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FORTESCUE METALS GROUP LIMITED

Cloudbreak Life of Mine Expansion

Surface Water Investigation and Impact Assessment

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PROJECT 201012-00252/CC011-00018-PH-HY-0001 - CLOUDBREAK LIFE OF MINE EXPANSION

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Appendices

1. INTRODUCTION

1.1 This Document

This report describes the potential impacts on the existing hydrological processes of the Cloudbreak Life of Mine Expansion and surface water management strategies to mitigate any impact. The report also describes the expected level of impact of the development after the application of the proposed surface water management strategies. This report is intended to guide ongoing development of the Project Surface Water Management Plan.

1.2 Purpose and Scope

This report defines the management strategies to be applied during construction and operation of the proposed Cloudbreak Life of Mine Expansion.

The objectives relating to surface water management include:

- Maintain the existing integrity, functions and environmental values of watercourses and sheet flow areas;
- Maintain quantity and quality of surface water flows to the Fortescue Marsh;
- Maintain runoff processes and landform integrity around the Fortescue Marsh;
- Limit disturbance from clearing, excavation and construction in and around watercourses and sheet flow areas; and
- Maintain the existing baseline quality of surface water so that existing and potential environmental values, including ecosystem maintenance, are protected consistent with the *Australian and New Zealand guidelines for fresh and marine water quality* (ANZECC & ARMCANZ, 2000).

In achieving these objectives, the report will also assist in maintaining functions addressed through the Project Groundwater Management Plan.

Key project surface water management performance indicators are:

- Maintain the quantity and quality of surface water flows upstream and downstream of disturbance areas;

- Surface water runoff does not result in significantly increased offsite sediment transport or water turbidity (based on Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand Guidelines for Fresh and Marine Water Quality 2000 (ANZECC/ARMCANZ, 2000); and
- Maintenance of significant vegetation beyond the approved disturbance corridor due to alterations in surface water flow, quality or quantity.

1.3 Relevant Legislation

- *Rights in Water and Irrigation (RiWI) Act 1914 (WA)*
- *Wildlife Conservation Act 1950* (WA)
- *Dangerous Goods Safety Act 2004* (WA)
- *Environmental Protection Act 1986* (WA)
- *Environmental Protection (Unauthorised Discharge) Regulations 2004 (WA)*

1.4 Definitions and Abbreviations

Table 1 - Definitions and Abbreviations

Abbreviation	Description
ANZECC	Australian and New Zealand Environment Conservation Council
DoW	Department of Water
EMP	Environmental Management Plan
EMS	Environmental Management System
FMG	Fortescue Metals Group Limited
GMP	Groundwater Management Plan
SWMP	Surface Water Management Plan
TPI	The Pilbara Iron Ore and Infrastructure Project

2. SITE DETAILS

2.1 Life of Mine Plan

The full plan for the Cloudbreak Life of Mine is shown in Appendix 1. An outline of the current Part IV (EPA act, 1986) approved disturbance areas is shown in Appendix 4. This report concerns the impacts this development has outside the existing approved disturbance areas. This includes activities that take place within the existing approved disturbance areas that may have impacts further downstream, away from the development.

The Cloudbreak Life of Mine plan shows a series of pit developments, waste dumps, haul roads, dewatering infrastructure and a proposed above ground ore conveyor, developed in 16 mining stages over the next 14 years, commencing in July 2010. The initial developments are mostly within the existing approved disturbance area and from the 7th stage onwards, gradually extend further west. While pits progressively open and close, being finished at the natural surface level, this study assumes that waste dumps are retained and remain after the completion of the project.

Infrastructure associated with the proposed Cloudbreak Life of Mine Expansion is sited on the band south of the ranges and within the foothills of the ranges themselves. The proposed infrastructure includes:

- Pit developments and waste dumps, typically located between 3 and 5 km north of the Fortescue Marsh shoreline on the band of low relief terrain and occasionally within the steeper foothills of the Chichester Ranges;
- De-watering infrastructure including settlement and transfer ponds, typically located just outside the southern extremity of the proposed future pit expansions;
- Groundwater re-injection infrastructure including pipes, pumps and bores typically located south of the de-watering infrastructure, in some cases within 1 km of the Fortescue Marsh shoreline;
- Ancillary facilities including administration buildings, workshops, crib rooms and fuel farms;
- Access and haul roads connecting the various elements of the mine site; and
- An above ground conveyor transporting ore back to the Cloudbreak Ore Processing Facility.

Existing infrastructure including railways, existing pits and dumps and the Ore Processing Facility are within the bounds of an existing approved disturbance area.

2.2 Development Scenario Assumptions

Mine planning activity associated with the Cloudbreak minesite can be broadly split into short, medium and long term planning. The Cloudbreak Life of Mine plan falls within the long term planning, while medium term planning addresses a period 6 to 18 months ahead. Short term planning is effectively operational planning, assessing a window from 2 weeks to 12 months in advance of current developments. This distinction is important because this study addresses the impact of the Life of Mine plan. The operating reality is slightly more detailed and assumptions have been made to enable assessment at the Life of Mine timescale.

During operations, typically only a small proportion of a pit shell is open at any one time. Furthermore, a typical development (removal of overburden, ore mining and backfilling) of a given area takes place over a shorter period than 12 months. Usually only the area within the pit shell being mined is acting as a hydraulic obstruction – not the entire pit shell. So while a pit shell may be open throughout a given mining stage, only a small proportion is acting as a hydraulic obstruction at any one time. The Life of Mine plan provides no details as to the sequence of development at within a given mining stage and spatial scales smaller than an entire pit shell. Therefore the following assumptions are required to estimate the impacts of pit developments on surface hydrology:

1. The entire area of a pit footprint in a given phase is developed (and therefore acting as a hydraulic obstruction) at the same time.

2. Pits are developed (opened, mined and closed) over the entire period within each phase.

These assumptions are expected to lead to higher estimates of impact discussed in section 4. Cases where full continuous pit development is not technically feasible have been identified and are also discussed in section 4.

3. HYDROLOGY

3.1 Regional Hydrology

The local region surrounding the proposed life of mine development area includes several significant water features and ecosystems that may be impacted on by the development. The Cloudbreak Life of Mine Expansion covers an area of the Chichester Range which drains in a southerly direction towards the Fortescue Marsh. Over time, the larger catchments draining the Chichester Ranges have formed a series of floodplains, alluvial fans and sheet flow zones that form a band of low relief terrain between ranges and the Fortescue Marsh. This band runs east-west along the northern edge of the marsh, between 5 and 10 km from the base of the Chichester Ranges and sloping at around 0.3%.

3.1.1 Fortescue Marsh

The Fortescue Marsh is an extensive, intermittent wetland, bound by the Chichester Range to the north and the Hamersley Range to the south, occupying an area of approximately 1,000 km^2 when in flood (Department of Environment, Heritage, Water and the Arts (DEHWA) 2008). Previous studies have established that the Marsh is predominantly a surface water fed rather than a groundwater fed feature, on the basis that water levels in the uppermost (alluvium) aquifer within the surrounding plain are below the bed of the Marsh, and the marsh water is hypersaline (Environ Australia Pty Ltd 2005).

3.1.2 Sheet Flow Areas and Dependent Vegetation

Mulga communities around the Fortescue Marsh occur in banded patterns across low relief terrain. The distinctive vegetation pattern is comprised of bands or groves of *Acacia anerua* trees of about 30% canopy cover and an intergrove area of grass or forb-land (Anderson & Hodgkinson, 1997). The banded patterns, (Figure 1 and Figure 4), are thought to be dependent on sheet flow from the intergrove areas immediately upslope of each band and on the high infiltration of water flowing overland into the soil of the mulga bands. The water transports nutrients and organic matter creating fertile patches of land in the mulga groves where the flow is concentrated and distributed around the plants that act as obstructions to flow across the slopes (Anderson & Hodgkinson 1997). The groves are the fertile patches of land where water and nutrients are concentrated in the mulga ecosystems. Grove/Intergrove mulga communities are mainly concentrated on the lower flanks of the Chichester and Hamersely Ranges adjacent to the Fortescue Marshes.

3.1.3 Cultural Significance

The Fortescue Marsh and some semi-permanent water pools along its northern shoreline have been identified as having high cultural significance. The semi-permanent water pools or “yintas” are

typically located near where major creeks such as Goman Creek and Christmas Creek discharge into the Fortescue Marsh.

3.2 Site Hydrology

Within the development site itself, there are several different forms of surface water flow, each requiring a unique management approach. In a hydrological sense, the catchment of the study area and surrounds can be divided into several zones based on runoff generating mechanisms, including:

- Hillslope Runoff;
- Channel Flow;
- Diverging Flow; and
- Sheet flow.

Some areas, including those closer to the shore of the Marsh, may exhibit one or more of these characteristics.

3.2.1 Hillslope Runoff

Hillslope runoff zones are located in the portion of catchments where the majority of runoff is contained within small creeks, broad swales or gullies. Naturally, flows are generally convergent which concentrate flows, increases velocities, promotes scour and enhances channel formation. Catchment sizes are usually small but can be larger in cases where the terrain is flat and velocities are insufficient to maintain well defined channels. Areas with Hillslope runoff characteristics are shown in Figure 1.

Location 'A' is an area typical of the broader Chichester Ranges including most of the catchments with concentrated flows and small, well defined channels with characteristics of gullies and small creeks. These catchments have steep slopes and surface runoff travels short distances before reaching the channel.

Location 'B' is more typical of waterways with large catchment areas and mainly low relief terrain. Most of these catchments are characterised by channels which have a similar appearance to broad swales. In some cases channels are not easily distinguished, so preferential flow paths can be identified through analysis of vegetation patterns. This is distinct from sheet flow areas where there are no preferred flow paths and vegetation forms banded mosaic patterns (figure 1).

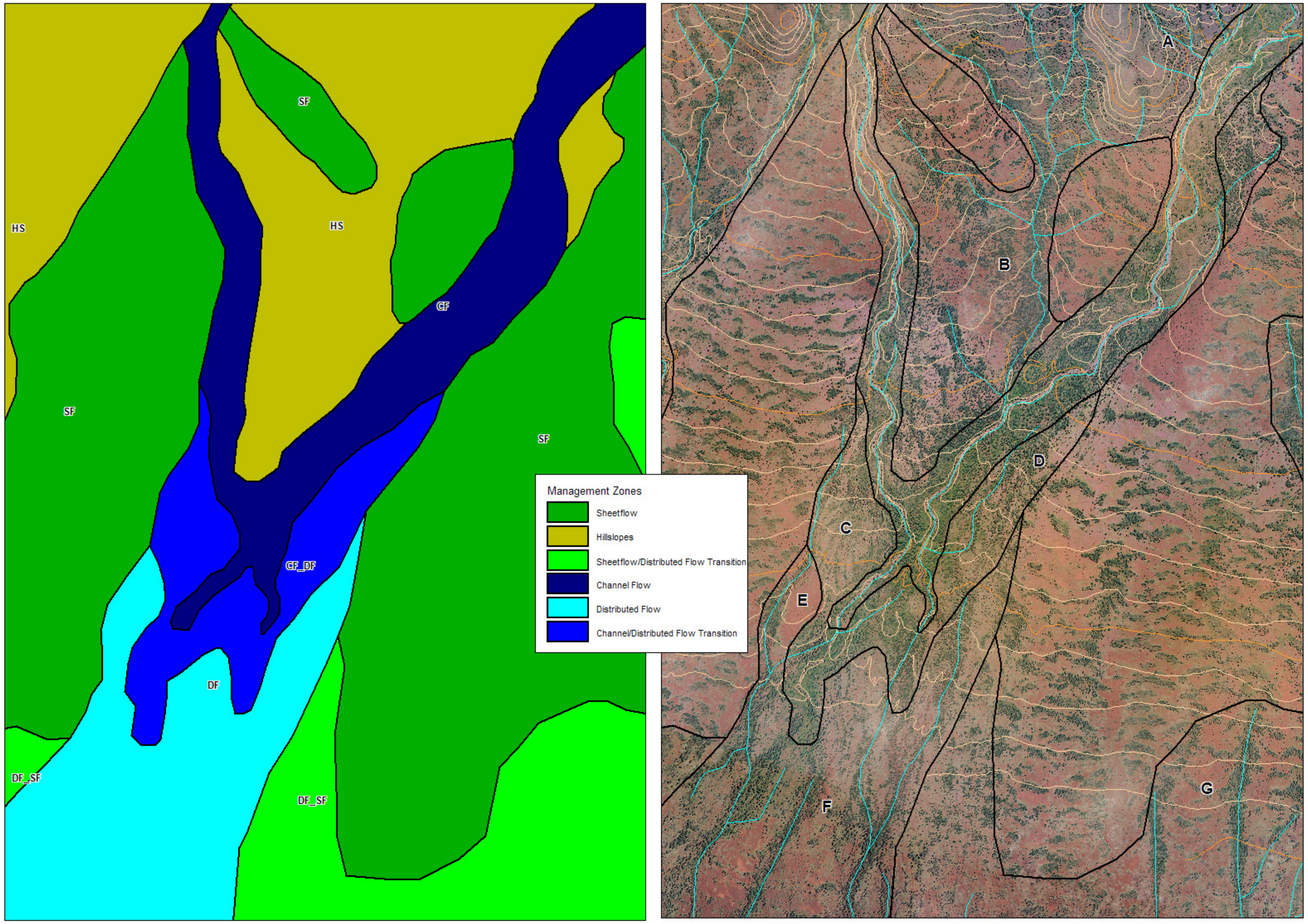

Figure 1 - Example of Flow Type Mapping in the Cloudbreak Project Area

3.2.2 Channel Flow

Channel Flow zones are located in the portion of catchments with large channels and adjacent floodplains. These zones are associated with large catchments that predominantly drain the steep areas of the Chichester Range rather than the low relief terrain closer to the Fortescue Marsh. Large convergent flows, high velocities and large, well defined channels are typical of these creeks. Smaller, more frequent flows are mostly confined to the channel while larger and less frequent flood flows break out onto the adjacent floodplain. These zones can be identified using topographic information and vegetation patterns in aerial photos. Channels are usually devoid of vegetation due to bed load movement during flood events. Vegetation on the adjacent floodplains is maintained either by periodic inundation or has rooting depths sufficient to access the superficial fresh aquifer replenished by more frequent smaller flows.

Areas with concentrated Channel Flow are shown in Figure 1. Two large channels discharge floodwater south from the Chichester Range onto the low relief terrain north of the Marsh. Catchment areas for creeks at location ‘C’ and ‘D’ are 12 and 18 km^2 respectively. The aerial photo shows that the resulting creeks have main channels widths between 30 and 40 m and adjacent floodplains between 100 and 200 m in width. As the creeks flow further south, the low gradient reduces stream velocities and the creek transitions into diverging flow.

The results from 2D hydraulic flood modelling conducted for the TPI Project are shown in Figure 2 and Figure 3 with an aerial image of the area shown in Figure 4. These figures show modelled inundation extents for a 20 and 100 year average recurrence interval (ARI) design storm events. In the 20 year ARI flood, the model predicts that the inundated area would be confined to the floodplain with no connectivity with the adjacent sheet flow area. Some shallow inundation of sheet flow areas is shown resulting from the 100 year ARI flood. The two creeks shown in these figures have larger catchments (22 and 40 km^2 respectively) with 50 m wide creeks and 500 m wide floodplains.

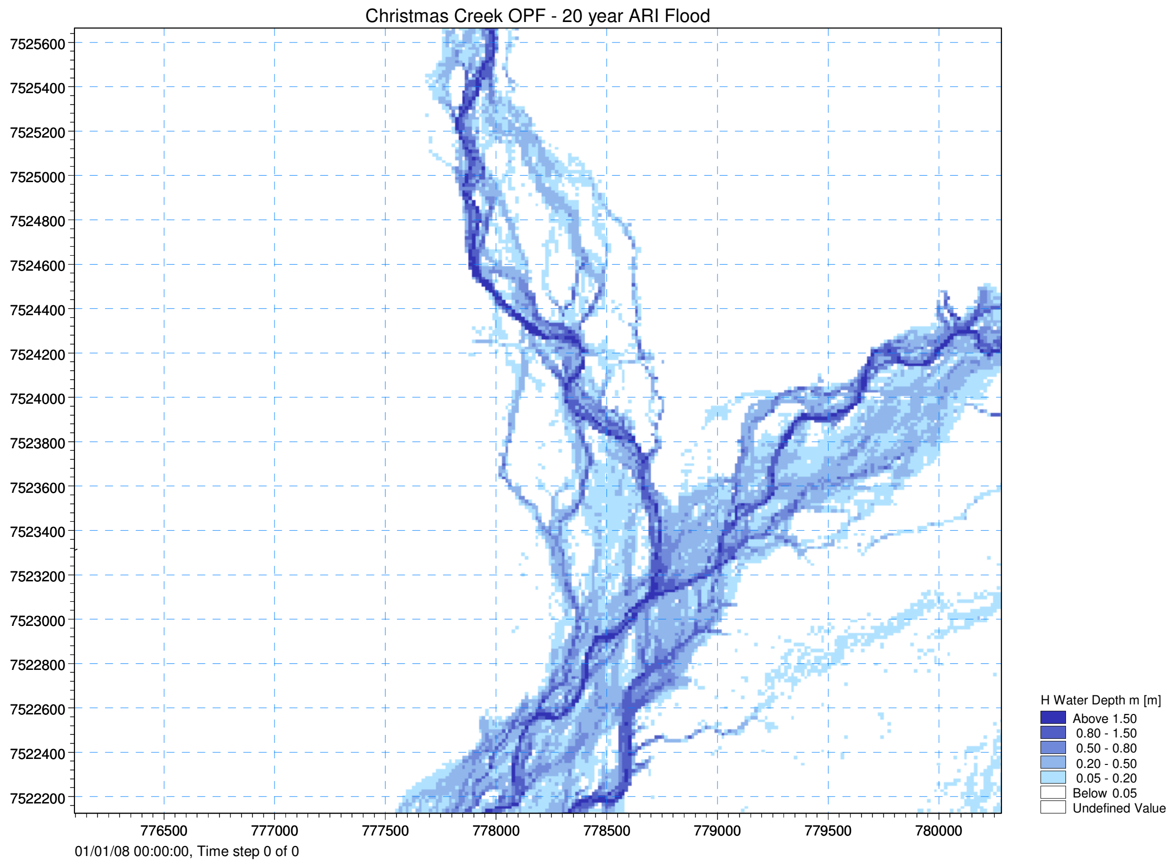

Figure 2 – Estimated 20 year ARI Flood Extent for two creeks discharging from the north into the Fortescue Marsh

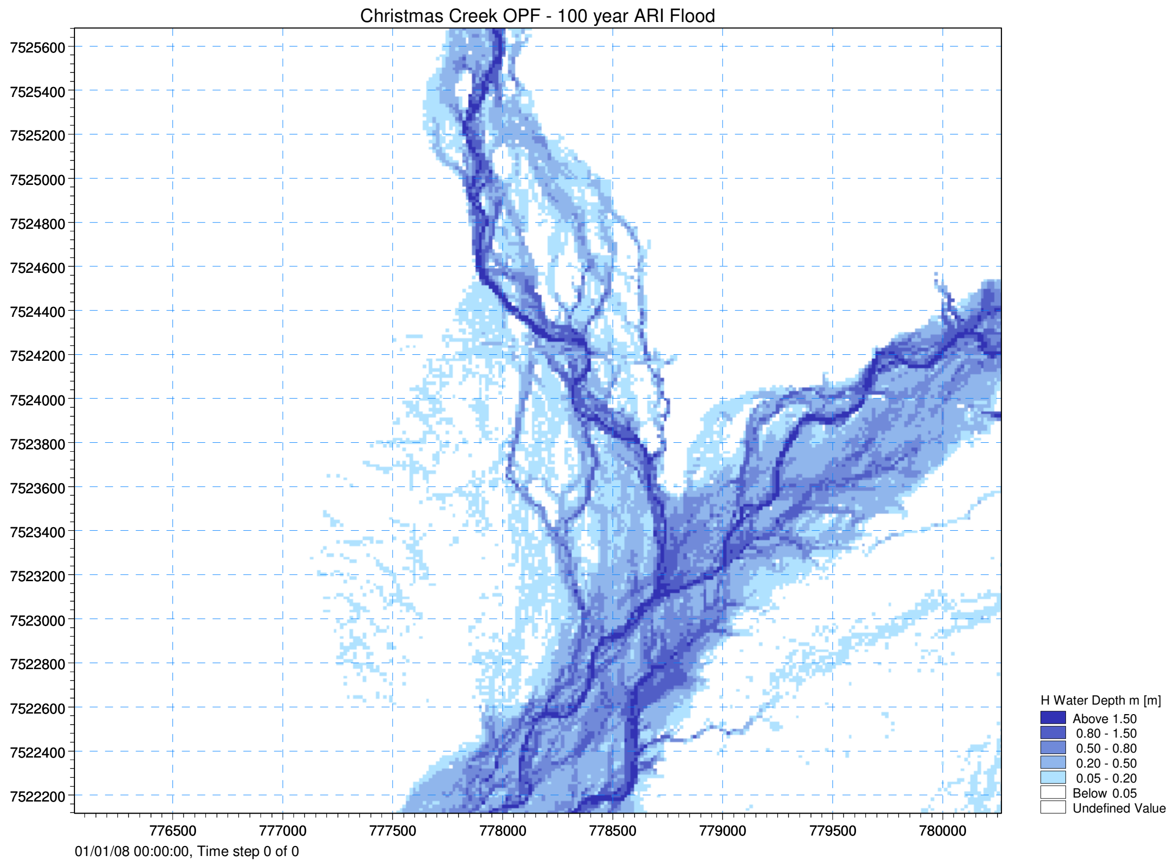

Figure 3 - Estimated 100 year ARI Flood Extent for two creeks discharging from the north into the Fortescue Marsh

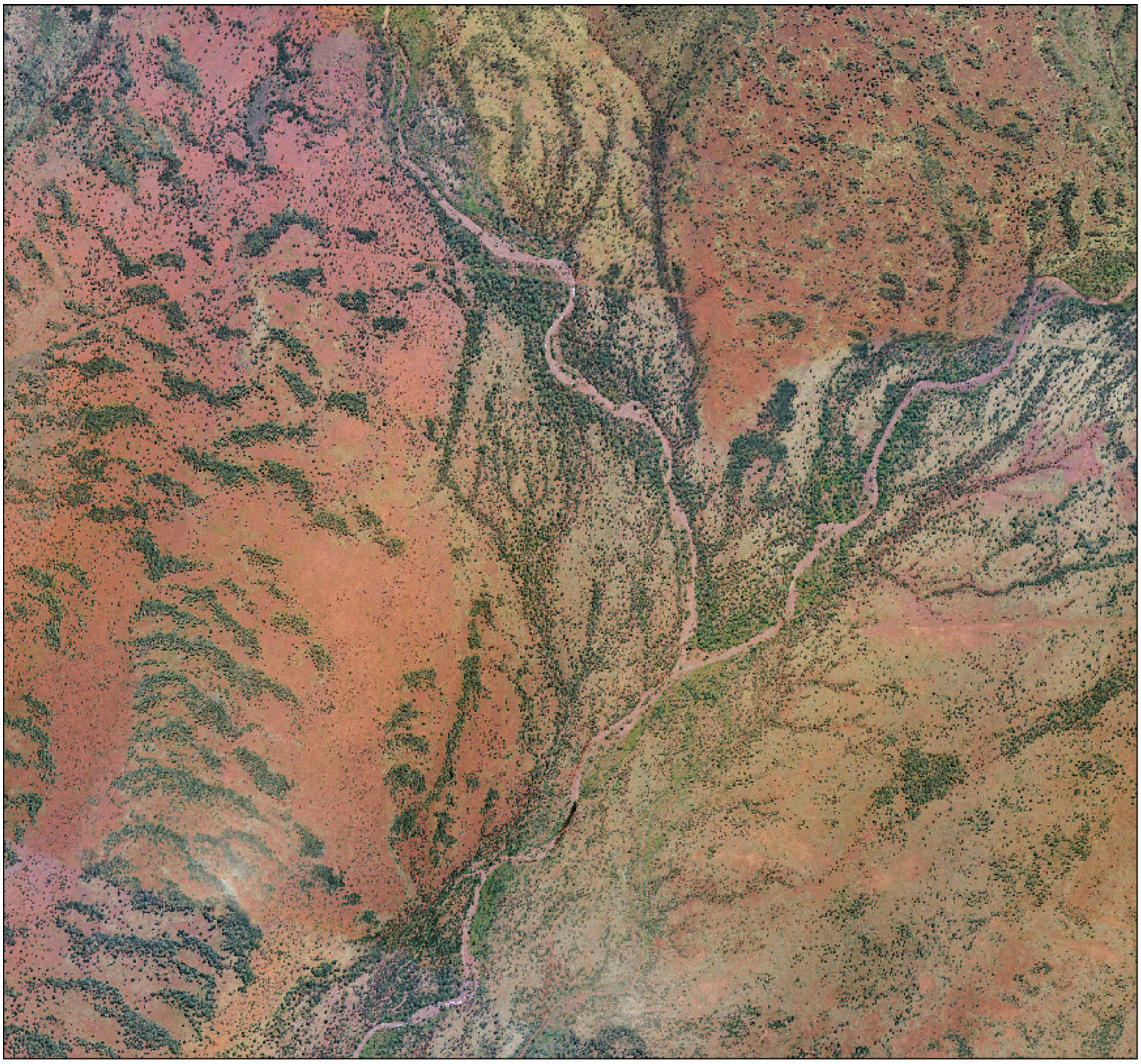

Figure 4 - Aerial Imagery of for two creeks discharging from the north into the Fortescue Marsh

3.2.3 Diverging Flow

Diverging flow areas are located in the portion of catchments where channel flow has become dispersed, leading to a loss of channel form. The transition from channel flow to diverging flow normally occurs on the low relief terrain after large rivers have discharged from the Chichester Ranges. The distance that the channel form is maintained is proportional to the slope of terrain and the size of the flows generated by a catchment (i.e. the greater the flow, the more well defined the channel is further downstream). Sandy Creek is an example where although flows disperse across

the alluvial fan, some channel form is maintained all the way to the Marsh shoreline. The width of the main Sandy Creek channel reduces from 50 m at the base of the Chichester Ranges to around 5 m at the Marsh.

Diverging flow zones are shown in figure 1a and 1b. The initial transition from channel flow to diverging flow is seen at 'C' and 'D', where breakout channels begin to form and the floodplains become wider. Other breakouts and bifurcation occur further upstream, but within a clearly defined floodplain of a relatively constant width. As the creeks progress downstream, a higher proportion of flows are conveyed over the floodplains and the channels become narrower. At 'F' the floodplain is over 1 km wide with the two main creeks having transformed into a series of small, interconnected swales which combine to convey the flow.

Banded grove-intergrove vegetation patterns typical of sheet flow areas are not normally found downstream of areas where diverging flows intersect with sheet flow zones. Sheet flow zones form in 'fan' like terrain such as seen at location 'B' on figure 1a. Once sheet flow reaches a swale, the flows are concentrated, which supports continuous tracts of vegetation.

3.2.4 Sheet Flow

Sheet flow zones form in areas where overland flow moves down slope while maintaining a broad shallow front. This is the initial hillslope response to infiltration excess prior to channel initiation. Channel initiation is dependent on a threshold level of stream power, controlled in part by the extent of flow convergence and gradient. There are many examples in the study area where the terrain has been formed by remnant alluvial fans. These areas do not promote convergence of flows and are relatively flat, causing sheet flow zones to be maintained over large areas.

The banded Mulga (*Acacia aneura*) formations common throughout the study area as discussed in section 3.1.2, are part of an ecological response to the sheet flow patterns. The banded patterns, shown in figure 1a, are thought to be a result of ecohydrological processes that concentrate water and nutrients at the grove areas. The "trigger-transfer-reserve-pulse" concept (Ludwig, *et al*. 2005, Ludwig, *et al*. 1997) suggests that following rainfall (the "trigger"), low infiltration rates at intergrove areas (10-15 mm/hr) result in sheet flow and the transport ("transfer") of water and nutrients (via leaf litter) downstream to the grove areas. Higher infiltration rates at the grove areas (75 mm/hr) enable storage of water and nutrients ("reserve") leading to a "pulse" of plant growth. These points of accumulation are critical for arid rangeland ecology, they form biological hot spots in which organic matter and nutrient cycling processes are prevalent. The accumulation of moisture and nutrients provide the conditions for biogeochemical cycling required to sustain arid rangeland ecosystems.

Other papers have suggested that mulga groves are less dependent for survival on intergrove processes and more dependent on direct rainfall. Dunkerley (2002) suggests that the leaf structure and inward sloping stems of Mulga trees promote "stem flow", directing rainfall towards the stem at

the base of the trees where infiltration capacity is highest (up to 292 mm/hr). This is due to not only the direct physical distribution of water along the stem but also the improved soil structure due to higher organic matter. Infiltration rates were shown to decrease as distance away from the stem increases. Dunkerley (2002) also states based on earlier studies that "…rather than the survival of groves being consequent upon the additional water supplied from the intergrove upslope, there was considerable dependence on the internal processes of canopy interception and stem flow, together with marked spatial variability of grove soil properties."

3.3 Catchment Characteristics

A series of large catchments run through the site, from north to south. The headwaters of these catchments are located in the Chichester Ranges, where hillslope processes initiate surface runoff. Typically, channel form is enhanced as flows move further south before water discharges onto the flatter zones closer to the Fortescue Marsh. Channel form diminishes as water flows over the flat terrain becoming more distributed. The proposed Cloudbreak Life of Mine Expansion includes areas within the hilly terrain of the Chichesters and on the lower slopes of the flat area adjacent to the Fortescue Marsh. This means all flow types discussed in section 3.2 are encountered.

Catchment outlines and mainstreams are shown in Appendix 2. This includes a summary of catchment details. 100 year ARI flow estimates shown in Appendix 2 were estimated using the Regional Flood Frequency Procedure (RFFP - Flavell, 2005). The RFFP is a proprietary flood estimation methodology. Standard Australian Rainfall and Runoff flood estimates have not been updated since 1987 and the RFFP incorporates extensive flow records taken since then.

4. POTENTIAL SURFACE WATER IMPACTS

This section describes how surface water impacts were quantified, either in terms of area impacted or changes in water balance. These methods were then used to estimate potential impact relative to natural conditions. The management strategies outlined in section 5 are aimed at mitigating adverse impacts of development. Potential impact (relative to natural conditions where applicable) are presented in more detail in Appendices 3, 4 and 5.

4.1 Altered Flood Regime

The Life of Mine Expansion has the potential to alter the areas subject to inundation and flow velocities resulting from both infrequent extreme flooding and more regular, lower magnitude flows. A range of vegetation types depend on or are sensitive to periodic inundation while velocity changes can lead to water quality issues and sedimentation. Hydraulic modelling of extreme floods was conducted to assess the changes to inundated areas and velocity for each phase of the Cloudbreak Life of Mine Expansion including post-closure.

4.1.1 Assumptions and Methodology

Pits and dumps are the specific elements in the Cloudbreak Life of Mine Expansion which are likely to have the greatest impact on flood inundation extents and velocities. Pits are bunded while dumps are raised well above the ground level. In both cases, these features were assumed to be hydraulic obstructions blocking flow and not subject to inundation. Other infrastructure such as haul roads and dewatering pipes are only expected to have a small impact at their immediate location and were not included in the large scale hydraulic models.

