Conservation Assessment of *Veronica blakelyi,* (B.G.Briggs & Ehrend.) B.G.Briggs (Plantaginaceae)

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Veronica blakelyi (B.G.Briggs & Ehrend.) B.G.Briggs (Plantaginaceae)

Distribution: Endemic to NSW.
Current EPBC Act Status: Not listed.
Current NSW BC Act Status: Vulnerable.
Proposed listing on NSW BC Act: Endangered

Reason for change: Genuine change from loss of entire subpopulation at Nullo Mountain from severe drought impacts that can be reasonably inferred to be related to ongoing climate change.

Summary of Conservation Assessment

Veronica blakelyi was found to be Endangered under B1ab(ii,iii,v)+2ab(ii,iii,v).

The main reasons for this species being eligible are: i) it has a highly restricted geographical range (EOO 222 km$^{2;}$ AOO 196 km^2), ii) it occurs at 2–5 locations, and iii) there is an estimated and inferred continuing decline in AOO, extent and quality of habitat, and number of mature individuals from changes to hydrology and erosion from the impact of underground coal mining and increased average temperatures and severity of drought from climate change, and an observed and inferred decline from vegetation clearing and habitat damage from track and trail maintenance and by off-road vehicles.

Description and Taxonomy

Veronica blakelyi is a small, slender, softly woody herb endemic to the Central Tablelands of New South Wales (NSW). *Veronica blakelyi* was previously known as *Derwentia blakelyi* (Briggs and Ehrendorfer 1992) and '*Parahebe* sp. E.' in Jacobs and Pickard (1981). In 2007, species in the genus *Derwentia* were transferred to the genus *Veronica* (Garnock-Jones *et al.* 2007).

NSW Flora Online (PlantNET 2022) states *Veronica blakelyi* is a "Small glabrous and glaucous shrub or woody herb to 50 cm high, with one to several erect softly woody stems from a narrow rootstock; stems mostly unbranched below inflorescence and dying back after fruiting, internodes to 1.5–6 cm long. Leaves usually recurved, V-shaped in cross section, ovate to lanceolate, mostly 2.5–5.5 cm long, 10–20 mm wide, apex ± acute, base cordate or truncate or cuneate, margins with 8–18 pairs of shallow teeth; sessile. Racemes mostly 8–40 cm long, 15–35-flowered. Calyx lobes 3–5.5 mm long and 0.7–1.3 mm wide in fruit. Corolla 6–7 mm long, bright blue-violet. Capsule broad-ovate, 4–6.5 mm long, 3–3.5 mm wide, truncate or emarginate, glabrous, glaucous."

Distribution and Abundance

Veronica blakelyi is concentrated in the greater Newnes area, from Clarence to near Cullen Bullen. There are a small number of other records around Nullo

Mountain, near Mt Horrible, the Coricudgy Range, Peel and Jaunter area (Map I and II in Appendix II). Since its initial listing by the NSW Scientific Committee (2000) new sites have been found within the greater Newnes area. In this conservation assessment a site is defined as a geographically distinct area that may contain one or more occurrences, or records, of *V. blakelyi* that is separated by at least 100 metres from any other records of this species. Each occurrence may represent one or more individuals.

Veronica blakelyi is recorded from across the greater Newnes area at over 50 sites. The largest known site is Happy Valley Swamp and creek, with over 2000 individuals. Ben Bullen State Forest and Springvale Ridge are the next largest sites with around 200 individual plants. Other occurrences are smaller with 1–100 individuals.

In the late 1990s *Veronica blakelyi* was recorded in large numbers at three sites on Nullo Mountain; however, surveys in 2018 and 2022 could not relocate any of these plants, and it is likely that the species is no longer extant or has very severely declined at these sites (Hayden Washington pers. comm. September 2022; V. Wong pers. obs. October 2022). The prolonged drought of 2017-2020 is inferred to have killed most plants (Hayden Washington pers. comm. September 2022) and subsequent dense post-fire understory regrowth has likely inhibited or prevented resprouting or recruitment by *V. blakelyi* (V. Wong pers. obs. September 2022). Dense post-fire regrowth encountered in 2022 made surveying difficult, and there is a possibility that this species still persists in small numbers in inaccessible sites on Nullo Mountain. However, given the historic size of reported stands and the subsequent failure of recent surveys to relocate these individuals, it is assumed for this assessment that they have become locally extinct.

There are six other uncertain and historic records previously used to assess distribution for *Veronica blakelyi* where the species is unlikely to be extant:
(i) two records from Mt Horrible from 1955 and 1975 (EMU 39743 and 297730);
(ii) an 1897 record from the Coricudgy Range (EMU 297730). Specimens associated with the Mt Horrible and Coricudgy Range records were examined for the description by Briggs and Ehrendorfer (1992). The Coricudgy record is thought to have come from Clarence and is incorrectly geolocated in the database (C. Jonker pers. comm. August 2022).
(iii) an 1860 record from “Peel River” (EMU 6227), which has an assumed location near Limekilns;
(iv) a record near Jaunter (BioNet SPJGI3257585) where the identification could not be confirmed (it could also have been *V. perfoliata*; G. Steenbeeke pers. comm. January 2018); and
(v) a 1913 record from northern NSW, from east of Barraba (MEL 2255454A). This record is believed very likely to be a misidentification (*Veronica arcuata,* which has a generally similar appearance to *V. blakelyi*, but is generally larger, with leaves more strongly recurved, PlantNET 2022).

The current distribution estimate is based on 366 unique records compiled from NSW Bionet Atlas, Atlas of Living Australia and herbarium specimens. The georeferences of 17 records were revised based on their descriptions.

Until recently, the majority of *Veronica blakelyi* records were from two State Forests, Newnes and Ben Bullen. The Gardens of Stone State Conservation Area

(SCA) was gazetted in May 2022 and included all of Newnes SF and part of Ben Bullen SF (NSW NPWS 2022a), and as a result the majority of the *V. blakelyi* population is now on lands managed for conservation rather than forestry activities. *V. blakelyi* has also been recorded in the adjacent Maiyinga Marrahu Aboriginal Place and on private land.

Area of Occupancy and Extent of Occurrence

The Extent of Occurrence (EOO) is 222 km^2 and the Area of Occupancy (AOO) is 196 km^2. The EOO and AOO are minimum estimates for the species and consists of all records from the greater Newnes area but excludes records that are likely to be locally extinct from Nullo Mountain, Peel, Mt Horrible and Coricudgy. The AOO is based on 2 x 2 km grid cells, the scale recommended for assessing area of occupancy by IUCN (2022) and the Extent of Occurrence (EOO) is based on a minimum convex polygon enclosing all mapped occurrences of the species, the method of assessment recommended by IUCN (2022). The EOO and AOO were calculated using Kew Geospatial Conservation Assessment Tool (GeoCAT; Bachman *et al.* 2011).

