Appendix 16 – WA Mining and Haul Road Drainage Design Manual

Alcoa

ALCOA WA MINING OPERATIONS

Drainage Design Manual

Mining Pits & Haul Roads

REV	DATE	REVISION DESCRIPTION	STATUS	CREATED	REVIEWED	APPROVED
A	1990	Original manual	Issued for use	J.C. Croton		
B	2020	Update with current standards	Issued for use	Advisian	L. Gossage & T. Stokes	
C	11 Nov 2022	Update with pits and design tools	Issued for review	Advisian	B. Smith & E. Lum	
D	25 Nov 2022	Update with Alcoa feedback	Issued for use	Advisian	B. Smith & E. Lum	

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EXECUTIVE SUMMARY

Drainage management is based on an inherently inexact science and should be continually improved with the collection of additional data, monitoring and maintenance of existing drainage features and consideration of regulatory feedback.

ALCOA are committed to this continuous improvement. This revised Drainage Design Manual reflects the objectives for improved drainage management at Alcoa's mine operations.

This manual provides guidance to Alcoa's mine operations on designing and constructing drainage facilities for mine pits and haul roads and associated infrastructure at the Huntly and Willowdale Bauxite Mines on the Darling Plateau in the South-West of Western Australia.

Stormwater runoff collected in Alcoa's drainage system can discharge into forest and streams of the receiving environment, which is particularly sensitive to turbidity due to suspended solids. The mines and adjacent forest areas lie within public drinking water source areas crucial to the water supplies of Perth and the South-west of the State. The water discharging from the mine drainage facilities must be of a quality that does not compromise the public drinking water supply.

The historical development of this Drainage Design Manual is summarised below:

- The original 1990 *Minesite Drainage Book* (MDB) was prepared by J. T. Croton of Water and Environmental Consultants for Alcoa of Australia, as a guide to design of drainage facilities to serve the mine and its haul roads. It contained Basis of Design information as well as design criteria and detailed methodologies for delivering the designs.
- In 2020, an update of the MDB was undertaken and retitled *Drainage Design Manual for Haul Roads and Associated Infrastructure*. This update retained elements of the original document. The manual provides modern standards for the design, construction and management of drainage infrastructure associated with haul roads. Key Standards that were updated as part of this manual review included:
  - The Bureau of Meteorology has released, in 2016, significantly updated design rainfall intensity-frequency-duration data for all of Australia.
  - The Australian Rainfall and Runoff guidelines (updated 2016 and 2019) with significant changes to recommended methods and to terminology.
  - The Australian Runoff Quality 2006 (Engineers Australia) which includes guidance on designing sedimentation and infiltration facilities to manage stormwater runoff.
  - The Stormwater Management Manual for Western Australia (2007 update) includes further guidance on design of these facilities.
- This latest 2022 revision, titled *Drainage Design Manual - Mining Pits & Haul Roads* includes the following updates:
  - the inclusion of drainage design associated with mining pits,
  - the inclusion of groundwater aspects including groundwater interaction and current infiltration estimates,

- the inclusion of methods to estimate the sediment retention efficiency of a sedimentation sump design and water balance assessments to determine the capacity of infiltration sumps, and
- a design tool developed in MS EXCEL to facilitate quick and accurate design of multiples sumps.

This manual is intended to be used by personnel with appropriate and recognised technical qualification and experience, relevant to tasks associated with drainage systems at Alcoa facilities.

It is a common industry practice that the individual would possess a civil or environmental engineering degree, or equivalent, with a minimum of 5 years' experience in drainage design, hydrology, hydraulics, water resources and associated civil engineering.

1 INTRODUCTION & DRAINAGE OBJECTIVES

1.1 Background

Alcoa's mining operations on the Darling Plateau, Western Australia, are located within jarrah forest and water catchments which include Priority 1 public drinking water source areas (PDWSA's) associated with water supply reservoirs managed and operated by the Water Corporation. Minimising turbid water runoff from Alcoa's operations is important in complying with Alcoa's commitments under the Water Working Arrangements between Alcoa World Alumina, the Department of Water and Environmental Regulation and the Water Corporation.

Alcoa has developed this manual to ensure the design and construction of mining pits, haul roads and associated infrastructure do not impact the surrounding environment and PDWSAs and to support continuous improvement in drainage management. The key drainage design aspects and challenges identified as needing addressing, are summarised below in Figure 1-1. Each aspect is addressed in this Drainage Design Manual as summarised in Appendix G.

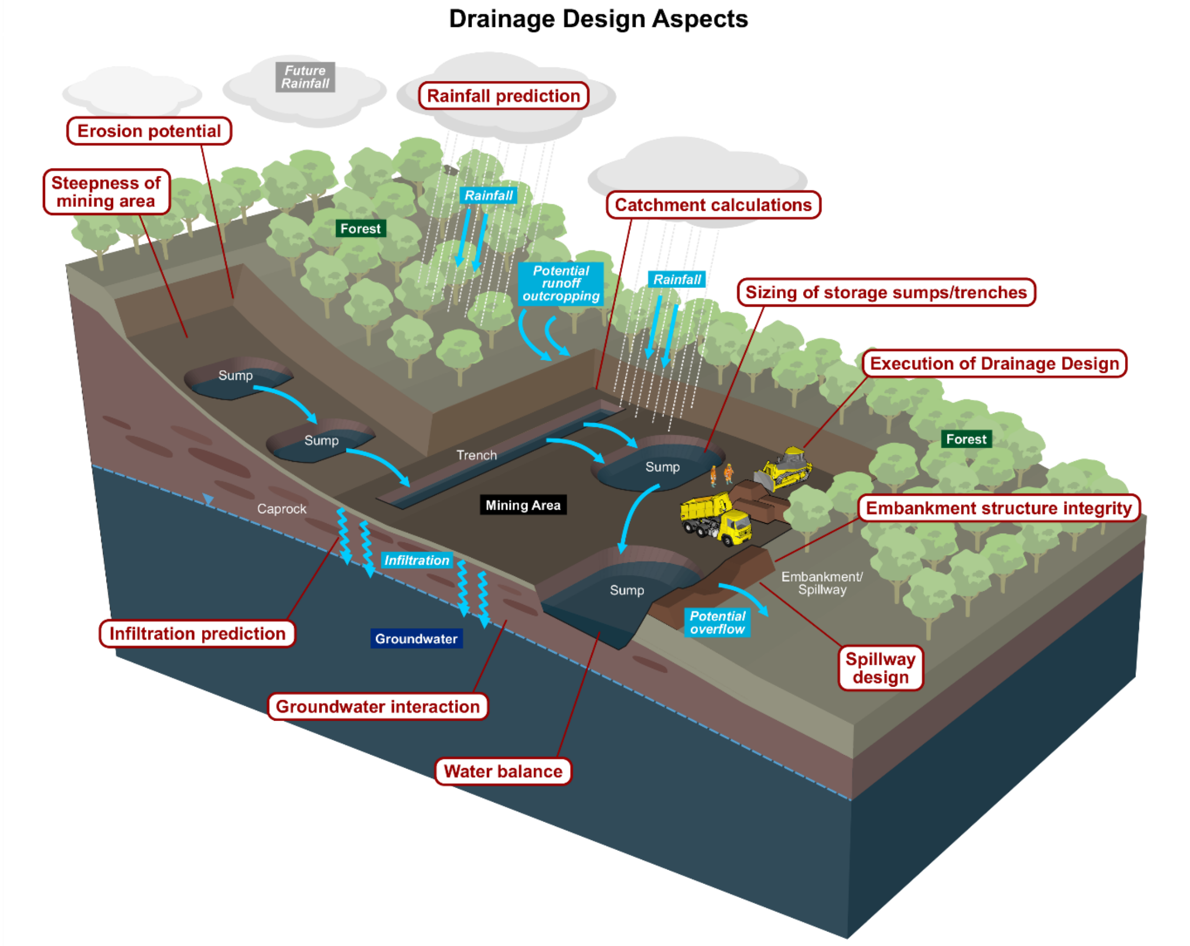

Figure 1-1 Drainage Design Aspects addressed in Drainage Design Manual

The manual provides guidance to design and implement best practice in pit and haul road drainage infrastructure construction, to minimise the potential for adverse turbidity impacts on the downstream environments.

This document is an update of Alcoa's Minesite Drainage Book (MDB)[1]. The original 1990 document was prepared by J. T. Croton of Water and Environmental Consultants for Alcoa of Australia, as a guide to design of drainage facilities to serve the mine and its haul roads. This update retains many elements of the original document but focuses on the mining pits, mine's haul road drainage and associated drainage facilities. It contains Basis of Design information as well as design criteria and detailed methodologies for delivering the designs.

1.2 Objectives of Pit and Haul Road Drainage

Stream turbidity levels of undisturbed catchments in the jarrah forest are normally low and have allowed the Water Corporation to draw from its supply reservoirs with little water quality treatment other than chlorination. To ensure reliable supply of high-quality drinking water, strict conditions are placed on access to, and activities within, designated water supply catchments. Alcoa's strong commitment to minimising turbid runoff from its operations has ensured that bauxite mining is one of the permitted land uses within these catchments.

Turbidity is caused by fine particles of inorganic solids (fine silts and clays) and/or organic matter (algae, plant particles, ash, etc) suspended in the water column. Turbidity is measured by an instrument which determines the amount of light that is diffracted by these particles. The measurement units used to define the degree of turbidity are Nephelometric Turbidity Units (NTU). The Australian Drinking Water Guidelines (ADWG, 2011)[2] published by the National Health and Medical Research Council (NHMRC) suggest a turbidity upper limit for drinking water of 5 NTU, based on aesthetics. It is evident however that turbidity exceeding 1 NTU adversely affects the disinfection processes used to treat drinking water.

> *"If the turbidity in a water supply exceeds 1 NTU, adequate disinfection may be more difficult to maintain, but may nevertheless be achievable." ADWG.*

Table 3.3.7 in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ, 2000)[3] provided a range of trigger values from 10 to 100 NTU for turbidity in slightly disturbed ecosystems of lakes, reservoirs and wetlands of south-west Australia. It stated also that lakes and reservoirs in catchments with highly dispersible soils will have high turbidity. While the current version of the guidelines (ANZG, 2018)[4] provides design guideline values (DGV's) for toxicants in sediment, it no longer provides specific trigger values for turbidity.

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[1] Croton , J. T., 1990 *Minesite Drainage Book*. Water and Environmental Consultants for Alcoa of Australia.
[2] National Health and Medical Research Council, 2011. *Australian Drinking Water Guidelines*
[3] ANZECC & ARMCANZ, 2000. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality.*
[4] ANZG 2018. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. www.waterquality.gov.au/anz-guidelines

Alcoa's objective is to ensure the turbidity of discharging water is managed to avoid adverse impact on the environment or downstream receptors, including the PDWSAs.

Coarse sediments, such as coarse silts, sands and gravels, present a different risk to the finer sediments that are generally associated with turbidity. If discharging mine water carries these sediments to the stream zone, the resulting sedimentation can form unstable deltas and sand banks which may smother aquatic vegetation and modify stream behaviour. The coarse sediments may eventually choke the stream channel and lead to erosion of the banks.

The methods used on Alcoa's mine sites to control the discharge of turbid water and sediments fall into three categories:

1. Those designed to limit the problem at the source by controlling erosion (e.g. stable lining),
2. Those designed to remove sediment from the runoff water prior to its release to the stream (e.g. sedimentation sump), and
3. Those designed to ensure a maximum capture of the potentially turbid water and promote infiltration (e.g. storages within mining pits, infiltration sumps).

1.3 Minesite Drainage and the Control of Jarrah Dieback

Jarrah dieback is primarily caused by the fungus *Phytophthora cinnamomi*. The survival and spread of this fungus is strongly linked to the presence of moist and saturated soil conditions. Mine drainage must be managed to avoid creation of artificial wet areas and surface water discharge into dieback free forest. To achieve this, mine runoff should be collected and channelled away from downslope areas of significant forest for release at or near to the stream zone. It is important to minimise the release of water into infected as well as uninfected forest as the extra water could result in an escalation of the infection and total stand collapse resulting in what is termed "graveyard" forest.

A single uncontrolled discharge of dieback infected water can start an infection. If dieback is of local concern, drains and sumps that are adjacent to the forest should also be made as impervious as possible to minimise the amount of water that seeps into the forest, and to prevent any fungal spores from within the mining area from escaping. Research has shown that the spores can move easily through uncompacted road gravel material but are unable to pass through a compacted clay.

1.4 Selected Design Aspects

1.4.1 Design Charts

The design charts included in this manual are for information. They are included for consistency with the approach used in the previous manual and for comparison with the previous manual's charts to demonstrate the magnitude of change resulting from the updates in documents and practices from those used to develop the original charts. Final designs should be based on computed flow rates and volumes. The charts provided herein are recommended for use for preliminary sizing and order of magnitude checking only.

1.4.2 Sump/Pit Storage Design Validation

The design process referenced in this document is based on a single design rainfall event, followed by the validation using the longer rainfall time series when appropriate. The tools have been developed to facilitate both aspects.

Simulation modelling of the sump/pit storage designs or of the system of sumps/pit storages and associated drainage controls is required to confirm structures' performance over the life of the sump. This may be as an audit or preferably integrated into the design process as the technology is implemented. Verification inspections and audits of installed structures should be carried out to monitor sump performance against design.

Validation of drainage system construction shall also be completed through as constructed survey and ongoing targeted post-cleanout surveys.

1.4.3 Sump/Pit Storage Maintenance

All sumps/pit storages must be maintained in order to retain their functionality. Structures shall be inspected at least annually to identify maintenance needs, such as embankment or weir erosion, and whether the structures' design capacity is affected by build-up of sediment and requires clean out as per Alcoa *AUACDS-2053-1783 Audit and Cleanout Sump* maintenance procedure.

1.4.4 Sump/Pit Storage Design Process Flow

A process flow map for design of sumps is found in Appendix A. It addresses both sedimentation and infiltration sumps.