The selected modelling methodology was deemed to be the best available approach that could be applied within the time constraints associated with the study. A 1-dimensional hydraulic modelling program (HEC-RAS) was used to estimate water levels while the HEC-GeoRAS add-on to the GIS software ArcGIS was used to determine the extent of inundation based on the modelled water levels.

The open channel flow modelling program HEC-RAS 4.0 (US Army Corps of Engineers, 2006) was used to estimate the inundation extent and channel velocities resulting from 2 and 100 year ARI flows through a series of major catchments near the site. HEC-RAS takes channel information such as stream cross section geometry, bed roughness and long-section slope and solves the one dimensional energy equation for steady open channel flow for the user specified flow rates. The model outputs water levels and velocities at each cross section. A summary of input data, hydraulic parameters and cross section details is provided in Appendix 6.

For this project, cross section geometry was derived from 1 m contour data supplied by the client. Contours were used to interpolate a TIN model which were in turn used to generate cross sections, centrelines and overbank stations at selected river reaches. The cross sections were imported into HEC-RAS and assigned uniform Manning's N roughness values of 0.045 for channel areas and 0.055 for overbank areas. The peak flows in table 2.1 were applied to the model as steady state flows. The resulting water levels were then exported out of HEC-RAS. Flood extents for areas between the cross sections were derived from the interface lines resulting from the intersection of by intersecting the water surface TIN estimated in HEC-RAS with the TIN models used to generate the cross sections.

4.1.2 Model Results

Modelled water levels, velocities and inundation extents are shown in Appendix 3. The hydraulic model setup and estimated 100 year flood extents shown in Appendix 6 demonstrate some of the limitations of the modelling approach. While the modelled extents are highly sensitive to the TIN interpolation process and the placement of cross sections, it is expected that model water levels and average cross-sectional velocities are conservative, but representative of on ground conditions and suitable for this level of investigation. The limitations of the adopted approach also include:

- The use of steady state flows rather than time varying hydrographs discounts the role of in-stream storage in attenuating flood peaks, leading to slight over prediction of water levels.
- dimensional (1-D) models can have difficulties representing flows in areas with poorly defined channels and unconfined floodplains. Flows are confined to the model domain which are determined by the chosen cross sections. These models are likely to under-predict the out of channel flood extents, and over predict the depth of flooding.
- Low resolution topographic data used to generate the TIN was the best quality data available at the time. Errors associated with interpolating a TIN from contours tend to be greater around ridges and valleys as well as around the main channels of waterways and drainage lines.
- The HEC-GeoRAS program does not handle overlapping 1-dimensional domains well, which can lead to irregularities in the predicted flood extents. Evidence of this can be seen in the flood boundaries presented in WCB02 and WCB03.

Flood flows in the study area would be better represented by a 2-dimensional (2-D) model such as MIKE-FLOOD. Figures 2 to 4 show the results of 2-D hydraulic modelling using MIKE-FLOOD in terrain similar to the study area (area north of the Fortescue Marsh). The results more accurately predict the depth and extent of flooding. While 2-D modelling produces more accurate results, the time needed to set up and run 2-D models is far greater than what is needed to set up 1-D models.

4.1.3 Potential Impacts - Flood Extents

The resulting 100 year ARI inundation extents for each phase of the Cloudbreak Life of Mine Expansion and post-closure are shown compared to a pre-development case in Appendix 3. In some cases, a pit is shown completely blocking the path of a main channel with no reasonable prospect of diverting the water around the pit. For such a pit arrangement to be technically feasible and avoid the high risk of pit inundation, the assumptions in section 2.2 must be ignored. In the cases shown, a narrow section of the main channel has been retained in the hydraulic model for the indicated reaches.

The estimated impact areas for each mining phase is shown in Appendix 3, table 3.1 and 3.2 for 2 and 100 year ARI floods respectively. Prior to the 7th phase, developments and their impacts are confined to existing approved disturbance areas. In the 7th and 8th phase, no significant impacts are seen, with pit developments either in existing approved disturbance areas or hilly terrain away from major creeks. From the 10th phase onwards, the impacts vary with typically around 2-3 km^2 of inundated areas becoming dry during a 100 year event (0.1-0.7 km^2 for a 2 year event) with around 0.7 km^2 of previously dry areas becoming inundated. The increasing and lasting impact of the dumps is seen in the post closure stage where the dumps remain after mine closure.

4.1.4 Potential Impacts - Flow Velocities

The estimated cross sectional velocities for 2 and 100 year ARI floods at selected sections of each river are shown in Appendix 3, table 3.3 and 3.4. The tables also contains a comparison between each mining phase and pre-development conditions. The entire cross section was used for the analysis, including the floodplain areas. Actual channel velocities are expected to be much higher within the channels, however the percentage increase or decrease in overall cross sectional velocity is indicative of changes to channel velocity.

For the 100 year ARI flood, the impact was typically an increase in flow velocity. Proposed pits and dumps encroach on the floodplains, reducing the overall flow path width resulting in a velocity increase. The biggest impacts are seen in the 10th and 11th phases, where velocities increase up to 100% for WCB03 and WCB04 catchments. The remaining phases have similar impacts, increasing west into WCB02, WCB01 and WCB00 catchments.

For the 2 year ARI flood, the estimated impact was often a decrease in velocity. This is likely to be the result of flows being pushed out of the main channels, into the flatter floodplain areas. In some cases where flows returns to the main channel, large increases in velocity, up to a tripling of the initial value can be seen. The biggest impacts are seen in the 10th and 11th phases, where velocities greatly vary in WCB04, WCB05 and WCB06 catchments, with changes ranging from 80% decreases to 300% increases. The remaining phases have much lower impacts, with velocities typically not changing by more than 40%.

4.2 Disrupted Sheet Flow Processes

As discussed in section 3.2.4, sheet flow is an important process on which high conservation value vegetation communities (Mulga) depend for survival. Pits, dumps, haul roads and access roads associated with dewatering infrastructure all have impacts both directly within the development footprint and areas on the downstream side. Management strategies for mitigating the overall potential impacted area focus on minimising the disruption to downstream impacts.

4.2.1 Assumptions and Methodology

Areas where sheet flow coincides with Mulga have been mapped throughout the project area. All areas where the typical banded grove-intergrove formation was seen in the project area was assumed to be sheetflow dependent mulga. These patterns discussed in section 3.1.2 were identified via aerial photo interpretation. The aerial photographs, supplied by FMG were taken as part of an airborne terrain survey and can be considered to be of a high quality. An example of such interpretation and an indication of the quality of images is shown in Figure 1.

The potential impact on sheet flow processes has been described in terms of the level of impact. An area is considered to have a high potential impact where a development results in clearing of sheet flow areas. The shadow area downstream of a development is considered to have a moderate potential impact. The shadow areas shown in Appendix D were estimated based on an assumed approach to drainage management including the following civil works required as part of standard engineering design:

- Installation of perimeter drains around the outside of pits and dumps;
- Installation of engineering culverts or floodways where required on haul roads and access roads; and
- Provision of rock aprons at the outlet of perimeter drains, culverts and floodways.

Based on these typical civil works associated with drainage management, it was assumed that on the downstream side of engineered waterway features flows disperse at approximately a 45 degree angle. The moderately impacted areas were mapped as the “shadow zones” where the normal dispersion of flows on the downstream size of the development does not reach.

4.2.2 Potential Impacts

Anywhere that the development footprint of a pit or dump overlapped a mapped sheet flow zone was considered to be highly impacted. Some dumps are set to be retained post closure and where these overlapped sheet flow areas, the impact was also considered to be high.

The impacted areas are shown in Appendix 4. The tabulated area estimates show the amount of potential moderate impacts (shadow zones) and potential high impacts (pits and dumps) that occur within sheet flow zones. All remaining sheet flow zones are not expected to be impacted.

The majority of the additional impacts take place after the 7th phase, when most new pits are outside the existing approved disturbance area. In the first 7 mining phases, some dump areas placed at the edge of this area create shadow zone further downstream. From the 5th phase onwards, pits begin to impact small areas of sheet flow, increasing to between 1 and 4 km^2 in the 10th and 16th phases. As dumps are retained throughout the project, the impacted areas increase continually, to a maximum of 3 km^2 in the 14th phase through to and following mine closure.

4.3 Upstream Water Ponding

Pit and dump developments have the potential to cause prolonged upstream water ponding. Such a scenario may have adverse impacts on the vegetation in these areas.

4.3.1 Assumptions and Methodology

Potentially impacted areas were mapped where a pit or dump development obstructs drainage and creates localised depressions with no defined outlet. The pits and dumps were assumed to effectively act as a dam wall. The maximum possible ponded area was determined by identifying the "spill point", the level at which the pond would overflow around the edge of the obstruction. The potential ponded area was considered to be all terrain upstream of the obstruction and below the level of the spill point. Any water below the spill point would not flow downstream and would either infiltrate into the ground or evaporate.

4.3.2 Potential Impacts

The areas susceptible to ponding are shown in Appendix 4. For most development stage, the areas potentially impacted by ponding is less than 0.1 km2. In the 8th and 10th development stages some significant ponded areas could potentially form, covering areas up to 1.3 km2. A small area potentially susceptible to ponding remains following mine closure.

4.4 Water Balance for Areas of Significance

Fortescue Marsh and localised permanent water pools (Yintas) have been identified as areas with high environmental and/or cultural significance. The Cloudbreak Life of Mine Expansion has the potential to impact on the water balance of these features.

4.4.1 Assumptions and Methodology

The overall impact of the development has been expressed in terms of changes to the catchment areas upstream of these water bodies. This relies on the assumption that areas within a catchment contribute evenly to the discharge from that catchment. This is more likely to be the case over an extended period such as an entire wet season rather than on an event by event basis.

Catchment areas were mapped based on pit and dump configurations. For the Fortescue Marsh and Yintas, potential and actual reductions in catchment areas were mapped. Potential reductions included those catchments where pits or dumps may create an obstruction to flow. Actual reductions are discussed in section 6.4. If not correctly managed, these flows may potentially be cut off from the receiving water bodies.

4.4.2 Potential Impacts

The potential changes to catchment areas of the Fortescue Marsh and Yintas is shown in Appendix 5. Table 5.1 shows contributing catchment area reductions of the Fortescue Marsh at each stage of the Cloudbreak Life of Mine expansion. The potential reductions in contributing catchment area range from 30 km2 in mining phase 7 to 204 km2 in mining phase 10, or between 0.3% and 0.8% of the total Fortescue Marsh catchment area.

Table 5.2 shows contributing catchment area reductions of the Yintas at each stage of the Cloudbreak Life of Mine expansion. The catchments roughly correspond to the Goman and CRE06 catchments shown in Appendix 2. The potential reductions in contributing catchment area can reach up to 66% for Goman and 71% for CRE06.

4.5 Water Quality Impacts

The Cloudbreak Life of Mine Expansion has the potential to impact aspects of water quality including sediment load, turbidity and levels of hydrocarbons. These potential and actual impacts have been assessed only in qualitative terms. Potential hazards which may adversely impact water quality include:

- Increased channel velocities and sediment mobilisation in existing streams as a result of altered extreme flood regimes, discussed in section 4.1.

- Discharge of untreated stormwater from disturbed areas leading to increased sediment load and turbidity.
- Mobilisation of surface material in closed out areas.
- Release of contaminants, such as hydrocarbons, into natural waterways.

Each of these hazards are addressed in the management strategies outlined in section 5.

5. SURFACE WATER MANAGEMENT

Surface water related impacts that could potentially arise throughout the Cloudbreak Life of Mine Expansion have been discussed in section 4. This section describes in more detail the impacts of the individual components of the development and outlines management techniques aimed at mitigating the adverse impacts of the development.

5.1 Mine Pit and Waste Dump Developments

Mine pits and waste dumps impact on surface water flows by potentially obstructing upstream flows and reducing the effective catchment area for downstream flows. During operation, mine pits and waste dumps are effectively closed catchments from which no surface water runoff is generated. Direct rainfall onto pit areas are usually managed as part of the dewatering infrastructure and diverted via sump pumps into settlement or transfer ponds, prior to reinjection into the aquifer.

The top of waste dumps are typically finished of level and surrounded by windrows or are "paddock dumped" with waste material placed in unlevelled piles, creating an uneven surface. In the case of the levelled waste dump, some compaction has occurred and surface flows are typically captured and absorbed by loose material in the windrows at the edge of the dumps. For paddock dumped finishing, water is easily absorbed into the uncompacted surface material. In both cases, little or no surface runoff is generated by the waste dumps.

Pits and dumps can obstruct the natural downstream progression of surface water runoff. When these developments impinge on or block channel flows. Management of flows originating upstream of pit and dump areas means effective diversion of these flows around the operating areas.

Implementation of the following management strategies is expected to:

- Reduce the risk of moderate impacts to sheet flow shadow zones created by pits and dumps
- Reduce the risk of increased sediment mobilisation in natural channels
- Greatly reduce or eliminate the occurrence of upstream ponding
- Slightly reduce the impacts on the water balance of the Fortescue Marsh and Yintas

Table 2 - Development of Mine Pits and Waste Dumps

Development of Mine Pits and Waste Dumps	
Objective	Maintain water quality and quantity reaching downstream areas.
Key Performance Indicators	• Maintain the existing quantity and quality of the surface water flows upstream and downstream of the pit and dump areas. • Maintain the existing quantity and quality of surface water flows originating within the pit and dump areas.
Management Strategies	• All pits and dumps will be constructed with perimeter drains of a sufficient size to manage upstream flows obstructed by the pit or dump • Perimeter drains will be constructed to include sufficient scour protection in order to minimise sediment mobilisation. • Where perimeter drains discharge onto sheet flow zones, rock aprons and cutoff drains will be used to maximise the dispersal of flows. • Where perimeter drains discharge into existing streams, rock aprons will be placed to reduce flow energy and lower velocities to a level resembling that of natural flow conditions. • Stormwater reaching pit de-watering sumps will be pumped to settlement ponds prior to either groundwater injection or discharge to the natural environment (see section 5.8.5). • Stormwater discharging from dump areas will be collected and routed to settlement ponds prior to discharge to the environment (see section 5.8.5). • Vegetation condition monitoring discussed in Table 7 will include Mulga groves 200 m downstream of pit and dump boundaries.

5.2 Construction and Maintenance of Linear Infrastructure

Linear infrastructure takes several forms across the Christmas Creek expansion project including access tracks, haul roads and dewatering pipes. Access roads are typically used by light vehicles only and are built at grade with varying degrees of compaction and trafficability and traffic volume. Haul roads are typically only used by heavy vehicles have common, higher standards of safety and trafficability and high traffic volumes. Dewatering pipes are typically laid on the ground and are

associated with adjacent access roads with low levels of compaction and traffic. No compaction is involved other than that of the weight of the pipe itself.

Several road design and operational requirements need to be considered when developing surface water management strategies. Access roads with high traffic volumes and haul roads require regular grading. This results in uncompacted grade spoil or “windrows” at the edge of the roads. In the case of haul roads, windrows of a height reaching half the tyre radius of the design vehicle are a safety requirement. Road construction typically requires a cross fall of between 1.5 and 3% to promote road drainage, minimise damage of the road pavement and maintain road safety. In many areas of the project, required cross fall is greater than the natural surface gradient.

Drainage management controls to be incorporated into road design and operation to minimise the risk of up-gradient ponding and extent of down-gradient drainage shadows are further discussed in Section 5.8. Proposed management strategies to mitigate the potential impacts of the linear infrastructure of the Cloudbreak Life of Mine Expansion are summarised below.

Implementation of the following management strategies is expected to:

- Greatly reduce the risk of moderate impacts to sheet flow shadow zones created haul roads
- Reduce the occurrence of upstream ponding

Table 3 - Construction and Maintenance of Linear Infrastructure

Construction and Maintenance of Linear Infrastructure	
Objective	Minimise alterations to the natural flow regime and maintain existing water quality and quantity reaching downstream areas
Key Performance Indicators	• Sheet flows are maintained, waterways crossings do not result in concentration of flows and downstream channelisation • Surface water runoff does not result in significantly increased offsite sediment transport or water turbidity.
Management Strategies	• An initial desk top study, based on analysis of aerial photography and topographic information, will be undertaken to locate optimal positions for environmental and engineering culverts. Results from the desk-top study will be verified (and revised as necessary) based on hydrological modelling and field verification surveys as appropriate. • Install and maintain drainage controls (as described in Section 5.8).

Construction and Maintenance of Linear Infrastructure	
	• Where haul roads and high traffic access roads cross large channels, large diameter culverts will be required to maintain downstream flow quantities. The culverts and associated scour protection will be sized based on at least the expected 5 year ARI peak flows. In order to minimise the risk of catastrophic culvert failure, floodways will be placed where appropriate and sized based on at least the expected 20 year ARI peak flows and culverts will be installed using cement stabilised fill. • Where low traffic access roads cross channel flow areas or diverted channel flow areas, roads should either be treated as high traffic access roads (as above) or be built at grade. Where a channel crossing is built at grade, the road pavement should include either cement stabilised fill or if appropriate comprise of existing bedload material. • Existing procedures for burial of dewatering pipes at channel crossings have been documented and are appropriate for managing channel crossings of dewatering pipes. • Runoff generated in non-sheet flow areas shall be diverted along roadside drains into nearby floodways or culvert crossings. Roadside drains should include appropriate rock protection to minimse sediment mobilisation. • Where broad swales have formed, floodways should be installed on all roads including gaps in windrows and dewatering pipes should be raised. • Where roads cross sheet flow areas, the road surface will be constructed at grade with regularly spaced floodways or on a raised formation with regularly spaced culvert crossings. Typical design for these crossings are shown in section 5.8 • During maintenance of access roads constructed at grade, grading will take place in a manner that either avoids small windrows or provides gaps in these small windrows at regularly spaced intervals. • Where de-watering pipes are laid across sheet flow zones, the pipes will be raised at regularly spaced intervals. • Mulga groves 200 metres downstream of linear infrastructure will be included in the regular vegetation condition monitoring outlined in Table 7.

The management strategies identified in Section 5.1 will also apply to construction of the access road.

5.3 Other Ground Disturbance Activities

Other ground disturbance activities may include construction of mine site services and infrastructure, dewatering infrastructure including sedimentation and transfer ponds and preparation of laydown areas for third party contractors. Each of these activities may result in clearing of vegetation and topsoil, importation of fill and compaction. These areas often produce surface runoff of varying quality. In order to maintain quantity and quality of flows, runoff should be captured and treated prior to discharge to the environment.

Implementation of the following management strategies is expected to:

- Reduce adverse impacts of stormwater discharge from disturbed areas
- Reduce adverse impacts of discharge from rehabilitated areas

Table 4 - Ground Disturbance Activities

Ground Disturbance Activities	
Objective	No significant erosion is caused by ground disturbance activities.
Key Performance Indicators	• Surface water runoff does not result in significantly increased offsite sediment transport or water turbidity.
Management Strategies	• Clearly define areas to be cleared in the vicinity of watercourses, drainage lines and sheet flow areas, and supervise clearing operations to ensure clearing is confined to the defined areas. • Progressively rehabilitate temporarily disturbed areas in accordance with the Project Revegetation and Rehabilitation Management Plan. • In areas that will remain cleared for the operational phase of the project, culverts, levees and other drainage management controls will be used to maintain the natural drainage patterns. • Stormwater discharging from disturbed areas will be collected and routed to settlement ponds prior to discharge to the environment (see section 5.8.5). • Erosion control measures will be maintained until vegetation cover is restored and can stabilise soils.

5.4 Mine Closure

Mine closure involves the return of the area impacted by mine pits and waste dumps to a condition as close to natural conditions as possible. The bulking factor associated with mining the Marra Mamba formation means that finished surface levels on average, will be greater than the pre-development surface levels. This means excess material will need to be managed in a way that does not adversely impact on surface water quality and quantity following the closure of the project.

Implementation of the following management strategies is expected to:

- Reduce the risk of high impacts to sheet flow zones caused by pits
- Not alter the level or extent of severe impacts caused by dumps

Table 5 – Mine Closure

Development of Mine Pits and Waste Dumps	
Objective	Maintain water quality and quantity reaching downstream areas following mine closure.
Key Performance Indicators	• Maintain the existing quantity and quality of the surface water flows upstream and downstream of the former pit and dump areas. • Return ground levels as close as possible to pre-development levels. • Where excess material is placed in hillslope areas, retain the original catchment divides and discharge location and minimise slope.
Management Strategies	• Progressively rehabilitate temporarily disturbed areas in accordance with the Project Revegetation and Rehabilitation Management Plan. • Major channels will be built back to as close to original surface level as possible, lined with a compacted, low permeability layer and finished off with rip rap or rock sized to closely match that of bedload material in undisturbed areas. • Final finished surface levels should as closely as possible match the pre-development levels. • Closed out areas will be included in the ongoing monitoring described in Table 7

5.5 Storage and Handling of Hydrocarbons

The storage and handling of hydrocarbons products represents the most likely source of potential contamination associated with the Project although, as indicated above, the typically intense rainfall and flooding patterns within the project area are likely to preclude construction near waterways during the wet season, thereby reducing this risk.

Table 6 - Storage and Handling of Hydrocarbons

Storage and Handling of Hydrocarbons	
Objective	Minimise the risk of hydrocarbon spillage during all facets of Project operation.
Key Performance Indicators	• Number and magnitude of hydrocarbon spills.
Management Strategies	• Develop and implement Project hydrocarbon management and handling procedures. • Establish dedicated, contained hydrocarbon storage and vehicle/machinery refuelling sites. • Locate the hydrocarbon storage and vehicle/machinery refuelling sites a minimum of 100 m from surface drainage features and sheet flow areas. • Equip all hydrocarbon storage and vehicle/machinery refuelling sites, and all vehicles/machines transporting bulk fuel or other hydrocarbon product with spill recovery equipment and within storage bunds.

5.6 Monitoring and Maintenance of Drainage Controls and Environmentally and Culturally Sensitive Areas

The operational effectiveness of the drainage controls is dependent on ongoing maintenance. Culverts can become blocked by sediment and other material if not adequately maintained. Ineffective drainage controls can also adversely impact areas of cultural and environmental significance including permanent water pools (Yintas) and sheet flow dependent vegetation comminities (Mulga). Ongoing condition monitoring and reporting for these areas is summarised below.

Implementation of the following management strategies is expected to greatly reduce the risk of moderate impacts to sheet flow shadow zones

Table 7 - Monitoring and Maintenance of Drainage Controls and Environmentally and Culturally Sensitive Areas

Monitoring and Maintenance of Drainage Controls and Environmentally and Culturally Sensitive Areas	
Objective	Ensure the on-going effectiveness of drainage controls and their ability to maintain areas of environmental and cultural significance.
Key Performance Indicators	• Maintain the quantity and quality of the surface water flows throughout the project area • Maintain water levels in permanent pools of cultural significance • Maintain vegetation health at or above the level observed in nearby unimpacted areas.
Management Strategies	Drainage Condition Monitoring and Maintenance • Visual monitoring of drainage controls will be undertaken by Project environmental personnel prior to the onset of the wet season and following significant rainfall events. • Drainage structures will be regularly inspected to identify whether down-gradient sheet flows are being maintained, and any occurrence of up-gradient surface ponding at culvert inverts. • Remedial maintenance of drainage structures will be undertaken as required based on outcomes from the regular inspections. • Results of visual monitoring, and the remedial maintenance undertaken, will be reported annually to provide an ongoing assessment of surface water flow in sheet flow areas of the rail alignment • Annual and event-based inspections and maintenance will be carried out to maintain the effectiveness of the installed works at redistributing flows to the downstream Mulga communities Sheet Flow Dependent Vegetation Condition Monitoring and Reporting: • Indicators of ecological health will be developed for Mulga grove communities including parameters such as soil organic content, litter depth, plant vigour, leaf area index and other biological indicators • Monitoring areas will be identified based on the expected locations of

Monitoring and Maintenance of Drainage Controls and Environmentally and Culturally Sensitive Areas	
	pits, waste dumps and linear infrastructure within sheet flow zones • "Control sample" monitoring areas will be identified where no impact is expected • Monitoring will take place at appropriate spatial scales throughout the identified monitoring areas both prior to the installation of the relevant infrastructure and quarterly there after. • A response strategy for the early detection of any impacts on sheet flow dependent mulga communities will be developed and remedial actions as required will be implemented to manage any identified adverse impacts. • Monitoring results, any actions taken or recommended will be reported annually. • Install peizometers at yintas to monitor groundwater level response to seasonal and event based surface water flows

5.7 Ongoing Development of Management Strategies

This report outlines a series of concepts on which the surface water management strategies have been based. Further investigations and development of these concepts as well as additional information obtained through collection of monitoring and field data can be used to build upon the management strategies identified so far. Works that can aid the ongoing development of management strategies are outlined below.

Table 8 - Ongoing Development of Management Strategies

Ongoing Development of Management Strategies	
Objective	Identify opportunities to further develop Management Strategies.
Key Performance Indicators	• Use monitoring data to assess the effectiveness of current management practices • Collect additional data to enhance the current understanding of surface water characteristics throughout the project • Review current surface water management strategies as required.
Management Strategies	• Collect more comprehensive flow and rainfall data by installing pluviometers at Cloudbreak and flow gauges at selected major culvert

Ongoing Development of Management Strategies	
	crossings. • Engage relevant research organisations to guide data collection, experimentation and vegetation condition monitoring across the site • Revise the current understandings of surface water impacts by taking into account new information provided from field data. • Conduct annual reviews of the effectiveness of the current surface water management strategies

5.8 Design of Drainage Management Controls

A combination of culverts, scour protection, riprap rock aprons, contour drains and interceptor embankments (guide banks) will be used as appropriate to manage the potential impact on surface water flows. Design specifications, including the size of environmental culverts, nature and extent of scour protection, design and materials used for riprap rock aprons, dimensions of interceptor embankments and contour drains will be developed as mine site infrastructure layouts are finalised. Specific locations of the drainage management controls will also be selected at this time and will be based on hydrological studies and a visual assessment of the route.

Muller Consulting (2005) has assessed the performance of surface flow redistribution structures in the Pilbara through field trials to determine the most effective methods for preventing distribution shadow effects. The trials investigated the use of interceptor embankments and contour drains to redistribute sheet flow after it passes through a culvert and included an evaluation of the optimum material for interceptor embankments for spread and permeability.

The recommendations from this assessment will guide drainage design and management. Drainage structures will be regularly inspected and maintained to ensure their functional effectiveness during expansion of the mine.

The following drainage management controls will be used to maintain the natural drainage and sedimentation patterns.

5.8.1 Culverts

Engineering culverts will be installed at all major creek crossings and will be located as required based on topographic survey data and visual in-field assessments. The engineering culverts will be designed to accommodate flows up to the 5-year average recurrence interval flood.

Environmental culverts can be used to re-establish sheet flow within 50 m down-gradient of disturbed areas (pits, dumps and roads) containing sheet flow dependent mulga communities. Typically environmental culverts range from 300 mm to 600 mm diameter.

5.8.2 Riprap rock aprons

Aprons of rock riprap will be installed at all outlets of culverts and drains and inlets of culverts as a design standard. The rock aprons act to reduce the energy of inflows and discharge lowering the risk of scour at culvert inlets and outlets. The aprons also slow and laterally spread flows at the culvert outlets, reducing drainage shadows. Schematics showing the function of the rip rock aprons are shown in Figure 5 and Figure 6.

5.8.3 Interceptor Embankments (Guide Banks)

Where environmental culverts have been installed, interceptor embankments (guide banks) will be included to avoid flows running along the relevant linear infrastructure. This will direct flow through the culvert, prevent scour and help to reduce concentration of runoff flows at the incised creek lines.

Schematics showing the function of the interceptor embankments are shown in Figure 5 and Figure 6.

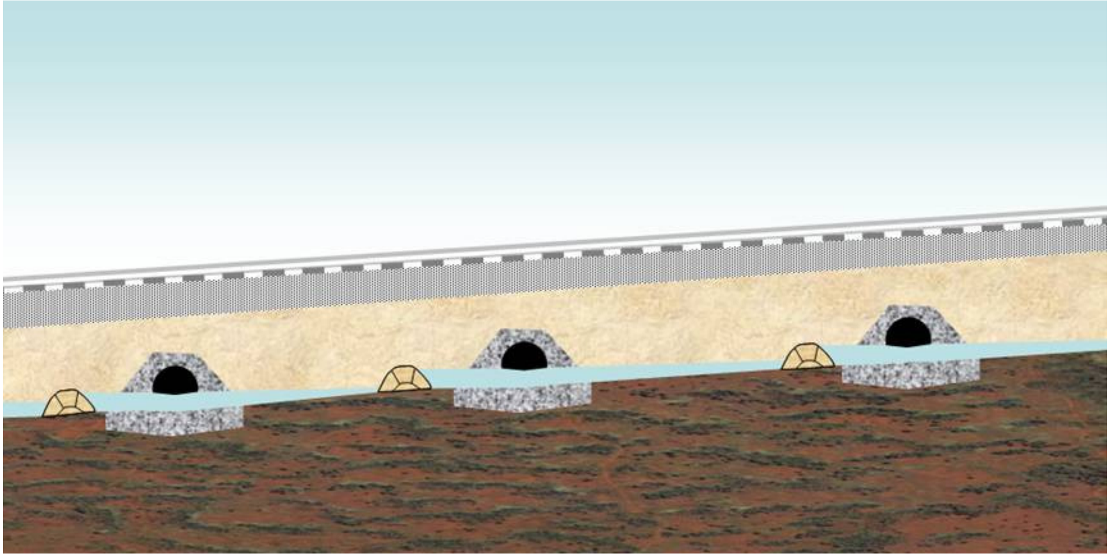

Figure 5. Schematic (elevation view) showing function of rip rock aprons and guide banks to assist with the redistribution of culvert flows.

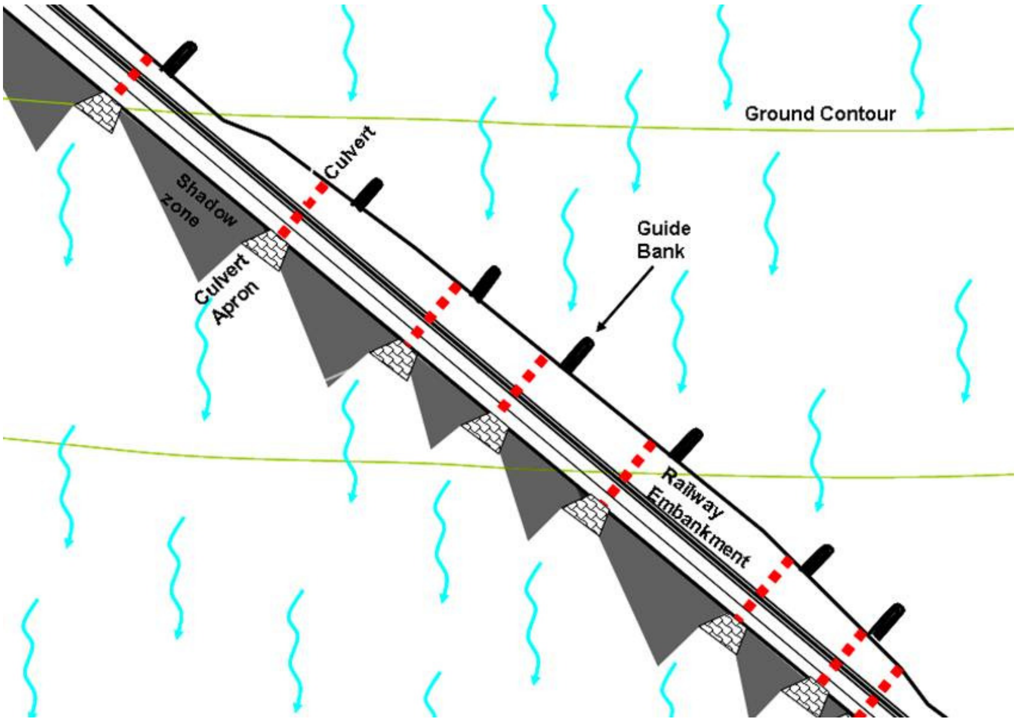

Figure 6. Schematic (plan view) showing function of rip rock aprons and guide banks to assist with the redistribution of culvert flows.

