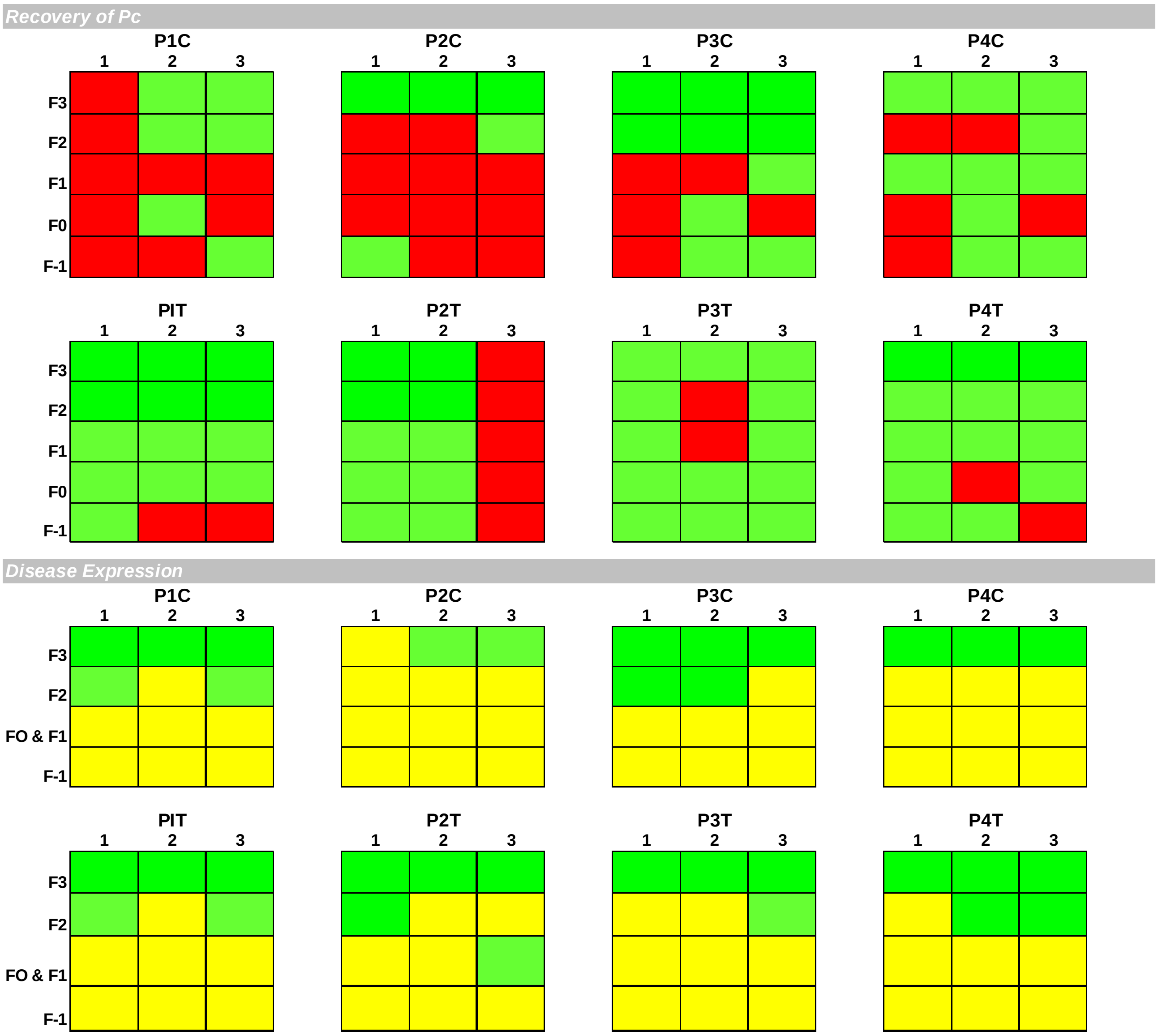
	boundaries to determine where the pathogen is at greatest risk of spreading. The results of modeling demonstrated that the pathogen was contained within one sub-catchment that is connected via defined drainage system to Lake Pabelup further downstream. Therefore the goal was to contain the pathogen in the current sub-catchment and not to allow the pathogen to enter the defined drainage connections that would lead to rapid spread of the pathogen into the surrounding health native vegetation. Two dimensional hydraulic models were used to assess the response of the catchment to both short duration high intensity events and longer duration lower intensity events. The model determined the suitable heights of bunding that would be required to contain the pathogen in its current extent after extreme rainfall up to a 1:500 year rainfall event.