The AOO of *Veronica blakelyi* is likely to be an underestimate as survey effort for *V. blakelyi* has not been systematic across its distribution and it often occurs in small, sometimes difficult to locate, isolated patches.

Population Size and Trends

The total population size of *Veronica blakelyi* is uncertain but estimated to be 3,700–4,300. The lower bound of the total population size has been estimated by collating the most recent count data for each site and only for sites where count data has been recorded. The upper bound has been estimated by adding an estimate of individuals for populations with no recorded count data to the minimum known population size. Records that had no count data recorded were assigned a count based on either of the following methods:

(i) If *V. blakelyi* was recorded as locally common, numerous or abundant then it was assigned a site count of 50 plants. Fifty is the most common site count number over 10 in database records, and therefore assumed as the number of a common cluster of the species.

(ii) If *V. blakelyi* was recorded without a count of individuals then it was assigned the mean record size of 12 (excluding the large Happy Valley cluster as it is a very large outlier compared to other sites and would greatly skew the mean). The mean record size was calculated from the sum of all recorded individuals from any date (except Happy Valley), which totals 2,400, divided by the number of these records (n=200).

Additional uncertainties in data quality come from likely changes in occurrence counts since fire, which have only been accounted for in 72 occurrences recorded since the most recent 2019-20 fire. Also, count data from database records do not differentiate between mature and immature individuals, as resprouting stems and juvenile forms look the same (Briggs and Ehrendorfer 1992) and are all assumed to be mature individuals.

The population estimate for this assessment is almost double the population estimate calculated in 1999 of 2,400. The 1999 estimate was based on extrapolation of a count of 220 plants from six known sites along two thirds (13 km)

of the potentially suitable creeks, or 2000 ha, in Newnes Plateau (D. Binns *in litt.* 1999). A comparison of the two estimates might suggest an increasing population; however, neither estimate is of sufficient data quality to confidently make any inference of overall population trend over time.

Both increases and decreases of *Veronica blakelyi* have been recorded from a small number of sites (C. Jonker pers. comm. August 2022; V. Wong pers. obs. October 2022). Large increases in individuals have been observed at two sites: at Happy Valley Swamp from 300 in 2007 to 1700 in 2022 (over 500% in 15 years) and at a site in upper Marangaroo Swamp from 50 in 2019 to 165 in 2022 (330% in three years) (V. Wong pers. obs. September 2022). These increases may have been caused by fire stimulating germination (V. Wong pers. obs. September 2022) and three years of above average rainfall (Bureau of Meteorology 2022) in a species that grows in wet habitats. Different survey methods, such as the use of rough estimates versus complete counts, may also be a factor.

Veronica blakelyi has disappeared at local sites in the greater Newnes area after the 2013 State Mine Fire and the 2019-20 fire (H. Evans *in. litt.* September 2022; C. Jonkers pers. comm. August 2022; Zimmer and Tierney 2018). After the 2019-2020 wildfires, *V. blakelyi* is suspected to have disappeared from the margins of undermined swamps that suffered extensive peat incineration (Gang Gang East and West, Carne West Swamp; Sunnyside and Sunnyside East and West Wolgan) (Keith *et al.* 2021). Loss of individuals on these swamp margins is likely to be only a small proportion of a swamp-side stand of *V. blakelyi*, which resprouted on the slopes above these swamps after fire. The disappearance of local stands has also been caused by extensive post-fire track and trail clearing (200 individuals killed at Long Swamp) (H. Evans *in. litt.* September 2022). Some of the reported post-fire extirpations are from observations made too soon after fire for plants to have resprouted; *V. blakelyi* resprouts and recovers well after even extreme intensity fire (V. Wong pers. obs. September 2022).

Mortality from drought is thought to be responsible for the loss of hundreds of individuals of *Veronica blakelyi* at Nullo Mountain (Hayden Washington pers. comm. September 2022; V. Wong pers. obs. October 2022). On the Newnes plateau, *V. blakelyi* was observed to die back on upper southern slopes during severe drought conditions in 2019 and during the drought of the late 2012 (C. Jonkers pers. comm. August 2022).

Aboriginal Cultural and Community Significance

Aboriginal Peoples are Australia's first scientists and environmental managers and have a long history of biocultural knowledge, which comes from observing and being on Country, and evolves as it is tested, validated, and passed through generations (Woodward *et al.* (Eds.) 2020). Species have traditional ecological knowledge held by Aboriginal knowledge holders and are connected within the Kinship system. The Kinship system connects Aboriginal Peoples within a network of other people, plants, animals and features of the landscape (Woodward *et al.* (Eds.) 2020).

Veronica blakelyi grows on the lands of the Wiradjuri people who have a strong and ongoing cultural connection with their traditional lands and waters (AIATSIS 2022). *Veronica blakelyi* grows in the Maiyingu Marragu Aboriginal Place – a well-known rock art site and cultural education precinct (NSW NPWS 2022a).

Aboriginal Peoples have cared for Country for tens of thousands of years (Clarkson *et al.* 2017). It is not known if *V. blakelyi* was used by the Traditional Owners; however, *Veronica* species from other parts of the world have been traditionally used in medicine for wound healing and the treatment of rheumatism and other diseases (Salehi *et al.* 2019). *Veronica* species exhibit a wide spectrum of anti-microbial and antioxidant activities (Salehi *et al.* 2019).

Ecology

Veronica blakelyi is a long-lived perennial that produces annual stems from its perennial base. The stems emerge in late winter and spring (V. Wong pers. obs. September 2022) and flower in summer with a spray of small bright blue-violet flowers and dieback after fruiting (PlantNET 2022). *Veronica* spp. do not have markedly different adult and juvenile forms (Briggs and Ehrendorfer 1992).

The lifespan of *Veronica blakelyi* is unknown; however, estimates of longevity can be inferred from other species of *Veronica* from the Austraits database (Falster *et al.* 2021). In Austraits, most species of *Veronica* have estimates of longevity of <50 years or <100 years (Falster *et al.* 2021) or 10–30 years for the obligate seeder *V. hillebrandii* (DELWP 2021). For clonal species like *V. blakelyi* longevity can be considered at either the level of the genet (in this case, a colony) or ramet (clump of tillers capable of producing further offshoots) to estimate generation time (IUCN 2022). In this assessment, ramets are used as they emerge, reproduce and decay independently. Having a ramet lifespan of 50-100 years would mean the generation length of *V. blakelyi* is 25–50 years.