5.8.4 Contour Drains

Where environmental culverts have been installed, contour drains may be used to distribute flow uniformly immediately down gradient of the road/rail formation. Drains will be constructed along the contour, as near as practicable to the formation to spread the water. Figure 7 provides a schematic representation of the function of the contour drains.

If the drains retain water, they may attract stock and wildlife and therefore be susceptible to trampling and erosion. Accordingly, they will be regularly maintained to prevent sediment accumulation and erosion. Contour drains should only be installed at the outlet of environmental culverts in areas where rock aprons alone are not considered sufficient to redistribute to down-gradient sheet flow dependent mulga communities and other sensitive ecosystems.

In the event that visual monitoring indicates that the culverts are not redistributing sheet flow effectively, contour drains would be retrospectively installed following construction completion.

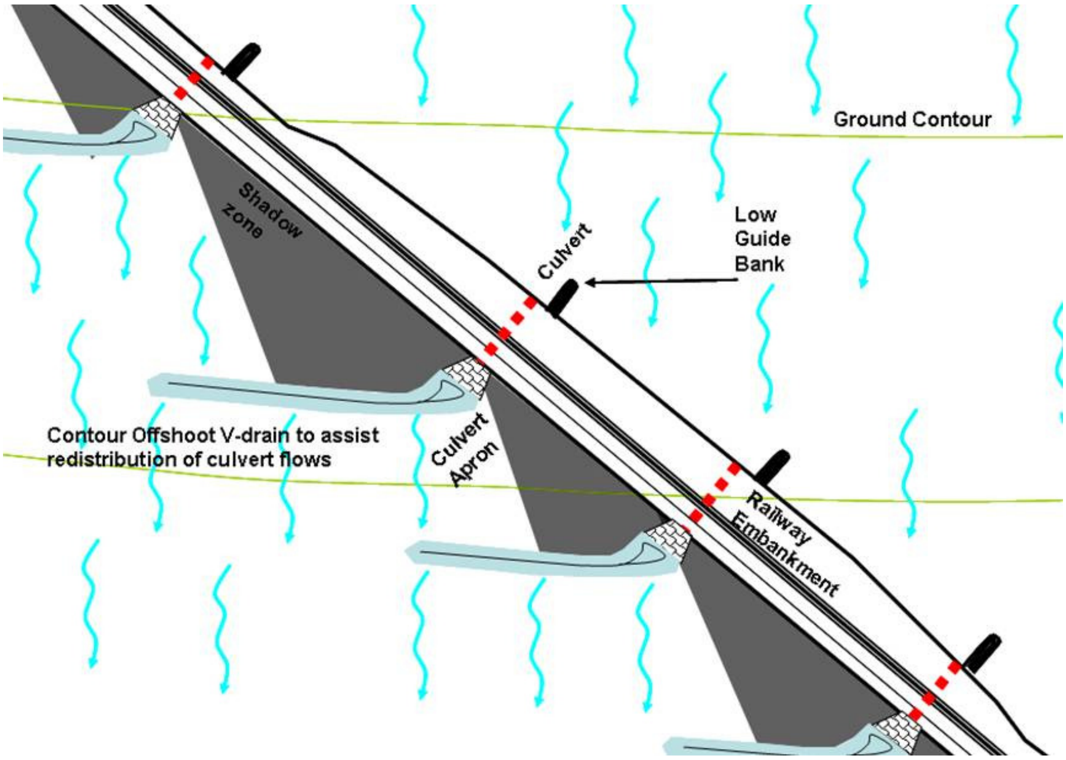

Figure 7. Schematic showing function of rip rap aprons, guide banks and contour drains to assist with the redistribution of culvert flows

5.8.5 Sedimentation Basins

Two types of sedimentation basins will be constructed as part of the Cloudbreak Life of Mine expansion to treat pit de-water and stormwater.

Sedimentation Basins for pit de-water typically retain water on an ongoing basis. De-water is transferred from pit sumps into settlement basins. Following settlement of particles, water is pumped to transfer ponds prior to aquifer re-injection. Sediment reduction in this case aims to minimise damage to pumping and re-injection equipment. Sedimentation Basins for pit de-water are typically sized based on expected rates of ongoing groundwater ingress into pit sumps.

Sedimentation Basins for stormwater are designed to completely drain following rainfall events. Stormwater is collected from disturbed areas and routed through sedimentation basins via the drainage network. Following settlement of particles, water is discharged to the environment. Sediment reduction in this case aims to reduce total suspended sediment to levels observed in the local natural watercourses.

Sedimentation Basins for stormwater are typically sized based on a target reduction of a given particle size for and given storm event. Target reductions for overall TSS are problematic as they vary according to particle size distribution. Sedimentation Basin design will be guided by Camp's Theory as outlined in *Australian Runoff Quality* (Engineers Australia, 2006).

It is expected that under natural conditions, water courses will have high turbidity and high concentrations of fine silts and clays. For this reason, treatment targets will focus on settlement of medium silts and larger particles. Removal of larger particles is expected to be much more effective while smaller particles including fine silts and clays is expected to be less effective.

Direct rainfall onto pit areas is expected to generate stormwater flows which reach pit de-watering sumps. Pit de-water may be saline and not suitable for discharge to waterways. For this reason any water reaching the pit de-watering sumps either through groundwater ingress or direct rainfall should be directed into the pit de-watering system for re-injection. Adequate perimeter drainage and internal drainage controls should be installed to minimise the risk of stormwater reaching the pit other than via direct rainfall.

6. ACTUAL SURFACE WATER IMPACTS

This section describes the expected impact on each of the surface water aspects discussed in section 4, following the application of the management actions described in section 5. In most cases, the management actions are assumed to confine the highly impacted area to within the pit and dump footprint.

6.1 Altered Flood Regime

6.1.1 Flood Extents

Table 1 and 2 in Appendix 3 show how the 2 and 100 year ARI flood extents change during each development stage. The figures show that the areas becoming dry are predominantly within the footprint of the pits and dumps. Table 1 and 2 in Appendix 3 suggests that only small areas become inundated that were previously not subject to flooding during the 2 and 100 year ARI events.

External flooding such as that shown in Appendix 3 will be managed with diversions around or through the pit footprints, as outlined in table 2.

The actual impact following the application of management measures is likely to include:

- "Dry Areas" listed in table 3.1 and 3.2 in Appendix 3 are cut off from extreme floods during the period covered by each development stage
- Larger areas may be cut off from flooding depending on how the final pit sequence is arranged and the necessity for temporary creek diversions.
- "Dry Areas" following mine closure are located mainly where permanent dumps are proposed
- "New wet areas" are likely to be subject to temporary inundation (typically less than 24 hours) during extreme floods

The level of impact is especially low for the 100 year ARI event due to the low probability of that occurring at any time during each development phase.

6.1.2 Flow Velocities

Table 4.3 and 4.4 in Appendix 3 show how the velocities of the 2 and 100 year ARI flood events change between each of the development stages. The locations in the table relate to one of the cross sections at each creek shown in the model setup in Appendix 6. These velocities do not consider the construction of external perimeter drains and scour protection discussed in table 2, Actual velocities will be highly dependent on the on how the final pit sequence is arranged and the necessity for temporary creek diversions. While flow velocities are likely to increase in diversion channels, the placement of scour protection will be designed to minimise the impact of the higher velocities and reduce sediment mobilisation.

6.2 Disrupted Sheet Flow Processes

The management actions outlined in section 5 are expected to reduce the level of impact, rather than the spatial extent of the impact resulting from the Life of Mine development. While the management controls discussed in section 5 would increase the water that reaches shadow zones, the ecohydrological responses are unclear. Section 5 includes provisions for periodic vegetation condition monitoring in shadow zones as well as regular review and if required updating of, the Surface Water Management Plan.

The actual impacts of the development include:

- Sheet flow areas within pit and dump footprints shown in Appendix 3 are expected to be highly impacted by the development
- Some impact is still possible in shadow zones after the application of the management controls outlined in section 5. Considering the temporary nature of pit and dump areas (other than those still present after mine closure) such an impact is expected to be low.
- Shadow zones downstream of permanent dumps which remain post mine closure are expected to be moderately impacted.

6.3 Upstream Water Ponding

A combination of standard engineering practises and management controls described in section 5 are likely to prevent ponding upstream of the developed areas. Prolonged periods of ponding against rail embankments, diversion bunds and mine dumps are detrimental to the structural stability of the asset. Poor drainage design can also lead to loss of production by delaying recovery from large rainfall events. It is expected diversion drains and perimeter drains will remove the potential for ponding to occur and there will be no actual impact.

6.4 Water Balance for Areas of Significance

Similarly with ponded areas, a combination of standard engineering practises and management controls described in section 5 are likely to minimise the impact on water balances for areas of significance. With the use of flood levees, diversions and perimeter drains, flows originating upstream are expected to pass through or around the mine area. Actual impacts include small reductions in catchment area associated with pits and dumps. Pits are internally draining while dumps are frequently finished with paddock dumping, where loose material is dumped over the compacted trafficked surface promoting rapid infiltration and ponding.

The actual impact, in the form of reduced Fortescue Marsh catchment area varies from 3.6 km2 in the first mining phase to 16.8 km2 in the 14th phase, or between 0.01% and 0.06% of the total Fortescue Marsh catchment area. In the case of the Yintas, the actual reduction in catchment areas are not expected to exceed 4% and 2% for Goman Creek and CRE06 respectively.

7. CONCLUSIONS

This report describes the impact of the Cloudbreak Life of Mine Expansion on aspects of the hydrological processes within the developed area. The impacted areas have been estimated based on the spatial distribution of mine site infrastructure in relation to different landforms and the expected hydrological processes that take place within them. A series of management strategies are then presented which are expected to reduce the level of impact and or the spatial extent of the impact. The key outcomes of this strategy include:

- All high or severe impact on sheet flow zones are confined to within the footprint of pits and dumps
- Sheet flow shadow zones are considered to be moderately impacted – the risk of this level of impact being felt can be reduced through the implementation of management strategies outlined in section 5.
- Changes to the extreme flood inundation are mainly confined to the areas within the footprint of pits and dumps. The impacted areas are typically less than 4 km^2 during any one phase of mine development.
- While ponding areas have been identified, management strategies outlined in section 5 are expected to greatly reduce or eliminate these occurrences
- Changes to the catchment areas of the Fortescue Marsh and Yintas are mainly the direct result of pit and dump development, not blockage of upstream areas. The impacted areas typically less than 1% and 10% for the Fortescue Marsh and Yintas (respectively) during any one phase of mine development.
- The high level of this assessment, associated low level of detail around future mine development scenarios and limitations associated with the adopted modelling approach increase the level of uncertainty associated with modelled flood estimates. It is recommended that further investigations be undertaken using more advanced hydraulic modelling techniques at such a time when better terrain data and more detailed development scenarios are available.

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Appendix 1 – Site Map and Life of Mine Plan

Location Map

Port Hedland

Project

Perth

Kalgoorlie

Waste Dump

Conveyor

Conveyor Safety Zone

Dump Pocket

Tailings Dams

cb_haul_roads_optimized by Type

Ore H Road

Waste H Road

CB Pits by Sequence

Pits Names displayed by Mining Period

1, 2, 3, 4, 5, 6, 7, 8, 10, 12, 14, 16, all others

0 1.5 3

kilometres

Fortescue Metals Group Ltd

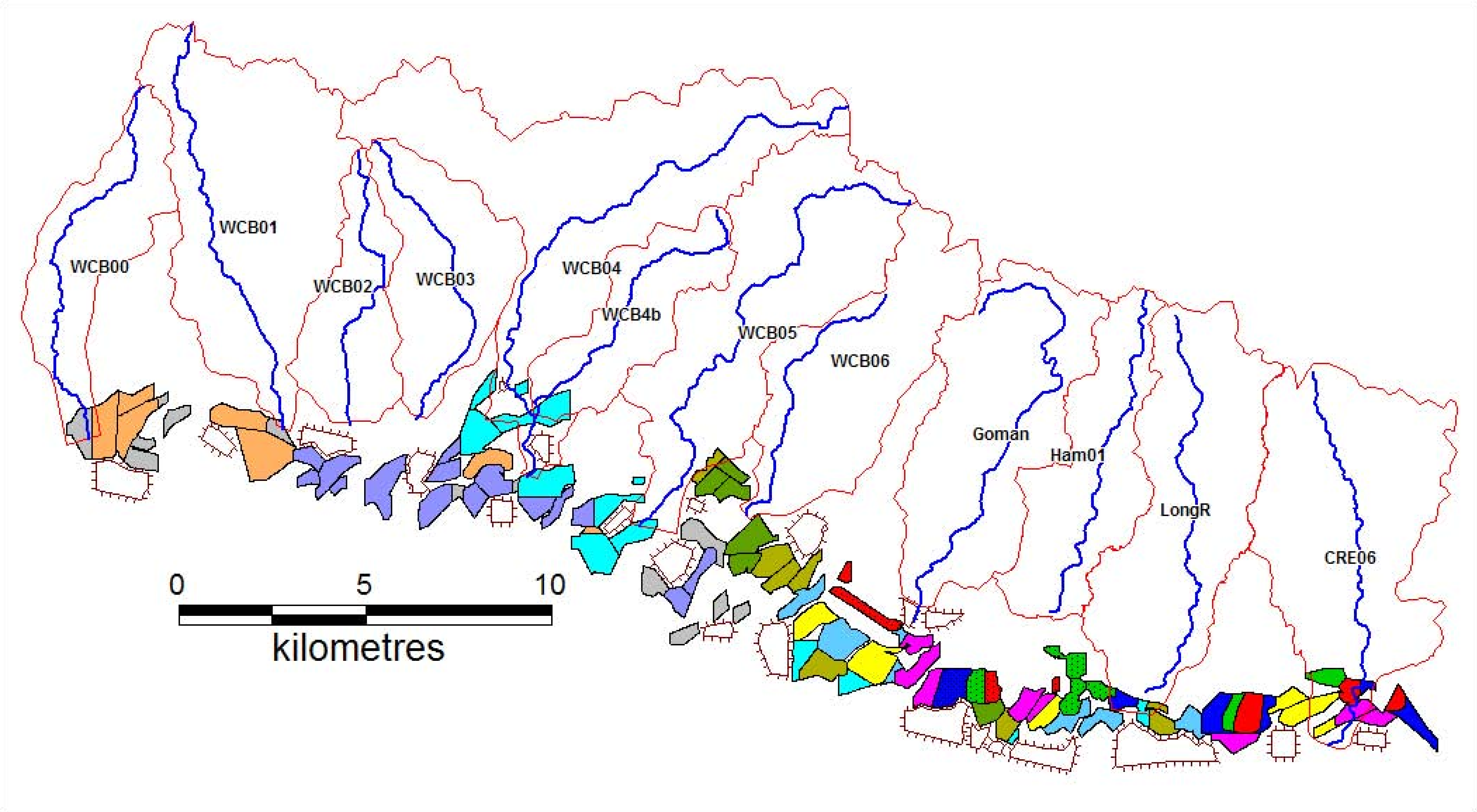
CLOUDBREAK
Mine Plan 35Mtpa
from July 2010 onwards

Author: G. Bull	Date: 13/08/2010
Drawn By: MD	Revision: 1
Doc No: CB_LOM_35Mtpa	Confidentiality:
Projection: MGA (GDA 94)	Scale: 1:50000

Appendix 2 – Major Catchment Details

Table 2.1 - Major Catchments of the Cloudbreak Life of Mine Development Area

ID	Catchment Area	Catchment Centroid		Catchment Main		Time of Conc.,	L^2/A	RFFP Peak Flow Estimates (m3/s)					
		Latitude	Longitude	Length	Slope			2-yr ARI	5-yr ARI	10-yr ARI	20-yr ARI	50-yr ARI	100-yr ARI
	km²	°S	°E	km	m/km	Hours							
WCB00	16.712	22.240	119.16	12.07	7.2	1.63	8.7	3.407	11.686	23.708	50.002	89.15	138.35
WCB01	37.446	22.230	119.20	12.67	6.5	2.22	4.3	13.399	35.582	58.693	92.310	166.34	260.30
WCB02	12.976	22.244	119.23	8.77	8.9	1.48	5.9	4.619	13.660	24.715	44.862	79.72	123.39
WCB03	17.999	22.242	119.25	9.47	8.1	1.68	5.0	7.016	19.483	33.481	56.403	100.66	156.33
WCB04	59.603	22.239	119.29	18.56	4.3	2.65	5.8	12.319	36.383	65.162	114.073	206.81	325.21
WCB4b	13.614	22.250	119.30	9.26	6.3	1.51	6.3	3.996	12.009	22.041	40.942	72.80	112.73
WCB05	34.300	22.254	119.34	16.04	5.8	2.15	7.5	6.822	22.003	42.405	82.692	148.83	232.70
WCB06	24.614	22.260	119.36	8.48	7.5	1.89	2.9	15.699	35.585	52.123	80.791	144.78	225.58
Goman	30.010	22.277	119.40	14.13	6.5	2.04	6.6	7.321	22.422	41.591	77.300	138.89	216.84
LongR	31.221	22.282	119.42	12.22	4.8	2.07	4.8	9.546	25.812	43.473	71.146	127.89	199.76
Ham01	19.299	22.282	119.42	10.91	6.1	1.72	6.2	5.449	16.125	29.232	53.205	95.04	147.71
CRE06	37.491	22.306	119.49	12.15	6.4	2.22	3.9	15.279	38.295	60.727	94.524	170.33	266.55


WCB00
WCB01
WCB02
WCB03
WCB04
WCB4b
WCB05
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Goman
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0
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kilometres

Appendix 3 – Extreme Flood Inundation Extents

This table presents the estimated impact areas for inundation extent

Flood extents were estimated before mining development and at every mining phase including post closure. The following maps show changes to inundation extents including:

a) Areas subject to inundation pre-development which have become dry
b) Areas not subject to inundation pre-development which have become wet
c) Areas which remain inundated (not impacted)
d) The total inundated area (b+c)

These are areas OUTSIDE existing approved disturbance areas

Areas are quoted in square kilometres

Table 3.1 - 100 year Flood Areas

Development Stage	a) Dry Areas	b) New Wet Areas	c) Not Impacted	d) Inundated Area
Pre development	-	-	-	23.19
7	0.07	0	23.12	23.12
8 and 9	0.01	0	23.18	23.18
10 and 11	2.57	0.74	20.62	21.36
12 and 13	3.37	0.71	19.82	20.53
14 and 15	2.81	0.43	20.38	20.81
16	3.35	0.79	19.84	20.63
Post Closure	1.7	0.45	21.49	21.94

Table 3.2 - 2 year Flood Areas

Development Stage	a) Dry Areas	b) New Wet Areas	c) Not Impacted	d) Inundated Area
Pre development	-	-	-	7.49
7	0.00	0.00	7.49	7.49
8 and 9	0.00	0.00	7.49	7.49
10 and 11	0.11	0.70	7.39	8.09
12 and 13	0.56	0.17	6.93	7.10
14 and 15	0.20	0.00	7.30	7.30
16	0.70	0.06	6.79	6.85
Post Closure	0.46	0.07	7.04	7.11

Tabele 3.3 - 2 year ARI Flood Velocity Impacts

This table presents the expected impacts of the development on stream velocities.
Average cross sectional velocities and estimated percentage increase or decreases resulting from the development are presented.
In the 2 year flood, the channel velocities are likely to be much higher than the average velocity, but the percentage increase or decrease is likely to be similar.
River station is expressed in metres upstream of the downstream outlet used in the model.

Reach	River Station	PreDev	Phase 7		Phase 8 and 9		Phase 10 and 11		Phase 12 and 13		Phase 14 and 15		Phase 16		PostDev	
			Velocity	% Increase	Velocity	% Increase	Velocity	% Increase	Velocity	% Increase	Velocity	% Increase	Velocity	% Increase	Velocity	% Increase
WCB00	3172	0.05	0.05	0.00	0.05	0.00	0.05	0.00	0.05	0.00	0.05	-0.09	0.05	-7.15	0.05	0.00
WCB00	2740	0.16	0.16	0.00	0.16	0.00	0.16	0.00	0.16	0.00	0.16	0.38	0.15	-5.15	0.16	0.00
WCB00	2332	0.06	0.06	0.00	0.06	0.00	0.06	0.00	0.06	0.00	0.06	1.17	0.07	7.16	0.06	0.00
WCB00	1783	0.70	0.70	0.00	0.70	0.00	0.70	0.00	0.70	0.00	0.73	4.27	0.70	0.21	0.70	0.00
WCB00	863	0.05	0.05	-0.11	0.05	0.00	0.05	-0.11	0.05	-0.11	0.05	-0.09	0.05	0.03	0.05	-0.09
WCB00	385	0.10	0.10	0.00	0.10	0.00	0.10	0.00	0.10	0.00	0.10	0.00	0.10	0.00	0.10	0.00
WCB01	6496	0.15	0.15	0.00	0.15	0.00	0.15	0.00	0.15	0.00	0.15	0.01	0.15	0.00	0.15	0.02
WCB01	6090	0.21	0.21	0.00	0.21	0.00	0.21	0.00	0.21	0.00	0.21	-0.06	0.21	-0.02	0.21	-0.03
WCB01	5773	0.15	0.15	0.00	0.15	0.00	0.15	0.00	0.15	0.00	0.15	0.17	0.15	0.08	0.15	0.10
WCB01	5518	0.22	0.22	0.00	0.22	0.00	0.22	0.00	0.22	0.00	0.22	-0.88	0.22	-0.36	0.22	-0.54
WCB01	5024	0.26	0.26	0.00	0.26	0.00	0.26	0.00	0.26	0.00	0.27	2.26	0.28	8.42	0.26	1.32
WCB01	4465	0.19	0.19	0.00	0.19	0.00	0.19	0.00	0.19	0.00	0.19	2.08	0.18	-2.01	0.18	-2.01
WCB01	3769	0.22	0.22	0.00	0.22	0.00	0.22	0.00	0.22	0.00	0.19	-12.72	0.19	-13.74	0.19	-13.74
WCB01	3023	0.35	0.35	0.00	0.35	0.00	0.35	0.00	0.35	0.00	0.35	-0.10	0.35	-0.10	0.35	-0.10
WCB01	2555	0.24	0.24	0.00	0.24	0.00	0.24	0.00	0.24	0.00	0.24	0.14	0.24	0.14	0.24	0.14
WCB01	1766	0.31	0.31	0.00	0.31	0.00	0.31	0.00	0.31	0.00	0.30	-0.95	0.30	-0.95	0.30	-0.91
WCB01	580	0.15	0.15	0.00	0.15	0.00	0.15	0.00	0.15	0.00	0.17	13.85	0.17	13.85	0.17	13.83
WCB02	3269	0.22	0.22	0.00	0.22	0.00	0.22	0.00	0.60	169.23	0.21	-6.31	0.21	-6.31	0.21	-6.31
WCB02	2685	0.07	0.07	0.00	0.07	0.00	0.07	0.00	0.07	-0.50	0.09	33.38	0.09	33.38	0.09	33.38
WCB02	2156	0.12	0.12	0.00	0.12	0.00	0.12	0.00	0.32	160.50	0.12	0.00	0.12	0.00	0.12	0.00
WCB02	1700	0.08	0.08	0.00	0.08	0.00	0.08	0.00	0.08	0.00	0.08	0.00	0.08	0.00	0.08	0.00
WCB02	1157	0.67	0.67	0.00	0.67	0.00	0.67	0.00	0.67	0.00	0.67	0.00	0.67	0.00	0.67	0.00
WCB02	578	0.08	0.08	0.12	0.08	0.00	0.08	0.12	0.08	0.00	0.08	0.00	0.08	0.00	0.08	0.00
WCB02	210	0.14	0.14	0.00	0.14	0.00	0.14	0.00	0.14	0.00	0.14	0.00	0.14	0.00	0.14	0.00
WCB03	3538	0.15	0.15	0.00	0.15	0.00	0.15	0.00	0.13	-8.80	0.15	0.00	0.15	0.00	0.15	0.00
WCB03	3177	0.25	0.25	0.00	0.25	0.00	0.25	-0.07	0.34	34.92	0.25	-0.07	0.25	-0.07	0.25	-0.07
WCB03	2829	0.14	0.14	0.00	0.14	0.00	0.14	0.10	0.08	-43.56	0.14	0.10	0.14	0.10	0.14	0.10
WCB03	2310	0.17	0.17	0.00	0.17	0.00	0.17	-0.15	0.16	-6.42	0.17	-0.15	0.17	-0.15	0.17	-0.15
WCB03	1946	0.13	0.13	0.00	0.13	0.00	0.13	0.00	0.12	-11.85	0.13	0.00	0.13	0.00	0.13	0.00
WCB03	1448	0.38	0.38	0.00	0.38	0.00	0.38	0.00	0.41	7.13	0.38	0.00	0.38	0.00	0.38	0.00
WCB03	868	0.09	0.09	0.00	0.09	0.00	0.09	0.00	0.10	22.60	0.09	0.00	0.09	0.00	0.09	0.00
WCB03	523	0.10	0.10	0.00	0.10	0.00	0.10	0.00	0.11	16.45	0.10	0.00	0.10	0.00	0.10	0.00
WCB03	80	0.13	0.13	0.00	0.13	0.00	0.13	0.00	0.13	0.00	0.13	0.00	0.13	0.00	0.13	0.00

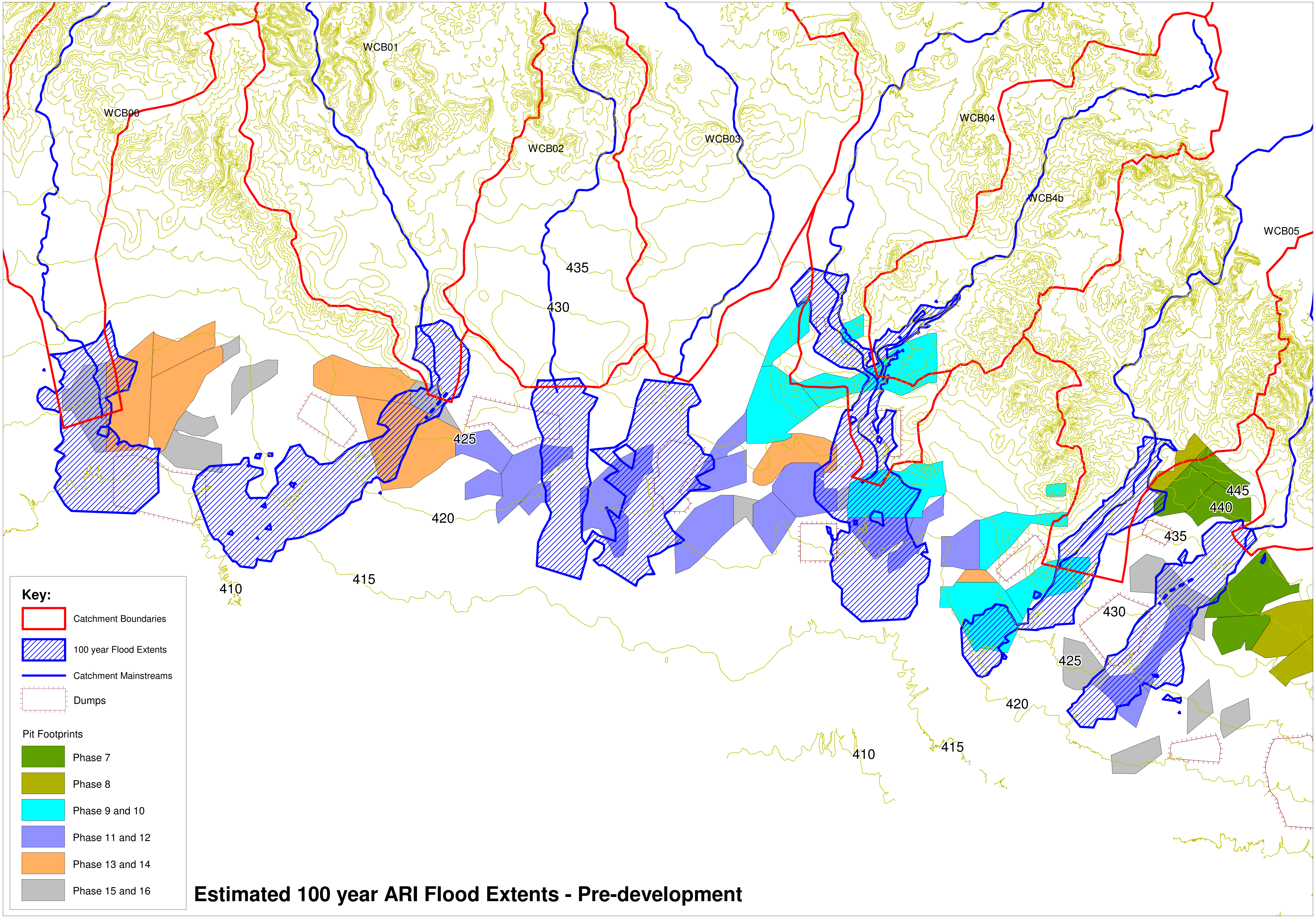
Reach	River Station	PreDev	Phase 7		Phase 8 and 9		Phase 10 and 11		Phase 12 and 13		Phase 14 and 15		Phase 16		PostDev	
			Velocity	% Increase	Velocity	% Increase	Velocity	% Increase	Velocity	% Increase	Velocity	% Increase	Velocity	% Increase	Velocity	% Increase
WCB04	6924	0.26	0.26	0.00	0.26	0.00	0.24	-6.96	0.26	1.25	0.26	1.25	0.26	1.25	0.26	1.25
WCB04	6363	0.25	0.25	0.00	0.25	0.00	0.29	14.73	0.25	-2.44	0.25	-2.42	0.25	-2.42	0.25	-2.42
WCB04	6015	0.12	0.12	0.00	0.12	0.00	0.11	-8.46	0.13	6.48	0.13	6.46	0.13	6.46	0.13	6.46
WCB04	5742	0.18	0.18	0.00	0.18	0.00	0.14	-22.32	0.18	-0.21	0.18	0.02	0.18	0.02	0.18	0.02
WCB04	5309	0.19	0.19	0.00	0.19	0.00	0.19	-3.69	0.19	0.38	0.19	-0.03	0.19	-0.03	0.19	-0.03
WCB04	4733	0.24	0.24	0.00	0.24	0.00	0.26	5.11	0.24	-0.47	0.24	0.02	0.24	0.02	0.24	0.02
WCB04	4390	0.18	0.18	0.00	0.18	0.00	0.16	-14.57	0.19	1.72	0.18	-0.07	0.18	-0.07	0.18	-0.07
WCB04	4072	0.15	0.15	0.00	0.15	0.00	0.19	25.96	0.15	-1.57	0.15	0.69	0.15	0.69	0.15	0.69
WCB04	3568	0.35	0.35	0.00	0.35	0.00	0.19	-44.30	0.38	10.65	0.35	0.00	0.35	0.00	0.35	0.00
WCB04	3124	0.16	0.16	0.00	0.16	0.00	0.08	-50.60	0.15	-7.33	0.16	0.00	0.16	0.00	0.16	0.00
WCB04	2780	0.30	0.30	0.00	0.30	0.00	0.10	-67.44	0.61	106.50	0.30	0.00	0.30	0.00	0.30	0.00
WCB04	2445	0.13	0.13	0.00	0.13	0.00	0.11	-18.28	0.06	-52.30	0.13	0.00	0.13	0.00	0.13	0.00
WCB04	1985	0.45	0.45	0.00	0.45	0.00	0.45	0.00	0.74	66.03	0.45	0.00	0.45	0.00	0.45	0.00
WCB04	1326	0.27	0.27	0.00	0.27	0.00	0.27	0.00	0.27	0.00	0.27	0.00	0.27	0.00	0.27	0.00
WCB04	257	0.14	0.14	0.00	0.14	0.00	0.14	0.00	0.14	0.00	0.14	0.00	0.14	0.00	0.14	0.00
WCB4b	1976	0.34	0.34	0.00	0.34	0.00	0.34	0.25	0.34	0.00	0.34	0.00	0.34	0.00	0.34	0.00
WCB4b	1739	0.20	0.20	0.00	0.20	0.00	0.20	-0.30	0.20	0.00	0.20	0.00	0.20	0.00	0.20	0.00
WCB4b	1416	0.50	0.50	0.00	0.50	0.00	0.52	4.17	0.50	0.00	0.50	0.00	0.50	0.00	0.50	0.00
WCB4b	1110	0.11	0.11	0.00	0.11	0.00	0.11	-0.69	0.11	0.00	0.11	0.00	0.11	0.00	0.11	0.00
WCB4b	897	0.88	0.88	0.00	0.88	0.00	1.07	21.33	0.88	0.00	0.88	0.00	0.88	0.00	0.88	0.00
WCB4b	465	0.15	0.15	0.00	0.15	0.00	0.03	-82.57	0.15	0.00	0.15	0.00	0.15	0.00	0.15	0.00
WCB4b	123	0.32	0.32	0.00	0.32	0.00	0.25	-22.87	0.32	0.00	0.32	0.00	0.32	0.00	0.32	0.00
WCB05	5244	0.17	0.17	0.00	0.17	0.00	0.17	-1.19	0.17	0.00	0.17	0.00	0.17	0.00	0.17	0.00
WCB05	4850	0.12	0.12	0.00	0.12	0.00	0.13	3.43	0.12	0.00	0.12	0.00	0.12	0.00	0.12	0.00
WCB05	4465	0.83	0.83	0.00	0.83	0.00	0.45	-44.96	0.83	0.00	0.83	0.00	0.83	0.00	0.83	0.00
WCB05	3989	0.16	0.16	0.00	0.16	0.00	0.17	8.04	0.16	0.00	0.16	0.00	0.16	0.00	0.16	0.00
WCB05	3672	0.19	0.19	0.00	0.19	0.00	0.13	-27.61	0.19	0.00	0.19	0.00	0.19	0.00	0.19	0.00
WCB05	3280	0.34	0.34	0.00	0.34	0.00	1.45	329.15	0.34	0.00	0.34	0.00	0.34	0.00	0.34	0.00
WCB05	2980	0.13	0.13	0.00	0.13	0.00	0.03	-75.04	0.13	0.00	0.13	0.00	0.13	0.00	0.13	0.00
WCB05	2599	0.21	0.21	0.00	0.21	0.00	0.12	-45.63	0.21	0.00	0.21	0.00	0.21	0.00	0.21	0.00
WCB05	2240	0.20	0.20	0.00	0.20	0.00	0.90	349.08	0.20	0.00	0.20	0.00	0.20	0.00	0.20	0.00
WCB05	1838	0.27	0.27	0.00	0.27	0.00	0.12	-55.82	0.27	0.00	0.27	0.00	0.27	0.00	0.27	0.00
WCB05	1175	0.34	0.34	0.00	0.34	0.00	0.31	-8.36	0.34	0.00	0.34	0.00	0.34	0.00	0.34	0.00
WCB05	287	0.42	0.42	0.00	0.42	0.00	0.42	0.00	0.42	0.00	0.42	0.00	0.42	0.00	0.42	0.00
WCB06	4628	0.41	0.41	0.00	0.41	0.00	0.37	-8.06	0.38	-7.49	0.37	-8.06	0.40	-1.98	0.37	-8.06
WCB06	4095	0.10	0.10	0.00	0.10	0.00	0.11	1.84	0.11	1.58	0.11	1.84	0.11	0.66	0.11	1.84
WCB06	3554	0.30	0.30	0.00	0.30	0.00	0.28	-6.61	0.29	-5.64	0.28	-6.61	0.30	-2.61	0.28	-6.61
WCB06	2874	0.18	0.18	0.00	0.18	0.00	0.19	4.52	0.19	3.74	0.19	4.52	0.21	16.41	0.19	4.52
WCB06	2204	0.27	0.27	0.00	0.27	0.00	0.26	-5.20	0.29	7.07	0.26	-5.20	0.27	-1.72	0.26	-5.20
WCB06	1690	0.16	0.16	0.00	0.16	0.00	0.19	20.94	0.21	35.08	0.19	20.94	0.18	18.32	0.19	20.94
WCB06	999	0.33	0.33	0.00	0.33	0.00	0.33	0.00	0.47	41.56	0.33	0.00	0.41	24.50	0.33	0.00
WCB06	165	0.27	0.27	0.00	0.27	0.00	0.27	0.00	0.27	0.00	0.27	0.00	0.27	0.00	0.27	0.00