1.5 Acronyms

Term	Definition
ACADS	Association of Computer Aided Design Studies
ADWG	Australian Drinking Water Guidelines
AEP	Annual Exceedance Probability, the likelihood of an event occurring or being exceeded within any given year, usually expressed as a percentage (e.g. 1% AEP) or as a fraction (e.g. 1:100 AEP). Specifically, to rainfall, it is the probability that a given rainfall total accumulated over a given duration will be exceeded in any one year.
ANCOLD	Australian National Committee on Large Dams
ANZECC	Australian and New Zealand Conservation Council
ANZG	Australian and New Zealand Guidelines
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ARQ	Australian Runoff Quality guideline document
ARR	Australian Rainfall and Runoff: A guide to flood estimation
AZ/NZS	Australian/New Zealand Standards
BGL	Below Ground Level
BoM	Bureau of Meteorology
CCF	Civil Contractors Federation
CSIRO	the Commonwealth Scientific and Industrial Research Organisation
CSP	Corrugated steel pipe
DCP	Dynamic Cone Penetrometer
DGV	Design guideline value
DN	Digital Number
DPS	Drainage Protection Slots
EI	Energy Intensity
EIA	Equivalent Impervious Area
EPA	Environmental Protection Agency
FFA	Flood Frequency Analysis, a technique, based on observed flood data at a location, used to predict the magnitude of floods corresponding to specific frequencies of occurrence or exceedance.
FoS	Factor of Safety
FTV	Flowthrough Volume
GW	Groundwater
HEC-HMS	Hydrologic Engineering Centre - Hydrologic Modeling System
HW	Headwater
IECA	International Erosion Control Association
IFD	Intensity-Frequency-Duration
LL	Liquid Limit
LS	Linear Shrinkage
MC	Moisture Content

MDB	Minesite Drainage Book, 1990
MDD	Maximum Dry Density
NATA	National Association of Testing Authorities
NHMRC	National Health and Medical Research Council
NTU	Nephelometric Turbidity Units
OMC	Optimum Moisture Content
PDWSA	Public drinking water source area
PI	Plasticity Index
PL	Plastic Limit
PPV	Permanent Pool Volume
PSD	Particle Size Distribution
RL	Reduced Level
RORB	Runoff Routing (initially developed and maintained on a Burroughs B6700 computer)
RUSLE	Revied Universal Soil Loss Equation
SDT	Sump Design Tool (haul roads)
SE	Sump (hydraulic) efficiency
SG	Specific Gravity
SHV	Sediment Holding Volume
SILO	Scientific Information for Landowners
SMDD	Standard Maximum Dry Density
SME	Subject Matter Expert
SRTM	Shuttle Radar Topography Mission
SWMM	Storm Water Management Model
TSS	Total Suspended Solids
USACE	United States Army Corps of Engineers

1.6 Selected Definitions (in context)

Term	Definition
Catchment	The area of land draining to a point in the landscape. In a drainage design context, the area of land contributing runoff to a point where a flow rate or flow volume is to be estimated.
Extended detention	The volume of water in a sump which lies at a level above the level of the outlet and which can only exist when there is flow passing through the sump. This represents the volume above the cease-to-flow level.
Freeboard	An allowance in structure design required to account for uncertainties that are inherent in the estimation of flood levels. Defined as a distance between the maximum water level within the storage, evaluated for the design rainfall, and the structure's crest.
Hydraulic efficiency	The efficiency of a flow-through sump (e.g. a sedimentation sump) to distribute flow evenly through the sump's cross section perpendicular to the direction of flow.
Hydrologic effectiveness	The effectiveness of a sump to capture, and, within its operating limits, to treat the stormwater passing into or through it.
Infiltration sump	A sump which is designed to capture and hold runoff water for recharge into the groundwater through the natural process of infiltration. Also referred to as a retention sump.
Mainstream length	The longest flow path within a catchment measured from the watershed boundary along the flow path to the catchment outlet.
Mean annual runoff	The estimated runoff volume occurring from average annual rainfall. Estimated by multiplying annual rainfall depth by the volumetric runoff coefficient.
Permanent pool	The water stored in a sump at a level below its outlet level, representing the volume of water retained after direct outflows have ceased.
Runoff coefficient	The Rational Method runoff coefficient represents the ratio of a peak flow and a rainfall rate of a selected duration for the same frequency of occurrence. The volumetric runoff coefficient represents the ratio of a runoff volume from a catchment and the rainfall volume falling on that catchment.
Sedimentation effectiveness	A measure of the ability of a sump to capture, through sedimentation, the particles of a particular size.
Sedimentation sump	A sump which is designed to detain runoff water to allow the natural process of sedimentation to settle solid particles from the water column. Also referred to as a detention sump.

Storage	the portion of a sump or pit that retains water or collected sediments.
Sump	A pit or hollow (constructed or natural) into which water collects.
Surcharge	The portion of water in a hydraulic structure which lies above the normal operating level for water in that structure. The extended detention storage in a sump represents the volume of surcharge above the outlet weir crest.
Surface hydraulic loading	The surface hydraulic loading (also referred to as surface loading or hydraulic loading) of water passing through a sump is the rate of water applied to the sump divided by its surface area. Based on Hazen's surface load theory, the maximum surface hydraulic loading for effective sedimentation is representative of the average settling velocity required for a particle to settle from the top of the water column to the base of the sump before the water leaves the sump. Refer also to Section 5.4.6.
Swale	A low or hollow area or depression between low ridges through which water can collect or pass.
Time of concentration	the time that it takes all parts of a catchment to contribute to runoff at a point of interest.
Watershed	A dividing ridge between adjacent drainage areas (catchments).

2 DESIGN CRITERIA

2.1 Design Limitations

Drainage design is not an exact science. Design rainfalls are based on records from widely spaced pluviographs which may have only been recording data for periods of 10 to 15 years. The actual rainfall data is only accurate to within 5%, while its conversion to design storms of various durations with Annual Exceedance Probabilities (AEP) of 5%, 1% or 0.02% requires the use of numerous assumptions and results in a final accuracy estimated to be typically between 10% and 20%.

The uncertainty does not stop with rainfall; it is further reduced by variations of catchment conditions from those assumed. An example of how much the changes in catchment conditions affect runoff may be shown by a comparison of the 5% AEP runoff generated from a compacted area of 10 ha (0.1 km^2) from Figure 3-4 with that for a well forested area of 10 ha from Figure 3-6. If Curve A is used in Figure 3-6 the two runoff values are different by a factor of 20. The sediment yields used in sediment sump design, may vary by over an order of magnitude depending on soil type, ground slope, vehicle traffic, etc.

It must be accepted that even the most careful design is based on data with significant uncertainty. It is more important to check that the design assumptions are realistic than it is to calculate numbers to the second decimal place. This checking should also include consideration of likely changes to the drainage system during its life and the quality of construction that will be done. Changes that will result in significant errors or deviations in the parameters used for design must be considered in the design process. Various "what if" cases should be considered. Any "rounding up" of design outcomes should be carried out only once, at the end of the design process – not at every stage through that process.

Effective design will require an understanding of what is being designed, the sensitivity of its location, how it will be constructed, and the risks associated with hydraulic failures which result in overflows to the environment.

The storage design effectiveness to manage catchment water quality within the 25 NTU over 1-hour trigger is a function of storage feature hydraulics (capacity, infiltration rate) and storage feature water quality relative to cumulative rainfall events and single large storm events.

2.2 Design Rainfall and Evaporation

A layered control approach to water storage containment is adopted by Alcoa. The design rainfall to be applied in design of the structure, and particularly the minimum storage capacity, shall be selected to reflect the likelihood of overtopping when considering the historical rainfall record, catchment hydrology and locally evaluated infiltration rates, identified by considering the local groundwater levels.

The minimum design event capacities for haul road storage and mine pit storage are outlined as follows:

- Mine pit minimum capacity design 1%AEP 24h,
- Haul road minimum capacity design 1%AEP 72h.

The hydrological design assumptions are slightly different between haul road storage and mine pit storage whereby the haul road storage catchment area (i.e. the haul road) is assumed to have zero infiltration while the mine pit storage catchment area is assumed to have a degree of infiltration due to the broken mining surface.

The water balance modelling has indicated the storage design criteria can achieve catchment runoff volume containment for mine pits >99% and haul roads 90-95% assuming infiltration rates within expected range. The water balance modelling undertaken demonstrates:

- the greater tendency, given the same rainfall input and storage design capacity, for haul road controlled water release when compared with mine pit storage, while
- the relatively lower haul road catchment areas relative to mine pit catchment areas, generate comparatively lower runoff volumes for haul road storage.

Where lower infiltration rates are identified, Alcoa commits to targeted water handling to manage storage design capacity extent (and additional clearing for haul road storage only) and/or increased storage capacity, to target runoff volume containment. Water quality monitoring shall be used to facilitate development of management measures and new designs to achieve catchment water quality objective.

Haul road sump storage capacity is based on a Sump Design Tool (components described in Section 5), incorporating infiltration rate, sump geometry and freeboard.

Greater storage capacity and/or targeted water handling requirements may be considered to meet catchment runoff water quality objectives.

Design flows for conveyance facilities (drains, channels, culverts, etc) shall convey the runoff associated with the design rainfall while maintaining the minimum freeboard as specified in Table 2-1 of Section 2.3.

Long term rainfall can be utilised to refine the final storage capacity, by reflecting the historical rainfall sequences.

All infiltration sumps must be modelled to understand cumulative impacts of seasonal wet weather on storage.

Design rainfall Intensity-Frequency-Duration (IFD) data for a representative site at each of Huntly and Willowdale mines was obtained from the Bureau of Meteorology's Water Information website[5].

Included in Appendix B are design rainfall charts and tables, showing design rainfall depth and rainfall intensity for the Huntly and the Willowdale Mine. Also included in Appendix B, for direct computation of design rainfall depths using spreadsheets or other computational methods, is a description of the Bureau's polynomial curve fit to the design rainfall data, and the tabulated polynomial coefficients for the Huntly and Willowdale mines.

Daily rainfall data for the Huntly mine is included in Appendix B from 1980 to 2021 and for the Willowdale mine from 1982 to 2021. Daily evaporation is data has been obtained from the Scientific Information for

[5] Bureau of Meteorology's Water Information website http://www.bom.gov.au/water/designRainfalls/revised-ifd/

Landowners (SILO) database to enable long term review of rainfall and evaporation data. SILO is a database of Australian climate data from 1889 to the present. It provides daily meteorological datasets for a range of climate variables in ready-to-use formats suitable for biophysical modelling, research and climate applications. SILO datasets are constructed from observational records provided by the Bureau of Meteorology. SILO interpolates the raw data, which may contain missing values, to derive datasets which are both spatially and temporally complete.

For the Willowdale mine, BoM's Willowdale weather station was used (ID: 9893) as the data extends to 1982. For the Huntly mine, BoM's Dwellingup station was used (ID:9538) as the data extends to 1932 (the Huntly BoM station data only extends to 1990).

2.3 Freeboard Requirements

Freeboard is an allowance required in structure design to account for the uncertainties that are inherent in the estimation of flood levels.

Freeboard is the vertical distance measured from the estimated flood surface level to the structure level above which inundation would cause damage or otherwise adversely affect the functionality of the structure, as shown schematically in Figure 2-1.

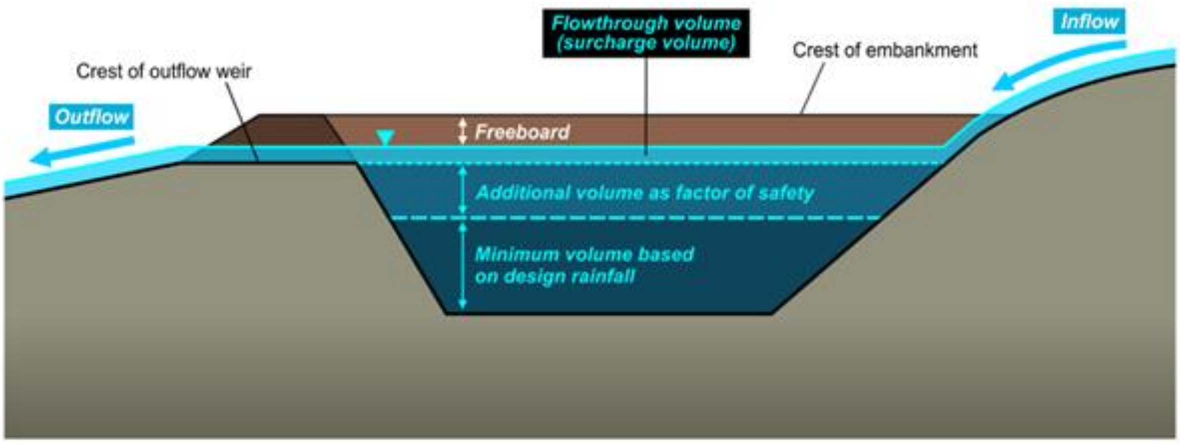

Figure 2-1 Definition of freeboard

Table 2-1. Design Minimum Freeboard

Structure	Minimum Freeboard Amount
Sedimentation sump	0.5 m
Infiltration sump	0.5 m
Channel/drain	The lesser of 0.3 m above design water level or 20% of the channel constructed depth.
Storages within a mining pit	0.5 m (if the available space allows)

2.4 Water Quality Criteria

The Water Corporation (as per the Water Working Arrangements[6]) identified the following Turbidity Event as reportable:

- Compliance Monitoring Point exceeding a 25NTU reading for 1 hour.

Alcoa's design objective is therefore to ensure compliance with the above criteria. Water quality monitoring shall inform planning of water management and storage design.

2.5 Spillway

Spillway design for controlled water release during above design basis rainfall should include an assessment of the downstream slope, for flow energy dissipation control and turbidity minimisation.

[6] Alcoa World Alumina, Department of Water and Environmental Regulation and Water Corporation, 2018. *Water Working Arrangements; Version 5. Effective Years of Operations 2018-2023*

3 COMMON DESIGN ASPECTS AND STRUCTURES

3.1 Interaction with Groundwater

Depth to groundwater has a direct effect on infiltration capacity. It varies, based on topography, and typically reduces from 10 to 30 m below ground level in elevated areas to several metres close to valley floors and drainage lines, where it can enter surface in form of seepages and springs. Groundwater was a key factor of lateritisation process which formed the duricrust (ferruginous cap) at the surface.

In addition, winter rainfalls typically raise groundwater levels (and reduce depth to groundwater) by several metres before they dissipate during the dry season.

Depth to groundwater is controlled by a number of geological and hydrological factors which contribute to the lack of accurate predictability of groundwater levels. The presence of local features such as rock outcrops, obstructing the groundwater flow, often causes shallow, near surface groundwater conditions. Evapotranspiration removes groundwater in forested areas where groundwater is within the reach of the root system and substantially contributes to control its depth. Removal of forest cover leads to elimination of this evapotranspiration control (and reduction of depth to groundwater).

Depth to groundwater and its seasonal variations are measured by a network of monitoring bores which are typically installed around cleared areas in transects from elevated areas to valley floors or drainages, and also around pit perimeters in downgradient positions. Direct measurements from these monitoring locations are used to inform the drainage assessment. Where these are not available, depth to groundwater has to be estimated.

Groundwater flow in the Darling Range is topographically controlled which allows for its estimation, with a reasonable degree of accuracy in absence of direct measurements. Advisian developed an average condition (steady-state) groundwater surface using a sub-regional dataset obtained from a simple groundwater flow model. It uses the SRTM data to inform the sub-regional model topography, lumped hydraulic conductivity and estimates of recharge and evapotranspiration rates that have been used in other studies (eg. GHD, 2021[7]).

Local parameter variations would lead to changes in groundwater level predictions/estimates; however these are typically not available. An example of estimated depth to groundwater is shown in Figure 3-1.