Veronica blakelyi grows in eucalypt forest, often in moist areas such as drainage lines, gullies, beside creeks and into the edges of swamps (NSW Scientific Committee 2000; habitat notes from NSW Bionet Atlas, Atlas of Living Australia and herbarium specimen records) or on the lower slopes of southerly facing hills (C. Jonkers pers. comm. August 2022), often below small cliffs or rock outcrops (D. Binns *in litt.* May 1999). Briggs and Leigh (1998) note *V. blakelyi* is found on sandstone and shale soils of low fertility. *Veronica blakelyi* has often been recorded on the edges of tracks and trails (Map 1 in Appendix II) indicating that it grows well in areas of disturbance. The swamp habitats of *V. blakelyi* are threatened ecological communities (TECs): Newnes Plateau Shrub Swamps in the Sydney Basin Bioregion which is listed as Endangered under the *Biodiversity Conservation Act 2016* (BC Act), and Temperate Highland Peat Swamps on Sandstone TEC which is listed as Endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

On the Newnes Plateau, Nullo Mountain and near Mt Horrible, *Veronica blakelyi* has been recorded growing at around 1,000 m elevation. Benson and Baird (2012) speculate that *V. blakelyi* may be a species indicative of the prior flora of the Newnes plateau during and following the Last Glacial Maximum when conditions were colder and drier. This time was concurrent with development of the swamps of the plateau. Subsequently, the plateau was invaded by taller growing eucalypts and shrubs.

Hybridisation is common in *Veronica* spp. (Albach and Briggs 2012) and has been observed between *V. blakelyi and V. perfoliata* and *V. derwentiana* subsp. *subglauca* in the area of the former Ben Bullen State Forest and between *V. blakelyi* and *V. perfoliata* in the area of the former Ben Bullen State Forest and

Wolgan Valley (C. Jonkers pers. comm. August 2022). In the Wolgan Valley it has been observed to hybridse with *V. perfoliata* (H. Washington pers. comm. September 2022). There is some evidence that hybridization among plants is increased with disturbance (Lamont *et al.* 2003; Riesberg and Carney 1998) and this may be relevant in the Newnes area. Hybridized records are not included in this assessment.

Veronica blakelyi seeds are likely to have morphophysiological dormancy, based on other species of *Veronica* from South Australia. These species have morphophysiological dormancy that can be broken by fire-related cues including heat and smoke water, seasonal cues and temperature preference (Guerin *et al*. 2013; Plants of South Australia 2022). Despite the morphological similarities between adult and juvenile forms of *V. blakelyi*, field observations of single stemmed individuals with single downward growing roots indicate successful seedling recruitment (V. Wong pers. obs. September 2022). The presence of the species in areas of disturbance and its linear distribution along waterways and tracks also infers successful seed dispersal and recruitment.

The longevity of the seedbank of *Veronica blakelyi* is unknown. At Nullo Mountain, no seedling recruitment has been observed since 2020 following drought and fire, suggesting the seedbank may be short lived (H. Washington pers. comm. September 2022; V. Wong pers. obs. September 2022). Seeds of two English *Veronica* species have been found to quickly lose their viability in the soil, with germination rates declining from around 40% in the first year to 10-20% in the second year and to 1% in the sixth year (Roberts and Feast 1973). A South Australian obligate seeding species of *Veronica*, *V. parnkalliana,* was found to have seeds with morphophysiological dormancy that persisted between fire events (Guerin *et al.* 2013).

Fire Ecology

Veronica blakelyi resprouts after fire. The 2013 State Mine Fire burnt one-fifth of the distribution of *V. blakelyi* in the greater Newnes area and the 2019-20 fire burnt the entire Newnes distribution (NPWS Fire History Spatial Layer). Both fires included extensive areas burnt at high fire severity and extreme fire severity (full tree canopy consumption) (Department of Planning and Environment (DPE) 2022a). Multiple database records since the 2019-20 fire note *V. blakelyi* resprouting, including at Marangaroo Creek, Dingo Creek and near Carne West Swamp.

A 2022 survey of the Happy Valley Swamp site found individuals of roughly three different age classes that may correspond to historical fire events, suggesting fire stimulates seedling germination (V Wong pers. obs. September 2022). The largest clumps had tens of stems that spread up to 500 mm wide. There were hundreds of medium-sized, multi-stemmed clumps and a few small, single-stemmed individuals, assumed to be seedlings (V Wong pers. obs. September 2022). The fire intervals at this site are two years, nine years and >40 years (NPWS Fire History Spatial Layer).

Pollination, seed dispersal and gene flow

Veronica blakelyi flowers are short-tubed and subactinomorphic (nearly radially symmetrical). They are pollinated by bees and flies or are self-pollinated (Albach *et al.* 2004; Kampny and Dengler 1997; Preston *et al.* 2011). As such, pollination

can potentially occur over many kilometres, with the foraging range of exotic honeybees *Apis mellifera* known to be a maximum of 11-12 km, although they usually forage much closer to the hive influenced by the locations of suitable foraging patches (Beekman and Ratnieks 2000).

Veronica blakelyi seeds are very small: the average weight of 1,000 *V. blakelyi* seeds is 0.394 g (Kew Seed Information Database 2019). Seeds of *Veronica* spp. are dispersed primarily by septicidal capsule dehiscence (Briggs and Ehrendorfer 1992), which means that most of the seeds will fall beneath the adult plant. *V. blakelyi* seed is likely be dispersed longer distances by wind, water, animals and vehicles. *V. blakelyi* is inferred to be wind dispersed based on having a similar seed size to *V. persica* (average weight of 1,000 seeds is 0.99 g), which is thought dispersed by wind based on morphology and seed size (Kew Seed Information Database 2019; McIntyre *et al*. 1995). Seed dispersal could occur across relatively short distance by wind. The importance of water as a long-distance dispersal agent is reflected in the distribution of occurrences along drainages; many wetland species having morphological adaptations to float on water (Middleton *et al*. 2006).

Subpopulations

All occurrences of *Veronica blakelyi* on the Newnes plateau are likely to be one subpopulation, with gene flow from pollination possible between all recorded sites. All sites, except the Clarence and Dargan area, are less than 3 km from another site, which is within the possible pollination and dispersal distances of the species. The potential for gene flow between *V. blakelyi* individuals increases when the very high likelihood of undiscovered clusters between known sites is considered, as they are all linked by continuous bushland (Map 1 in Appendix II).