Table 3.4 - 100 year ARI Flood Velocity Impacts

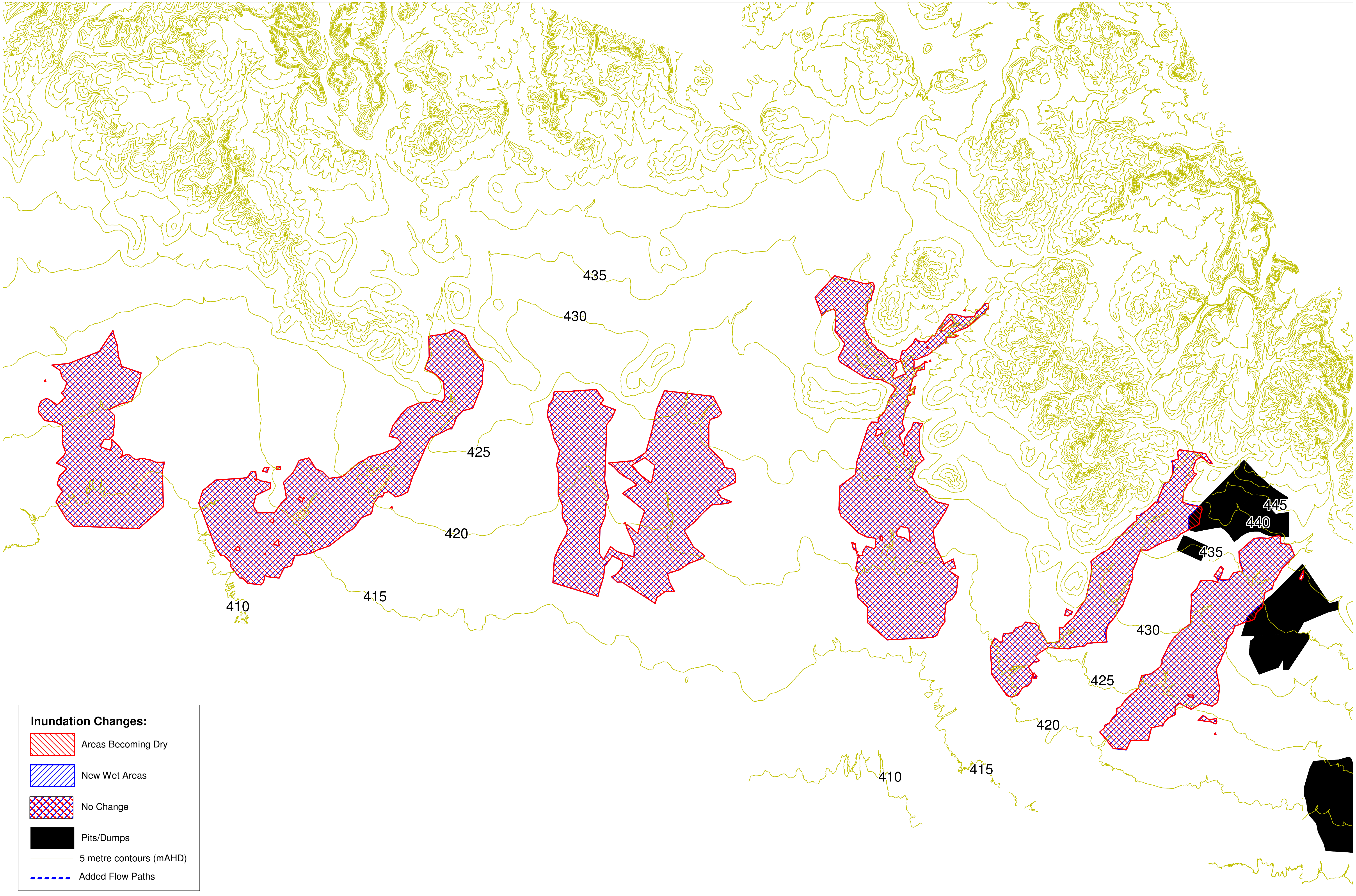
This table presents the expected impacts of the development on stream velocities.
Average cross sectional velocities and estimated percentage increase or decreases resulting from the development are presented.
In the 100 year flood, the channel velocities are likely to be much higher than the average velocity, but the percentage increase or decrease is likely to be similar.
River station is expressed in metres upstream of the downstream outlet used in the model.

Reach	River Station	PreDev	Phase 7		Phase 8 and 9		Phase 10 and 11		Phase 12 and 13		Phase 14 and 15		Phase 16		PostDev	
			Velocity	% Increase	Velocity	% Increase	Velocity	% Increase	Velocity	% Increase	Velocity	% Increase	Velocity	% Increase	Velocity	% Increase
WCB00	3172	0.19	0.19	0.01	0.19	0.00	0.19	0.01	0.19	0.00	0.19	3.52	0.17	-8.51	0.19	1.70
WCB00	2740	0.32	0.32	-0.01	0.32	0.00	0.32	-0.01	0.32	0.00	0.29	-10.64	0.29	-10.78	0.31	-5.34
WCB00	2332	0.19	0.19	0.02	0.19	0.00	0.19	0.02	0.19	0.00	0.24	29.19	0.22	19.23	0.19	4.74
WCB00	1783	0.60	0.60	-0.18	0.60	0.00	0.60	-0.18	0.60	0.00	0.51	-16.44	0.63	3.86	0.49	-18.74
WCB00	863	0.14	0.14	0.04	0.14	0.00	0.14	0.04	0.14	0.00	0.17	23.36	0.14	2.66	0.17	21.89
WCB00	385	0.28	0.28	0.00	0.28	0.00	0.28	0.00	0.28	0.00	0.32	14.25	0.32	14.25	0.32	14.25
WCB01	6496	0.37	0.37	0.00	0.37	0.00	0.37	0.00	0.37	0.00	0.37	0.00	0.36	-0.01	0.37	0.00
WCB01	6090	0.25	0.25	0.00	0.25	0.00	0.25	0.00	0.25	0.00	0.25	-0.04	0.25	0.18	0.25	0.00
WCB01	5773	0.28	0.28	0.00	0.28	0.00	0.28	0.00	0.28	0.00	0.28	-0.38	0.29	2.01	0.28	0.01
WCB01	5518	0.33	0.33	0.00	0.33	0.00	0.33	0.00	0.33	0.00	0.35	5.05	0.27	-18.95	0.33	-0.01
WCB01	5024	0.42	0.42	0.00	0.42	0.00	0.42	0.00	0.42	0.00	0.35	-16.05	0.89	112.09	0.42	0.11
WCB01	4465	0.33	0.33	0.00	0.33	0.00	0.33	0.00	0.33	0.00	0.62	87.33	0.33	-0.16	0.33	-0.16
WCB01	3769	0.36	0.36	0.00	0.36	0.00	0.36	0.00	0.36	0.00	0.45	25.16	0.36	0.32	0.36	0.33
WCB01	3023	0.39	0.39	0.00	0.39	0.00	0.39	0.00	0.39	0.00	0.38	-0.74	0.38	-0.73	0.38	-0.74
WCB01	2555	0.23	0.23	0.00	0.23	0.00	0.23	0.00	0.23	0.00	0.24	1.13	0.24	1.12	0.24	1.13
WCB01	1766	0.74	0.74	0.00	0.74	0.00	0.74	0.00	0.74	0.00	0.70	-6.33	0.70	-6.34	0.70	-6.37
WCB01	580	0.38	0.38	0.00	0.38	0.00	0.38	0.00	0.38	0.00	0.36	-4.06	0.36	-3.90	0.36	-4.05
WCB02	3269	0.42	0.42	0.00	0.42	0.00	0.42	0.00	0.81	92.70	0.33	-21.58	0.33	-21.58	0.33	-21.58
WCB02	2685	0.24	0.24	0.00	0.24	0.00	0.24	0.00	0.20	-17.16	0.34	40.60	0.34	40.60	0.34	40.60
WCB02	2156	0.22	0.22	0.00	0.22	0.00	0.22	0.00	0.35	60.11	0.22	0.00	0.22	0.00	0.22	0.00
WCB02	1700	0.22	0.22	-0.01	0.22	0.00	0.22	0.00	0.22	0.31	0.22	0.00	0.22	0.00	0.22	0.00
WCB02	1157	0.58	0.58	0.01	0.58	0.00	0.58	0.00	0.59	1.66	0.58	0.00	0.58	0.00	0.58	0.00
WCB02	578	0.22	0.22	-0.02	0.22	0.00	0.22	0.00	0.22	0.00	0.22	0.00	0.22	0.00	0.22	0.00
WCB02	210	0.38	0.38	0.00	0.38	0.00	0.38	0.00	0.38	0.00	0.38	0.00	0.38	0.00	0.38	0.00
WCB03	3538	0.26	0.26	0.00	0.26	0.00	0.26	-0.42	0.26	1.21	0.26	-0.42	0.26	-0.42	0.26	-0.42
WCB03	3177	0.25	0.25	0.00	0.25	0.00	0.25	1.04	0.24	-2.80	0.25	1.04	0.25	1.04	0.25	1.04
WCB03	2829	0.21	0.21	0.00	0.21	0.00	0.20	-5.86	0.14	-32.31	0.20	-5.86	0.20	-5.86	0.20	-5.86
WCB03	2310	0.19	0.19	0.00	0.19	0.00	0.26	32.13	0.30	55.54	0.26	32.13	0.26	32.13	0.26	32.13
WCB03	1946	0.16	0.16	0.01	0.16	0.00	0.20	22.88	0.31	89.48	0.20	22.88	0.20	22.88	0.20	22.88
WCB03	1448	0.40	0.40	0.05	0.40	0.00	0.44	10.85	0.50	26.21	0.44	10.85	0.44	10.85	0.44	10.85
WCB03	868	0.20	0.20	-0.02	0.20	0.00	0.20	-0.02	0.26	27.61	0.20	-0.02	0.20	-0.02	0.20	-0.02
WCB03	523	0.28	0.28	0.02	0.28	0.00	0.28	0.02	0.32	14.97	0.28	0.02	0.28	0.02	0.28	0.02
WCB03	80	0.38	0.38	0.00	0.38	0.00	0.38	0.00	0.38	0.00	0.38	0.00	0.38	0.00	0.38	0.00

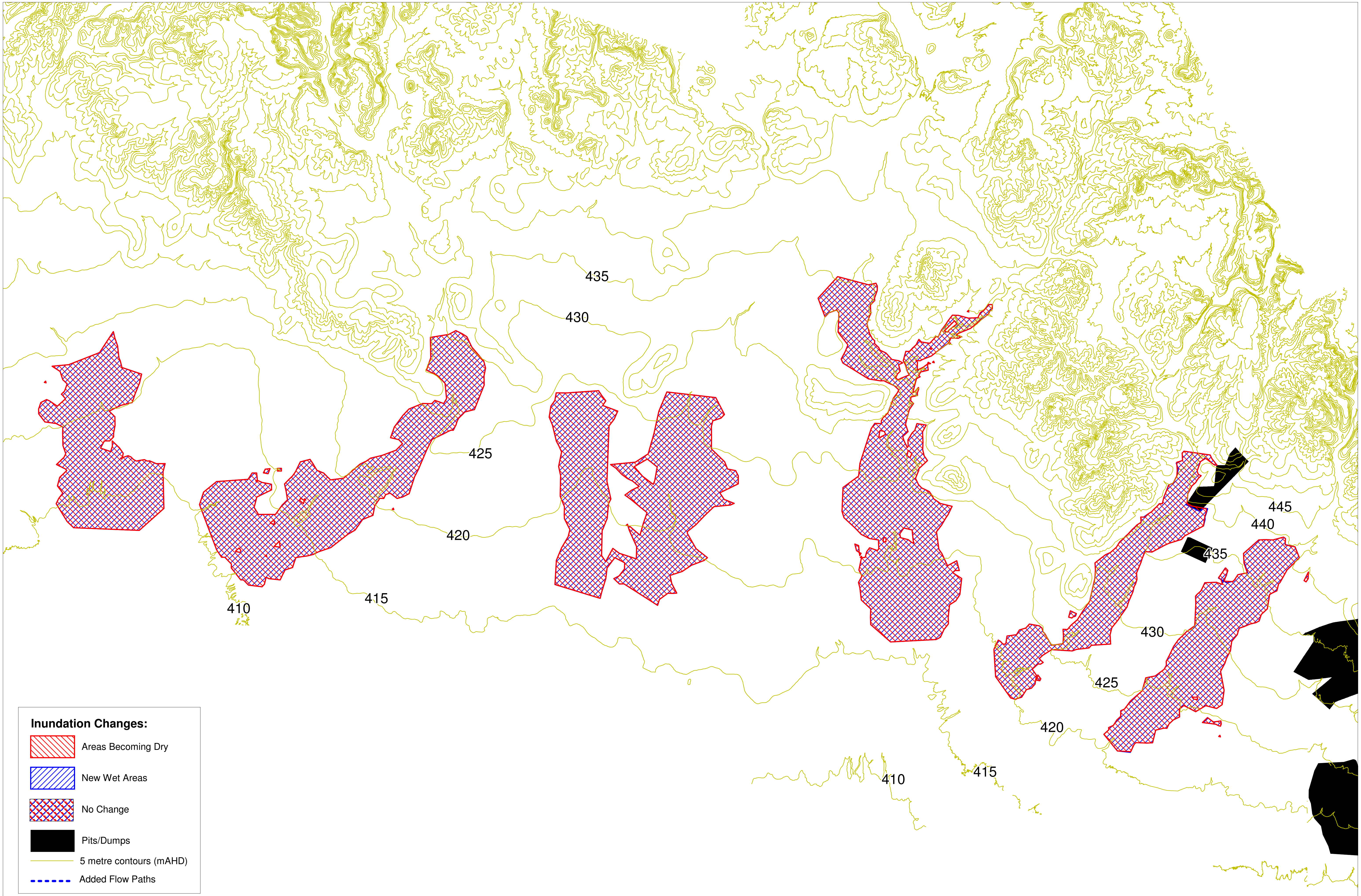
Reach	River Station	PreDev	Phase 7		Phase 8 and 9		Phase 10 and 11		Phase 12 and 13		Phase 14 and 15		Phase 16		PostDev	
			Velocity	% Increase	Velocity	% Increase	Velocity	% Increase	Velocity	% Increase	Velocity	% Increase	Velocity	% Increase	Velocity	% Increase
WCB04	6924	0.38	0.38	0.00	0.38	0.00	0.38	0.68	0.38	0.58	0.38	0.58	0.38	0.58	0.38	0.58
WCB04	6363	0.25	0.25	0.00	0.25	0.00	0.23	-7.59	0.24	-5.35	0.24	-5.35	0.24	-5.35	0.24	-5.35
WCB04	6015	0.38	0.38	0.00	0.38	0.00	0.46	21.41	0.48	27.78	0.48	27.78	0.48	27.78	0.48	27.78
WCB04	5742	0.36	0.36	0.00	0.36	0.00	0.38	7.07	0.36	0.00	0.36	0.00	0.36	0.00	0.36	0.00
WCB04	5309	0.39	0.39	0.00	0.39	0.00	0.37	-5.96	0.39	0.01	0.39	0.01	0.39	0.01	0.39	0.01
WCB04	4733	0.69	0.69	0.00	0.69	0.00	1.02	48.97	0.69	0.05	0.69	0.05	0.69	0.05	0.69	0.05
WCB04	4390	0.44	0.44	0.00	0.44	0.00	0.43	-2.00	0.43	-3.22	0.43	-3.20	0.43	-3.22	0.43	-3.21
WCB04	4072	0.46	0.46	0.00	0.46	0.00	0.61	33.45	0.55	19.49	0.55	19.79	0.55	19.45	0.55	19.54
WCB04	3568	0.36	0.36	0.00	0.36	0.00	0.30	-15.89	0.38	6.39	0.38	5.77	0.38	6.46	0.38	6.30
WCB04	3124	0.26	0.26	0.00	0.26	0.00	0.28	9.77	0.25	-0.25	0.26	0.16	0.25	-0.45	0.26	-0.03
WCB04	2780	0.29	0.29	0.00	0.29	0.00	0.37	27.55	0.30	0.76	0.29	0.10	0.30	2.02	0.29	0.10
WCB04	2445	0.25	0.25	0.00	0.25	0.00	0.41	60.02	0.24	-6.55	0.25	-0.32	0.29	13.98	0.25	-0.32
WCB04	1985	0.66	0.66	0.00	0.66	0.00	0.67	2.17	0.93	41.30	0.67	2.17	0.67	2.17	0.67	2.17
WCB04	1326	0.30	0.30	0.00	0.30	0.00	0.32	3.92	0.38	23.57	0.32	3.92	0.32	3.92	0.32	3.92
WCB04	257	0.44	0.44	0.00	0.44	0.00	0.44	0.00	0.44	0.00	0.44	0.00	0.44	0.00	0.44	0.00
WCB4b	1976	0.71	0.71	0.00	0.71	0.00	0.71	0.00	0.71	0.00	0.71	0.00	0.71	0.00	0.71	0.00
WCB4b	1739	0.97	0.97	0.00	0.97	0.00	0.96	-0.07	0.97	0.00	0.97	0.00	0.97	0.00	0.97	0.00
WCB4b	1416	0.46	0.46	0.00	0.46	0.00	0.46	0.23	0.46	0.00	0.46	0.00	0.46	0.00	0.46	0.00
WCB4b	1110	0.37	0.37	0.00	0.37	0.00	0.37	-1.21	0.37	0.00	0.37	0.00	0.37	0.00	0.37	0.00
WCB4b	897	1.03	1.03	0.00	1.03	0.00	1.45	41.23	1.03	0.00	1.03	0.00	1.03	0.00	1.03	0.00
WCB4b	465	0.39	0.39	0.00	0.39	0.00	0.19	-51.88	0.39	0.00	0.39	0.00	0.39	0.00	0.39	0.00
WCB4b	123	0.78	0.78	0.00	0.78	0.00	0.78	0.44	0.78	0.00	0.78	0.00	0.78	0.00	0.78	0.00
WCB05	5244	0.30	0.30	0.22	0.30	0.07	0.30	0.06	0.30	0.00	0.30	0.00	0.30	0.00	0.30	0.00
WCB05	4850	0.43	0.44	1.67	0.43	0.53	0.43	0.45	0.43	0.00	0.43	0.00	0.43	0.00	0.43	0.00
WCB05	4465	0.54	0.50	-6.25	0.55	1.57	0.55	1.84	0.54	0.00	0.54	0.00	0.54	0.00	0.54	0.00
WCB05	3989	0.22	0.25	10.69	0.22	0.00	0.22	-0.35	0.22	0.00	0.22	0.00	0.22	0.00	0.22	0.00
WCB05	3672	0.26	0.26	0.00	0.26	0.00	0.28	6.62	0.26	0.00	0.26	0.00	0.26	0.00	0.26	0.00
WCB05	3280	0.91	0.91	0.00	0.91	0.00	0.64	-29.32	0.91	0.00	0.91	0.00	0.91	0.00	0.91	0.00
WCB05	2980	0.26	0.26	0.00	0.26	0.00	0.13	-50.57	0.26	0.00	0.26	0.00	0.26	0.00	0.26	0.00
WCB05	2599	0.32	0.32	0.00	0.32	0.00	0.32	-2.55	0.32	0.00	0.32	0.00	0.32	0.00	0.32	0.00
WCB05	2240	0.40	0.40	0.00	0.40	0.00	0.66	64.92	0.40	0.00	0.40	0.00	0.40	0.00	0.40	0.00
WCB05	1838	0.41	0.41	0.00	0.41	0.00	0.28	-31.12	0.41	0.00	0.41	0.00	0.41	0.00	0.41	0.00
WCB05	1175	0.65	0.65	0.00	0.65	0.00	0.70	7.00	0.65	0.00	0.65	0.00	0.65	0.00	0.65	0.00
WCB05	287	0.44	0.44	0.00	0.44	0.00	0.44	-0.01	0.44	0.00	0.44	0.00	0.44	0.00	0.44	0.00
WCB06	4628	0.89	0.90	0.69	0.89	0.00	0.89	-0.36	0.93	4.00	0.89	-0.36	0.79	-12.18	0.89	-0.36
WCB06	4095	0.29	0.29	0.38	0.29	0.00	0.29	0.19	0.29	-2.11	0.29	0.19	0.31	6.68	0.29	0.19
WCB06	3554	0.50	0.52	4.11	0.50	0.00	0.50	-0.84	0.55	10.69	0.50	-0.84	0.40	-20.35	0.50	-0.84
WCB06	2874	0.34	0.34	0.00	0.34	0.00	0.34	0.66	0.31	-6.87	0.34	0.66	0.65	91.64	0.34	0.66
WCB06	2204	0.44	0.44	0.00	0.44	0.00	0.45	1.91	0.63	44.10	0.45	1.91	0.46	4.68	0.45	1.91
WCB06	1690	0.31	0.31	0.00	0.31	0.00	0.34	7.78	0.38	19.79	0.34	7.78	0.33	4.41	0.34	7.78
WCB06	999	0.56	0.56	0.00	0.56	0.00	0.56	0.00	0.65	15.14	0.56	0.00	0.58	2.64	0.56	0.00
WCB06	165	0.53	0.53	0.00	0.53	0.00	0.53	0.00	0.53	0.00	0.53	0.00	0.53	0.00	0.53	0.00



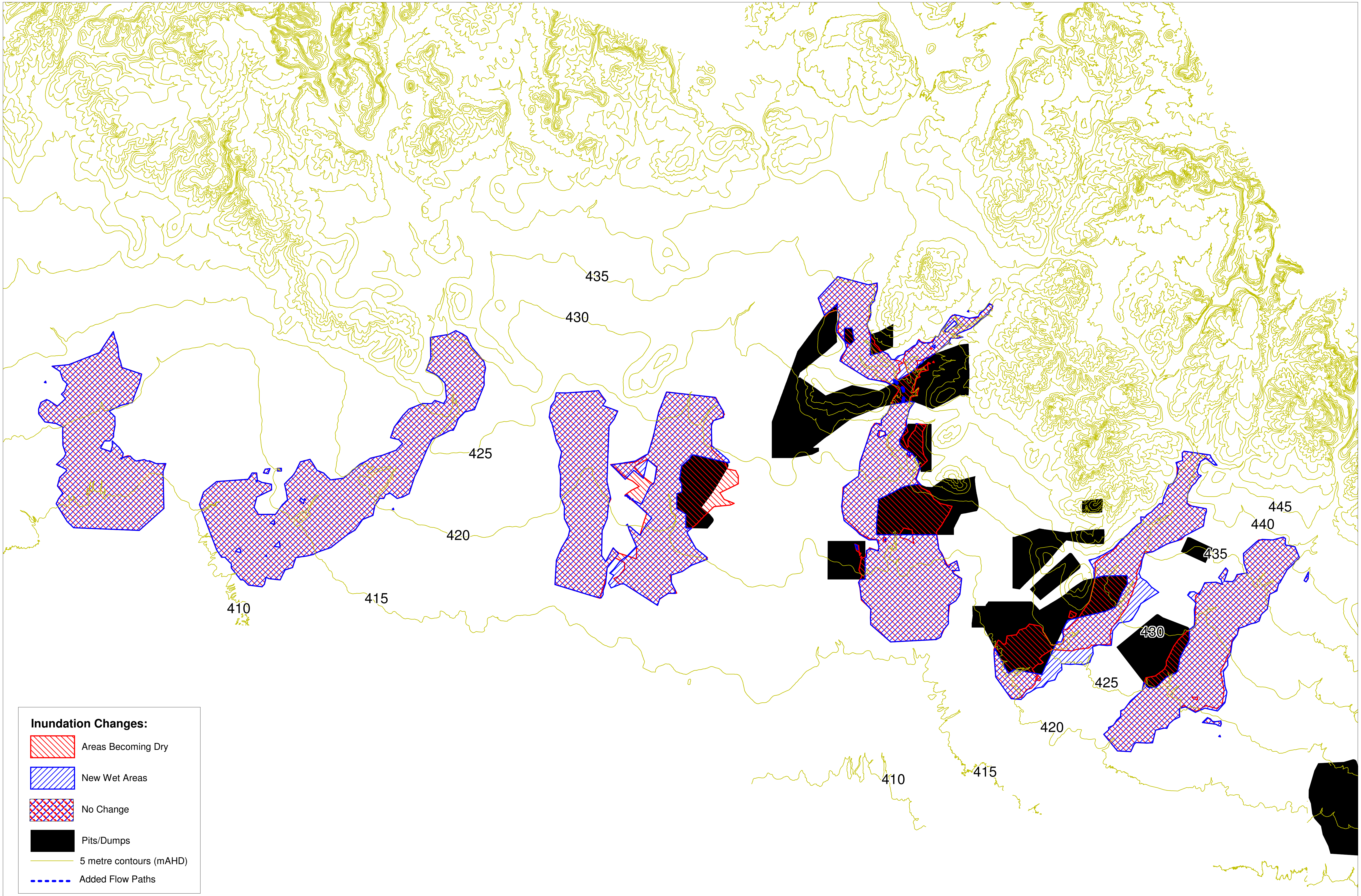
Estimated 100 year ARI Flood Extents - Pre-development