[7] GHD, 2021. *Alcoa Huntly Mine – Myara North Region Groundwater Modelling Report.* Technical report for Alcoa of Australia Limited

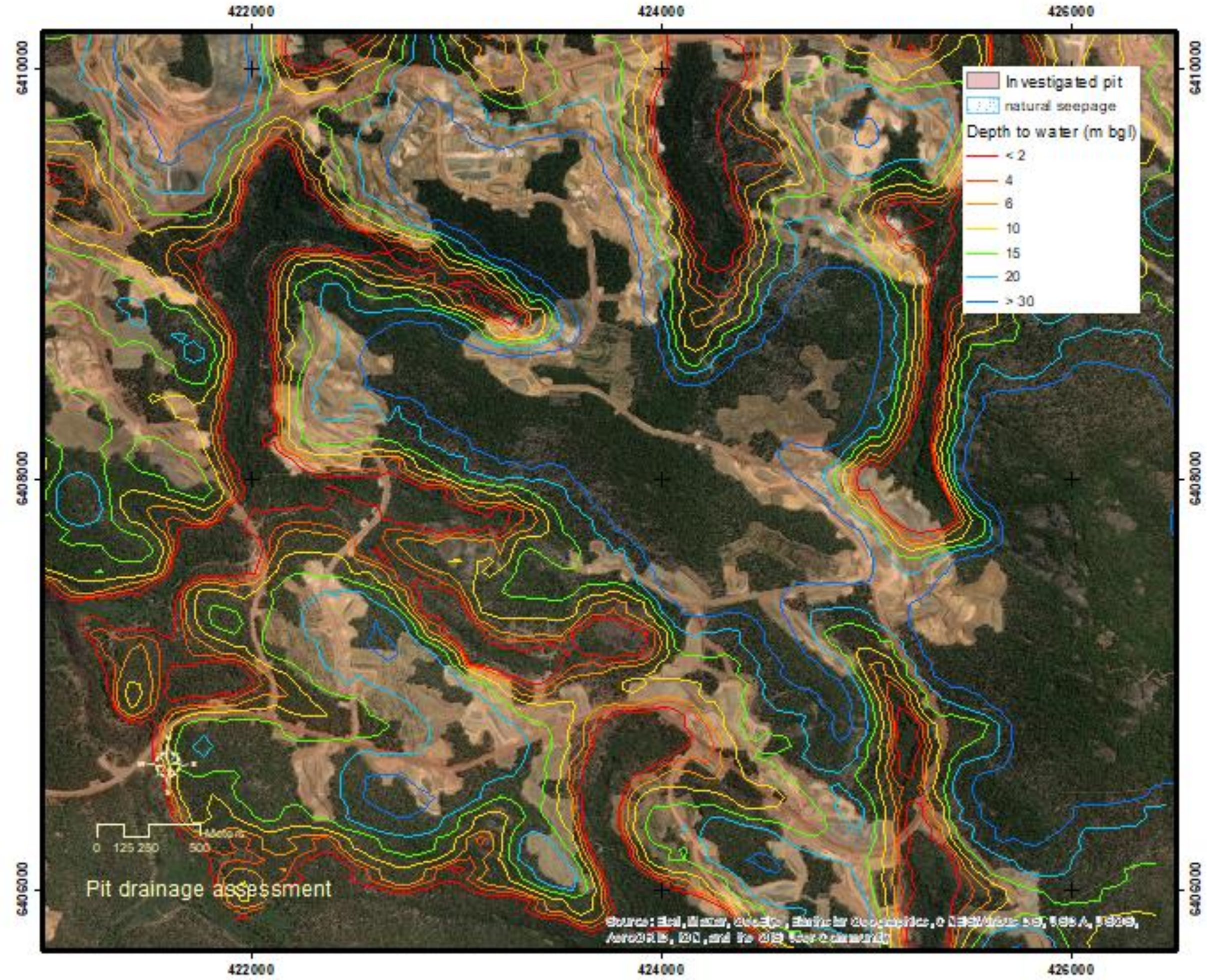

Figure 3-1 An example of average estimated depth to groundwater (measured from SRTM topography)

Since calculated depth is affected by the SRTM accuracy and its departure from more accurate up-to-date Lidar-produced topography, it may be appropriate estimated groundwater level (m RL) rather than depth (m BGL). An example is presented in Figure 3-2.

These water levels and depths are based on a number of simplifying assumptions and represent average conditions. This means, for example that winter rainfall would typically raise them by up to several metres which needs to be taken into consideration. They therefore offer a first pass information only and are not a replacement for water levels obtained from monitoring.

In parallel, Alcoa undertook groundwater proximity assessment to evaluate depth to groundwater and to inform haul road sump location and design.

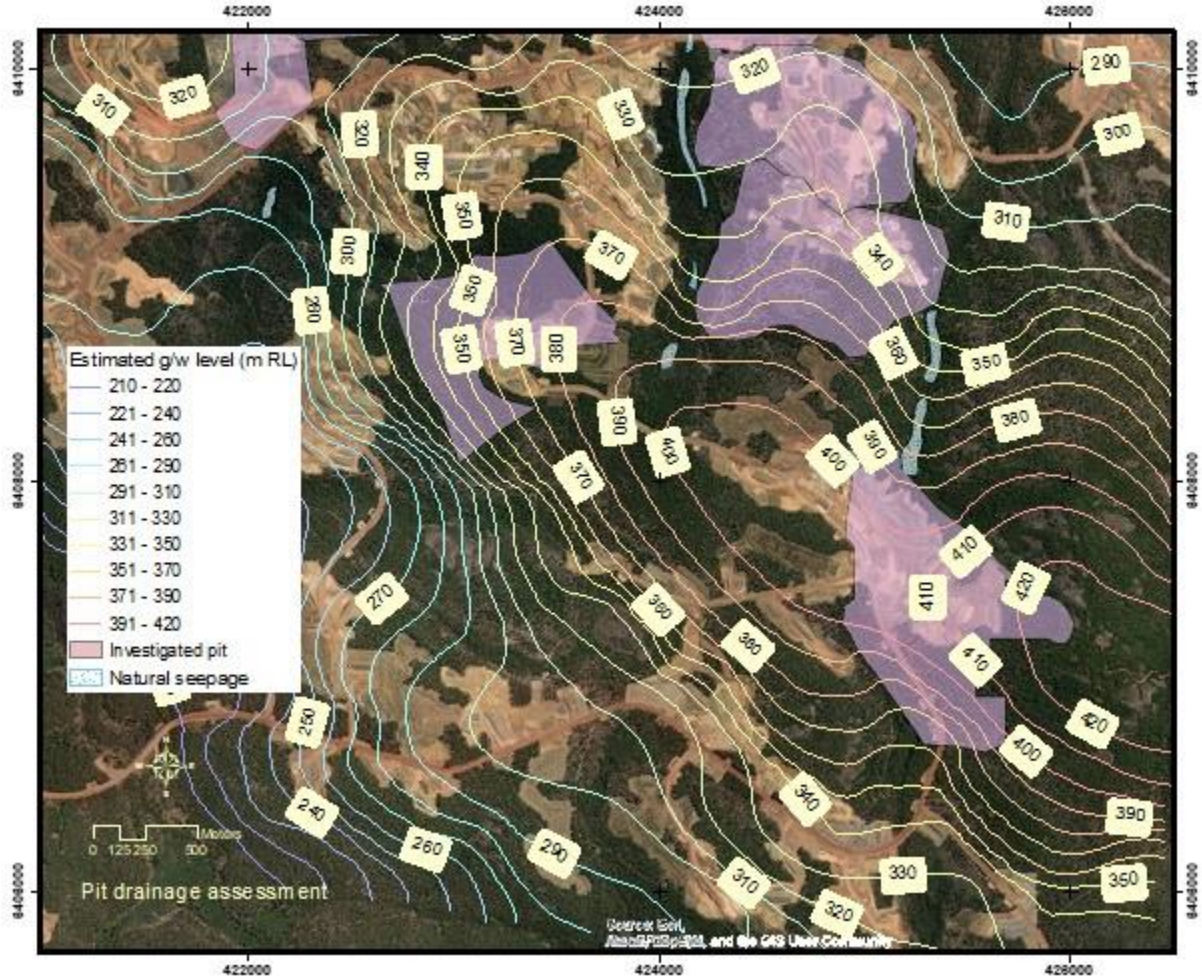

Figure 3-2 An example of estimated average groundwater levels

3.2 Current Infiltration Estimates

In addition to depth to groundwater (and therefore availability of material where water can infiltrate) infiltration rates are key to understanding and quantifying losses in the water balance estimation, and consequently for management of excess water. They are however challenging to constrain without detailed site-specific investigations and measurements.

Due to the nature of saprolitic weathering of the underlying granitoid basement, pit floors are often made of a clayey saprolite material, occasionally with coarser fraction where saprolite weathering is relatively shallow. Vertical hydraulic conductivity of these materials, which controls the infiltration rate, is often relatively small.

Existing investigation sources were reviewed to assist with estimation of infiltration rates – with direct relevance to bauxite mining in the Darling Range, and include Croton and Bari (1997)[8], Croton and Tierney (1996)[9], Raper and Croton (1996)[10], and Sharma and Barron (1987)[11].

Croton and Bari (1997) established reduction of saturated hydraulic conductivity Ksat from 11 m/d pre-mining to 1 to 2 m/d for rehabilitated sites (using a well permeameter). This reduction was considered not to be sufficient enough to explain ponding in rehabbed area after rainfall events 100 mm or less.

These authors refer to findings of other studies, focused on the clayey zone of a freshly exposed saprolite profile (i.e. not, for example, rehabilitated areas). For a typical hillslope transect Croton and Tierney (1996) established Ksat = 0.07 m/d and Raper and Croton (1996) determined a Ksat geometric mean for the mottled zone = 0.052 m/d.

The exposed base of the mining pits most closely relates to mottled or pallid zones (Ksat 0.01 to 0.05 m/d) for which Ksat values can be drawn from a table compiled by Croton and Tierney (1985).

Table 3-1. Recommended parameter values for Darling Range soils (after Raper and Croton, 1996)

Soil	Θ_{sat} (mm3/mm3)	K_{sat} (mm/d)	Ψ_e (mm)	b
Sandy Topsoil	0.24	6,800	-150	2.8
Upper slope topsoil	0.15	500	-150	4.4
Grey sand	0.44	1,570	-150	1.8
Clay layer	0.39	3	-1,500	20
Bauxite	0.46	470	-50	3.3
Western mottled zone	0.39	50	-400	12
Eastern mottled zone	0.31	50	-400	13
Western pallid zone	0.48	10	-400	11
Eastern pallid zone	0.31	10	-400	8
Doleritic pallid zone	0.55	10	-400	22
Weathering zone	0.42	225	-250	13

That surface is spatially heterogeneous, i.e. can also include sandy or bauxite sections (orders of magnitude higher) which would have generally higher infiltration rates.

Infiltration rates interpreted from the regional groundwater modelling study by GHD (2021)[12], undertaken for Myara North, when scaled to typical 10 to 12 days of substantial rainfall per season yield the rates of 50 to 60 mm/d which are comparable to Raper and Croton (1996).

[8] Croton, J.T., Bari, M.A., 1997. *The effect of mining on the infiltration characteristics of Darling Range soils*. Water and Research Commission Series, Report WRT 10 1997

[9] Croton, J.T., Tierney, D.T.A., 1996. *Red – A hydrological design model used in the rehabilitation of bauxite minepits in the Darling Range, Western Australia.* Alcoa Environmental Research Bulletin No 15.

[10] Raper and Croton, 1996. *Hydraulic properties of Darling range soils*. Preliminary report to Alcoa of Australia Ltd.

[11] Sharma, ML, Barron, RJW Fernie, MS, 1987: *Areal distribution of infiltration parameters and some soil properties in lateritic catchments.* J Hydrol 94: 109-127

[12] GHD, 2021. *Alcoa Huntly Mine – Myara North Region Groundwater Modelling Report*. Technical report for Alcoa of Australia Limited

The HEC-HMS Technical Reference Manual[13] also contains typical hydraulic conductivity for a range of soil types summarised in Table 3-2.

Table 3-2. Soil texture class estimates

Texture Class	Saturated Hydraulic conductivity, K_{sat} (mm/hr)	Saturated Hydraulic conductivity, K_{sat} (mm/day)
Sand	210.0	5040
Loamy sand	61.1	1470
Sandy loam	25.9	622
Loam	13.2	317
Silt loam	6.8	163
Sandy clay loam	4.3	103
Clay loam	2.3	55
Silty clay loam	1.5	36
Sandy clay	1.2	29
Silty clay	0.9	22
Clay	0.6	14

Alcoa has recently used a relatively conservative value of 24 mm/d which is within the range of measured, tabulated and modelled values. When site-specific data is not available it is recommended that the range of 16 to 30 mm/d is applied (the values applied should be selected based on ratio of areas ranging from sandy to clayey textures).

Site-specific investigation of the hydraulic conductivity of the aquifer at and below the lower portion of the sump for sump design purposes would be desirable for improvement of the design accuracy, especially where depth to groundwater may be small (e.g. less than 5 m). Estimation of the hydraulic conductivity of the base soils at each sump site, should be conducted by (in order of increasing uncertainty) either:

1. Measurement by falling head test in a test pit constructed on site
2. Measurement by falling head testing or a full pumping test at a nearby borehole, at notional sump base depth (pumping test may have limited value in clayey environments)
3. Estimation based on PSD analysis of borehole soil sample (where the base tested consists of unconsolidated material, i.e. sands, sandy clays, loams etc.)
4. Estimation by characterisation of typical soil properties.

It must also be recognised that the hydraulic conductivity of the sump's soils will reduce as sediments accumulate and the finer particles enter the soil voids to cause clogging and with decreasing depth to groundwater. Consequently, the infiltration rate will decrease with time of use (Figure 3-3).

The rate may be refreshed by removal of the accumulated sediments and the clogged surface layer of soil.

[13] Feldman, A. D. (ed.) 2000. *Hydrologic Modelling System HEC-HMS Technical Reference Manual*. U.S. Army Corps of Engineers, Davis CA.

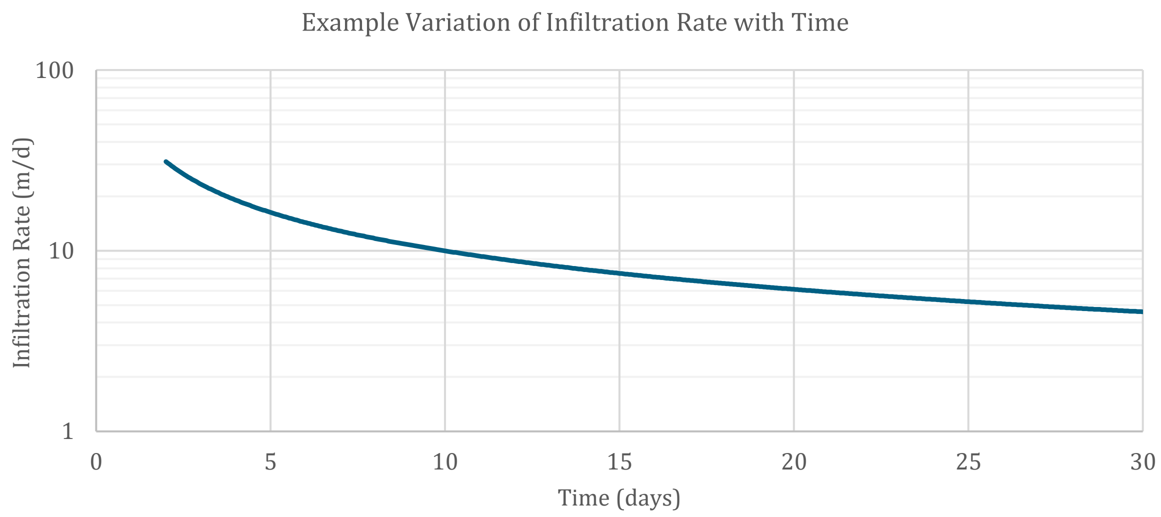

Figure 3-3. Typical variation of infiltration rate with time

The likely performance of the sump to infiltrate the collected water is evaluated through a water balance model (Section 5.5.2). Infiltration in the water balance is evaluated based on Darcy's Law and assumes that the base of the sump is above the water table and that sump discharge through the aquifer is under saturated flow conditions. The steps for the infiltration component assessment area:

1. Determine the area of infiltration area of the sump: the area typically comprises the base area of the sump, A_b, and the area of the sloping walls, A_w, up to the design water depth (outlet level). From this full level, water levels will drop as water is lost to infiltration so the infiltration area will reduce to zero as depth reduces to zero. To determine the infiltration area, the volume in the sump in the previous water balance timestep is calculated and converted into an area within the sump.