Threats

Veronica blakelyi is threatened by changes to hydrology and erosion from mining activities, vegetation clearing and habitat damage by track and trail maintenance and off-road vehicles, clearing by forestry operations, competition from weeds, habitat damage from hard-hoofed herbivores, disease (NSW Scientific Committee 2000; NSW Government 2022) and increasing severity of drought and increased temperature from ongoing climate change.

Changes to hydrology and erosion from mining

Longwall (underground) coal mining is an inferred, ongoing threat to the habitat of *Veronica blakelyi*. Underground coal mining threatens the habitat of *V. blakelyi* through two main processes: (i) altering swamp hydrology so that they become susceptible to peat fires and (ii) erosion in and around swamps and creeklines as a result of undermining and/or mine water discharge (Baird and Benson 2020; Mason *et al*. 2021; Keith *et al.* 2022; Krogh *et al*. 2022). Over the last two decades, 15 of approximately 100 swamps (13% of the area of the Newnes Plateau Shrub Swamps) have been impacted by longwall coal mining (Department of Planning Industry and Environment (DPIE) 2020; Krogh 2012).

Longwall mining causes irreversible destruction of groundwater dependant peat swamps by causing a major and persistent reduction in their water retention capacity (Baird and Benson 2020; Mason *et al*. 2021; Keith *et al.* 2022; Krogh *et al*. 2022). The groundwater is lost from swamps by longwall mining causing depressurisation/removal of the aquifer supplying water to the swamps, bedrock

fracturing and through drainage along geological faults and lineaments up to 2 km from longwall mines (DPIE 2021; M Krogh pers. comm. January 2022). Undermined swamps transition from groundwater to rainfall dependence, which means that they are subject to drying during periods of low rainfall and become susceptible to destruction from fire burning the dry peat (Keith *et al.* 2021, Mason *et al*. 2021). After the widespread 2019-20 fires, undermined swamps, unlike intact swamps, suffered a high level of peat loss from consumption by fire resulting in a substantial reduction in species richness and a shift in species composition (Keith *et al.* 2021, 2022). The undermined swamps failed to respond to good rain, with almost no resprouting of typical, and often long-lived, resprouter sedgeland and shrub species, including *V. blakelyi* (Baird and Benson 2020). The effects of undermining of swamps are permanent with a review of mitigation and remediation techniques finding that 'no strategies - other than changes in mine plan layout - have been proven to effectively mitigate longwall mining impacts', and that 'existing remediation techniques are unproven and appear insufficient without destruction of the surface' (Commonwealth of Australia 2014). In NSW, 'Alteration of habitat following subsidence due to longwall mining' has been listed as a Key Threatening Processes under the *Biodiversity Conservation Act 2016*.

Approximately 40 *V. blakelyi* sites are located on the edge of Newnes plateau swamps, including the largest clusters at Happy Valley and Marangaroo Swamps. *Veronica blakelyi* has disappeared from the margins of longwall impacted swamps (but not the slopes above the swamps): Gang Gang East and West, Carne West Swamp; Sunnyside and Sunnyside East and West Wolgan (Baird 2021; C. Jonkers pers. comm August 2022).

Ongoing erosion problems in longwall impacted swamps degrade habitat suitability, including beyond the footprint of the swamp (Lembit 2022). At former mine water discharge points at Narrow and East Wolgan swamps, deeply incised erosion channels have formed which is likely to have impacted *Veronica blakelyi* (Lembit 2022; A. Longeron *in litt*. May 2022). Cliff collapse caused by longwall mining near Kangaroo Creek Swamp resulted in the loss of some individuals of *V. blakelyi* (C. Jonkers *in litt.* Sept 2022).

Future approved longwall and proposed bord and pillar mines have the potential to impact a further four swamps: Marangaroo, Lamb, Long and Kangaroo Creek. (DCCEEW 2022; DPIE 2021, 2022). The Springvale mine continues to extract coal using longwalls located underneath the headwaters of the Marrangaroo Creek catchment, which threatens to undermine the Marangaroo Swamp and Creek system (DPIE 2021, 2022) where one of the larger occurrences *of V. blakelyi* is found. In 2022 a new bord and pillar mine extension was proposed by the Angus Place mine, the Angus Place West proposal (DCCEEW 2022). Bord and pillar mines involve less risk of significant bedrock fracture and alteration to hydrology than longwall mines (Krogh 2007, Krogh pers. comm. June 2022); however, the proposed mine is very shallow, with a depth of cover of rock above the coal seam as low as 43 m, which increases the possibility of bedrock fracture and resultant habitat impact (Krogh *et al.* 2022).

Most of the Newnes' swamps have been recently included in a new reserve, Gardens of Stone SCA; however unlike a national park, this reserve type has depth restrictions above the coal seams that do not preclude nor protect them from underground mining operations (NSW Scientific Committee 2012).

Increased severity of drought and increased temperature from ongoing climate change

Veronica blakelyi is inferred to be intolerant of prolonged drought and warmer, drier climatic conditions projected in the region under climate change. 'Anthropogenic climate change' is listed as a Key Threatening Process under the *Biodiversity Conservation Act 2016*. 'Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases' is listed as a Key Threatening Process under the *Environment Protection and Biodiversity Conservation Act 1999*.

Veronica blakelyi is suspected to have been locally extirpated from Nullo Mountain in 2018 as a result of drought. From 2017 to 2019, Nullo Mountain experienced three consecutive years of annual rainfall around 30-40% below the long-term average (Bureau of Meteorology 2022). In 2018, no individuals could be found from a population previously reported in its "hundreds" (H. Washington pers. comm. October 2022). This population is not expected to persist in the soil seedbank in large numbers (see Ecology section above). Similarly in 2022, after the 2019-20 fire and three years of above average rainfall, no resprouting individuals or seedlings could be found (V. Wong pers. obs. October 2022), suggesting that the soil seedbank did not survive the drought.

On the Newnes plateau, drought conditions were not as severe as at Nullo Mountain, with severe drought conditions only in 2019, and the impact on the species appears to have been more transient. While *Veronica blakelyi* was observed to die back on upper southern slopes in 2019 (C. Jonkers pers. comm. August 2022) it was observed to resprout and recruit seedlings during the following three years of above average rainfall (various database records; V. Wong pers. obs. October 2022). Negative impacts of warmer, drier condition at Newnes were also observed during the drought of the late 2012 when *V. blakelyi* died back on upper southern slopes (C. Jonkers pers. comm. August 2022). Intact groundwater-dependant peat swamps are likely to provide habitat refuge to *V. blakelyi* during severe drought (Keith *et al.* 2022); however, modelling of the effect of climate change on upland swamps forecasts a progressive contraction of swamp habitat (Keith *et al.* 2014). Drought conditions leave undermined swamps especially vulnerable to destruction by peat fires as occurred in the 2019–2020 bushfires (Keith *et al.* 2021, 2022; Mason *et al*. 2021).