Monitoring Containment Techniques	On-going monitoring of the containment area and surrounding vegetation to demonstrate containment. Broad scale soil and vegetation mapping was conducted across the infested catchment.



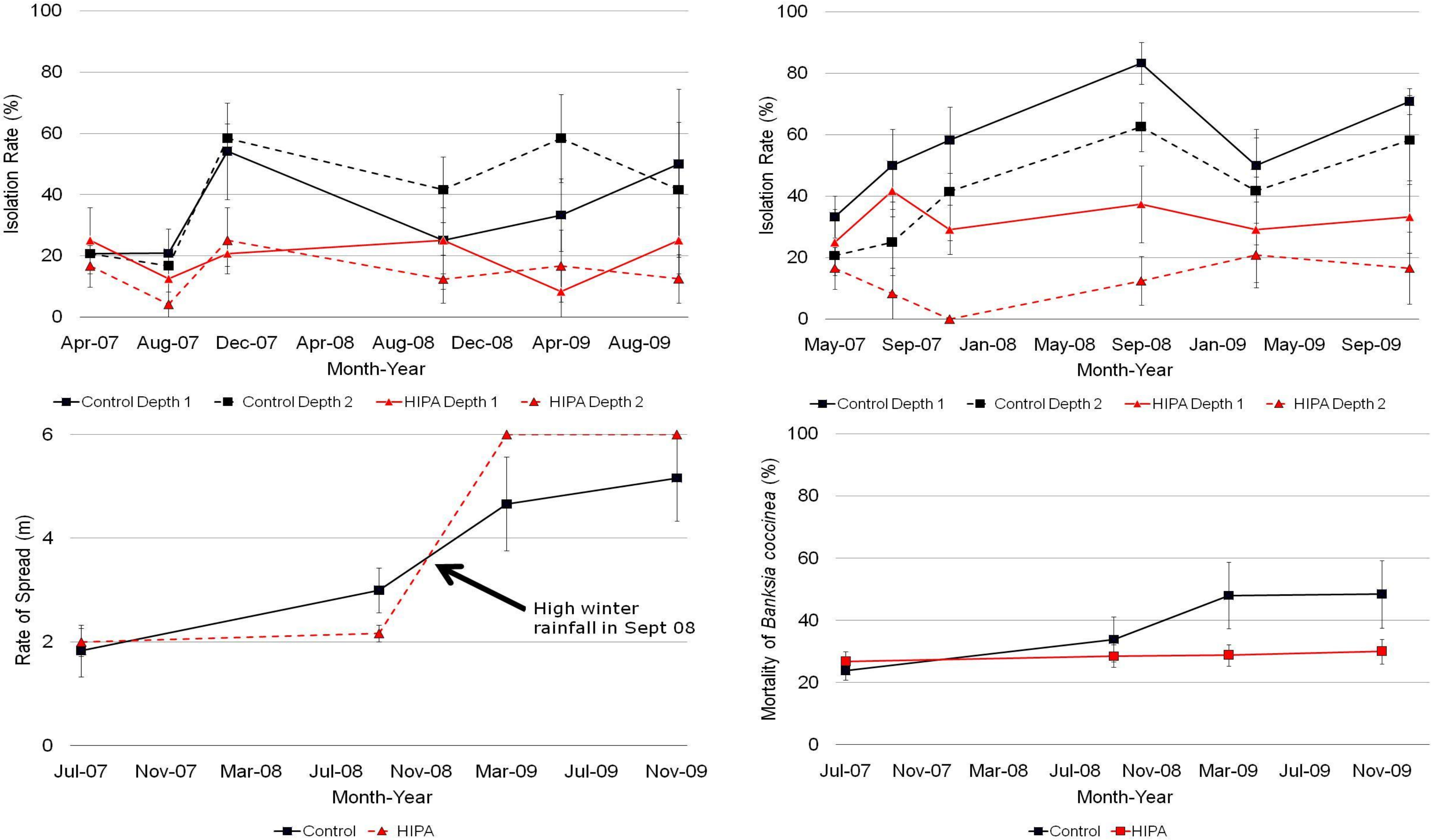
Appendix 6. Isolation frequency of *Phytophthora cinnamomi* from random soil samples collected in plots located on the front and from the old infested area between March 2007 and May 2008 at the Fitzgerald River (A), Gull Rock (B) and Stirling Range National Parks (C). Soil samples were collected from a depth of 10-20 cm (—) at all three sites and either from a depth of 40-60 cm (FRNP and GRNP) or 30-40 cm (SRNP) (---). Standard error bars are shown.