2. Determine the representative hydraulic conductivity, K_{sat}, for the sump, expressed in units of m/day.

3. Apply the Darcy equation:

$$Q_i = K_{sat} I A_i$$

Equation 1

where ***I*** is the hydraulic gradient through the aquifer and ***I*** may be set to 1
K_{sat} is the vertical hydraulic conductivity of the soil, m/day
Q_i is in units of m^3/day.

Therefore, the discharge rate through infiltration is approximated by ***$Q_i = K_{sat}.A_i$***

3.3 Runoff Estimation

Runoff estimation in the 1990 MDB[14] was fundamentally founded on the Rational Method, a simple event-based method which represented a common industry practice in Australia and overseas. The Rational Method transforms a preselected rainfall event of specific magnitude and duration into a runoff peak flow and volume. The variability of flow with time (the flow hydrograph) is not addressed, yet this variability is important in assessing characteristics of infiltration and sedimentation, two critical elements in Alcoa's drainage system. There is also the inherent assumption that the probability of occurrence of a flood of a particular magnitude is the same as the probability of occurrence of the storm magnitude which produced it. This is not the case, as flood magnitude is influenced by the time and spatial distributions of the storm event as well as by many other factors.

Simulation modelling could provide a better understanding of the combined effects of several/many basins in an area and provide improved estimates of runoff flows, required design volumes and resulting sediment loads.

The latest edition of Australian Rainfall & Runoff (ARR) 2019[15] provides detailed explanations on runoff estimation as well as various methods that can be used. Additional references have been quoted, as appropriate, in Chapter 5.5.3 for in-depth information on design rainfall and water quality and sediment management.

3.3.1 Rational Method

For design of drainage facilities in built environments, such as the mine and its roads, the Rational Method presents as a relatively simple method for peak flow estimation. For use in design, the Rational Method may be expressed as:

$$Q_p = FC_p{}^{p}I_{T_c}A$$

Equation 2

where $\boldsymbol{Q_p}$ is the peak flow estimate for a flood of $\boldsymbol{p}$ AEP
$\boldsymbol{C_p}$ is the coefficient of runoff for a $\boldsymbol{p}$ AEP event
${}^{\boldsymbol{p}}\boldsymbol{I_{Tc}}$ is the rainfall intensity for a $\boldsymbol{p}$ AEP design storm of critical duration, $\boldsymbol{T_c}$
$\boldsymbol{A}$ is the catchment area
$\boldsymbol{F}$ is a units conversion factor.

For $\boldsymbol{A}$ in hectares and ${}^{\boldsymbol{p}}\boldsymbol{I_{Tc}}$ in mm/hr, $\boldsymbol{F}$ = 1/360 yields $\boldsymbol{Q_p}$ in m^3/s.

Values of $\boldsymbol{C_p}$ should be derived from observed flood and rainfall data. Such data however is not available for the ungauged catchments of the Alcoa mine sites, so representative values must be used, such as those in Table 3-3, drawn from the MDB and from common practice.

[14] Croton , J. T., 1990 *Minesite Drainage Book*. Water and Environmental Consultants for Alcoa of Australia.
[15] Ball J, et al. (Editors), 2019*. Australian Rainfall and Runoff: A Guide to Flood Estimation,* Commonwealth of Australia

Table 3-3. Event based runoff coefficients

Land Surface Classification	$C_{5\%}$	$C_{1\%}$
Compacted areas, including pit floor, tracks, roads and other pavements	0.90	1.00
Rock Outcrops	1.00	1.00

3.3.2 Contributing Catchment Areas

The average contributing width of a catchment is equivalent to the total catchment area divided by the catchment's mainstream length, the longest flow path length measured along the flow path from the watershed boundary down to the catchment's outlet.

The catchments contributing runoff to a mine drainage facility may include areas of forest or rocky outcrops as defined in the following sections.

Figure 3-4 shows indicative relationships between compacted area and runoff, also called catchment discharge, for AEP's of 5% and 1% and for both Huntly and Willowdale Mines. It shows that there is little difference in runoff rates between the two sites. The chart, adapted from the MDB[16], is based on catchment areas which are roughly square in shape, with average flow velocity of 1.5 m/s, per the MDB. While a coefficient of runoff of 0.9 was assumed for the 5% AEP curve, a coefficient of 1.0 (the maximum) was used for the 1% AEP curves.

For a storm of fixed duration, such as a 24-hour event, runoff <u>volumes</u> generated from a complex mine area can be estimated by breaking the area up into logical contributing sub-catchments and calculating the runoff volume for each piece. These runoff volumes may then be added together to obtain the total runoff volume.

This simple arithmetic approach to combining the results from each sub-catchment is appropriate for runoff volume estimation but does not apply for peak flow estimation.

For a complex mine area, where there is variation in runoff coefficient, the contributing catchment is broken into logical sub-catchments with an appropriate runoff coefficient applied to each sub-catchment. The equivalent impervious area (EIA) is computed for each sub-catchment by multiplying its area by its runoff coefficient. The sum of the sub-catchment EIA's is the EIA of the contributing catchment.

$$EIA(total) = \sum_{i=1}^{n} C_i A_i$$

Equation 3

and

$$A(total) = \sum_{i=1}^{n} A_i$$

[16] Croton , J. T., 1990 *Minesite Drainage Book*. Water and Environmental Consultants for Alcoa of Australia.

Equation 4

where ***EIA(total)*** is the equivalent impervious area of the contributing catchment
C_i is the runoff coefficient applied to subcatchment **i**
A_i is the area of subcatchment ***i***
n is the number of subcatchments in the total contributing catchment
A(total) is the area of the contributing catchment.

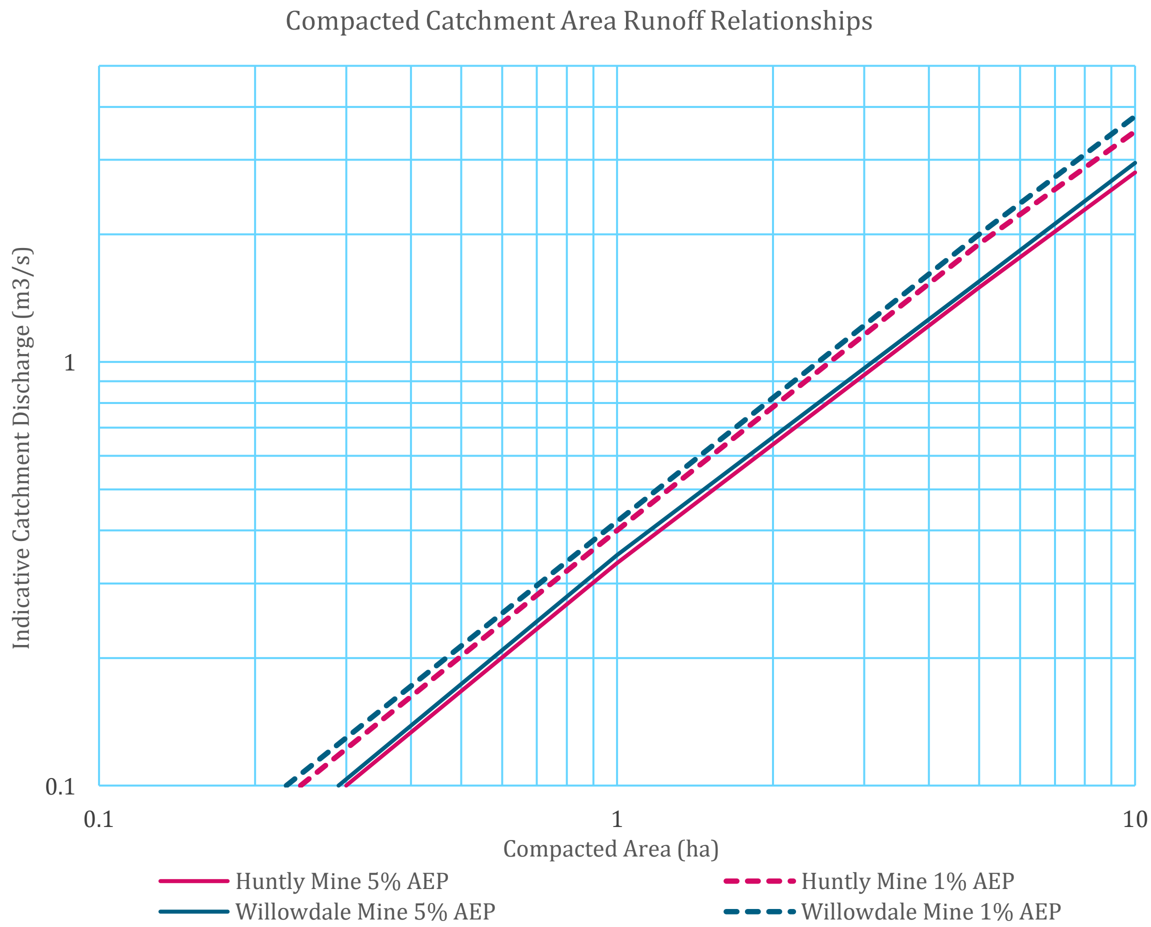

Figure 3-4. Catchment Area - Runoff Relationship for a Compacted Area

3.3.3 Time of Concentration

The mainstream is identified for each catchment (or sub-catchment) for which a flow estimate is required. The length and slope of the mainstream are also measured or estimated. For the mine and haul road catchments, which are relatively small areas, the average slope of the mainstream may be used to estimate flow travel time and therefore time of concentration. For larger, more complex catchments, the equal area slope (ARR87[17], ARR1999[18]) should be used.

The time of concentration may be defined as the time that it takes all parts of a catchment to contribute to runoff. Computationally it is estimated as the sum of an initial time of concentration (the time that it takes for runoff to commence after the onset of rainfall) plus the travel time of flow from the most remote part of the catchment to the catchment outlet.

$$t_c = t_{min} + t_{travel}$$

Equation 5

where t_c is the time of concentration to a point of interest (catchment outlet), and
t_{min} is the minimum time of concentration. For consistency with existing Alcoa practice:

- For haul roads, t_{min} = 3 minutes
- For mine areas, t_{min} = 5 minutes

t_{travel} is the travel time based on the average velocity ($V_{average}$) for shallow concentrated flow which, from slope (S), may be estimated from Figure 3-5.

$$t_{travel}(minutes) = \frac{Mainstream\ Length\ (m)}{60 \times V_{average}\ (m/s)}$$

Equation 6

For forested catchments, the time of concentration may be estimated using the regional formula from ARR (1987) for catchments in the jarrah forest:

$$t_c = 2.31 \times A^{0.54}$$

Equation 7

where A is the catchment area (km^2).

[17] Pilgrim, D. H. (ed.), 1987. *Australian Rainfall and Runoff: A guide to flood estimation, Vol.1.* The Institution of Engineers, Australia.
[18] Pilgrim, D. H. (ed.), 1998 (Reprint). *Australian Rainfall and Runoff: A guide to flood estimation, Vol.1.* The Institution of Engineers, Australia.

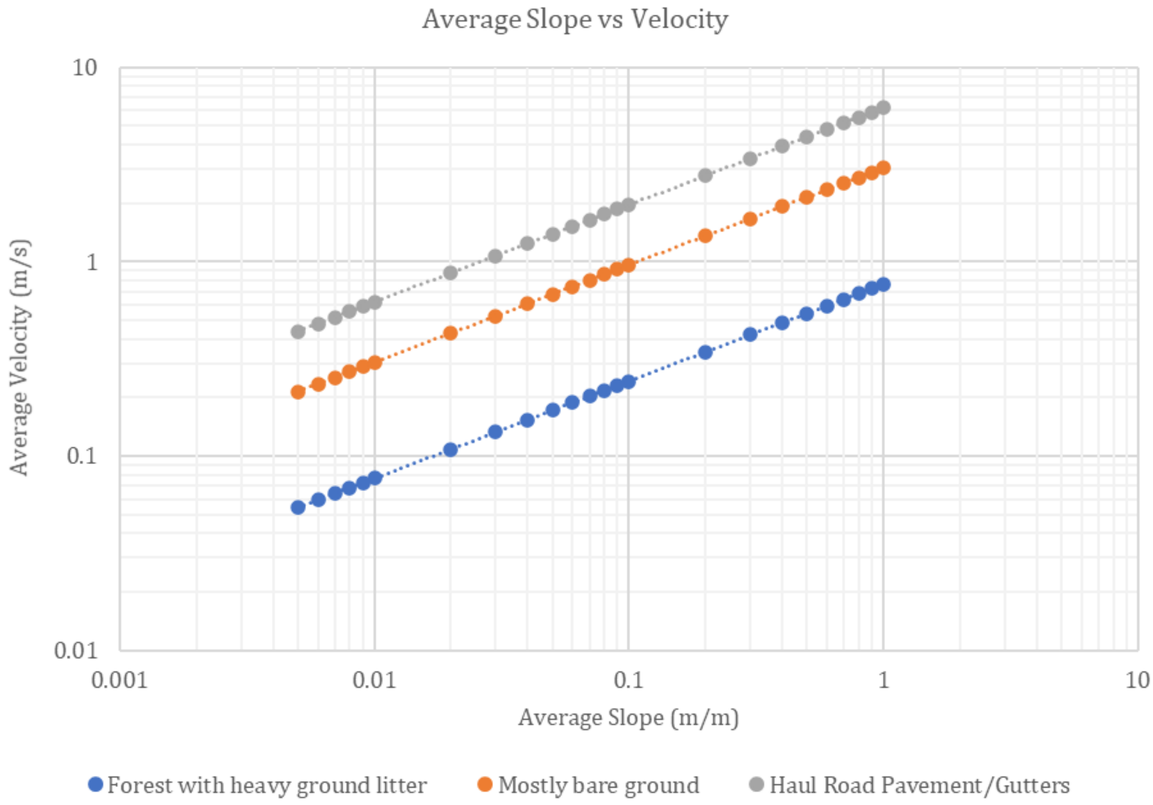

Figure 3-5. Estimated Velocity for Shallow Concentrated Flow

3.3.4 Forested Areas

Potential contributions of runoff from forested areas generally have been ignored due to significant interception losses in the tree canopy, understory and forest floor leaf litter together with recharge to the shallow groundwater which markedly reduces and delays runoff peak flows and volumes from these areas. The forest areas lying above mine areas are usually sections of hillslopes containing no swamp area. An area of swamp, indicating a zone of groundwater seepage, anecdotally is required within a forested catchment to generate significant runoff. If a significant swamp area exists in a forested area that may contribute to mine runoff, then that catchment should be included in the estimates of runoff.