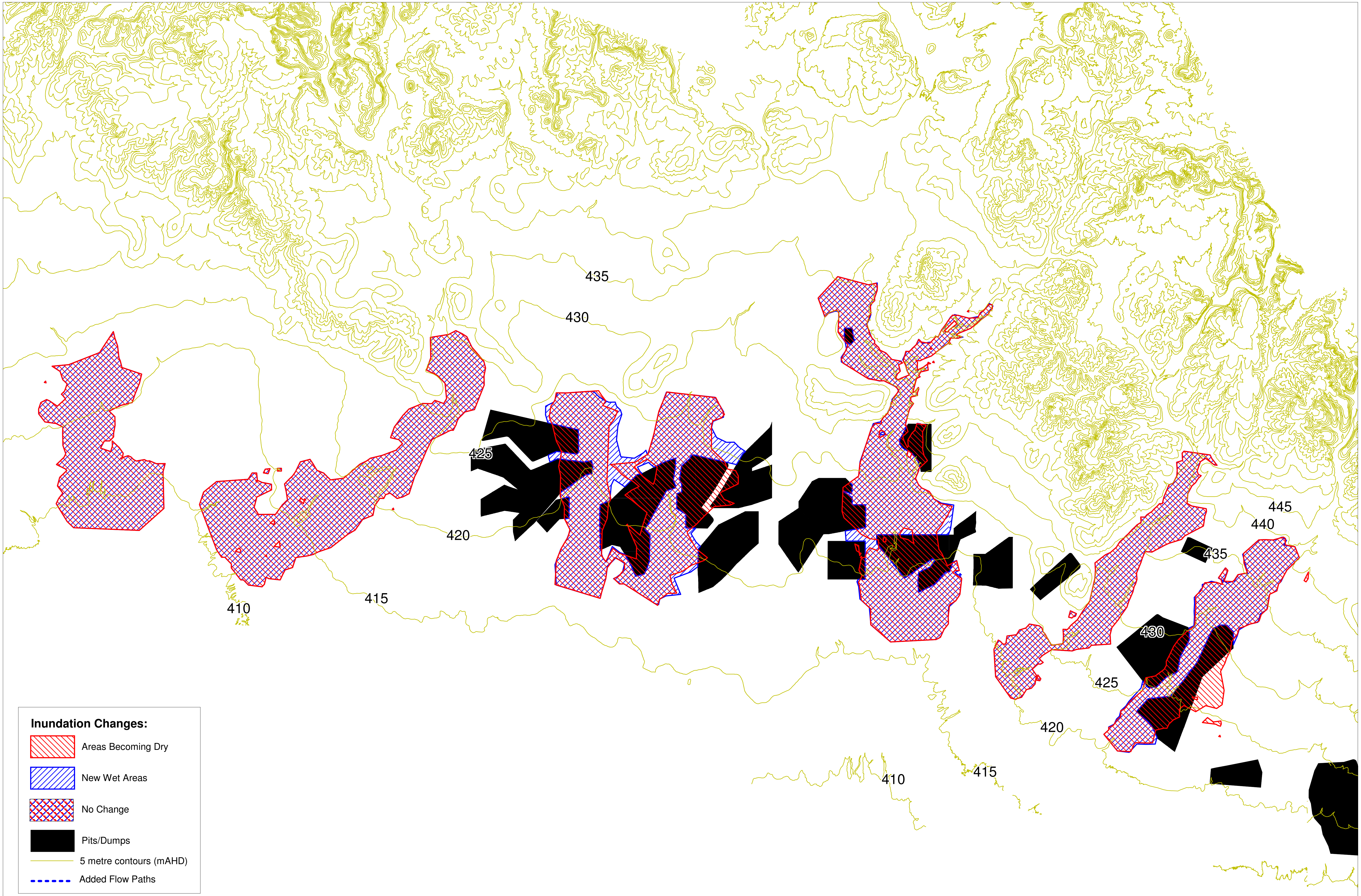
Estimated 100 year ARI Flood Extents - Mining Phase 7



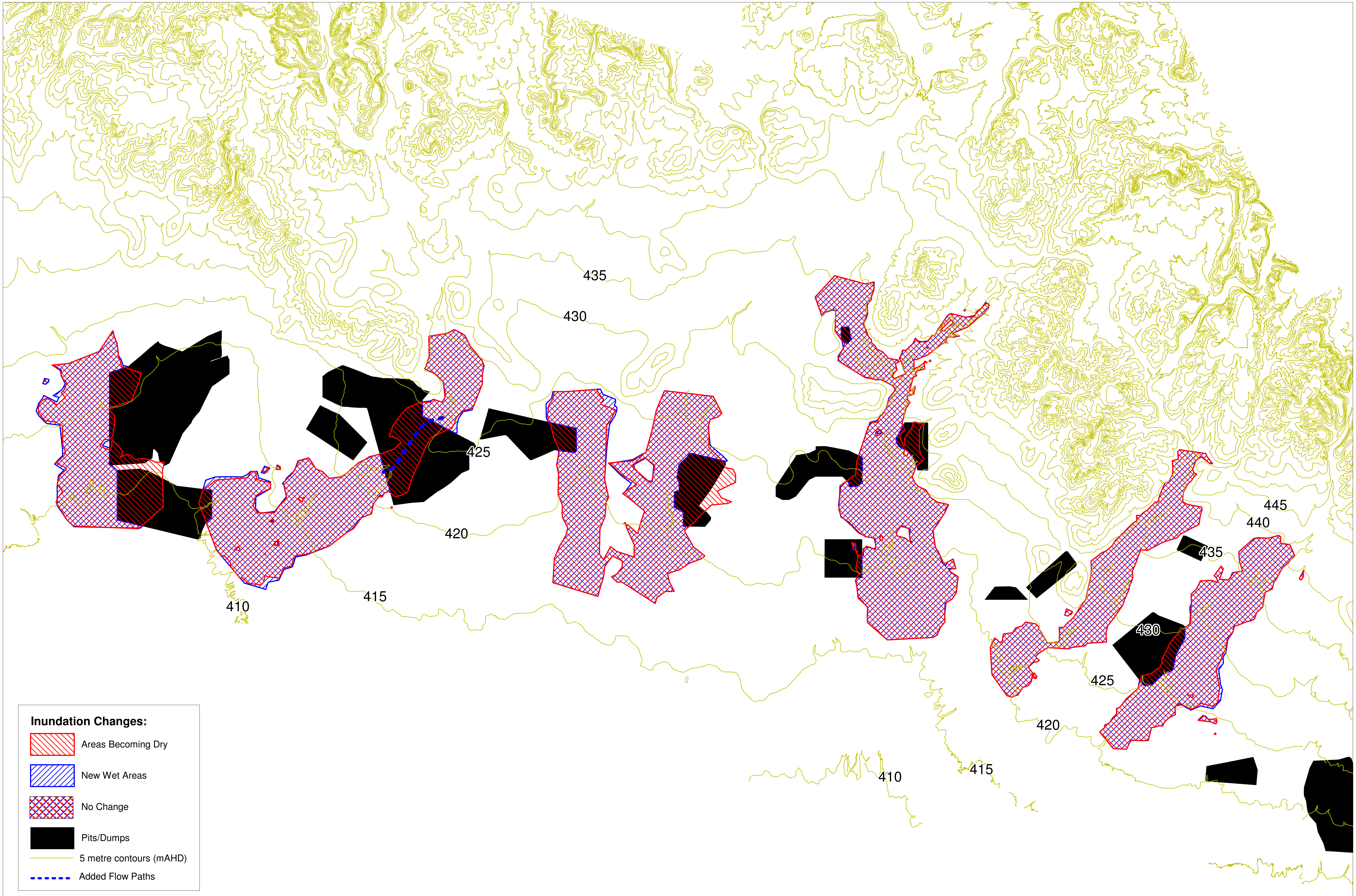
Estimated 100 year ARI Flood Extents - Mining Phase 8 and 9



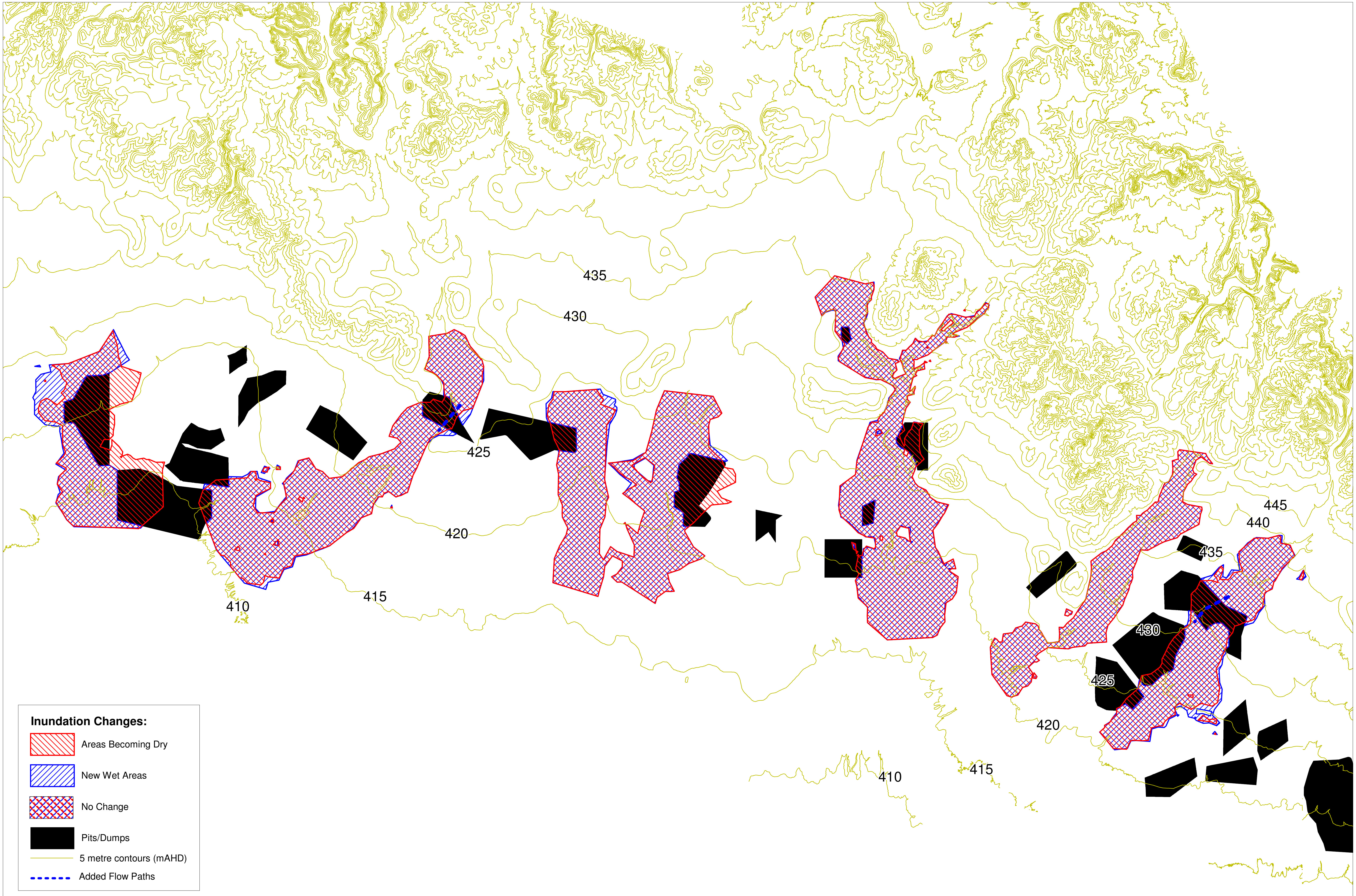
Estimated 100 year ARI Flood Extents - Mining Phase 10 and 11



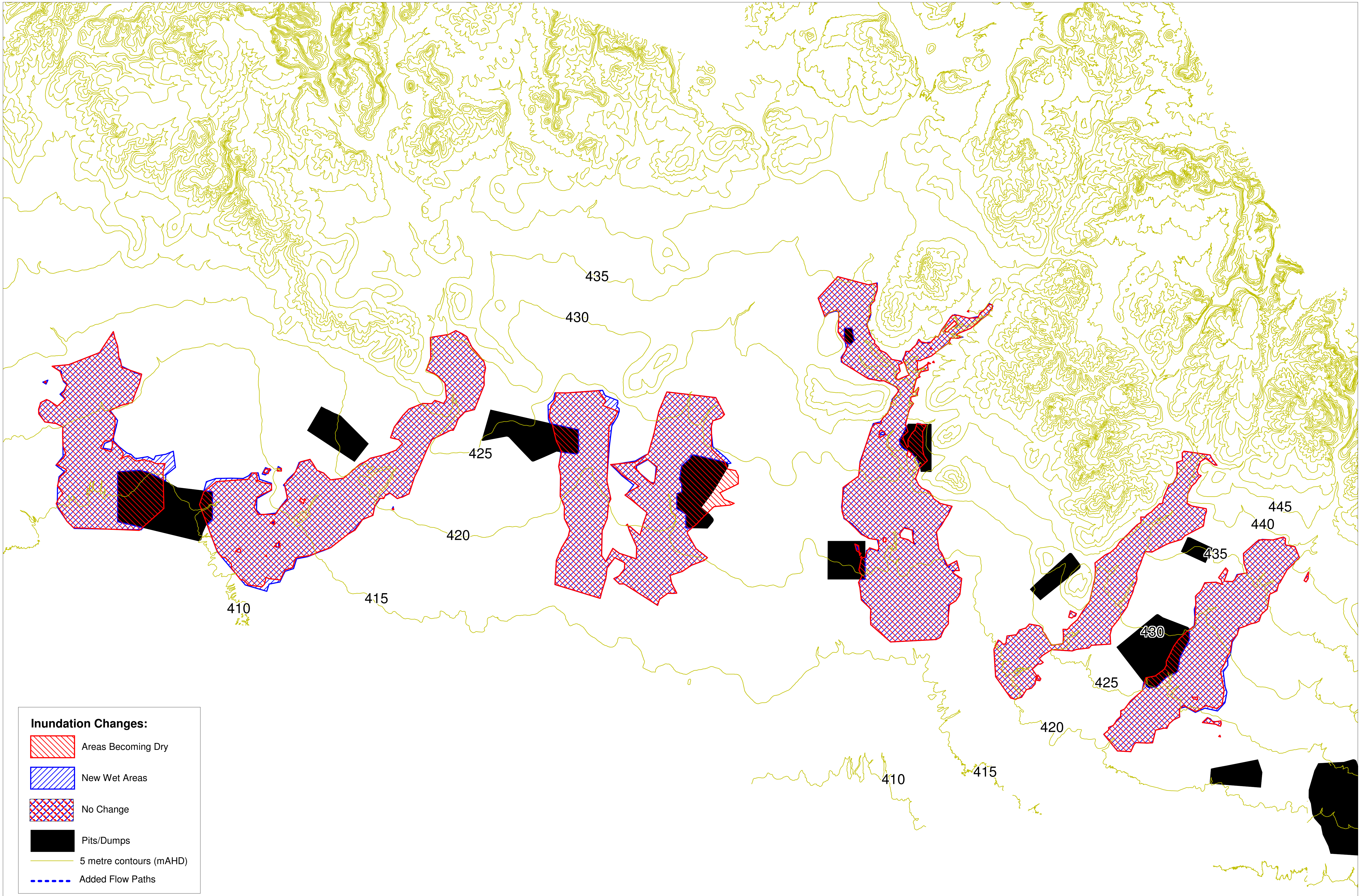
Estimated 100 year ARI Flood Extents - Mining Phase 12 and 13



Estimated 100 year ARI Flood Extents - Mining Phase 14 and 15



Estimated 100 year ARI Flood Extents - Mining Phase 16



Estimated 100 year ARI Flood Extents - Post Closure

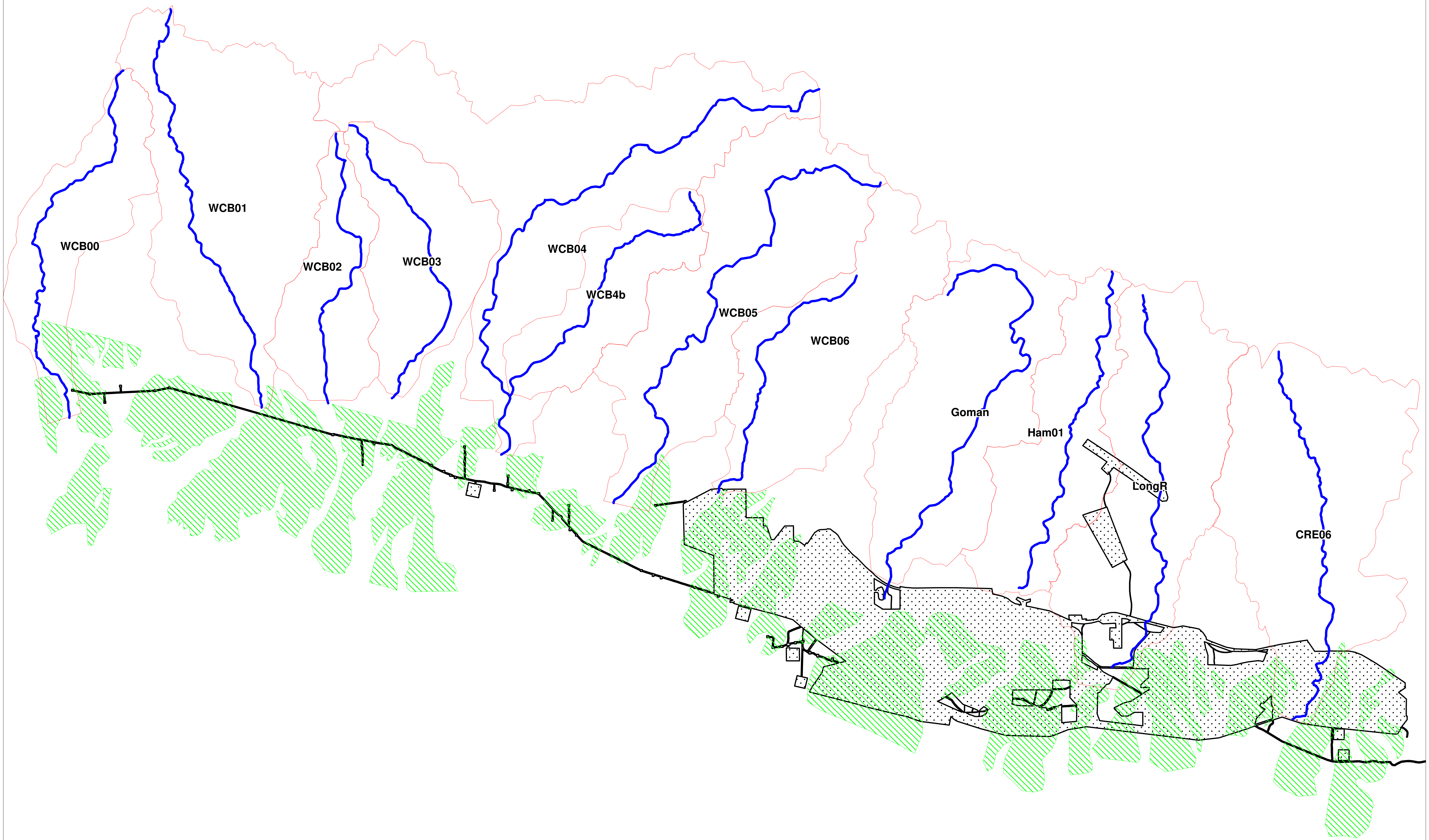
Appendix 4 – Ponded Areas Sheet Flow Impact Areas

Table 4.1 - Estimated impact areas for:

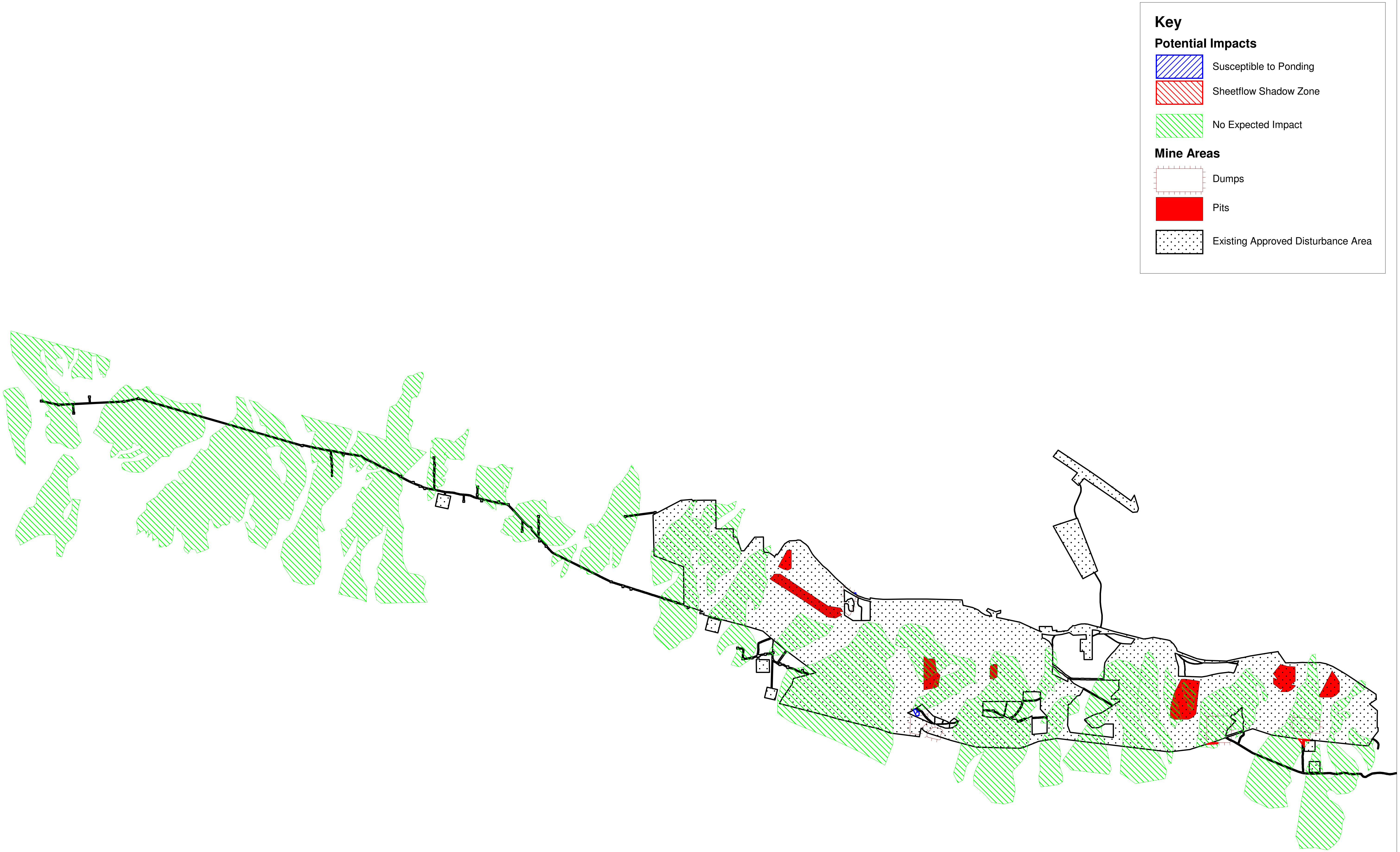
- Sheet flow shadow zones
- Sheet flow zones directly impacted by pits
- Sheet flow zones directly impacted by dumps
- Areas subject to ponding

These are areas OUTSIDE existing approved disturbance areas
Areas are quoted in square kilometres

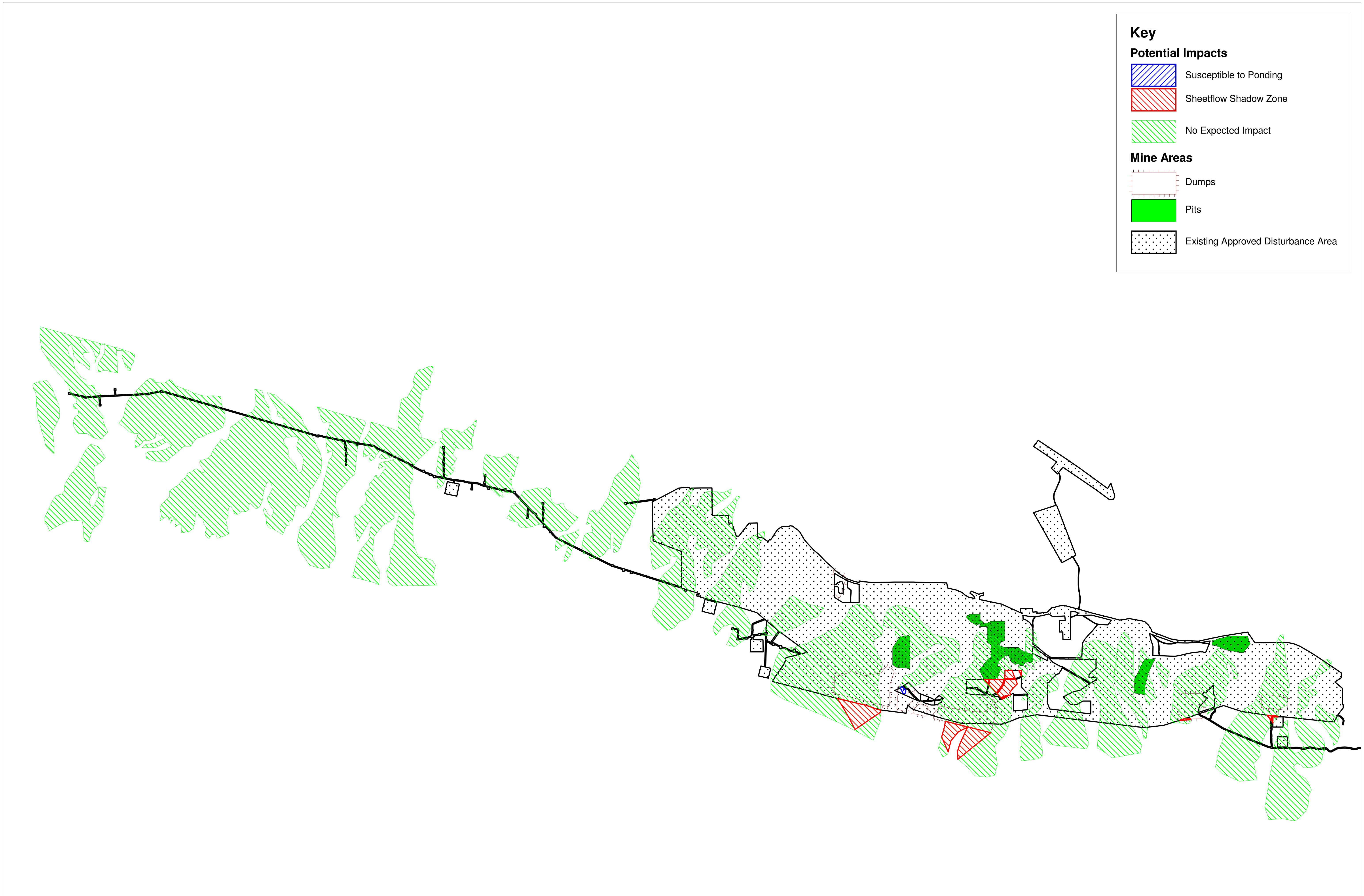
	Sheet flow Impact Type			
Mining Phase	Shadow Zones	Pit Areas	Dump Areas	Ponded Areas
Pre-development	0	0	0	0
1	0.02	0	0	0.02
2	1.48	0	0.18	0.02
3	2.5	0	0.55	0.06
4	2.5	0	0.6	0.06
5	2.93	0.08	0.7	0.06
6	2.57	0.48	0.7	0.06
7	2.98	0.03	0.84	0.08
8 and 9	2.54	0.48	0.84	0.38
10 and 11	3.37	1.86	1.36	1.3
12 and 13	4	3.83	2.25	0.38
14 and 15	7.97	3.06	2.98	0.65
16	3.94	1.59	2.98	0.32
Post Closure	2.98	0	2.98	0.2



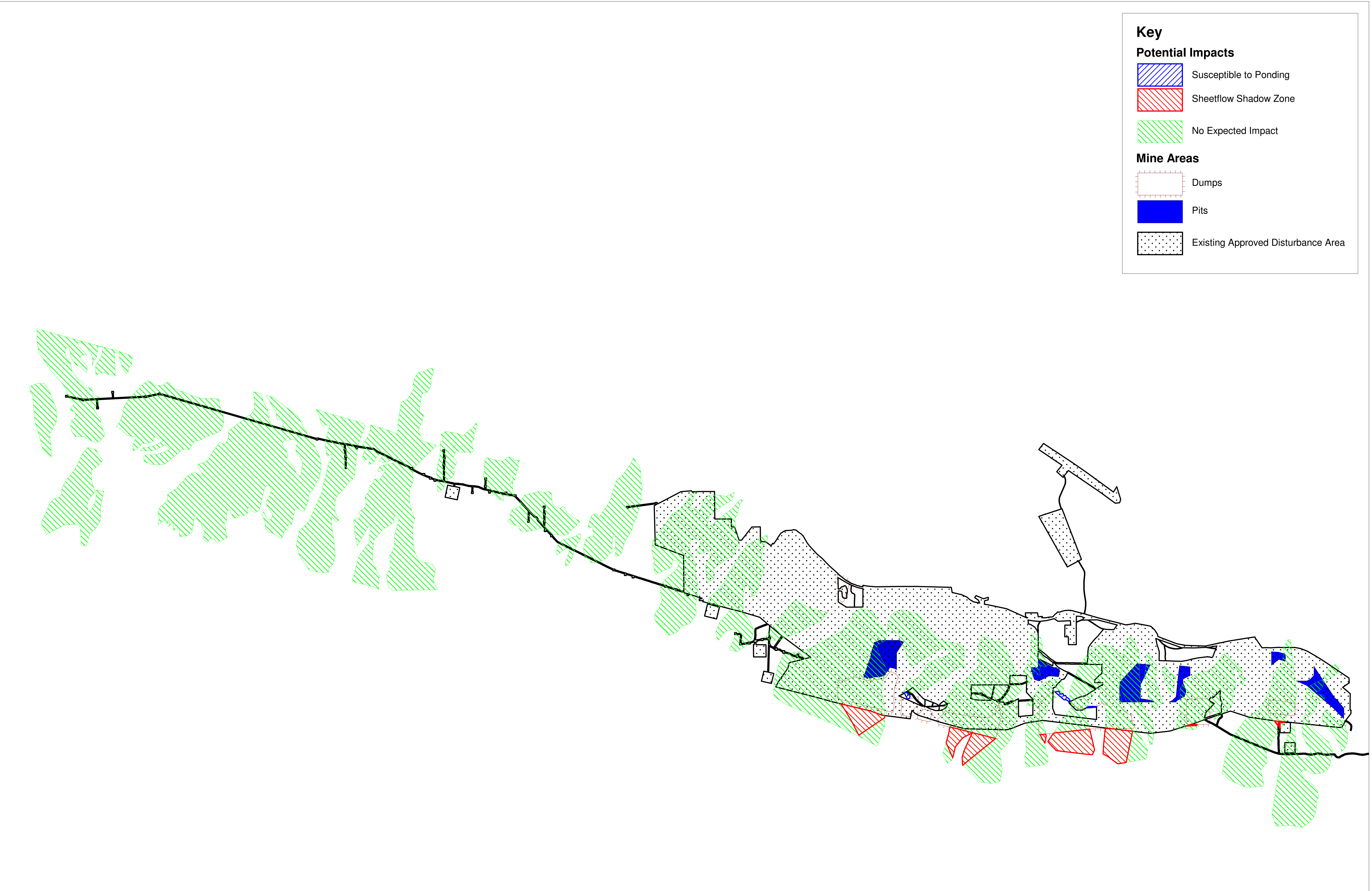
Major Catchments, Sheet flow Zones and Existing Part 4 Area (EPA Act, 1986)