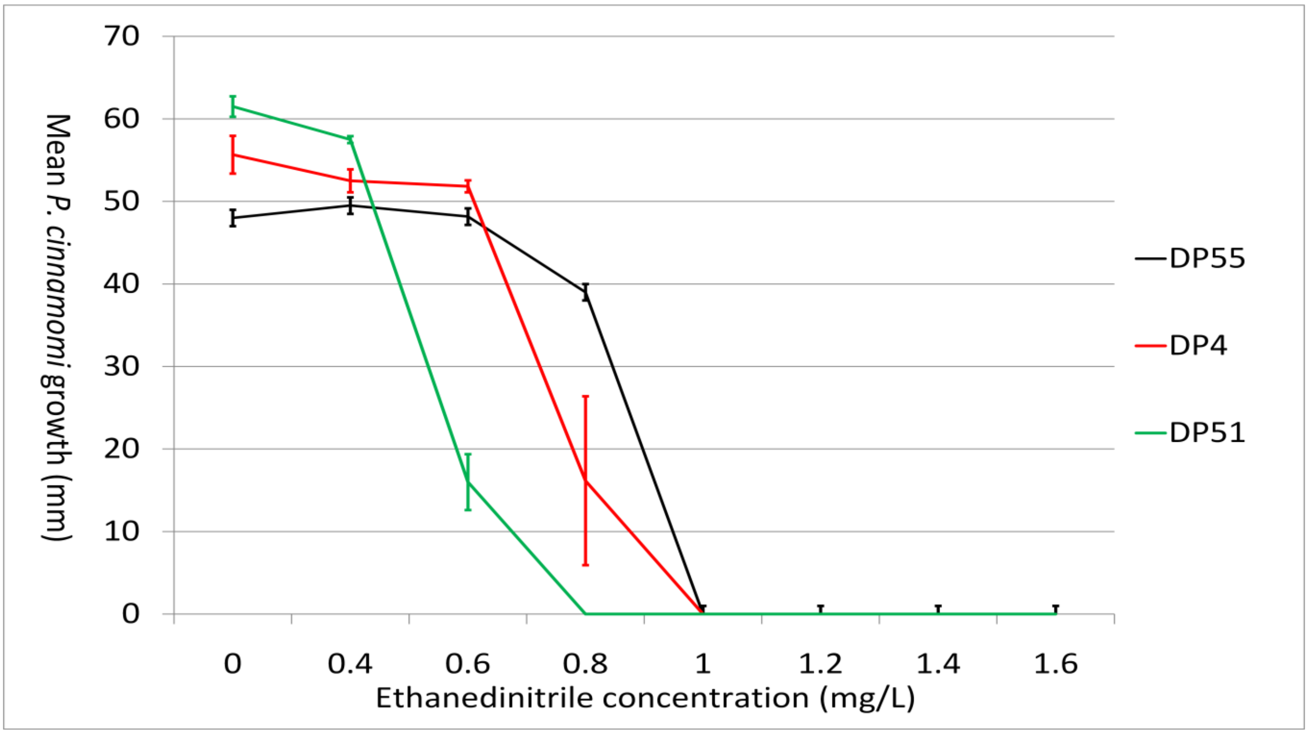
Appendix 7. Isolation frequency (%) of *Phytophthora cinnamomi* from targeted soil samples collected between March 2007 and May 2008 at the Fitzgerald River National Park (A), Gull Rock (B) and Stirling Range National Parks (C). Soil samples were collected from a depth of 10-20 cm (—) at all three sites and either from a depth of 40-60 cm (FRNP and GRNP) or 30-40 cm (SRNP) (---). Standard error bars are shown.