An intolerance of *Veronica blakelyi* to warmer, drier conditions is consistent with its suspected evolutionary history as a relic species from the Last Glacial Maximum when conditions were colder and drier (Benson and Baird 2012). Droughts across the Australian continent are becoming more severe and longer in duration as long-term climate conditions become more arid (Abram *et al.* 2021) and this is likely to increase the threat drought poses to *V. blakelyi*.

Average temperatures in the greater Newnes area are predicted to increase by over 2^{o}C by 2060–2079 (AdaptNSW 2022). If *V. blakelyi* is a climate specialist adapted to cooler climates (Bensen and Baird 2012), then it is inferred that warmer temperatures would adversely affect the population. *Veronica blakelyi* currently grows in the highest part of the landscape so cannot escape increasing temperature by migrating to higher altitude. Losses from more severe droughts and warmer temperatures on the Newnes Plateau may be offset to some degree

by increased annual average rainfall, which is predicted to increase by 1% by 2040 and 5% by 2060–2080.

Vegetation clearing and habitat damage from track and trail maintenance and off-road vehicle use

Vegetation clearing and habitat damage from track and trail maintenance and off-road vehicle use is an observed, ongoing threat to *Veronica blakelyi*. The native vegetation on the Newnes plateau has been damaged and extensively fragmented by the establishment of tracks to support mining, past forestry activities and off-road vehicle activity (trailbikes and 4WD vehicles) that use its extensive 700+ km network of tracks and unformed trails (NSW NPWS 2022b, D. Taylor pers. comm. October 2022).

Trail clearing and maintenance has been observed to kill *Veronica blakelyi* in the greater Newnes area. At Long Swamp extensive bulldozing and clearing of fire trails that followed the 2019-20 fires resulted in the loss of 200 individuals, locally extirpating the species from all but one site (C. Jonker pers. comm. August 2022). A NPWS proposal to build a recreation park at Lost City threatens *V. blakleyi* along the track from Marangaroo Army Depot to upper Marangaroo Dam (NSW NPWS 2022a; C. Jonkers pers. Comm. September 2022).

A 2022 swamp management plan for the Newnes Plateau (NSW NPWS 2022b) recommends substantially reducing the impact of vehicle and the trail network by rehabilitating swamp crossing points and closing and rehabilitating trails that traverse close to many of the swamps that are known habitat of *Veronica blakelyi*, including Dingo Creek, Murrays, Happy Valley, Long, Broad, Upper Wolgan River, Gang Gang East, Gang Gang West, Nine Mile, Marangaroo and North Pine swamps. Recent track rehabilitation projects have focused on closing and rehabilitating swamp crossings including upper Dingo Creek Swamp and Happy Valley Swamp. Despite recommended track closures, increasing recreation use of the greater Blue Mountains reserves (up 75% over the last 10 years (DPE 2022b) could increase habitat damage caused by off-road vehicles.

A subset of the fire trails that are planned to remain in use will be upgraded to meet NSW Fire trail standards (NSW RFS 2016), and this will result in impacts on the population and habitat at *Veronica blakelyi* sites. Maintenance works on major fire trails are more frequent and extensive than on minor fire trails. As a disturbance liking species, vehicle use and maintenance of fire trails can also open up habitat; however, these occurrences appear to be transient.

'Clearing of native vegetation' is listed as a Key Threatening Process under the *Biodiversity Conservation Act 2016*. 'Land clearance' is listed as a Key Threatening Process under the *Environment Protection and Biodiversity Conservation Act 1999*.

Forestry

Until the Gardens of Stone SCA was gazetted in May 2022, the majority of *V. blakelyi* records were from two State Forests, Newnes and Ben Bullen (NSW NPWS 2022a). Currently only a few known occurrences remain in Ben Bullen SF and future forestry poses little threat to the species as there are no plans for native hardwood harvest in Ben Bullen State Forest (Forestry Corporation NSW 2018). *Veronica blakelyi* is protected in State Forests because of its status as a

threatened species (State Forests of NSW 1998). There are specific conditions for harvest operations around wetlands (including swamps), variable exclusion zones of 10 m, 20 m or 40 m, depending on the size of the wetland (NSW Government 2014), which would provide incidental protection to any adjacent *V. blakelyi* populations. Zimmer and Tierney (2018) recorded the loss of at least one local site from an area adjacent to a (harvested) pine plantation.

Disease

Disease is a potential threat to *Veronica blakelyi*, especially considering the high level of human disturbance due to the extensive trail network on the Newnes plateau, and the subsequent increased probability of humans and vehicles acting as disease vectors. However, there is no information available on the susceptibility of *V. blakelyi* to disease, including Root Rot Fungus, *Phytophthora cinnamoni.* 'Infection of native plants by *Phytophthora cinnamomi*' and 'is listed as a Key Threatening Process under the *Biodiversity Conservation Act 2016* and 'Dieback caused by the root-rot fungus *Phytophthora cinnamomi'* is listed as a KTP under the *Environment Protection and Biodiversity Conservation Act 1999*.

Habitat damage by hard-hoofed herbivores

Feral pigs (*Sus scrofa*) and Sambar Deer (*Rusa unicolor)* may impact swamp and creek bank habitat of *V. blakelyi,* as they use wet areas of the landscape for feeding and wallowing (Bengsen *et al*. 2014; Forsyth *et al*. 2009). These hard-hoofed herbivores, as well as domestic stock, feral cattle and other wild herbivores, have the potential to cause damage through vegetation removal, soil disturbance and channelling of water flow, which in turn may lead to erosion or drying of wetlands. Feral pigs and wild deer are present in low numbers in the greater Newnes area and prior to the gazetting of the Gardens of Stone SCA were harvested in low numbers by private, permitted hunters (H. Evans *in litt*. August 2022). Currently, the damage they are causing to the Newnes area is minimal, but these pest species can increase rapidly in numbers if not controlled. As such, feral pigs and wild deer are considered a potential, ongoing threat to *V. blakelyi.* 'Herbivory and environmental degradation caused by feral deer' and 'Predation, habitat degradation, competition and disease transmission by Feral Pigs, *Sus scrofa* Linnaeus 1758' are listed as Key Threatening Processes under the Act. 'Predation, Habitat Degradation, Competition and Disease Transmission by Feral Pigs' is listed as a KTP under the *Environment Protection and Biodiversity Conservation Act 1999*.