Estimated Impact Areas - Mining Phase 1

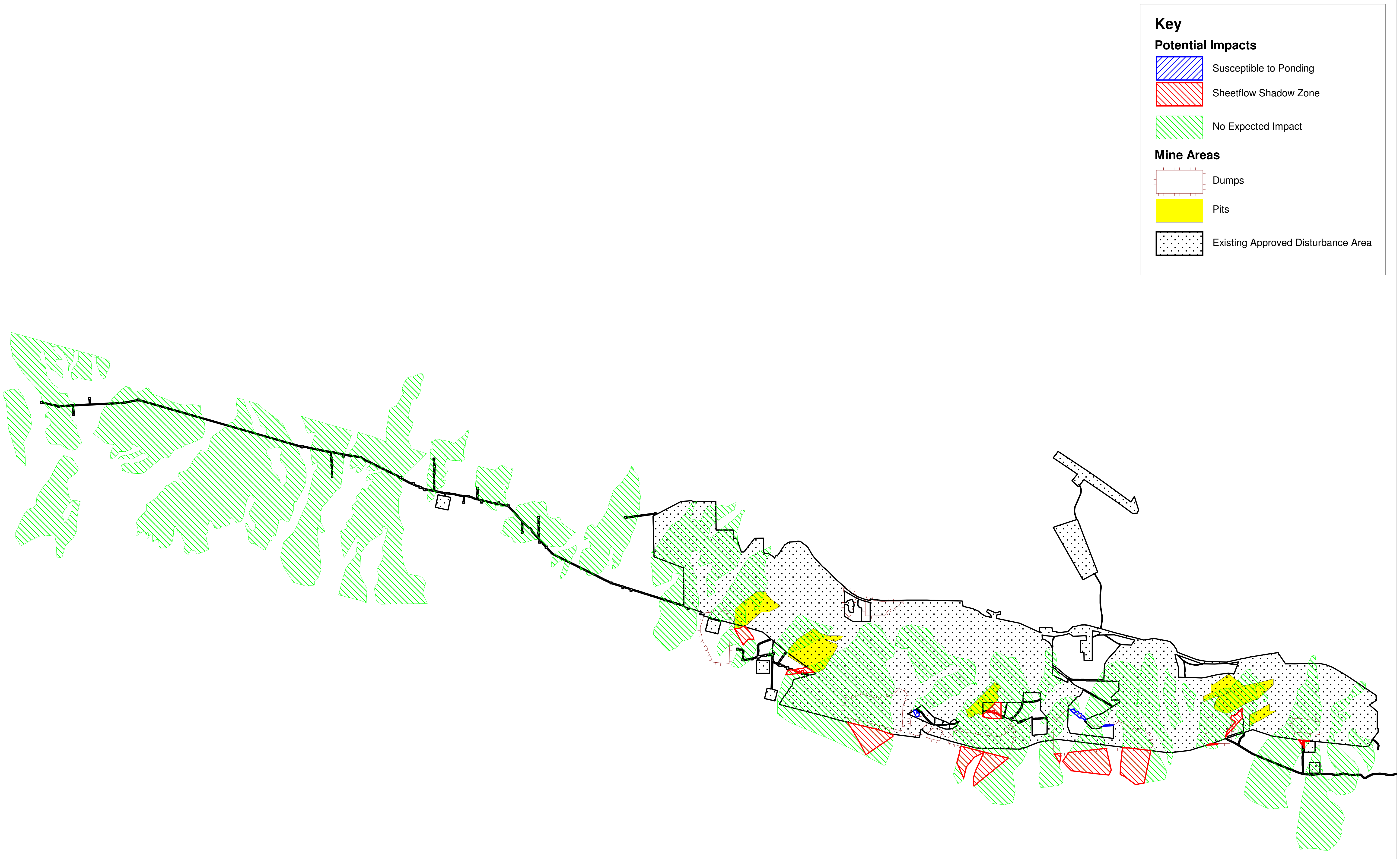


Estimated Impact Areas - Mining Phase 2

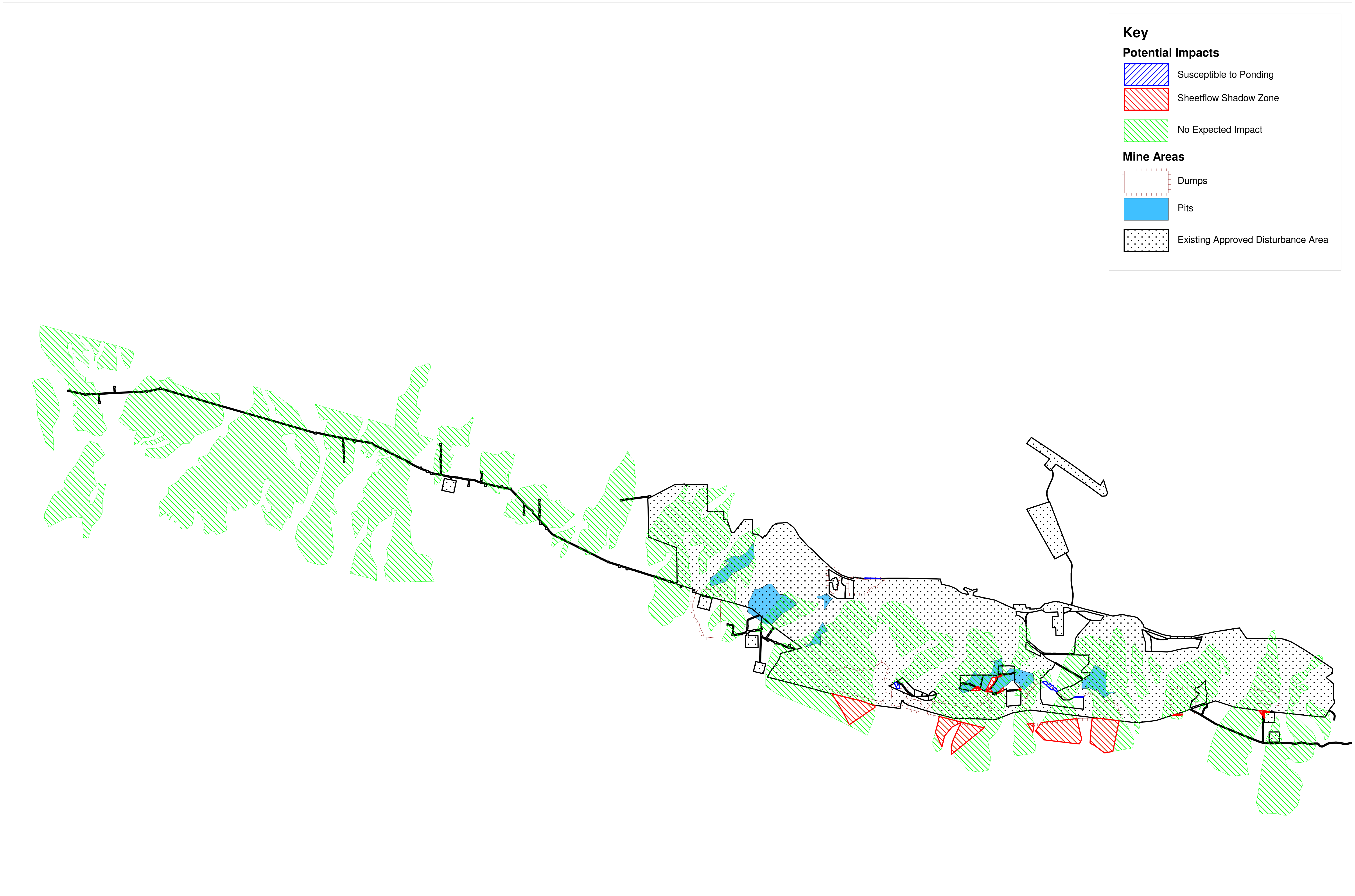


Estimated Impact Areas - Mining Phase 3

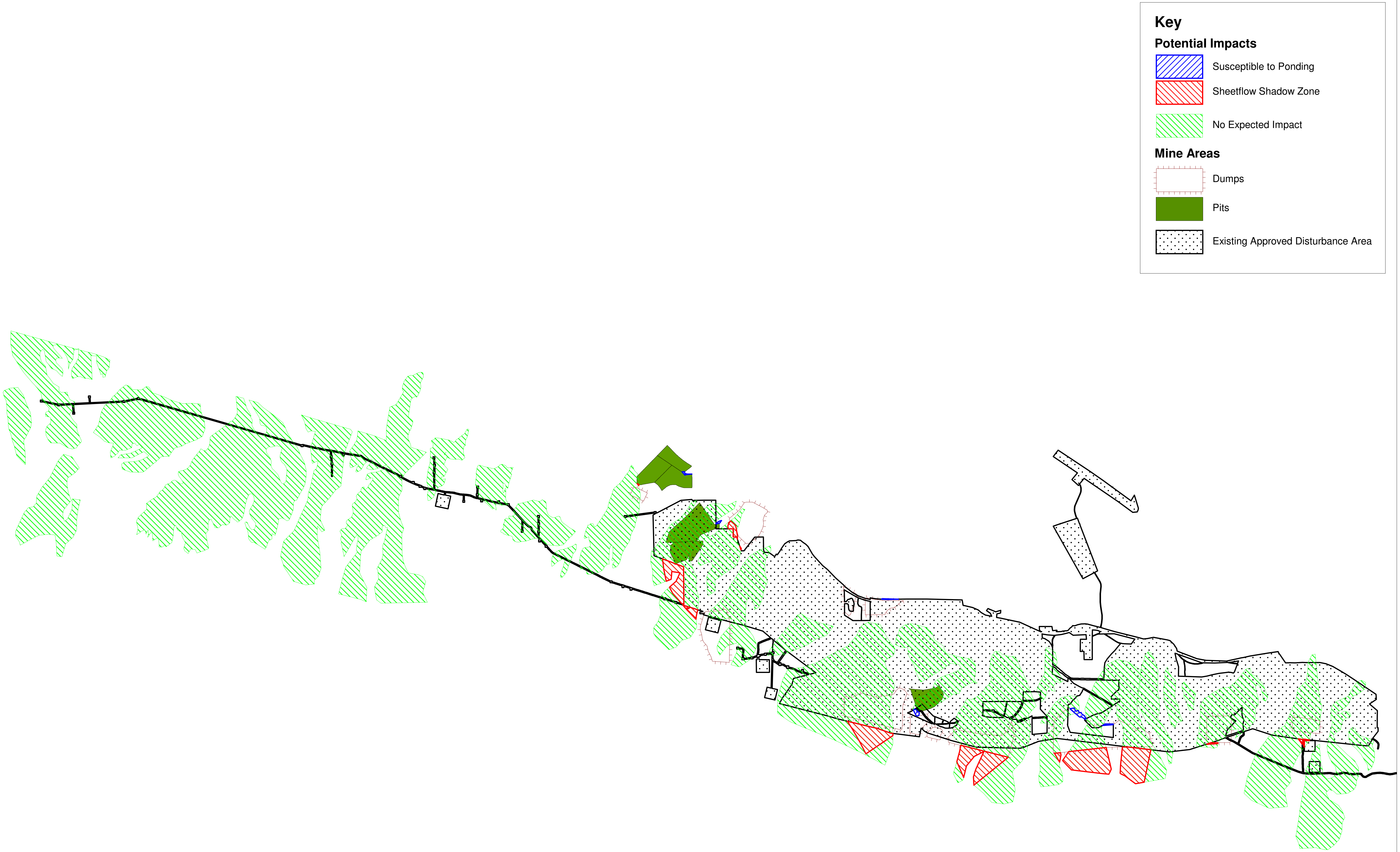
Estimated Impact Areas - Mining Phase 4



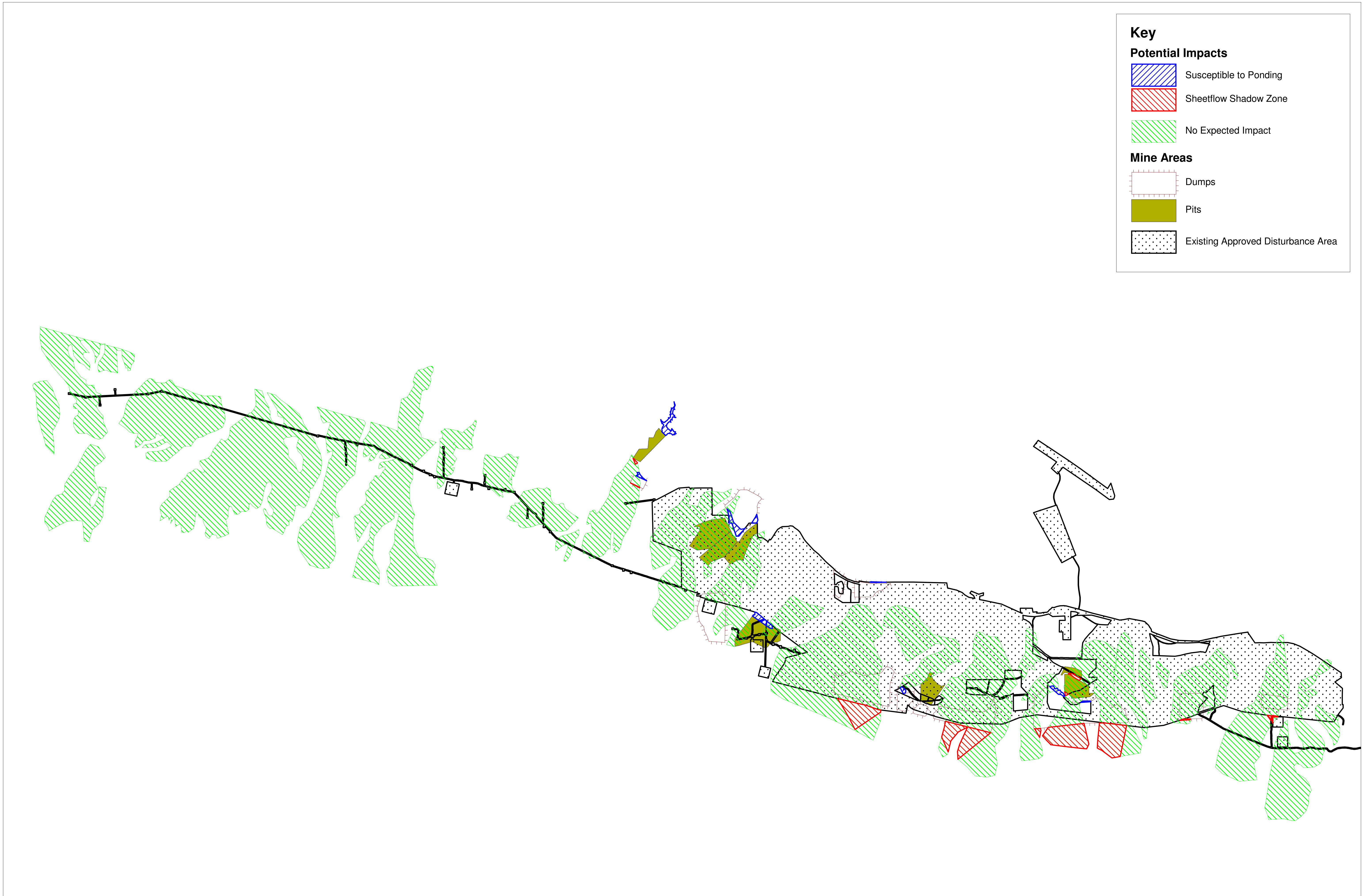
Estimated Impact Areas - Mining Phase 5



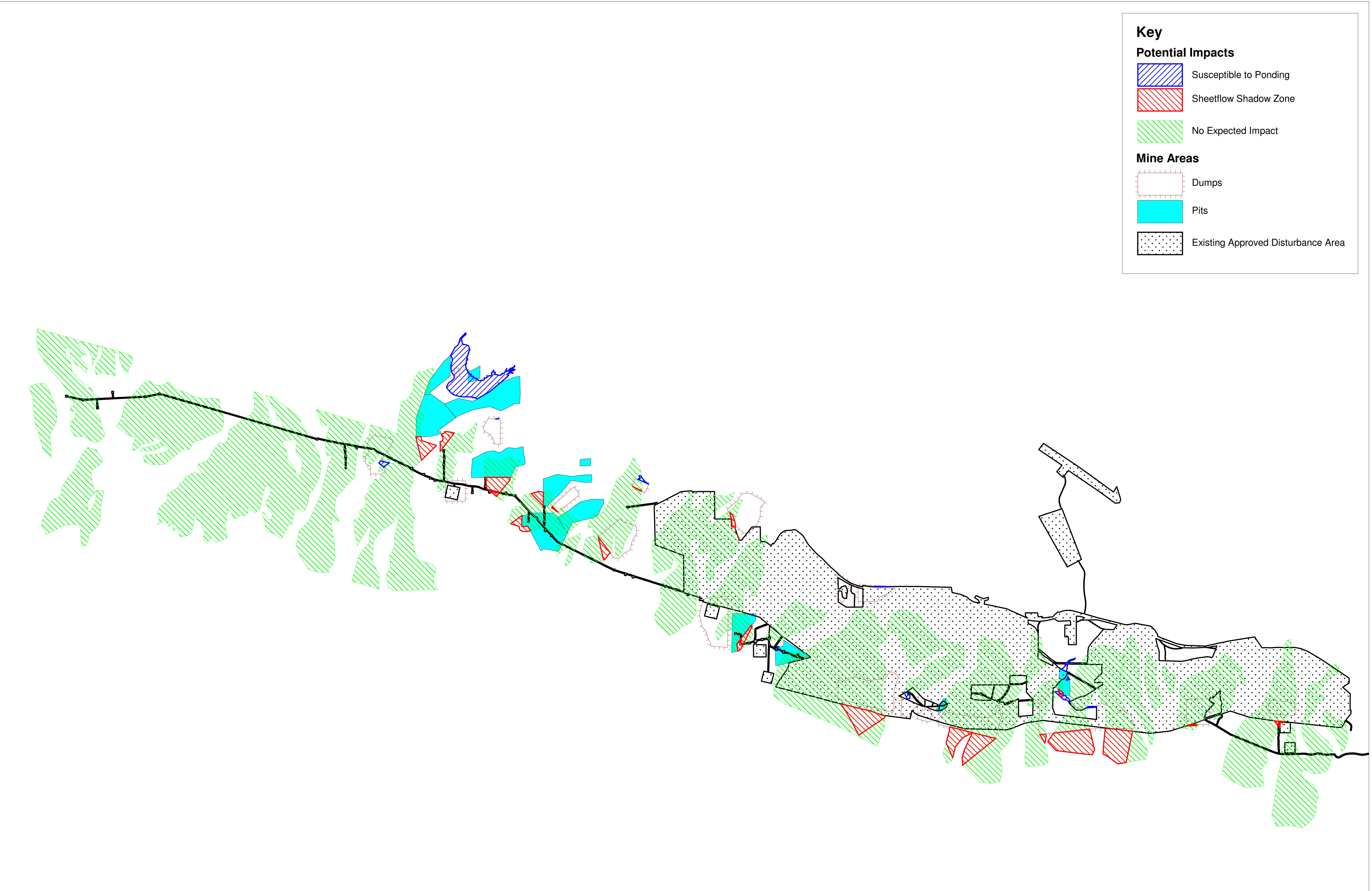
Estimated Impact Areas - Mining Phase 6



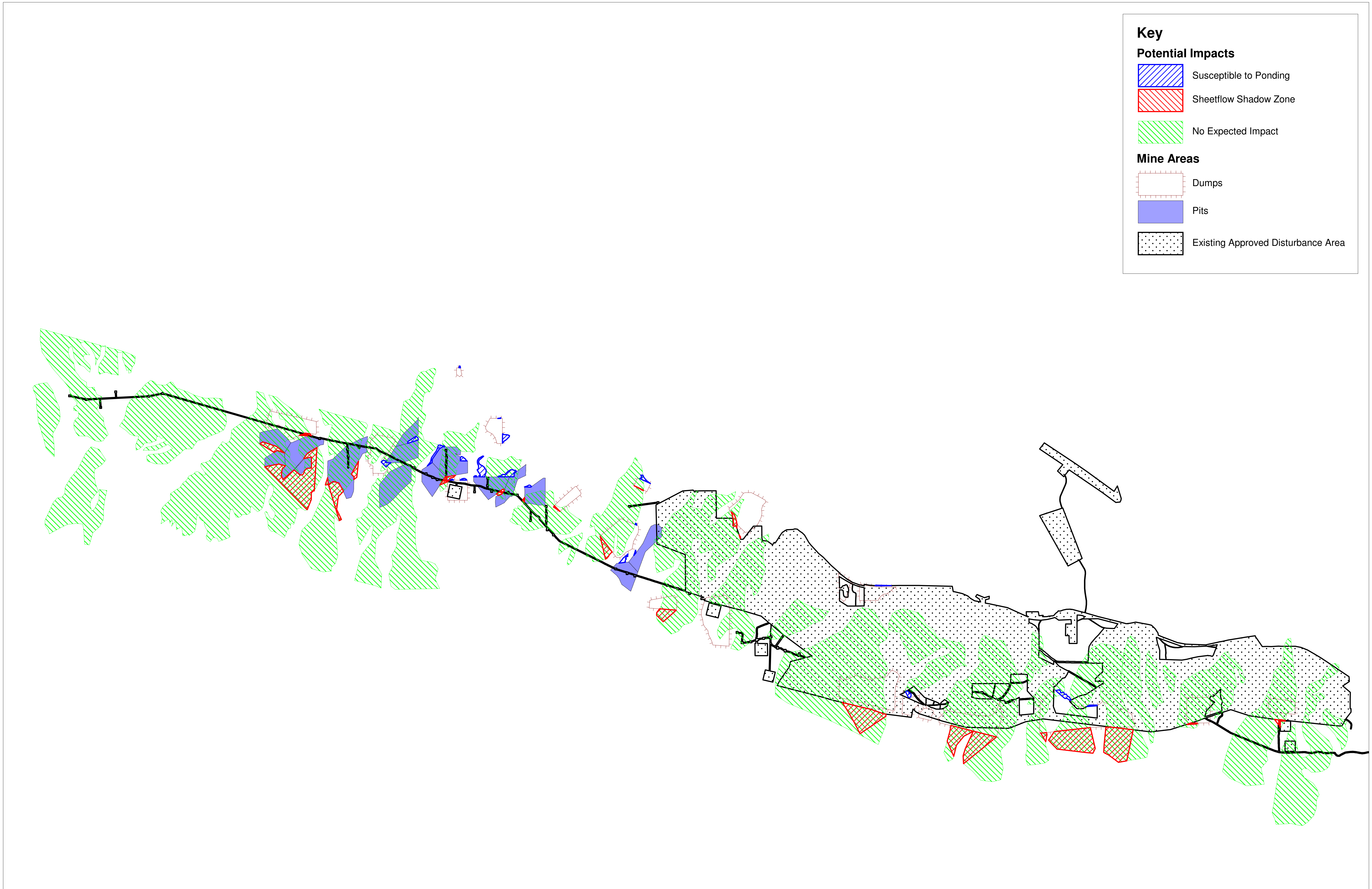
Estimated Impact Areas - Mining Phase 7



Estimated Impact Areas - Mining Phase 8 and 9

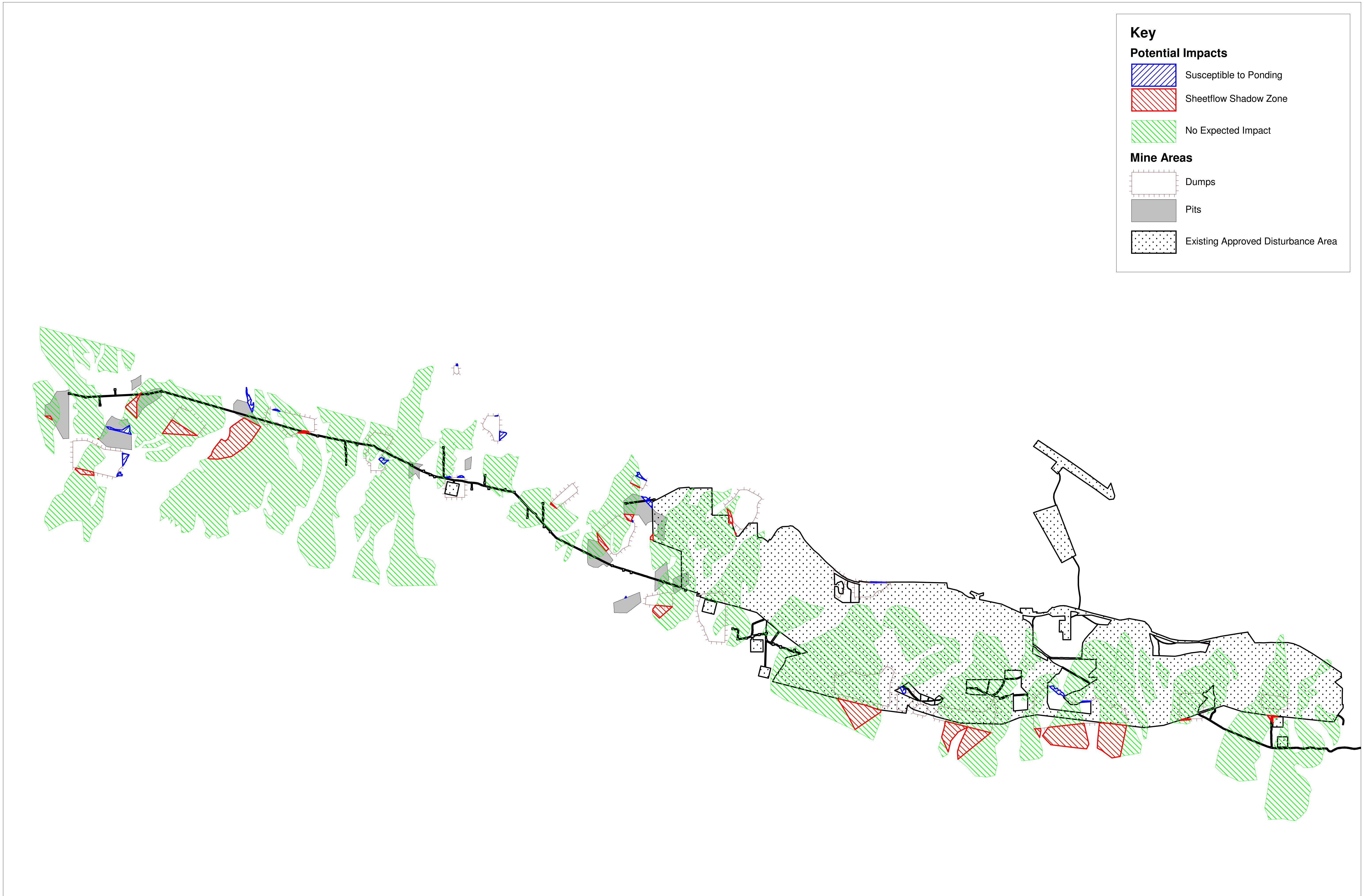


Estimated Impact Areas - Mining Phase 10 and 11

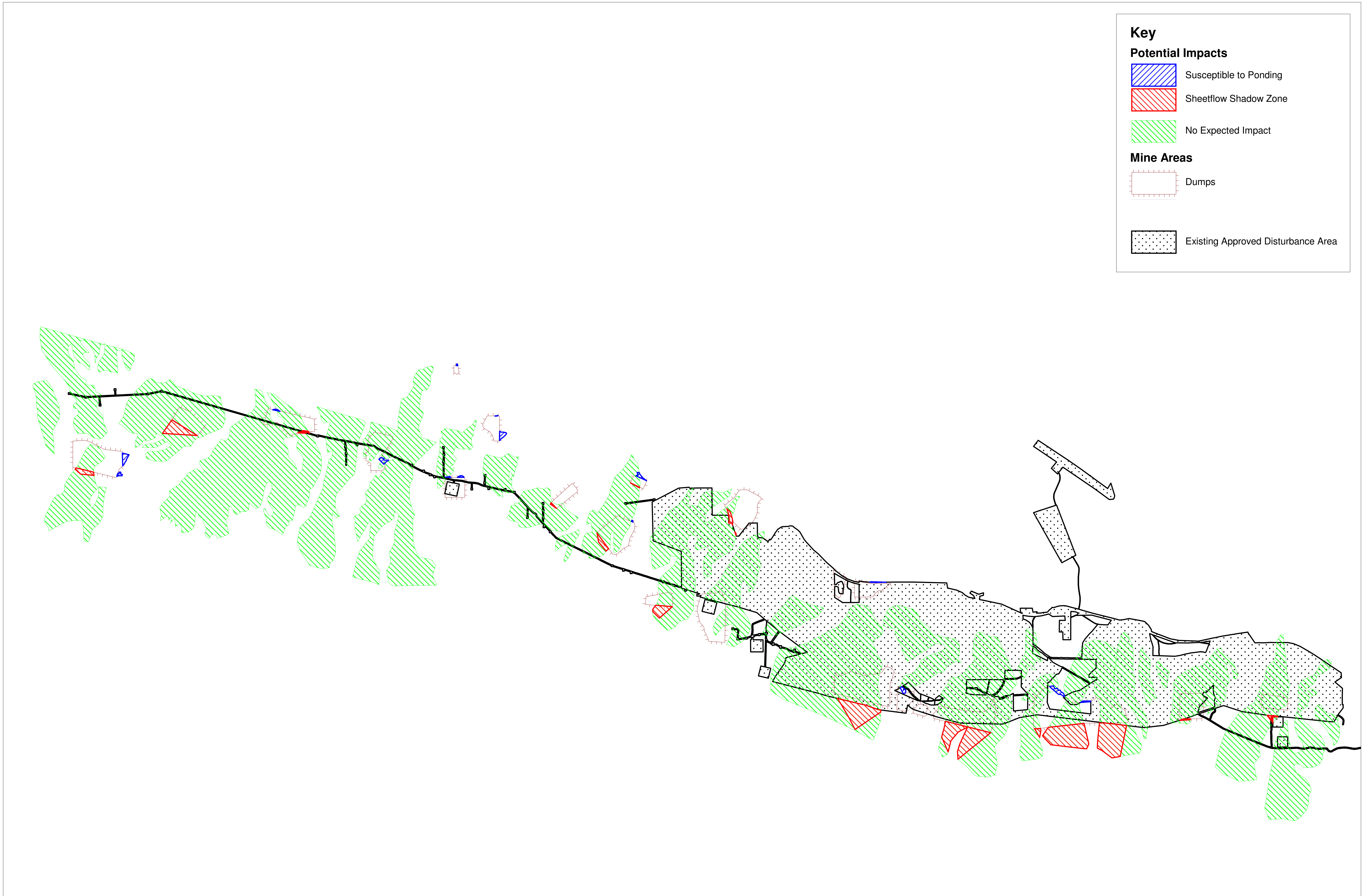


Estimated Impact Areas - Mining Phase 12 and 13

Estimated Impact Areas - Mining Phase 14 and 15



Estimated Impact Areas - Mining Phase 16



Estimated Impact Areas - Post Closure

Appendix 5 – Catchment Impact Areas for the Fortescue Marsh and Yintas

Appendix E shows the actual and potential reductions in catchment area for the Fortescue Marsh and the Yintas located downstream of the Cloudbreak Life of Mine expansion area. Actual reduction in catchment area is associated with pits and dumps which receive direct rainfall. Potential reductions are associated with catchment areas from which flow will be restricted by pits and dumps if suitable management measures are not implemented. The potential reductions include the areas covered by the actual reductions. The total catchment area of the Fortescue Marsh is approximately 26000 km^2.

All areas are expressed in square kilometres (km^2).