Figure 3-6 provides indicative runoff relationships for a range of forested areas based on several key assumptions:

- Based on Huntly Design Rainfall
- Forested catchment is square in shape
- Curves 'A' represent forest catchment areas in good condition with good forest cover, small to average wetland areas and no significant clearing or mining (cleared area nominally 5% or less)

- Curves 'B' represent forest catchment areas in poor condition with poor forest cover, large wetland areas and moderate clearing or mining (cleared area nominally 10%)
- Runoff coefficients (Table 3-4) are based on those used in the previous manual, with extrapolation of flow used to assign representative runoff coefficients for the 0.2% AEP curves.

Final designs however should be based on computed flow rates and volumes. The charts provided herein are for preliminary sizing and order of magnitude checking only.

Table 3-4. Adopted runoff coefficients for forest catchments

AEP	Curve 'A'	Curve 'B'
5%	0.10	0.18
1%	0.13	0.23
0.2%	0.15	0.25

3.3.5 Rock Outcrops

Where there are significant areas of outcropping rock adjacent to the mine and likely to contribute runoff to the mine, then these areas should be included in the mine catchment assessment with a runoff coefficient of 1.0 assigned for runoff estimation.

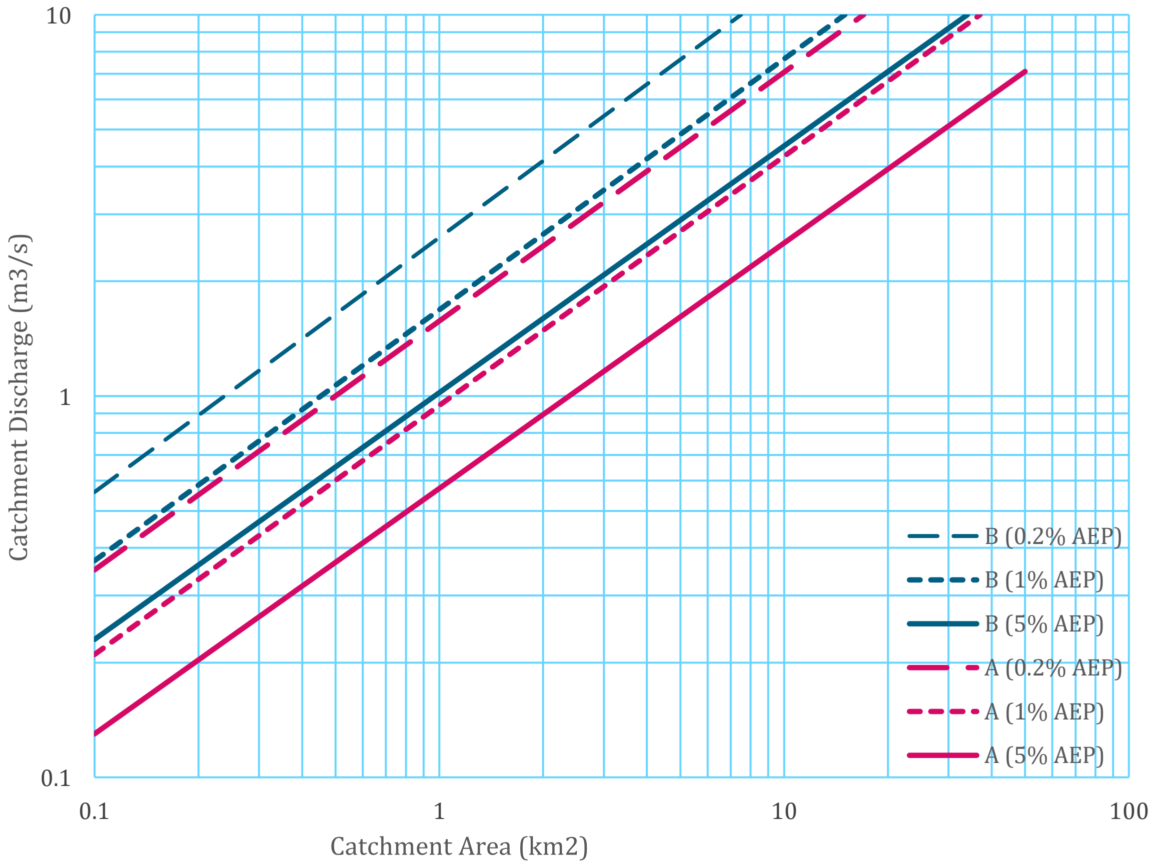

Figure 3-6. Typical Catchment Area-Discharge relationships for forested catchments

3.4 Culvert Design

3.4.1 General Design

The discharge capacity of a culvert pipe may be dependent on its length, slope, internal surface finish and geometry at the inlet, as well as the tailwater conditions. These factors combine to create a complex set of conditions that are difficult to solve analytically.

The flow conditions that can exist within a culvert are usually divided into two categories:

1. inlet controlled flow where the geometry of the culvert inlet dominates the losses in the culvert essentially restricting the amount of flow that can enter the culvert; and
2. outlet controlled flow where the friction losses within the culvert and at its outlet also contribute to the restriction in flow passing through the culvert.

The changes in flow patterns and velocities at the inlet and outlet commonly contribute the greatest energy losses within a culvert and therefore control the discharge capacity. To estimate the discharge capacity of a culvert it is necessary to determine its capacity under both flow control conditions with the lower discharge capacity governing. In circumstances where a flow is predetermined by design and a culvert diameter is being examined the control condition (inlet or outlet) which produces the greater headwater is the one which governs.

<u>Due to these complexities, culvert design should be conducted using appropriate engineering principles.</u>

$\frac{b}{D}$	$\frac{a}{D}$	$\frac{c}{D}$	$\frac{d}{D}$	ENTRANCE TYPE
0.042	0.063	0.042	0.083	A
0.083	0.125	0.042	0.125	B

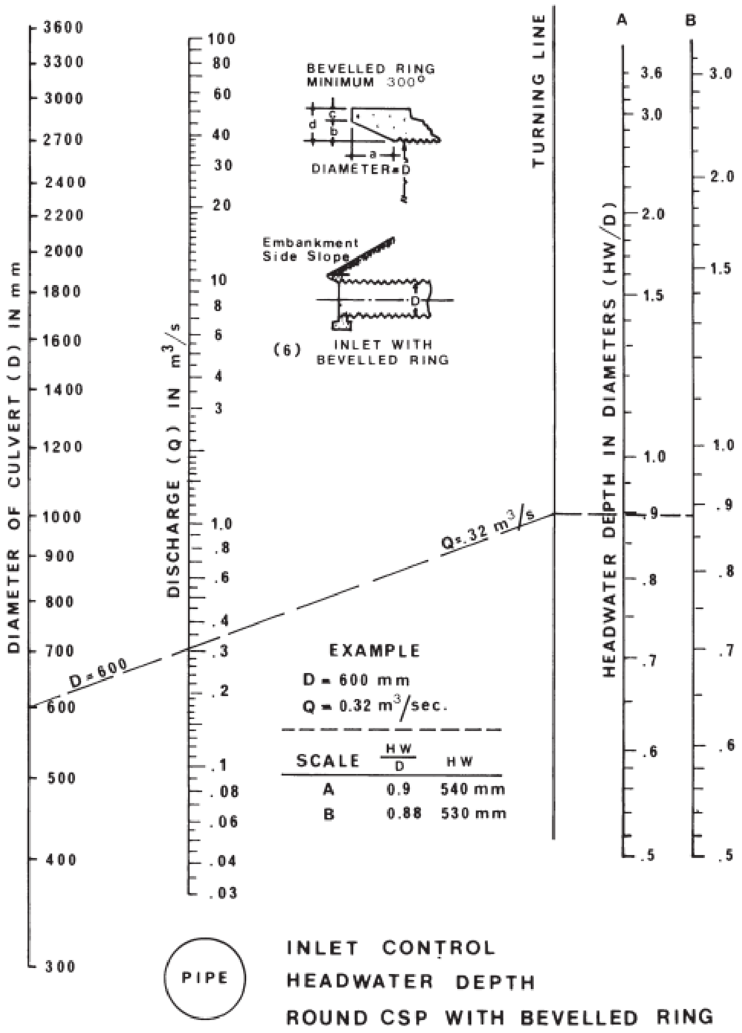

Figure 3-7. Design nomograph for CSP culverts operating under inlet conditions (Corrugated Steel Pipe Institute. 2007)[19].

[19] Corrugated Steel Pipe Institute, 2007. *Handbook of steel drainage and highway construction products.*

3.4.2 Other Design Considerations

Structural design of CSP culverts should comply with AS/NZS 2041.1. All culverts and particularly thin-walled culverts such as CSP's must be installed in accordance with the manufacturer's specifications and with AS/NZS 2041.2. The design process must account for issues such as adequacy of cover and minimum clearances between pipe barrels to enable effective compaction of the haunch and backfill.

3.4.3 Special Requirements for Stream Crossings

The design shall, as far as practical, look to limit the headwater depth to diameter ratio (HW/D) to no greater than 1.5. As HW/D increases, velocity also increases together with risk of scour, culvert uplift and culvert implosion. It is advisable to limit culvert flow velocities to below 3.0 m/sec.

So, additional design criteria for stream crossings are:

- Construct headwalls at culvert inlet and outlet
- At design flow, limit HW/D ≤ 1.5.
- At design flow, limit culvert velocity to < 3 m/s.

3.5 Channel Design

3.5.1 Sizing of Channels

The average velocity of water flowing in a channel for a given depth of water may be determined using the Manning Equation:

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

Equation 8

Combining this with the flow equation:

$$Q = VA$$

Equation 9

yields:

$$Q = \frac{A}{n} R^{2/3} S^{1/2}$$

Equation 10

where $\boldsymbol{Q}$ is the flow rate, m^3/s
$\boldsymbol{A}$ is the flow area, m^2
$\boldsymbol{V}$ is the average velocity, m/s

n is Manning's roughness coefficient
R is the hydraulic radius, m, and ***R =A/P***
P is the wetted perimeter, m
S is the slope of the energy line, m/m.

Tables of Manning's n values for various channel types and materials may be sourced from many hydraulics texts or online. Table 5-6 from Chow[20] suggests the following selected values:

- For excavated earth channels in gravels which are relatively straight, uniform and clean (no vegetation), a value of n = 0.022
- For channels lined with mortared rubble (rip rap), n = 0.023
- For channels lined with loose rubble (rip rap), n = 0.033.

The flow area (A) and wetted perimeter (P) are functions of the flow depth (d) and the channel sectional geometry. For trapezoidal channels with side slopes of $1\!:x$ (1 vertical to x horizontal), the following equations derived from the section geometry apply:

- The width of flow at the water surface, $T = B + 2 \times x \times d$, where B is the channel base width, x is the reciprocal of side slope and d is flow depth
- The flow area, $A = \frac{d(T+B)}{2}$ and wetted perimeter $P = B + 2 \times d \times (1 + x^2) \times 0.5$, from which R can be calculated.

For uniform flow conditions, (constant flow at constant depth in a channel of uniform cross section and roughness at constant gradient) S may be adopted as the channel gradient. Note however that near locations where flow rate, channel geometry, slope or roughness change, so will depth and the slope of the energy line.

For uniform flow conditions, with energy slope S equal to a known channel slope, and A, and R computed from a known depth (to evaluate channel capacity), average velocity and flow rate can be computed from the Manning Equation (Equation 8).

If, however, design flow is known and a solution for depth is sought, then either:

1. Solve the above equations iteratively by varying the value of depth
2. Solve the above equations for a range of depths that result in a range of flows about the design flow, and then interpolate the depth from those results.

Rectangular and V-shaped channels are special cases of trapezoidal channels for which the above equations still apply. For rectangular channels, side slopes are vertical, so x = 0. For V-shaped channels, the channel base width, B = 0. For trapezoidal channels where the slopes on each side are different, the average of the left and right-side slopes at the section, $x = \frac{x_L + x_R}{2}$, can be used in the geometric equations.

[20] Ven Te Chow, 1959. Open-Channel Hydraulics, McGraw Hill Inc.

3.5.2 Channel Protection

The drainage channels used on Alcoa's mine areas can be categorised into three groups according to the type of bed and bank protection used. The three groups are: armoured, lined and natural (meaning unlined excavated channel in natural ground).

3.5.2.1 Armoured

Armoured channels use heavy materials such as stone to provide a substantial protection layer. Extensive erosion can still take place beneath stone armour as fine subgrade, bed or embankment material is washed out by water movement through the voids between rocks forming larger voids under the rocks. The armour may settle under its own weight and largely disguise this process.

To reduce risk of such a process occurring, provide filter layer or effective seal within or beneath the stones of the armour. A filter, to reduce velocities to which the fine subgrade particles are exposed, could be a "blue metal" gravel layer or a suitable a geotextile filter. Blue metal is relatively expensive and may be difficult to lay properly, particularly on side slopes. Geotextiles are being increasingly used for this function. Concrete provides the best seal and durability but is also the most expensive option. Mortaring of rock rip rap can be a cost-effective seal (less costly than reinforced concrete) but will tend to be effective only in the short to medium term. Mortared rock requires the bed and banks to be properly prepared (compacted and trimmed) and the mortar correctly mixed and laid with full penetration through the voids between rocks. Over time however, cracks develop between the rocks and the mortar, creating pathways for water flow and potentially resulting in scouring of the subgrade, and ultimately destabilization and breaking up of the armour layer.

The use of a geotextile under the stones is considered the least costly, easiest and quickest to install. A good quality polypropylene non-woven geotextile such as TS500 by Polyfelt, Bidim A34 or equivalents, could provide effective filter protection. The upper edges of the geotextile layer must be anchored in accordance with the manufacturer's specifications or guidelines. This usually takes the form of an anchor trench typically 0.3 m wide by 0.3 m deep into which the sheet edge is rolled to the full depth and width of the trench which is then backfilled and compacted to secure the edge.

Curve 'A' of Figure 3-8, adopted from the MDB[21], provides guidance on the conditions suitable for armouring channels with 100 mm stone over a geotextile filter layer. Figure 3-9, originally from the MDB, provides basic construction details for this type of channel.

Tables 5.11 and 5.12 from Austroads Guide to Bridge Technology – Part 8[22] provides further guidance on selection of rock classes and sizes for channel slope protection.

3.5.2.2 Lined

Materials such as jute mesh and bitumen may be used to produce a thin protective layer over the soil surface. Providing the lining is well laid with no holes, and is well bonded to the soil surface, it can provide effective protection against erosion. If even a small hole is present, then the bed and bank material will be

[21] Croton , J. T., 1990 *Minesite Drainage Book*. Water and Environmental Consultants for Alcoa of Australia.
[22] Austroads, 2019. *Guide to Bridge Technology Part 8: Hydraulic Design of Waterway Structures*. AGBT08-19.

washed out forming a large void and causing the lining to destabilize and be torn away by the turbulence around the void. Even when the lining is intact, if it is not bonded or anchored to the soil surface, the flowing water will cause it to flap and beat out the soil fines. This process can quickly escalate forming large voids and causing the lining to fail.