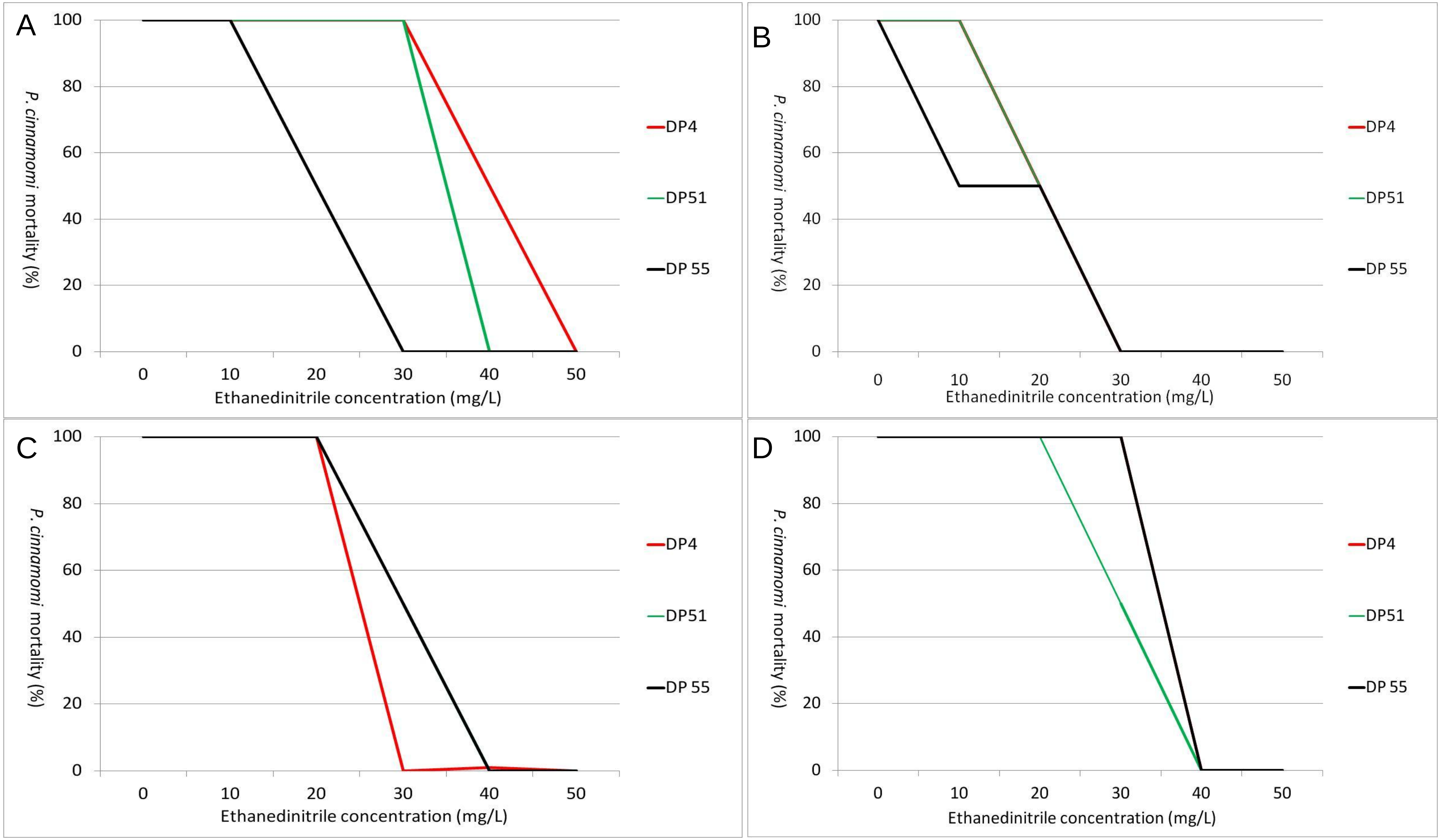
Appendix 8: A graphical representation of the pathogen invasion of monitoring quadrants at Gull Rock National Park as of the November 2009 harvest. In brief the graphic shows: that the pathogen is invading untreated bushland (P1C, P2C, P3C, P4C) faster than the areas treated with 30% phosphite (P1T, P2T, P3T, P4T). This data was 24 months after the treatment was applied. In March 2007 the disease front was located between F0 and F1.



Appendix 9. The frequency of isolating *Phytophthora cinnamomi* within soil samples after High Intensity Phosphite Application (HIPA) at the Stirling Range (A) and Gull Rock National Parks. The treatment had only a minor reduction on the rate of spread of the pathogen at the Stirling Ranges (C) but was highly effective on the deep sand heathlands at Gull Rock with reduced mortality of *Banksia coccinea*.



Appendix 10. The effiacy of the fumigant, Ethanedinitrile on the survvial of *Phytophthora cinnamomi* grown on agar plugs. Three different *P. cinnamomi* isolates were tested (DP55 from Bell Track plus DP4, DP51).



Appendix 11. The effectiveness of the fumigant ethanedinitrile to eradicate *Phytophthora cinnamomi* in wooden plugs within flasks containing soil. Two soils types were tested including south Bell Track deep sands (A) at< 1 % and (B) 5 % soil moisture; and Pabelup clay soils(C) at< 1 % and (D) 5 % soil moisture. Three different *P. cinnamomi* isolates were tested (DP55 from Bell Track plus DP4, DP51).