Weeds

The greater Newnes area is highly disturbed from forestry activities, mining and off-road vehicle use which has promoted the introduction and localised spread of many weed species. Competition from weeds is a potential, ongoing threat to *V. blakelyi.* On the Newnes Plateau priority species to target for ongoing weed control include Blackberry (*Rubus fruticosus*), pine (*Pinus radiata*) wildlings, Himalayan Honeysuckle (*Leycesteria formosa*), Pampas Grass (*Cortaderia selloana*), Scotch Thistle (*Onopordum acanthium*) and other problematic herbaceous species. Priority areas for weed control are Brown Swamp and nearby roads and railway line and Long Swamp (Baird 2020). Weed spraying for St John's Wort *Hypericum perforatum* along Angus Place Colliery killed co-occuring *V. blakleyi* (C. Jonkers *in litt.* September 2022.)

Adverse Fire Regime

Veronica blakelyi resprouts after fire, even extreme fire and seedling recruitment appears to be stimulated. The most likely threat from fire would be multiple, short interval fires that could potentially kill immature plants prior to reinstatement of a soil seed bank. However, as the stems flower annually, it is highly unlikely that fires could occur at intervals that would prevent seed production, even with climate change projections of larger, more frequent fires or multiple very short-frequency fires are unlikely to occur (Abatzoglou *et al*. 2019; AdaptNSW 2022; Jones *et al.* 2022). The two most recent fires on the Newnes Plateau were six years apart and the increase in population size at Happy Valley Swamp suggests that this fire interval may have benefited species abundance.

Assessment against IUCN Red List criteria

For this assessment it is considered that the survey of *Veronica blakelyi* has been adequate and there is sufficient scientific evidence to support the listing outcome.

Criterion A Population Size reduction

Assessment Outcome: Data deficient

Justification: *Veronica blakelyi* has been estimated to have a current population of 3,700 to 4,300 individuals. In 1999 the population size was estimated as 2,400, which could suggest an increase in population size since then. However, data quality for both estimates is considered low, with uncertain methods used for most patch size estimates, and is therefore not sufficient to infer any changes over time for the assessment of Criterion A. The generation time of *V. blakelyi* is inferred to be 25-50 years and three generations 75-150 years (Falster *et al.* 2021).

Criterion B Geographic range

Assessment Outcome: Endangered under B1ab(ii,iii,v)+2ab(ii,iii,v).

Justification: *Veronica blakelyi* has a minimum Area of Occupancy (AOO) of 196 km^2 and a minimum Extent of Occurrence (EOO) of 222 km^2. Both AOO and EOO estimates are within the Endangered thresholds for this Criterion. The number of locations is five, based on the threats of changes to hydrology and erosion from mining, vegetation clearing and habitat damage from track and trail maintenance and off-road vehicles and increased temperature and severity of drought from climate change.

In addition to these thresholds, at least two of three other conditions must be met. These conditions are:

a) The population or habitat is observed or inferred to be severely fragmented or there is 1 (CR), ≤5 (EN) or ≤10 (VU) locations.

   Assessment Outcome: Met for Endangered.

   Justification: The most serious plausible threats to this species are changes to hydrology and erosion from mining and vegetation clearing and habitat damage from track and trail maintenance and off-road vehicles. Increasing severity of drought and increasing annual temperatures from climate change is a longer-term threat to the species.

There are 2–5 threat defined locations for *Veronica blakelyi,* driven primarily by drought and long wall mining, which meets the threshold for Endangered.

The threat of changes to hydrology and erosion from coal mining activities affects the greater Newnes subpopulation of *Veronica blakelyi* in three different locations. The first location is Narrow, East Wolgan, Sunnyside, Carne East, Carne West and Gang Swamps, which have been undermined by longwall mining and\or impacted by mine water discharge. Longwall impacted swamps are susceptible to peat consumption during fire causing high level of plant mortality and ongoing extensive erosion (Benson and Baird 2020; Keith *et al.* 2021; Lembit 2022; A. Longeron *in litt*. May 2022).

A second location threatened by changes to hydrology and erosion from mining is Marangaroo Swamp and Creek, which has approved longwall mines beneath (DPIE 2021; DPIE 2022). A third location is Long Swamp, Lamb Swamp and Kangaroo Creek Swamp which is potentially threatened by the proposed Augus West mine (DCCEEW 2022).

According to the IUCN Guidelines (2022) where the most serious threat does not affect all of the taxon's distribution, other threats may be used to define and count locations in those areas not affected by the most serious threats. The threat of increasing severity of drought and increased annual temperatures from climate change (Adapt NSW 2022) encompasses all *Veronica blakelyi* sites not included in locations one to three. Due to the difficulty on predicting the extent of future droughts, the number of locations under this threat is 1–2. *Veronica blakelyi* is inferred to be a cooler climate specialist (Baird and Benson 2012), intolerant to warmer, drier conditions. Negative impacts of warmer, drier conditions at Nullo Mountain in 2018 are suspected to have led to local disappearance of the species (H. Washington pers. comm. September 2022). On the Newnes plateau during the droughts of 2012 and 2019 the species was observed to die back on upper southern slopes (C. Jonkers pers. comm. August 2022). Although the threat of climate change affects all *V. blakelyi* sites, it is not the most immediate serious plausible threat, but a threat acting over an extended time.

Veronica blakelyi is not severely fragmented because >50% of its total AOO consist of occurrences that could support a viable population (IUCN 2022).

b) Continuing decline observed, estimated, inferred or projected in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals.

Assessment Outcome: Met for (ii), (iii), (v)

Justification: A continuing decline has been estimated and inferred in the AOO, extent and quality of habitat, and number of mature individuals from a) changes to hydrology and erosion from longwall coal mining, b) vegetation clearing and habitat loss caused by track and trail maintenance and off-road vehicles and c) increased severity of drought

and increased temperatures from climate change. This decline is continuing despite some large increases in mature individuals recorded in localised patches of *Veronica blakelyi* from fire stimulating germination and three years of above average rainfall,

Continuing decline is inferred in *Veronica blakelyi* from coal mining because undermined swamps remain vulnerable to damage from future fires and drought and ongoing erosion as the effects of undermining are permanent (Commonwealth of Australia 2014). Marangaroo Swamp is threatened by the impacts from approved longwall mines and Long, Kangaroo Creek and Lamb Swamps are threatened by a proposed shallow bord and pillar mine. Narrow and East Wolgan Swamps have extensive and ongoing erosion problems caused from mine water outlets (A. Longeron *in litt.* May 2022), which damages *V. blakelyi* habitat.