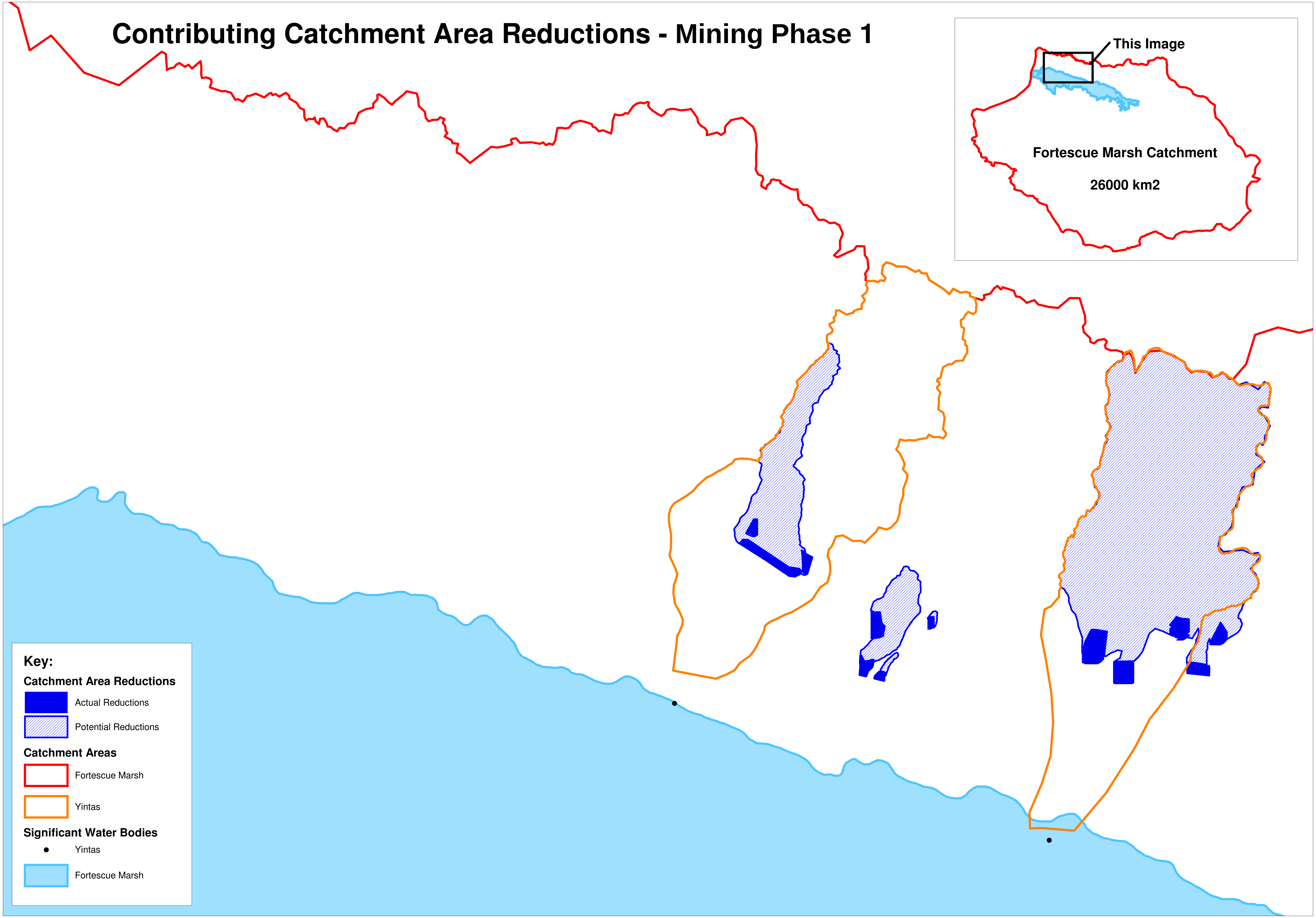
Table E1 – Catchment Area Reduction for the Fortescue Marsh

	Contributing Catchment Area Reductions	
Mining Phase	**Actual**	**Potential**
1	3.59	59.48
2	5.55	50.95
3	7.71	50.98
4	8.65	111.98
5	9.73	66.79
6	9.49	65.68
7	9.91	28.12
8 and 9	10.49	58.67
10 and 11	15.86	204.17
12 and 13	16.52	165.07
14 and 15	16.82	105.65
16	14.04	133.92
Post Closure	10.92	51.70

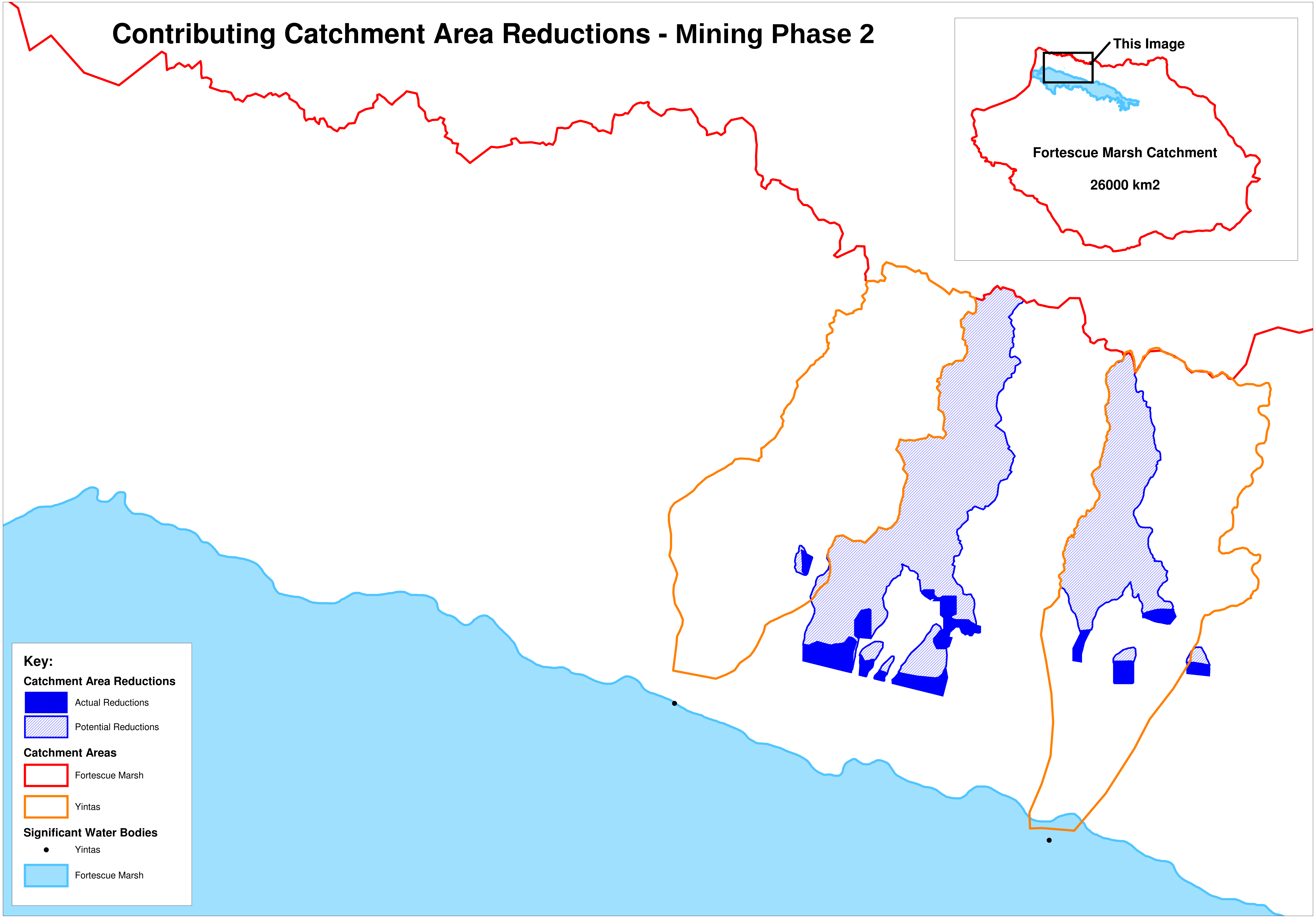
The two Yinta catchments roughly correspond to the Goman and CRE06 catchments shown in Appendix B. The potential and actual reductions in contributing catchment area for each of the Yintas is shown separately in Table E2. The total catchment areas are 57.7 km^2 for Goman and 63.4 km^2 for CRE06.

Table E2 - Catchment Area Reduction for the Yintas

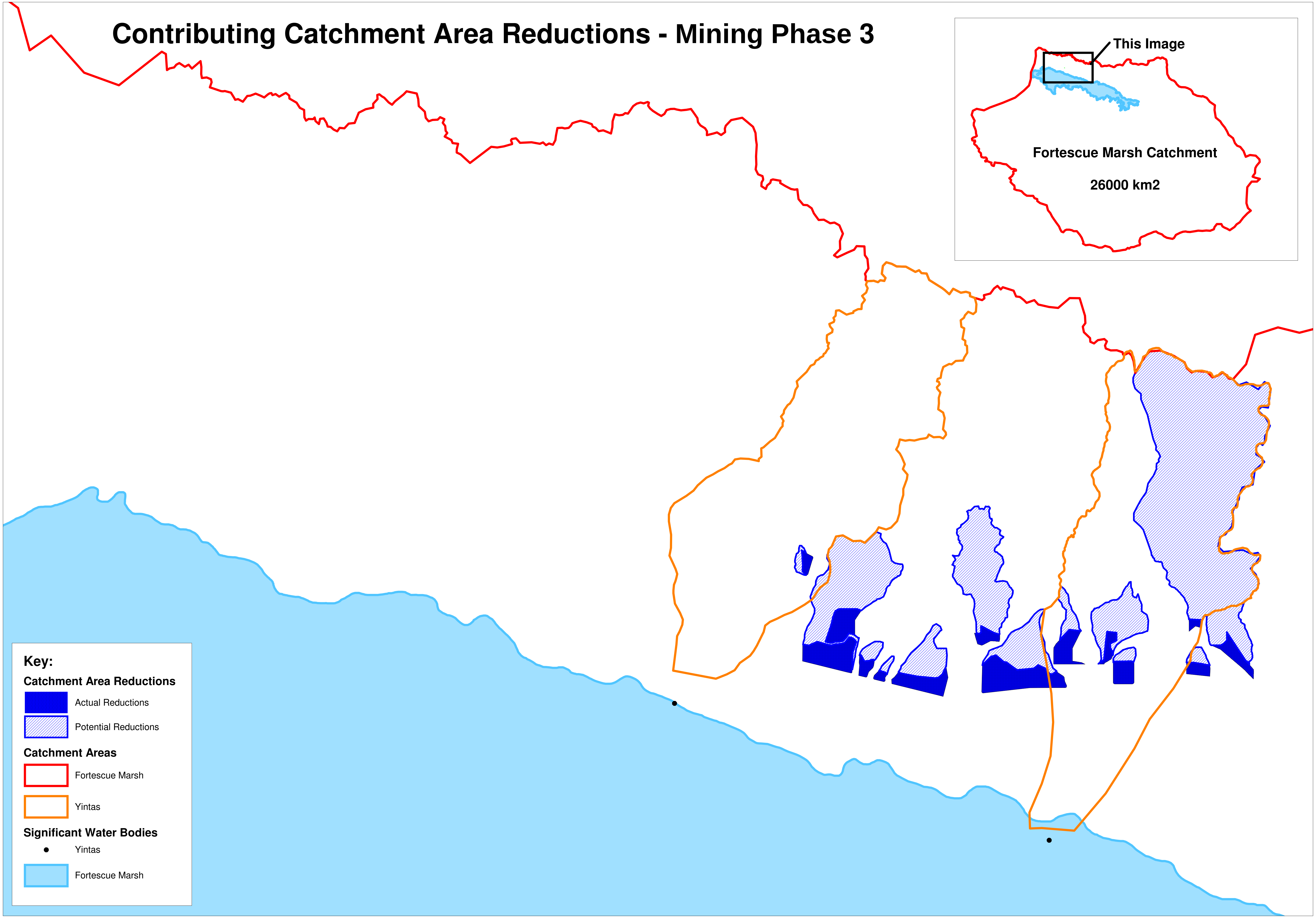
	Contributing Catchment Area Reductions			
	Goman		CRE06	
Phase	Actual	Potential	Actual	Potential
1	0.9	8.1	1.5	43.2
2	0.2	0.4	1.2	15.4
3	0.2	0.4	1.7	27.3
4	0.6	30.6	1.5	44.9
5	2.8	38.3	1.9	11.7
6	2.8	13.5	0.9	1.4
7	2.3	3.9	0.4	0.7
8 and 9	4.1	16.5	0.4	0.7
10 and 11	2.7	35.9	0.4	0.7
12 and 13	2.0	2.9	0.4	0.7
14 and 15	2.0	2.9	0.4	0.7
16	1.4	2.9	1.4	3.4
Post Closure	1.4	3.6	0.4	0.7


Contributing Catchment Area Reductions - Mining Phase 1
This Image
Fortescue Marsh Catchment
26000 km2
Key:
Catchment Area Reductions
Actual Reductions
Potential Reductions
Catchment Areas
Fortescue Marsh
Yintas
Significant Water Bodies
Yintas
Fortescue Marsh

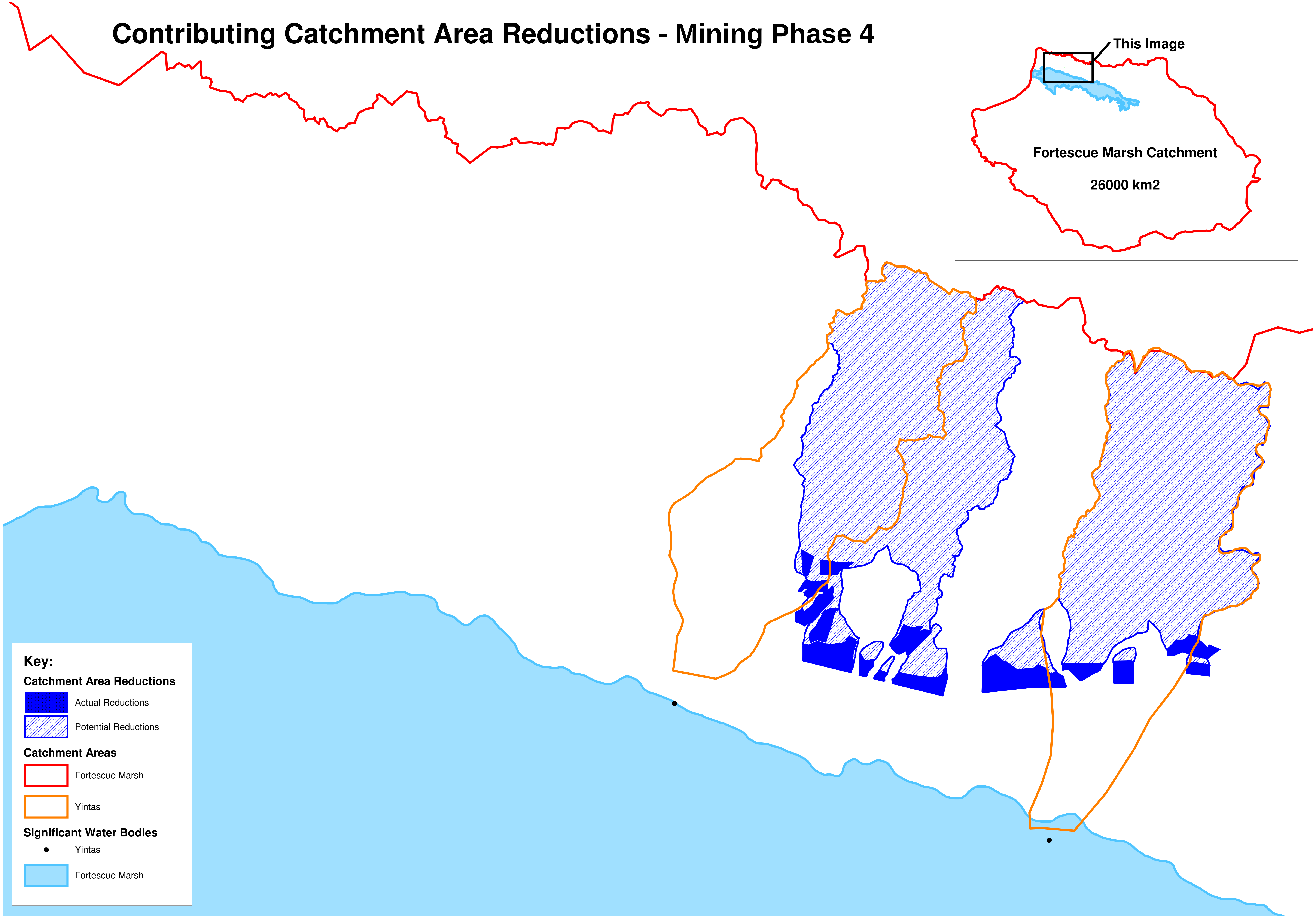
Contributing Catchment Area Reductions - Mining Phase 2



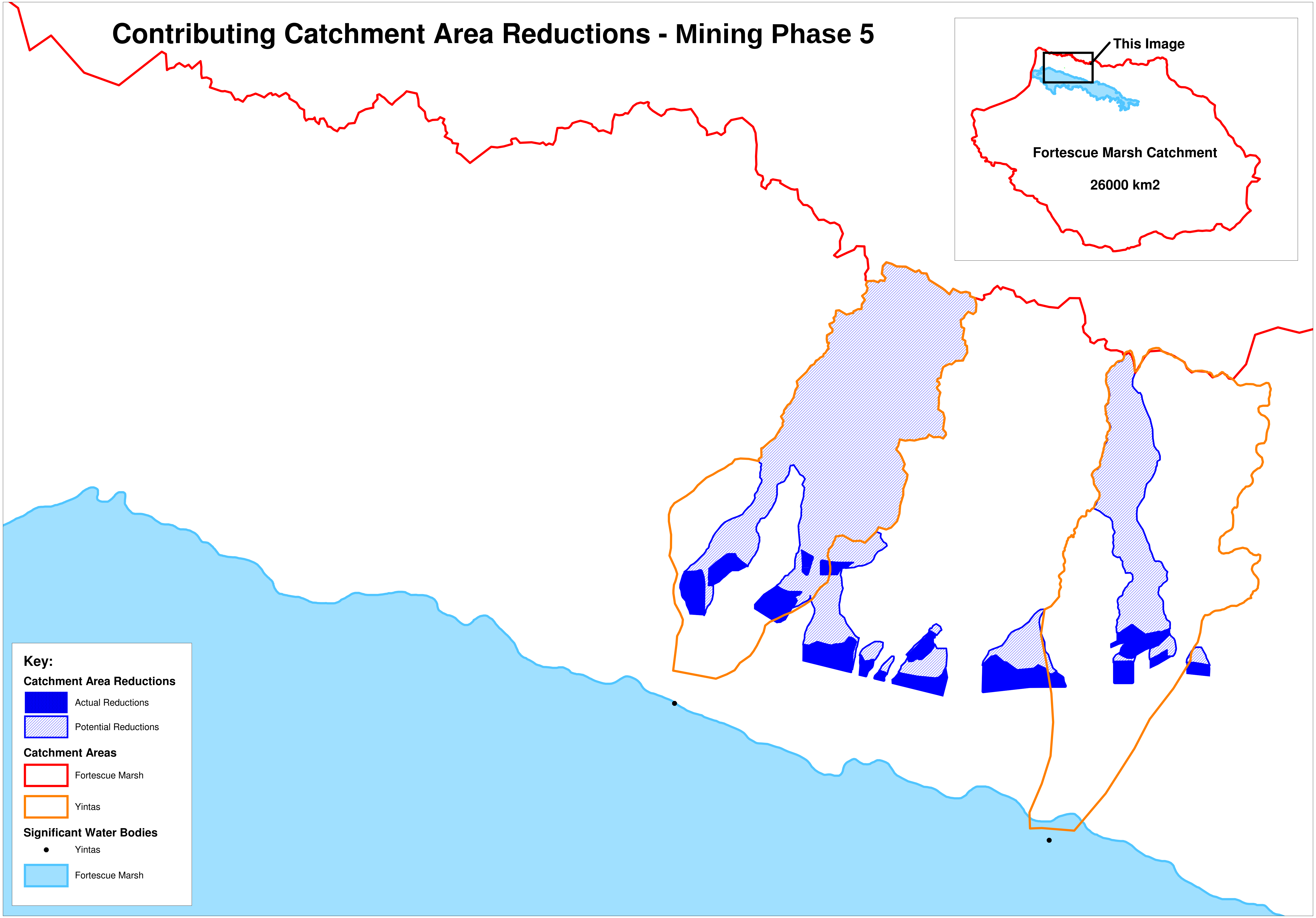
Contributing Catchment Area Reductions - Mining Phase 3

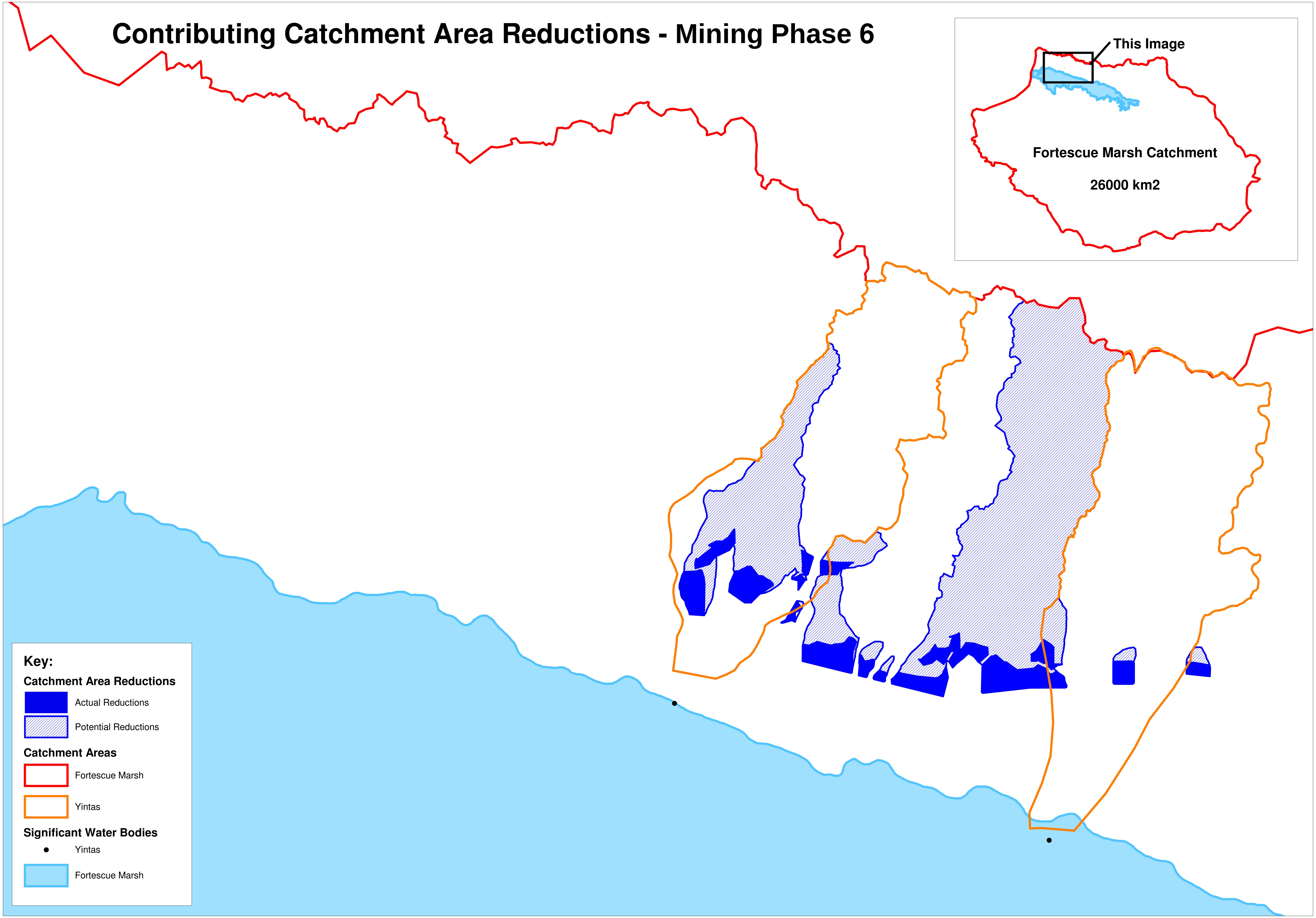


Contributing Catchment Area Reductions - Mining Phase 4

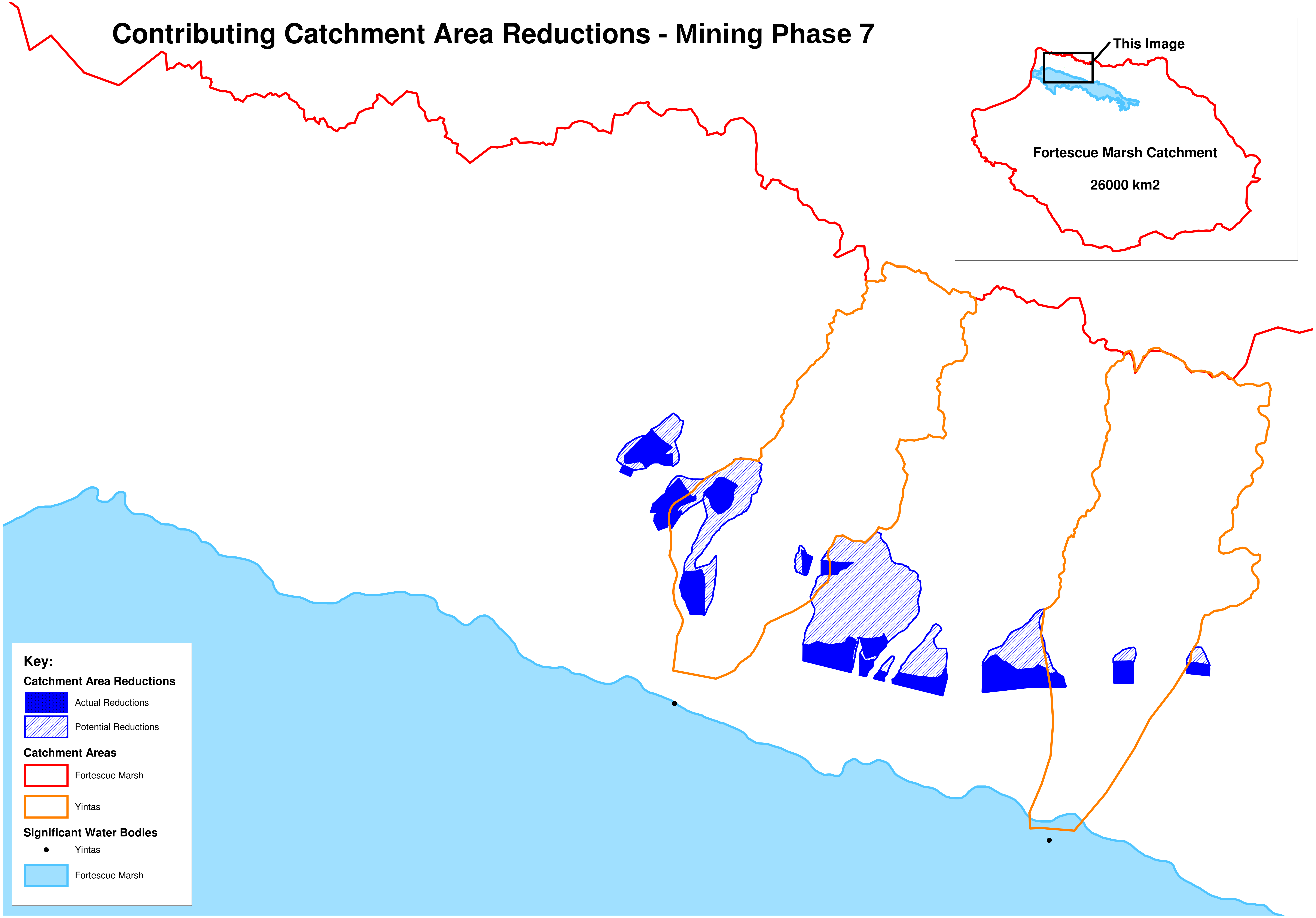


Contributing Catchment Area Reductions - Mining Phase 5

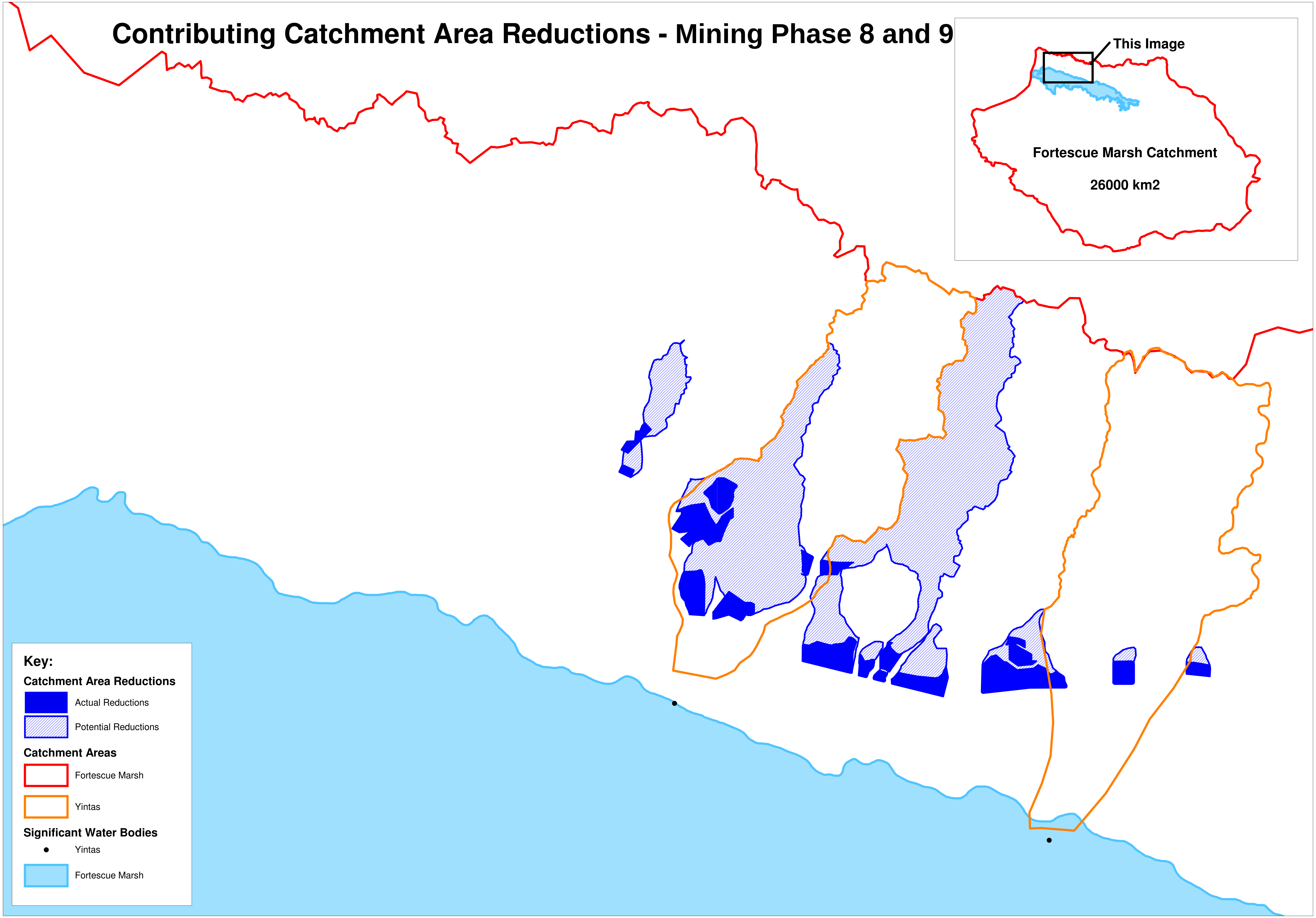



Contributing Catchment Area Reductions - Mining Phase 6
This Image
Fortescue Marsh Catchment
26000 km2
Key:
Catchment Area Reductions
Actual Reductions
Potential Reductions
Catchment Areas
Fortescue Marsh
Yintas
Significant Water Bodies
Yintas
Fortescue Marsh