If lapped joints are used, they must be aligned so that the upstream sheet overlaps the downstream sheet, to reduce risk of water flow lifting the edge of the sheet.

The open heavy weave of jute mesh allows flexibility to conform to the channel contours and easy penetration by the bitumen. Curve 'B' of Figure 3-8 provides guidance on conditions under which jute mesh and bitumen channel linings should be used and Figure 3-9 provides the construction details.

3.5.2.3 Natural (Unlined Excavated Channel in Natural Soils)

To reduce the risk of erosion in an unlined earth channel, the average water velocity within the channel must remain below 0.6 m/sec. For an average sized irrigation channel this velocity is achieved with a longitudinal channel grade of 0.06%. Such channel grades are impractical to achieve on mine areas and are difficult even in the relatively controlled environment of irrigation. A method commonly used to control velocities in channels where the ruling gradient encourages velocities higher than desired is to construct control weirs in the channel to maintain the correct hydraulic grade (longitudinal slope of water surface) in the channel reaches between the weirs, with a drop in water level occurring at each weir. A similar idea was introduced into mine areas in the form of small rock weirs that were placed along the channel at regular intervals. However, the dropping of water over a weir creates turbulence and scour requiring bed protection in the turbulent flow zone on the downstream side of the weir. The requirement to construct weirs with downstream bed protection can become onerous and costly. For this reason, the use of rock weirs to slow flow in natural channels is now no longer encouraged on Alcoa's mining areas.

Curve 'A' in Figure 3-8 gives the recommended upper limit of channel longitudinal grades and depths of water for which an unlined earth channel may be used.

3.5.2.4 Comments on the Use of Figure 3-8

Figure 3-8 was prepared specifically for use at Alcoa's bauxite mines on the Darling Plateau. The soils found in the high rainfall zone of the jarrah forest, where Alcoa mines bauxite, are relatively stable and a lower level of scour protection can be used there than might be considered normal in other areas.

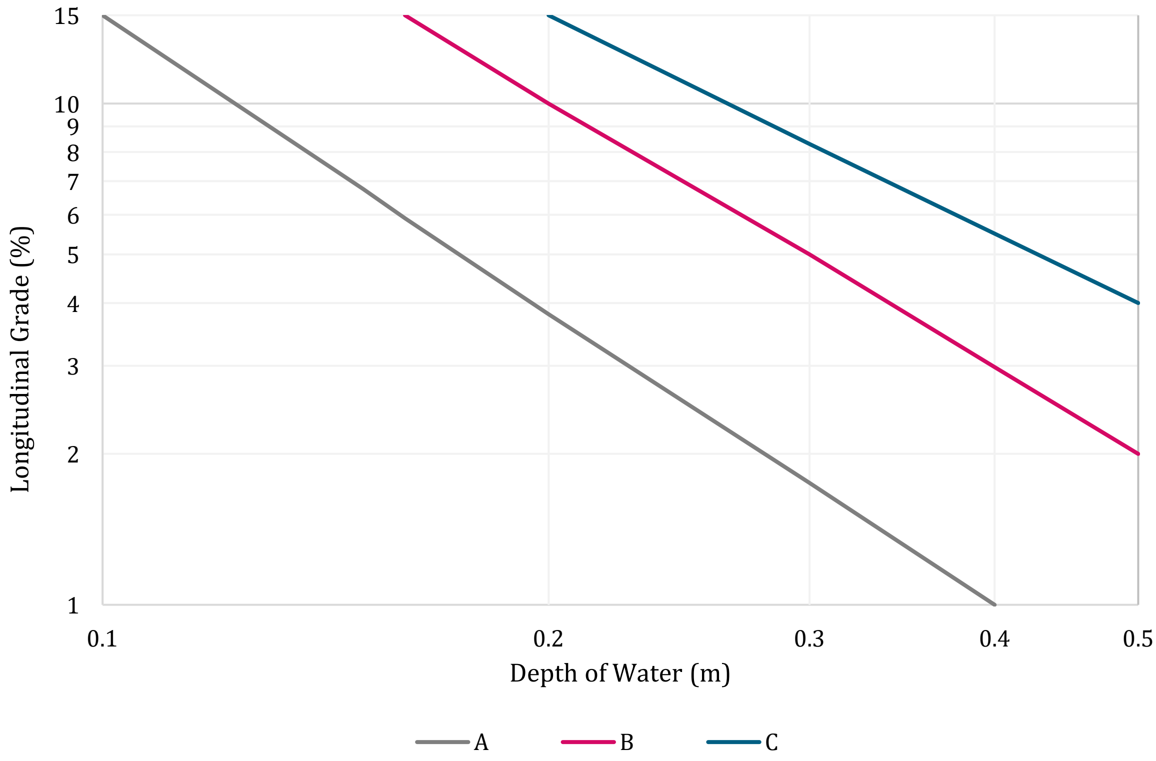

Figure 3-8. Recommended limits for various channel protection measures (from MDB)[23].

[23] Croton , J. T., 1990 *Minesite Drainage Book*. Water and Environmental Consultants for Alcoa of Australia.

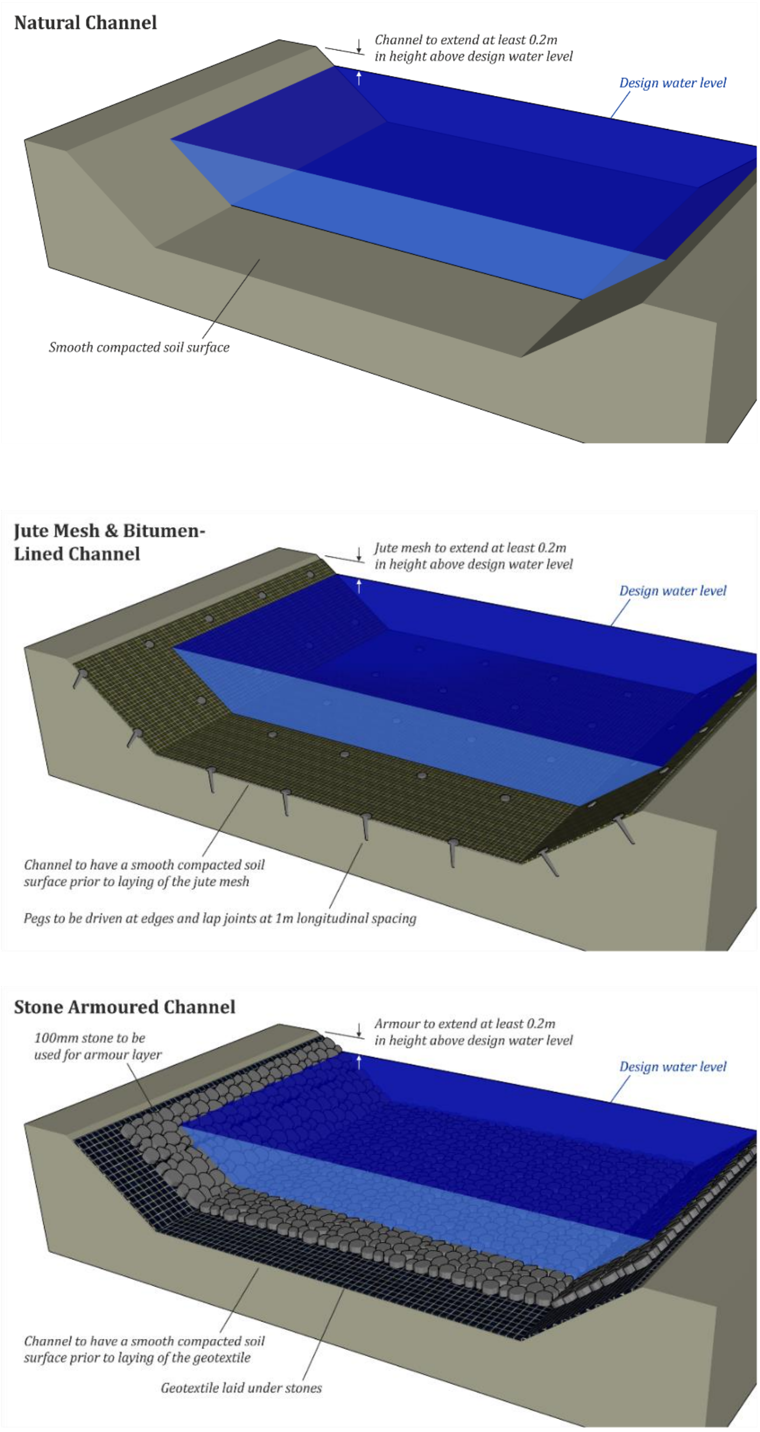

Figure 3-9. Construction details for natural, lined and armoured channels (from MDB)[24].

[24] Croton , J. T., 1990 *Minesite Drainage Book*. Water and Environmental Consultants for Alcoa of Australia.

4 MINE PITS

This chapter describes general requirements and parameters to be adopted in design of the civil works associated with the water management of the pits.

Management of surface runoff, once excavation has commenced within a pit, is via establishment of water holding capacity and infiltration to a risk-based AEP.

In-pit containment is the key drainage control once excavation of a pit has commenced and until rehabilitation landscaping is complete. Where multiple catchments contribute to a single pit, containment volumes shall be estimated from contributing catchments. The containment volume required shall be achieved for each catchment.

The in-pit containment volume shall be reviewed if the catchment area or design of a pit changes to ensure that the containment volume remains appropriate.

4.1 Hydrotechnical Aspects of Design

4.1.1 Storage Volume

The storage volume for the trenches and sumps shall contain the design rainfall depth across the corresponding catchment, i.e. the minimum storage volume is equal to the product of the design rainfall depth and the catchment area. Values of rainfall depths used in design, and selected based upon design criteria specified in Section 2, are shown in Appendix B.

Furthermore, the storage volume is to be calculated assuming:

- Daily infiltration of 24 mm in the absence of local infiltration data (Section 3.2)
- No evaporation losses across the catchment (evaporation only from water surface in storages)
- To accommodate sediment runoff the storage volume may be increased by 15% or evaluated using RUSLE method (Section 4.5), if the available space for both storages and spoils within a particular pit allows
- As stated in Section 2, 0.5 m freeboard between the discharge (lowest) point of the downstream most sump will be adopted if the available space for both storages and spoils within a particular pit allows.

4.1.2 Water Balance Assessment

Once the structures have been sized as per Section 4.1.1, a daily water balance, using the historical rainfall record, may be undertaken for selected pits to validate the hydraulic performance of the storage and the likelihood (risks) of spills. Details on the daily water balance are presented in Appendix C.

4.1.3 Groundwater and Infiltration

The site available data and information will be reviewed and used, if adequate, to evaluate the likely infiltration rate. Groundwater levels will be assessed based upon the available data.

No storage is to be planned in an area where the storage base is likely to be less than 1m above the maximum winter water table level. If, upon construction, a storage intercepts groundwater it must be relocated, or redesigned, to provide the required capacity without intercepting groundwater.

Pumping of the groundwater to approved locations can be used to control the storage capacity of the water containment structures.

4.1.4 Hydraulic Aspects

The pits are to be designed to minimise the uncontrolled discharge, either by designing the engineered embankment with an overflow spillway or by identifying the discharge location where the discharge is to take place over the natural terrain. The objective is to prevent discharge over the noncompacted soil which could lead to erosion, leading to discharge of sediment laden water.

An overflow spillway is to be designed to the following criteria (more details are provided in Section 4.4):

- Spillway – The design storm event for flood passage to apply the same AEP as used for storage capacity (Section 2)
- Embankment crest level – spillway design flood peak level plus wave runup allowance for 1:10 AEP or 300 mm freeboard as per ANCOLD (2012)[25]
- Spillway capacity for upstream sumps and trenches is assumed at overflow level or spillway crest at the start of the storm event.

For the overflow over the natural terrain, a freeboard of 100 mm to be allowed.

Runoff routing modelling will assume runoff coefficients outlined in Section 3.

4.1.5 Locations and Geometry of the Structures

There exists some limitations and opportunities in relation to the location of water containment structures within the pit:

- **Major haul roads:**
  - To be treated as a separate drainage system
  - Major haul road sumps are not to be used for in-pit drainage
- **In-pit roads:**
  - Can be modified within catchment, considering the winterisation scope
  - To be managed with trenches/sumps in-pit
- **Overburden stockpiles**
  - Not to be interfered with as these are required for rehab/closure; example in Figure 4-1.

[25] ANCOLD (2012). Guidelines on the Consequence Categories for Dams. Australian National Committee on Large Dams (ANCOLD) October 2012.

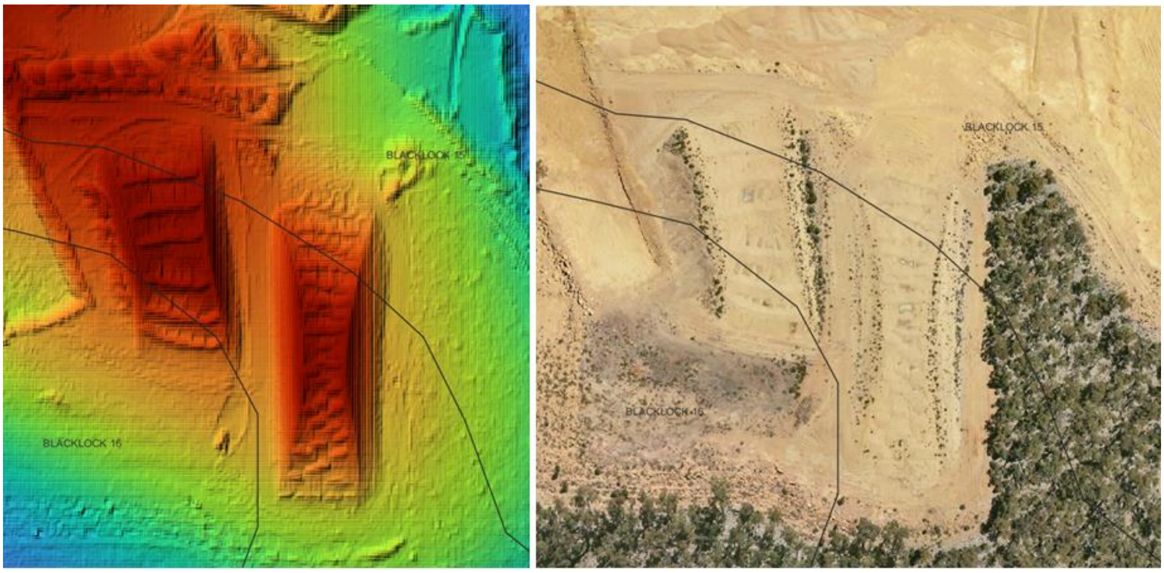

Figure 4-1 Example of the overburden stockpile

The geometrical elements to be used in designing of the trenches and sumps within the pit are as follows:

- **General**
    - Utilise existing pit faces/pit capacities where possible in the design
    - Trench/Sumps/Spoil to not be constructed within 10m of existing overburden stockpiles on site
- **Groundwater**
    - Base of Trench/Sumps/Spoil to be constructed minimum 1m above of winter ground water levels
- **Sumps**
    - Sump slopes to be 1V:3H batters on all sides. One side to be 1V:4H for access/egress to be selected by construction team on site
    - Spoil to be placed to suit site or to a location agreed upon with a construction team
- **Bulldozer Trenches**
    - Width 6m or 10m
    - Max depth (vertical sides = 4 m)
        - If trench depth greater than 4 m, slope ground above 4m up from the base of the trench at 1:4 to existing ground
    - No batters on trench side walls along the trench, as they are difficult to achieve operationally (i.e. design vertical batters on trenches)
    - At both ends of trenches provide a slope 1V:3H
    - Spoil to be stockpiled at each end of trench or to a nearby location agreed with a construction team
- **Excavator Trenches**
    - Min width 4 m, max width 8 m
    - Max depth at any point from the base to any side is 4 m
    - At both ends of trenches provide a slope 1V:3H
    - Spoil to be placed in a bund on downstream side of trench
        - If this is not possible, an alternative arrangement to be agreed with a construction team
    - No batters on trench designs on sides walls along the trench, as they are difficult to achieve operationally (i.e. design vertical batters on trenches)

- **Spoil bunds**
  - Max height of the spoil pile to be approx. 4 m
  - External batter of trench spoil 1V:1.3H
  - Spoil bunds are to avoid overlap with topsoil piles (If in doubt confirm with a construction team)
  - For spoil location refer relevant trench/sump design parameters
  - Minimise haul distance
  - Can be placed in existing stockpiles, if approved, if no space adjacent to sump/trench
- **Windrows**
  - Windrows to be formed on site to suit basis for trenches/sumps by the contractor or construction team.