Continuing decline is estimated and inferred in *Veronica blakelyi* from trail clearing and maintenance and off-road vehicle use by future fire-trail upgrades, ongoing maintenance and increasing visitor use.

Continuing decline is estimated and inferred from increasing severity of drought and increased average temperatures from ongoing climate change. *Veronica blakelyi* is inferred to be a cooler climate specialist that currently persists at the highest altitude part of the landscape, so cannot escape the effects of climate change (AdaptNSW 2022; Baird and Benson 2012).

c) Extreme fluctuations.

Assessment Outcome: Data deficient

Justification: There are insufficient data to assess against this subcriterion. There is no evidence that *Veronica blakelyi* experiences extreme fluctuations of population.

Criterion C Small population size and decline

Assessment Outcome: Vulnerable C2a(ii)

Justification: The total population size of *Veronica blakelyi* is uncertain but estimated 3,700–4,300, which is well within the threshold for Vulnerable. There is only one subpopulation of *V. blakelyi*, which is restricted to the greater Newnes area, meeting the threshold for Vulnerable.

At least one of two additional conditions must be met. These are:

C1. An observed, estimated or projected continuing decline of at least: 25% in 3 years or 1 generation (whichever is longer) (CR); 20% in 5 years or 2 generations (whichever is longer) (EN); or 10% in 10 years or 3 generations (whichever is longer) (VU).

Assessment Outcome: Data deficient.

Justification: *Veronica blakelyi* has been estimated to have a current population of 3,700–4,300. In 1999 the population size was estimated as 2,400 which could suggest an increase in population. However, confidence in both estimates is considered low due to uncertainties around methods for most patch size estimates.

C2. An observed, estimated, projected or inferred continuing decline in number of mature individuals.

Assessment Outcome: Met.

Justification: Continuing decline is estimated and inferred in the number of mature individuals from a) changes to hydrology and erosion from longwall mining, b) vegetation clearing and habitat loss caused by track and trail maintenance and off-road vehicles and c) increasing severity of drought and increased temperatures from climate change.

Full justification of continuing decline is described under Criterion B.

In addition, at least 1 of the following 3 conditions:

a (i). Number of mature individuals in each subpopulation ≤50 (CR); ≤250 (EN) or ≤1000 (VU).

Assessment Outcome: Not met.

Justification: *Veronica blakelyi* has one subpopulation, located in the greater Newnes area, of 3,700–4,300 individuals, which is above the thresholds and therefore does not meet this subcriteron.

a (ii). % of mature individuals in one subpopulation is 90-100% (CR); 95-100% (EN) or 100% (VU)

Assessment Outcome: Vulnerable.

Justification: There is one subpopulation of *Veronica blakelyi* located in the greater Newnes area which meets this Subcriterion for Vulnerable.

b. Extreme fluctuations in the number of mature individuals

Assessment Outcome: Data Deficient.

Justification: There are insufficient data to assess against this subcriterion. There is no evidence that *Veronica blakelyi* experiences extreme fluctuations of population.

Criterion D Very small or restricted population

Assessment Outcome: Not met.

Justification: *Veronica blakelyi* is estimated to have 3,700–4,500 individuals, which exceeds the thresholds for this criterion. In addition, *V.blakelyi* does not have a restricted AOO or a number of locations <5 and there is no currently known plausible future threat that could drive the taxon to CR or EX in a very short time.

To be listed as Vulnerable under D, a species must meet at least one of the two following conditions:

D1. Population size estimated to number fewer than 1,000 mature individuals

Assessment Outcome: Not met.

Justification: *Veronica blakelyi* is estimated to have 3,700–4,300 individuals, which exceeds the thresholds for this Criterion.

D2. Restricted area of occupancy (typically <20 km^2) or number of locations (typically <5) with a plausible future threat that could drive the taxon to CR or EX in a very short time.

Assessment Outcome: Not met.

Justification: *Veronica blakelyi* does not have a restricted AOO or a number of locations <5 and there is no known plausible future threat that could drive the taxon to CR or EX in a very short time.

Criterion E Quantitative Analysis

Assessment Outcome: Data Deficient

Justification: No quantitative analysis has been carried out to assess the probability of extinction in this taxon.

Conservation and Management Actions

Veronica blakelyi is currently listed on the NSW BC Act and a conservation project has been developed by the NSW Department of Planning and Environment under the Saving our Species program. The conservation project identifies priority locations, critical threats and required management actions to ensure the species is extant in the wild in 100 years. *Veronica blakelyi* sits within the Site-managed species stream of the SoS program and the conservation project can be viewed here:
https://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10217

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APPENDIX 1

Assessment against *Biodiversity Conservation Regulation 2017* criteria
The Clauses used for assessment are listed below for reference.

Overall Assessment Outcome: Endangered under Clause 4.3(b)(d)(e, i, ii, iii)

Clause 4.2 – Reduction in population size of species
(Equivalent to IUCN criterion A)
Assessment Outcome: Data Deficient

(1) - The species has undergone or is likely to undergo within a time frame appropriate to the life cycle and habitat characteristics of the taxon:			
	(a)	for critically endangered species	a very large reduction in population size, or
	(b)	for endangered species	a large reduction in population size, or
	(c)	for vulnerable species	a moderate reduction in population size.
(2) - The determination of that criteria is to be based on any of the following:			
	(a)	direct observation,	
	(b)	an index of abundance appropriate to the taxon,	
	(c)	a decline in the geographic distribution or habitat quality,	
	(d)	the actual or potential levels of exploitation of the species,	
	(e)	the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.	

Clause 4.3 - Restricted geographic distribution of species and other conditions
(Equivalent to IUCN criterion B)
Assessment Outcome: Endangered under Clause 4.3(b)(d)(e i, ii, iii)

The geographic distribution of the species is:			
	(a)	for critically endangered species	very highly restricted, or
	(b)	for endangered species	highly restricted, or
	(c)	for vulnerable species	moderately restricted,
and at least 2 of the following 3 conditions apply:			
	(d)	the population or habitat of the species is severely fragmented or nearly all the mature individuals of the species occur within a small number of locations,	
	(e)	there is a projected or continuing decline in any of the following:	
		(i)	an index of abundance appropriate to the taxon,
		(ii)	the geographic distribution of the species,
		(iii)	habitat area, extent or quality,
		(iv)	the number of locations in which the species occurs or of populations of the species,
	(f)	extreme fluctuations occur in any of the following:	
		(i)	an index of abundance appropriate to the taxon,

		(ii)	the geographic distribution of the species,
		(iii)	the number of locations in which the species occur or of populations of the species.