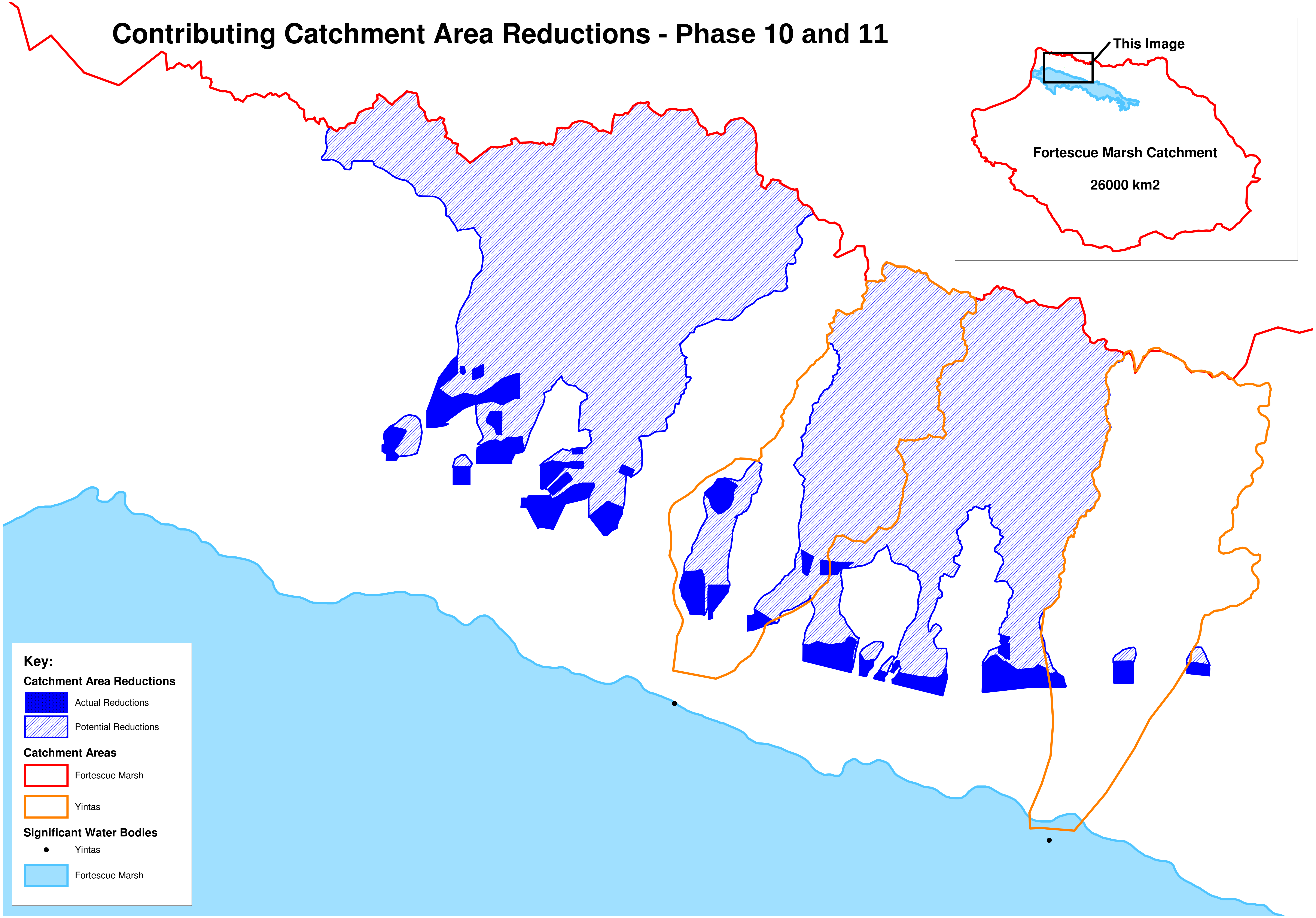
Contributing Catchment Area Reductions - Mining Phase 7

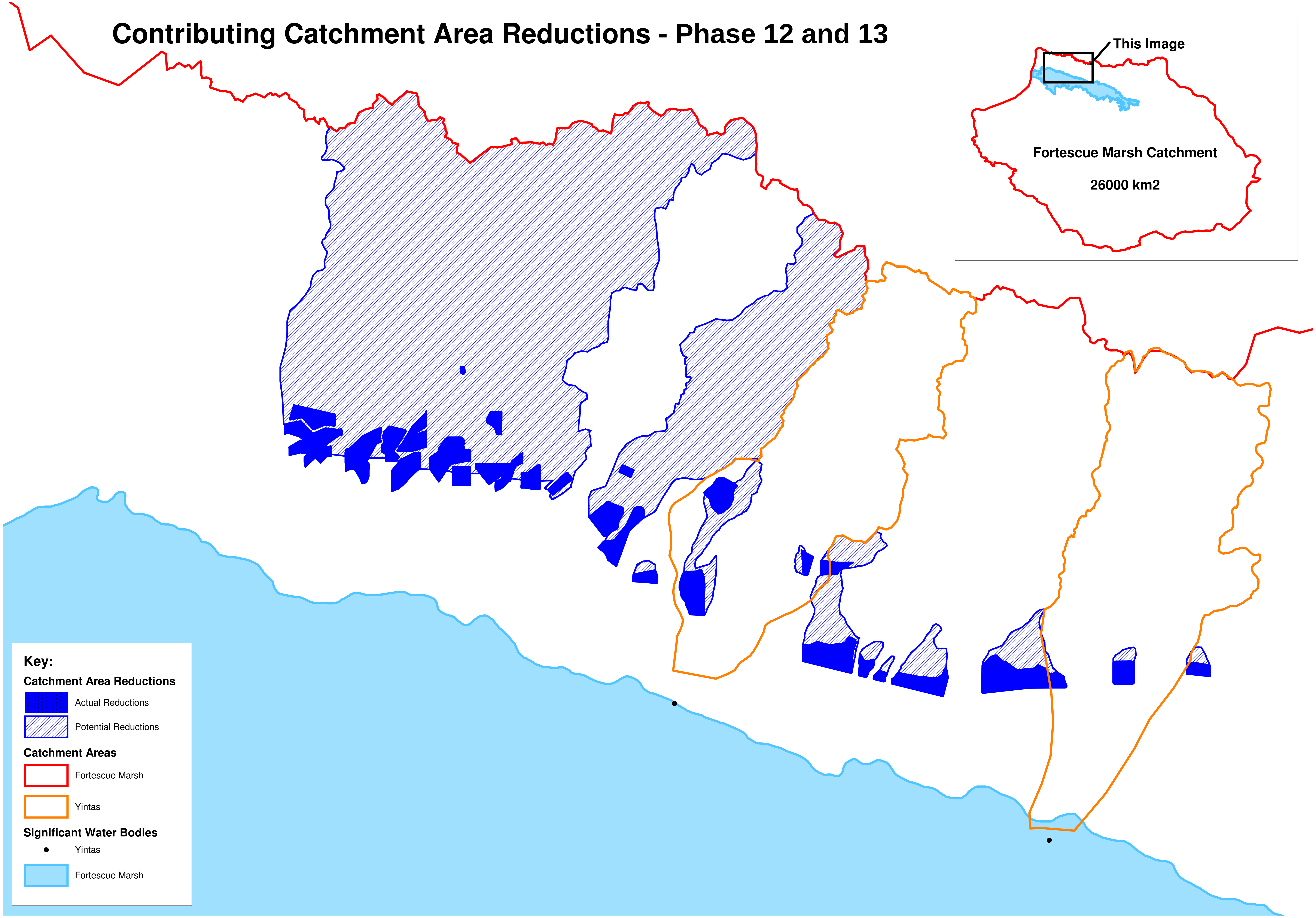


Contributing Catchment Area Reductions - Mining Phase 8 and 9



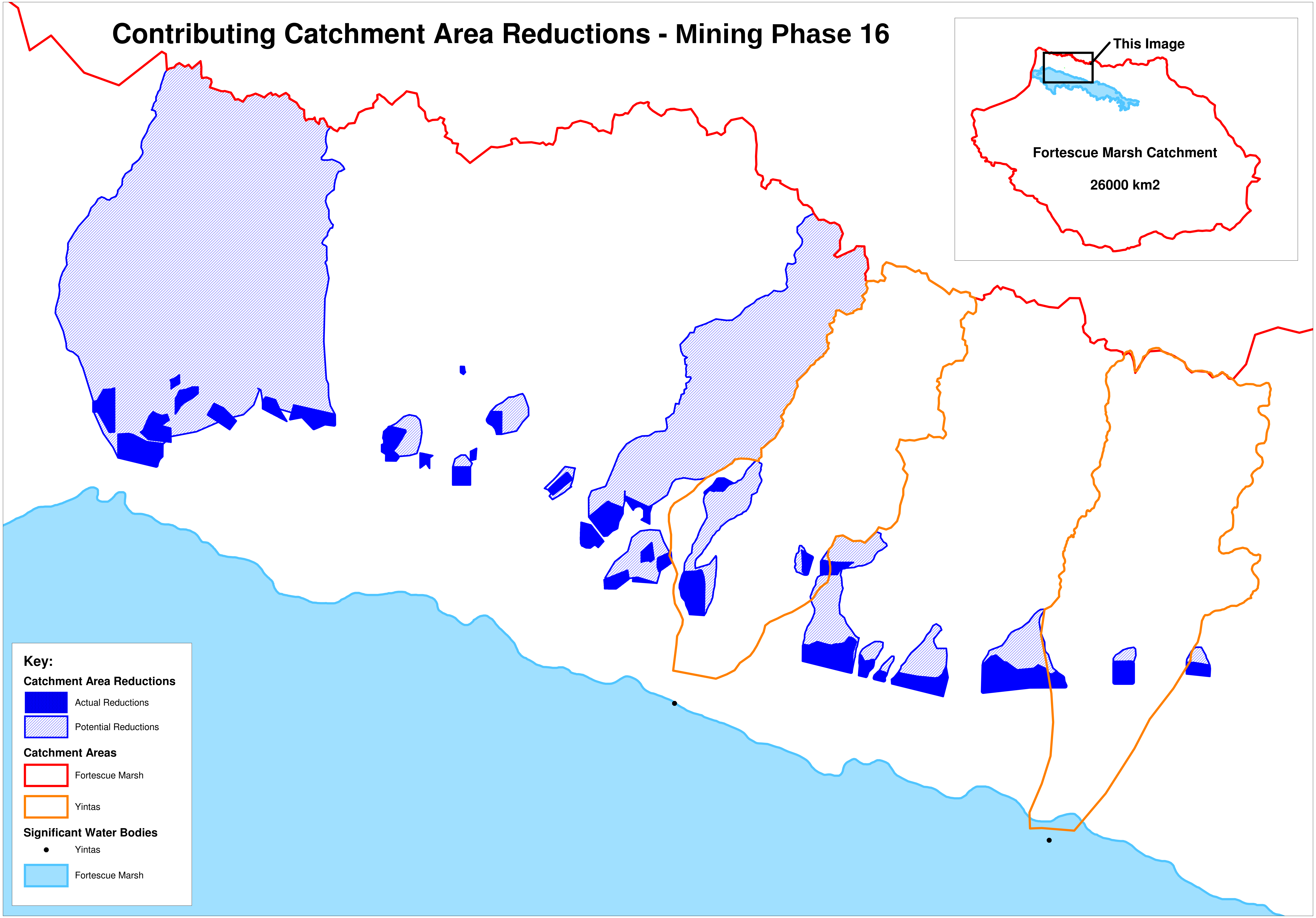
Contributing Catchment Area Reductions - Phase 10 and 11



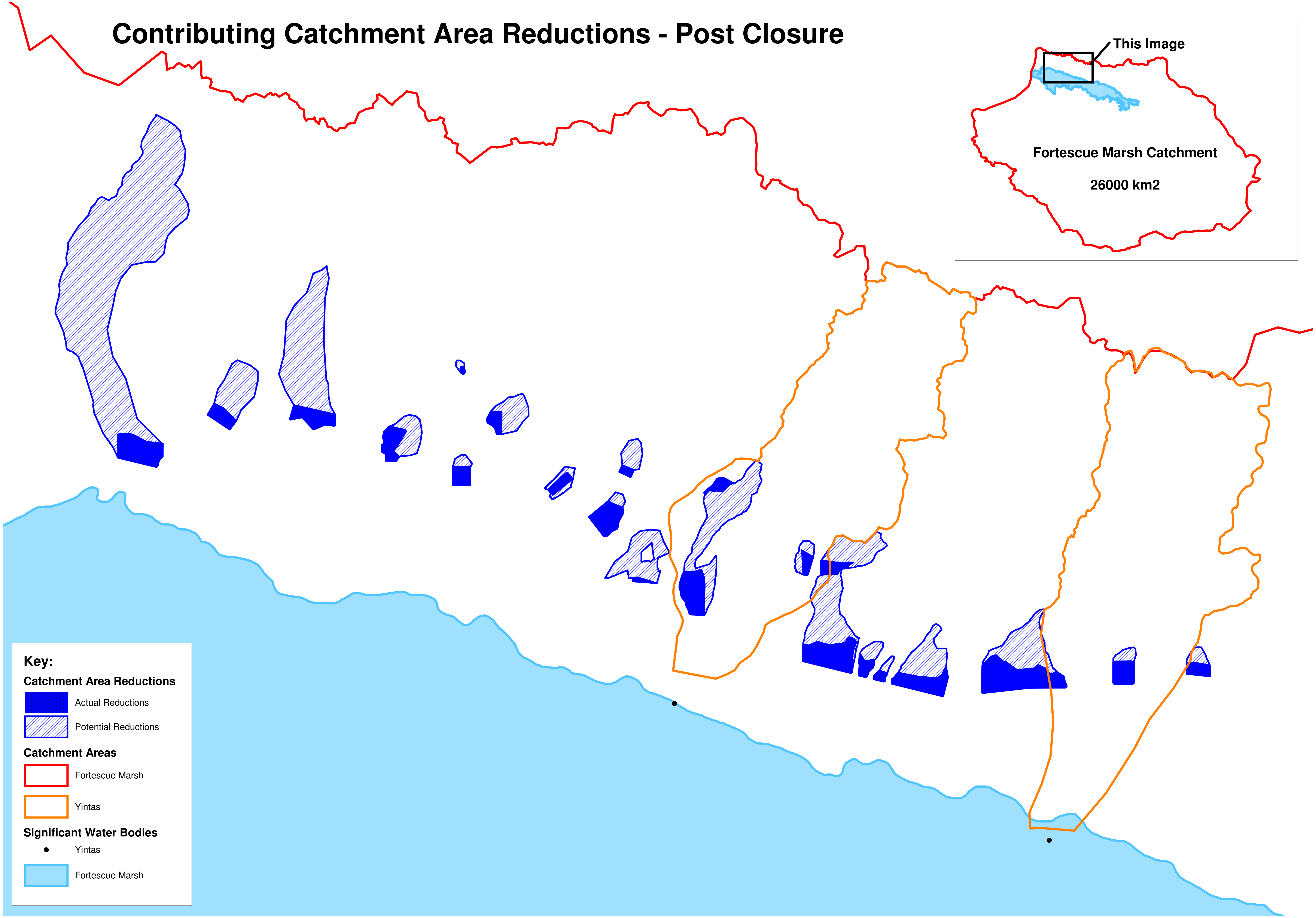

Contributing Catchment Area Reductions - Phase 12 and 13
This Image
Fortescue Marsh Catchment
26000 km2
Key:
Catchment Area Reductions
Actual Reductions
Potential Reductions
Catchment Areas
Fortescue Marsh
Yintas
Significant Water Bodies
Yintas
Fortescue Marsh

Contributing Catchment Area Reductions - Phase 14 and 15

Contributing Catchment Area Reductions - Mining Phase 16

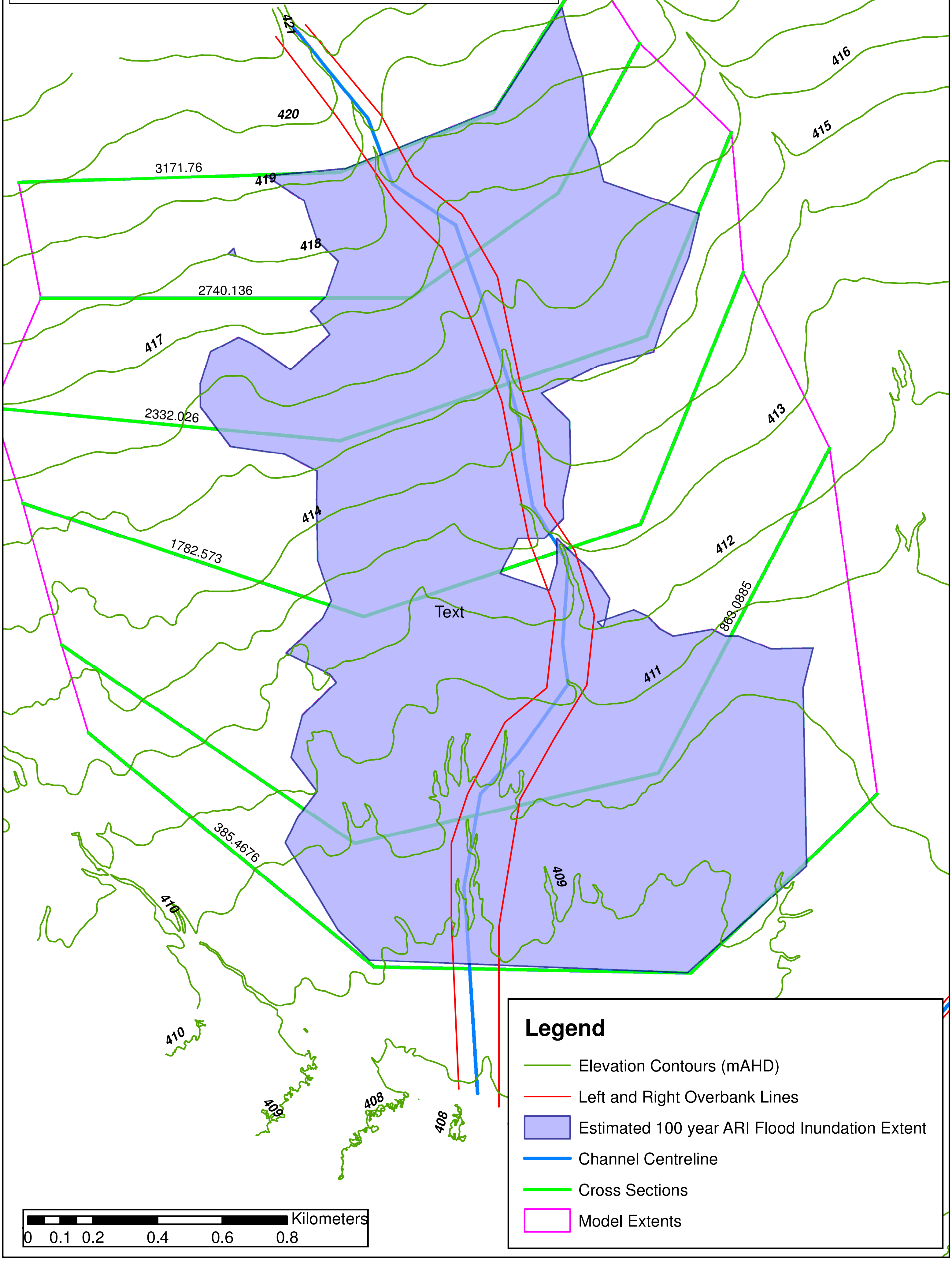


Contributing Catchment Area Reductions - Post Closure

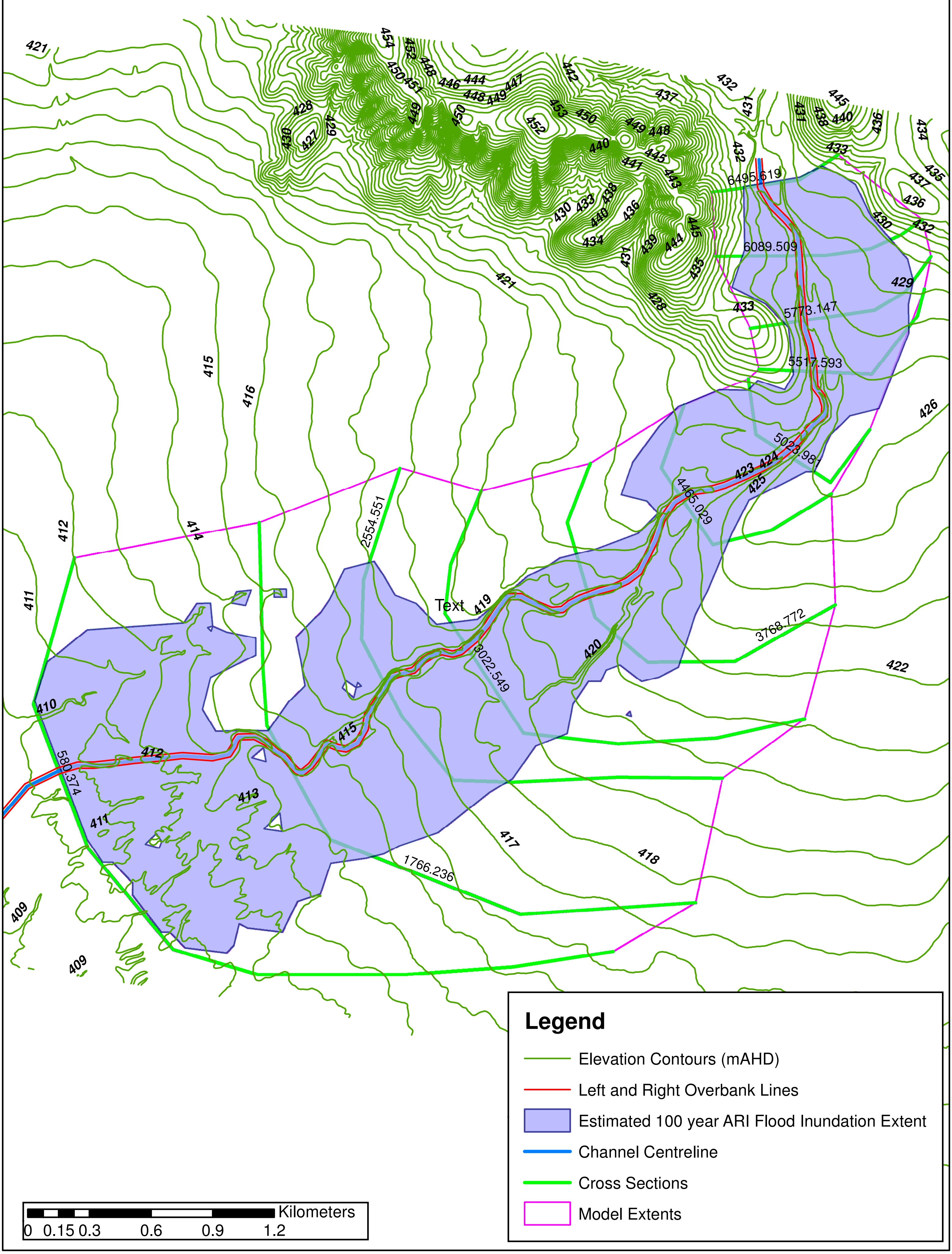


Appendix 6 – Hydraulic Model Setup

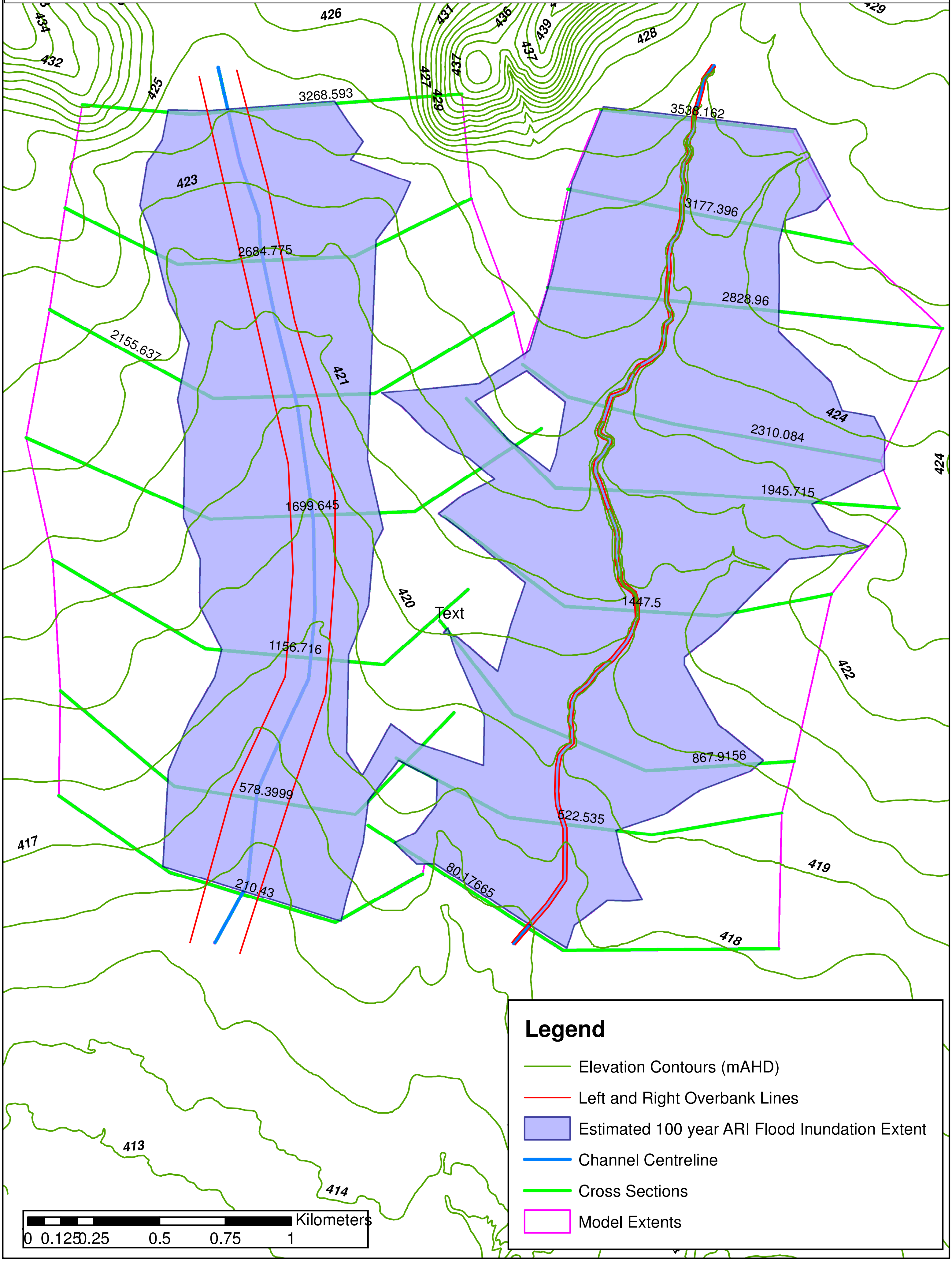
HECRAS Model Setup - WCB00



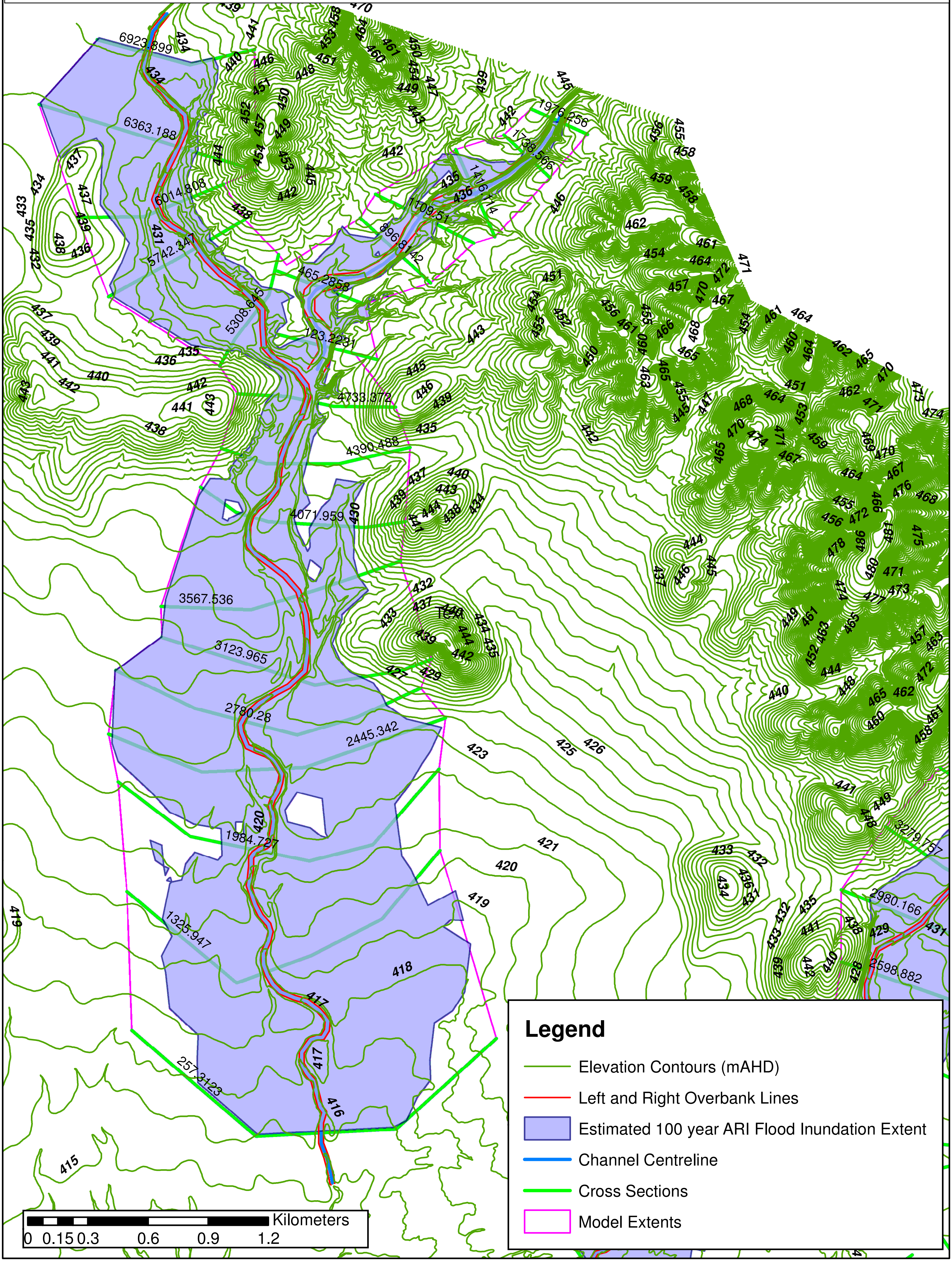
HECRAS Model Setup - WCB01



HECRAS Model Setup - WCB02 (Left) and WCB03 (Right)



HECRAS Model Setup - WCB04 and WCB04a



HECRAS Model Setup - WCB05 (left) and WCB06 (right)