4.1.6 In-pit Containment Maintenance

In pit containment shall be maintained as per the design requirements. As part of the design process, maintenance frequency can be adjusted depending on the needs of the site, following the method to be outlined in Alcoa's Complete in-pit catchment and containment assessment (document in preparation).

If no field data is available, an estimate of the potential soil loss using RUSLE equation (Equation 14) can be used to refine the maintenance frequency (see Section 4.5).

4.1.7 Diversion Bunds

Diversion bunds either divert runoff water away from areas sensitive to inundation, or towards natural or constructed drainage features intended to contain that runoff. Diversion bunds shall be used:

- To divert clean runoff from forest areas away from a mine pit to reduce risk of waterlogging and scour within the pit
- To divert runoff from dieback affected forest areas away from dieback free areas
- At a mine pit entry/exit to divert mine pit runoff away from a haul road
- As a contour bund within a cleared area or mine pit to slow the flow of runoff passing downslope, to reduce scour.

The design of a diversion bund is dependent on the functions it is intended to perform. For longitudinal flow along a bund, the bund can be designed hydraulically as a trapezoidal or V-shaped channel with unequal side slopes. The trapezoidal channels are preferred due to the easier maintenance.

Suggested minimum freeboard is presented in Section 2.3.

All earth bunds shall be compacted in accordance with the appropriate Alcoa or Australian Standards.

4.1.8 Contingency Measures

Contingency measures must be planned to respond to emergency events such as:

- A sump or pit condition, which is likely to result in a large release of water of high turbidity
- A sump or pit failure, which results in a large release of water of high turbidity
- An approaching storm system which is forecast to produce extreme rainfall beyond the capacity of the installed drainage.

The opportunities to manage excessive rainfall runoff may be limited, but an early identification of critical areas, considerations of and preparation for potential solutions could help to mitigate adverse outcomes.

The risk of an in-pit storage failing due to an uncontrolled accumulation of water could be mitigated by increasing the available storage volume via excavation or by pump out to a suitable destination.

A release of turbid water from a storage or a release which becomes turbid through erosion may be treated in the short-term using hay bales or coir logs placed across the discharge path. These and many other short-term controls are described in detail in the Civil Contractors Federation's publication "CCF Environmental Guidelines for Civil Construction"[26].

4.1.9 Contributing Catchment Areas

Refer to Section 3 for design considerations related to the contributing catchment areas, including forest and rock outcrops.

The catchments contributing runoff to a mine pit drainage facility shall consider areas of forest or rocky outcrops and explain the reasons for their inclusions in the analysis, or exclusion if that was deemed appropriate.

4.2 Hydrotechnical Assessment Steps

A step wise approach has been developed to ensure the progressive adherence to the sound water management principles and criteria, as well to ensure the close integration with all the internal stakeholders.

The following steps are proposed for each pit:

1. Undertake catchment delineation – subdivision in several sub-catchments, considering difference in soil cover (exposed soil, vegetation, soil type 1, soil type 2, etc.) as well as potential locations of various structures
2. Develop water management concepts (storages, infiltration trenches, etc.). Storage volumes are dependent on rainfall intensity, duration of storm, ground infiltration and area of catchment
3. Establish the basin overflow location, geometry and protection. This must be determined to allow controlled passing of a storm with a greater AEP than the design AEP. Rather than have a catastrophic overtopping of a drainage structure, the passing of the higher AEP storm event is controlled to protect the structure
4. Review the calculations
5. Present the concept to a wider team (as schematic)
6. Align on the concept
7. Evaluate local groundwater conditions if available information allows
8. Align with Alcoa SMEs on groundwater conditions (groundwater levels in downstream storages) to be used

[26] Civil Contractors Federation, 2010. *CCF Environmental Guidelines for Civil Construction.*

9. Set up hydrological model (RORB/HEC-HMS/SWMM[27]/EXCEL as appropriate) for the agreed concept using the average infiltration rates/soil properties relevant to the location
10. Evaluate runoff volumes to size structures at selected locations for:
    a. Design (single) rainfall event as specified in Section 2.2
    b. Critical (single) storm for the same AEP (for controlled pit outflows)
11. For selected pits, evaluate performance of the structures, sized under design conditions above, using the historical time series to identify a number and volumes of overtopping events (*Note: this addresses the storm ready state and emergency measures assessment*). The results of this assessment are presented in Appendix D
12. For selected pits, undertake limited sensitivity analysis calculations within the advised range of the selected parameters (e.g. infiltration rates, runoff coefficient, full or partially full basins at time of next storm) (*Note: this addresses the storm ready state, emergency measures assessment as well as site water harvesting aspects*)
13. Provide a summary of results (schematic of system, geometry considered, water levels and volumes) to internal stakeholders
14. Align with internal stakeholders on geometry of the structures to be used for geotechnical considerations and drafting.

4.3 Geotechnical Aspects of Design

4.3.1 Introduction

A limited geotechnical assessment was undertaken to provide preliminary geotechnical design parameters pertaining to water retention structures, based upon the local soils recovered from the site.

Soil samples were collected from MacQuarrie pit, shown in Figure 4-2.

[27] US EPA, 2022. Storm Water Management Model (SWMM).

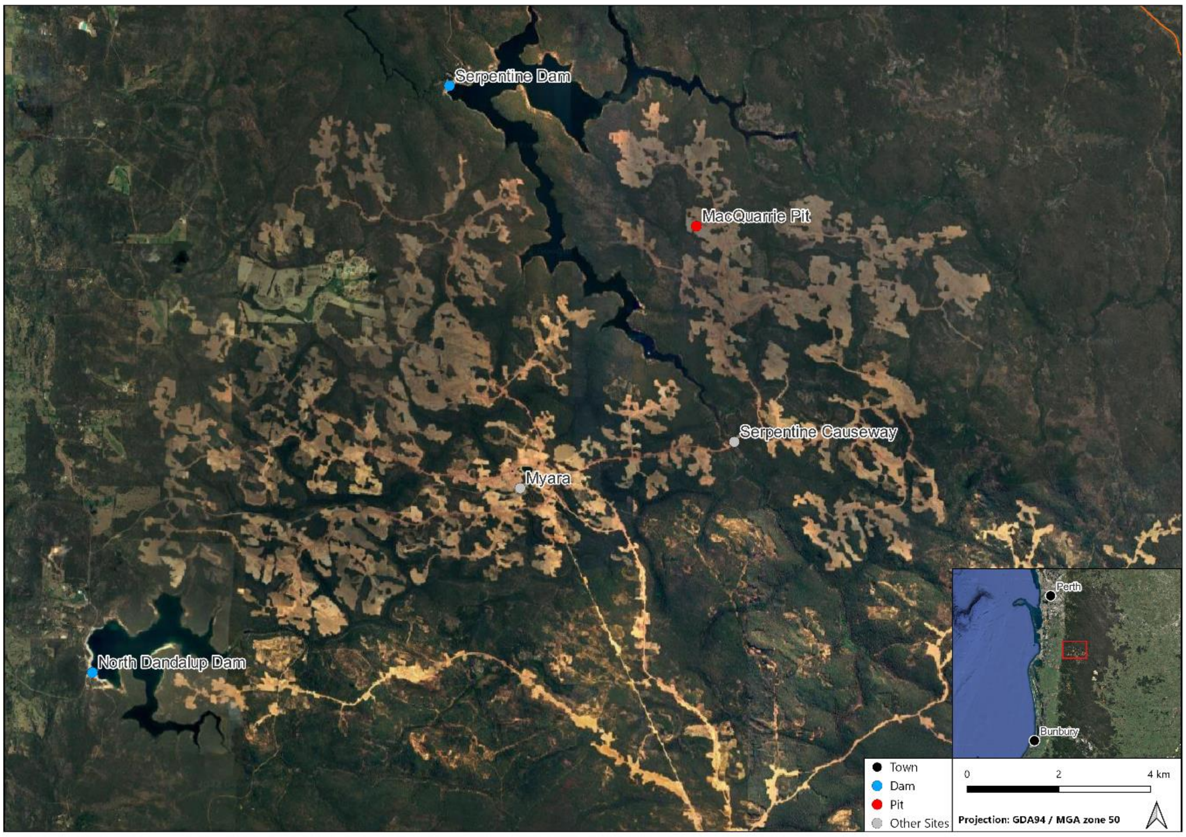

Figure 4-2: Locality: Samples taken at MacQuarrie pit

4.3.2 Laboratory Testing

In order to understand the material properties/geotechnical parameters of the soils anticipated to be used in construction of water attenuation structures/ponds, two disturbed soil samples representative of materials found at the site were retrieved and issued to a Perth based NATA accredited geotechnical laboratory (Trilab) for the following testing (per sample) and relevant Australian Standard:

- Particle Size Distribution Test – AS 1289 3.6.3, 3.5.1 & 2.1.1
- Atterberg Limits Test – AS 1289 2.1.1, 3.2.1, 3.3.1 & 3.4.1
- Direct Shear Test – AS 1289 6.2.2
- Moisture/Density Relationship Test – AS 1289 5.1.1 & 2.1.1
- Emerson Class Test – AS 1289 3.8.1
- Pinhole Dispersion Test – AS 1289 3.8.3.

4.3.3 Laboratory Test Results

The laboratory test results (Advisian, 2022) are summarised in Table 4-1.

Table 4-1: Summary of Geotechnical Laboratory Test Results

Sample ID	Particle Size Distribution (%)				Atterberg Limits (%)				Direct Shear				Moisture Density Relationship				Pinhole Dispersion	Emerson Class
	Gr	Sa	Si	Cl	LL	PL	PI	LS	Cohesion C (kPa)		Friction Angle Φ (°)		MDD (t/m³)	OMC (%)	MC (%)	SG*		
									Residual	Peak	Residual	Peak						
Sample 1 (Silty Sand)	10	65	13	12	19	15	4	2.5	33.0[1]	27.8	28.4[1]	33.6	1.84	12.6	3.3	2.58	ND1	6
Sample 2 (Gravelly/Silty Sand)	34	49	12	5	22	16	6	2	-1.7[2]	14.4	42.7[2]	42.9	1.98	10.7	0.8	2.64	ND1	3

Notes:

Particle Size Distribution
***Gr** = Gravel*
***Sa** = Sand*
***Si** = Silt*
***Cl** = Clay*

Atterberg Limits
***PI** = Plasticity Index*
***LS** = Linear Shrinkage*
***LL** = Liquid Limit*
***PL** = Plastic Limit*

Shear Test
[1]at 10 mm displacement
[2]at 8 mm displacement

Moisture Density Relationship
***SG** = Specific Gravity*

4.3.4 Material Characteristics

4.3.4.1 Particle Sieve Distribution

The results of geotechnical classification testing are presented in Figure 4-3. Based on the results, the tested samples comprise the following material classifications in accordance with AS1726-2017:

- Sample 1 - Silty SAND with gravel
- Sample 2 – Gravelly/Silty SAND.

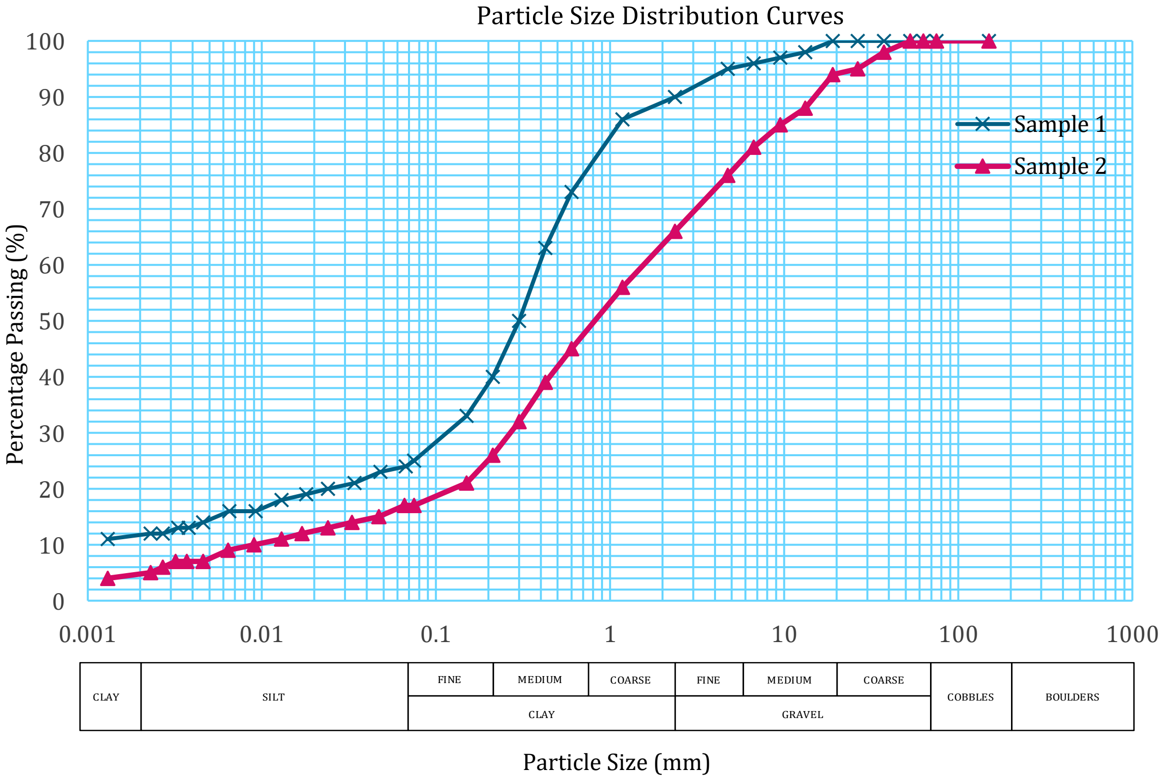

Figure 4-3: Particle Sieve Distribution

Based on the PSD data (expressed as particle sizes passing 10%, 30% and 60% and noted as d_{10}, d_{30} and d_{60}) the coefficient of uniformity (C_u) and coefficient of curvature (C_c) for each sample as tested, are presented in Table 4-2 where:

$$C_u = \frac{d_{60}}{d_{10}}$$

Equation 11

(Coefficient of uniformity should preferably be less than 20 to mitigate washing out of fines)

$$C_c = \frac{d_{30}^2}{(d_{10} \times d_{60})}$$

Equation 12

(Coefficient of Curvature should preferably be less than 3 to mitigate washing out of fines)

Table 4-2: Grading Coefficients

Sample ID	Coefficient of Uniformity (Cu)	Coefficient of Curvature (Cc)
1 (Silty Sand)	14	31
2 (Gravelly/Silty Sand)	500 (Regraded)	29 (Regraded)

4.3.4.2 Permeability

Based on the sieve analysis above, the estimated permeability of the soil is:

- Sample 1 - Silty Sand with gravel: 1.1E-5 m/s (~40 mm/hr)
- Sample 2 – Gravelly/Silty Sand: 4.1E-5 m/s (~150 mm/hr).