Clause 4.4 - Low numbers of mature individuals of species and other conditions
(Equivalent to IUCN criterion C)
Assessment Outcome: Vulnerable under Clause 4.4(c)(e ii (B))

The estimated total number of mature individuals of the species is:						
	(a)	for critically endangered species				very low, or
	(b)	for endangered species				low, or
	(c)	for vulnerable species				moderately low,
and either of the following 2 conditions apply:						
	(d)	a continuing decline in the number of mature individuals that is (according to an index of abundance appropriate to the species):				
		(i)	for critically endangered species			very large, or
		(ii)	for endangered species			large, or
		(iii)	for vulnerable species			moderate,
	(e)	both of the following apply:				
		(i)	a continuing decline in the number of mature individuals (according to an index of abundance appropriate to the species), and			
		(ii)	at least one of the following applies:			
			(A)	the number of individuals in each population of the species is:		
				(I)	for critically endangered species	extremely low, or
				(II)	for endangered species	very low, or
				(III)	for vulnerable species	low,
			(B)	all or nearly all mature individuals of the species occur within one population,		
			(C)	extreme fluctuations occur in an index of abundance appropriate to the species.		

Clause 4.5 - Low total numbers of mature individuals of species
(Equivalent to IUCN criterion D)
Assessment Outcome: Not met

The total number of mature individuals of the species is:			
	(a)	for critically endangered species	extremely low, or
	(b)	for endangered species	very low, or
	(c)	for vulnerable species	low.

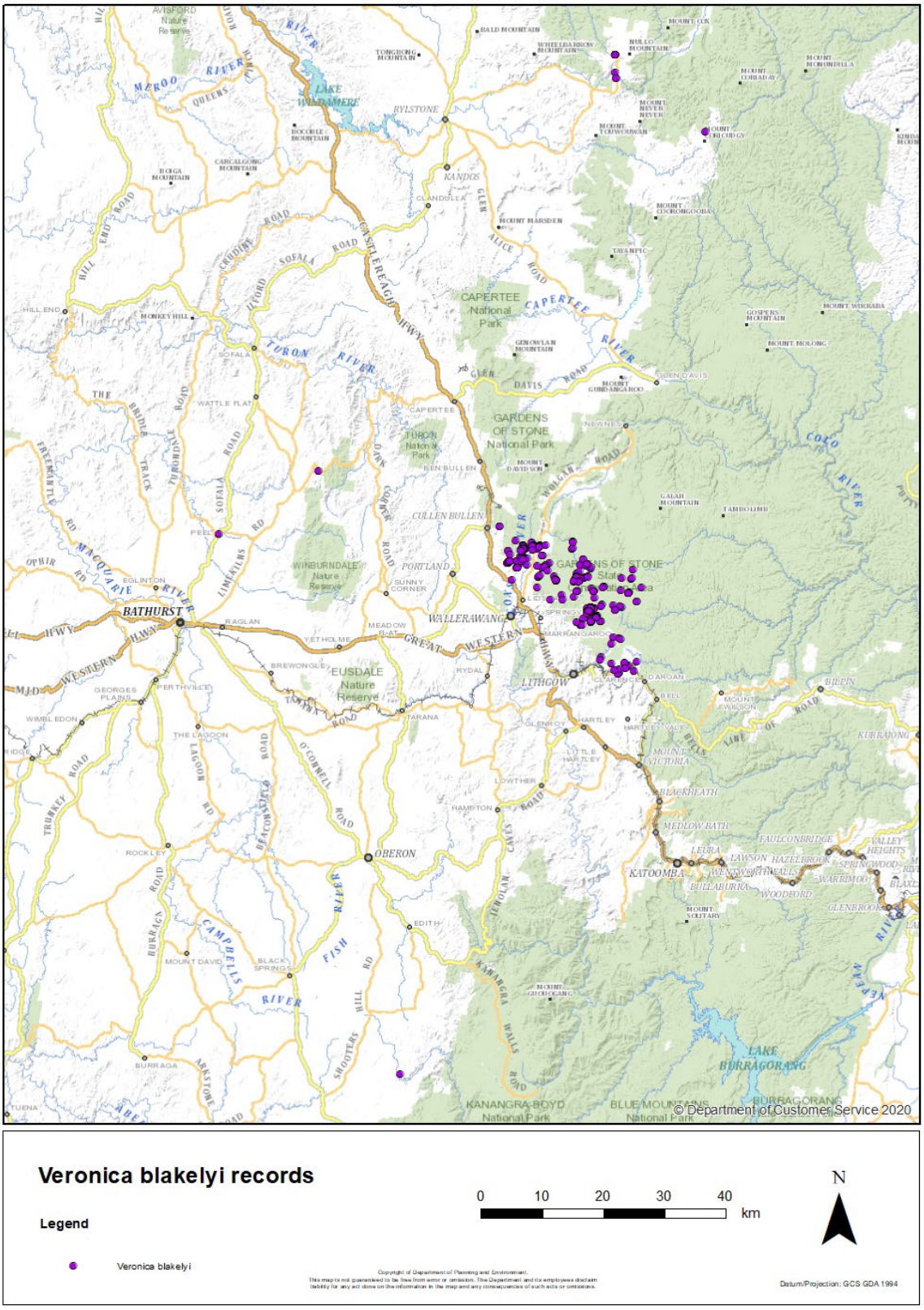
Clause 4.6 - Quantitative analysis of extinction probability
(Equivalent to IUCN criterion E)
Assessment Outcome: Not met

The probability of extinction of the species is estimated to be:			
	(a)	for critically endangered species	extremely high, or
	(b)	for endangered species	very high, or
	(c)	for vulnerable species	high.

Clause 4.7 - Very highly restricted geographic distribution of species– vulnerable species
(Equivalent to IUCN criterion D2)
Assessment Outcome: Not met

For vulnerable species,	the geographic distribution of the species or the number of locations of the species is very highly restricted such that the species is prone to the effects of human activities or stochastic events within a very short time period.

Appendix II - Map 1. *Veronica blakelyi* records in NSW including uncertain and very old records.



Map 2. *Veronica blakleyi* records in the greater Newnes area.