The above permeability correlates with a silty sand (Fell et al, Figure 6.51, 2005)[28]. The material consists mainly of sand (at least 65%) or gravelly sand (83%).

4.3.4.3 Possible Piping

The Emerson class 3 for Sample 2 indicates that the material is dispersive (Emmerson class 3 cation exchange) and that it may go into solution under favorable conditions (high hydraulic gradient).

A preliminary screening for piping is reflected in Figure 4-4 and Figure 4-5 below.

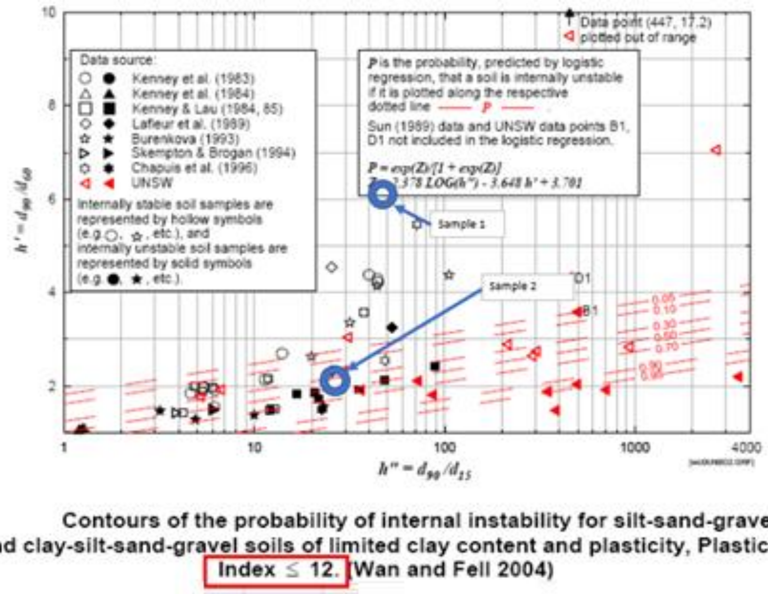

Figure 4-4: Preliminary piping screening (clayey silt material and PI <12) (Fell and Wan, 2005)[29]

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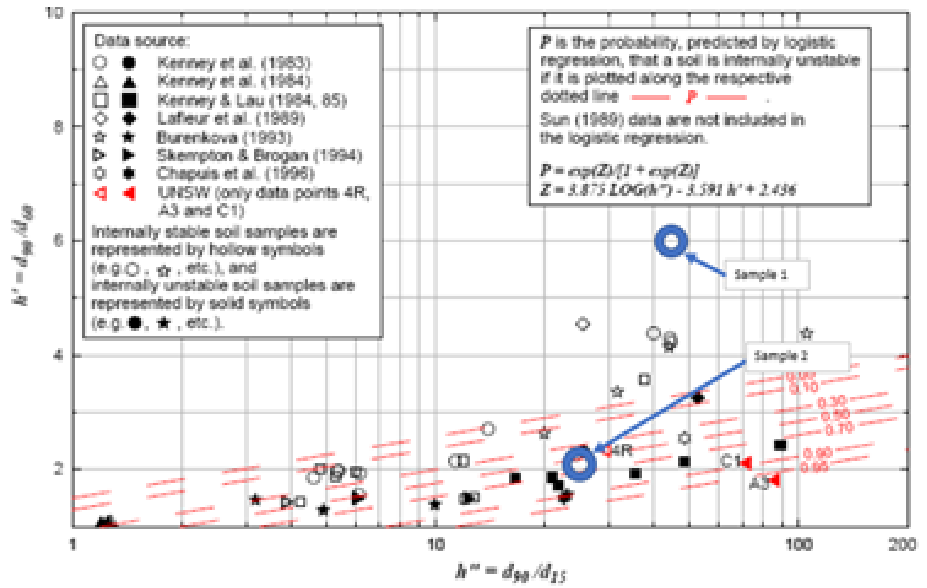
[28] Fell, R, MacGregor, P, Stapledon, A and Bell, G., 2005. *Geotechnical Engineering of Dams.*

[29] Fell, R, Wan C F., 2005. *Methods for Estimating the Probability of Failure of Embankment Dams by Internal Erosion and Piping in the Foundation and from Embankment to Foundation.*



Contours of the probability of internal instability for sand-gravel soils with less than 10% non-plastic fines passing 0.075 mm (Wan and Fell 2004).

Figure 4-5: Preliminary piping screening (sand/gravel soils)

Both screening methods illustrated above indicate 30% to 50% probability of possible piping for Sample 2 (the sample with the slightly higher PI). These concur with the Emmerson class 3 laboratory test result that the material is dispersive and may pipe.

Piping may be mitigated by engineering compaction and low hydraulic gradient (<0.1).

4.3.4.4 Plasticity

Figure 4-6 presents local data in the context of Atterberg limits.

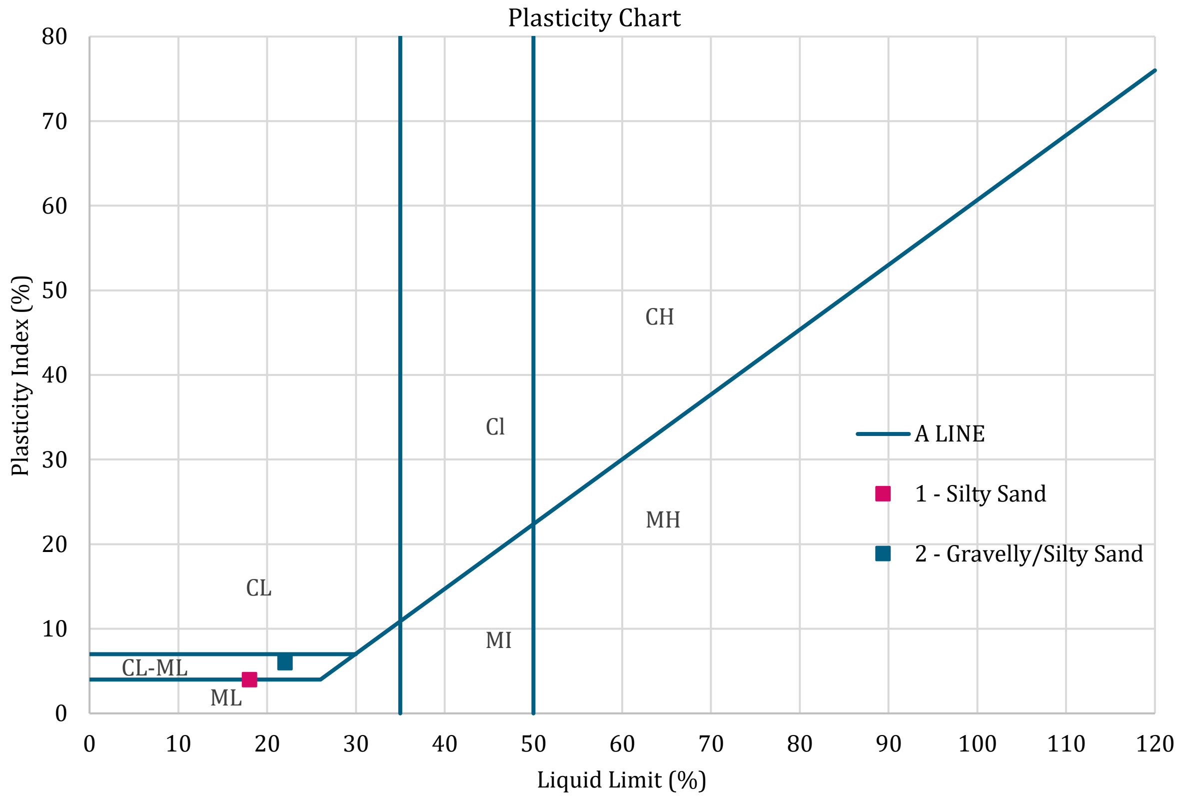


Figure 4-6: Atterberg Limits

It is evident from the above graphs that the material has a rather low Plasticity Index (low PI silty/sand).

4.3.5 Discussion of Geotechnical Aspects

The summary of above and implications are as follows:

- The material consists mainly of sand (at least 65%) or gravelly sand (83%)
- The estimated permeability of the material varies from 1.1E-5 m/s to 4.1E-5 m/s and it correlates with the sandy texture of the material
- The material (especially Sample 2) is gap graded (Cu>20 and Cc >3) and that it might be prone to piping (internal erosion)
- The fines (<0.075 mm which constitutes 20% of the sample) will tend to wash out from the coarse sand matrix. Good compaction will assist to mitigate the risk. Alternatively, the hydraulic gradient may be reduced by a clay core within an embankment
- The Emmerson class 3 of the gravelly/silty soil indicates that soil may be dispersive (cation exchange) and that a certain portion of the soil may go into solution and result in piping especially if the material is not protected by lesser prone material, and for poorly compacted embankments.

The probability of piping (as per the screening methods utilised) varies between 30% and 50%. Thus, piping is a concern, and the material should be protected or not exposed to a steep hydraulic head, by clay or well compacted material.

The outcome of the above indicates that the erosion from the disturbed areas would be high. Erosion should be substantially less when fully revegetated. The nature of the sandy material is erodible, and piping may occur through the embankments, especially with low compaction effort.

4.3.6 Geotechnical Recommendations

The embankment design should endeavour to incorporate the following aspects (based on the soil properties):

- The use of claylike material to be used as a core within an embankment (if available)
- Dispersive material in embankments should be covered with non-dispersive material
- Embankments could be wheel compacted
- Hydraulic gradient through embankment not to exceed 0.1 m/m unless a clay core is provided
- Typical geometry of embankment being 1V:4H upstream and downstream slopes with a minimum crest width as per Table 4-3
- Maximum height of embankment not to exceed 3 m
- Create spillways with rather flat channels (longitudinal grade to be flatter than 1V:8H)
- Make the spillway crest section wide enough to control flow velocity. Width is to mitigate possible head cut during spilling
- Place spillways at the lowest embankment height sections
- If site conditions allow, target the flow velocity of 0.7 m/s (no rip rap)
- If a maximum velocity is increased and reaches 2 m/s consider lining of spillway with rip rap, suitable placed on geotextile to mitigate the washing out of fines.

Table 4-3: Crest width as a function of embankment height

Embankment height (m)	Crest width (m)
3.0	8.0
2.0	6.5
1.0	5 (minimum)

The embankment material should have appropriate soil moisture content to ensure sufficient compaction. If the material is too dry or too wet, it will not suffice and it will result in poorly compacted material.

Compaction of embankments must be well executed, with compaction to be at least 98% SMDD at moisture content of OMC to OMC+2%. The site personnel could use DCP testing (cone) to determine whether the wheel compaction per layer is sufficient, else more passes. The DCP DN value for 98% SMDD is approximately 15 mm/blow or it should not penetrate more than 75 mm per 5 blows or maximum number of blows per 100 mm should not be less than 8 blows.

4.4 Spillway Design

Pit water management aims to control the possible adverse impact of mining water runoff on the downslope and downstream receiving environment.

Construction of various storages within a pit boundary aim to:

- Facilitate containment of sediment and turbidity impacted rainfall runoff above water quality threshold within the mining disturbance area

- Promote water infiltration through storage base and walls, providing containment capacity for future rainfall events (assuming groundwater interaction assessment avoids groundwater inundation within storage features).

However, at times of persistent and longer rainfall episodes, the rainfall water balance may exceed the design capacity criteria, and release from the perimeter of the pit may take place.

The design objective for the controlled release structures is to minimise the likelihood of excessive sediment load in these releases. This can occur if failure of the containment structure takes place.

Therefore, the aim is to convert potentially uncontrolled releases into controlled releases (i.e. where engineering measures are put in place to minimise adverse impacts). These include:

1. Identify the lowest points along the pit perimeter, i.e. possible release locations
2. Ensure that at those locations, water is not ponding against the non-engineered soil, i.e. against the temporarily placed soil
3. Ensure that the possible release is either:
    a. Along the natural ground which is always better compacted than the temporarily created windrows; often this opportunity exists when the release location is constructed on top of the existing pit face (i.e. at interface with undisturbed natural terrain)
    b. Via an engineered embankment, whose geometry and construction method, including compaction, follows sound geotechnical principles

    Note: Placing of soil to create a temporary barrier to arrest the water propagation downstream is a common technique. However this effective short-term measure needs to be avoided as a permanent solution as it can be a subject of piping, (even at times without significant rainfall), driven by the head of the stored water, and at risk of uncontrolled overtopping at times of higher rainfall. Both of these scenarios (i.e. piping and uncontrolled overtopping) could lead to a failure of the structure, generating an uncontrolled sediment laden release to the environment
4. Downslope of spillway terrain geometry assessment with regard to water flow energy dissipation measures required for turbidity and erosion control into the forest. IECA (2008)[30] presents a number of practical solutions applicable to local conditions
5. Surface water detection alarm and downgradient water quality measurement
6. Management of groundwater via controlled pumping/transfer to a higher storage within the pit.

Key elements of the hydraulic design and construction are outlined below. Geotechnical aspects are presented in Section 4.3.

4.4.1 Hydraulic Design

A spillway is to be designed using the following approach and criteria:

- Spillway –The design storm event for controlled flood passage to apply the same AEP as used for storage capacity (Section 2)

[30] International Erosion Control Association (IECA), Australasia, 2008. *Best Practice Erosion and Sediment Control*.

- Spillway capacity for upstream sumps and trenches is assumed at overflow level at the start of the storm event
- Embankment crest level – spillway design flood peak level plus wave runup allowance for 10% AEP or 300 mm freeboard as per ANCOLD (2012)[31]
- For the overflow over the natural terrain, a freeboard of 100 mm to be allowed
- Runoff assessment, based upon the rational method (see Section 3.3), will assume runoff coefficients outlined in Section 3.

The outflow capacity will be analysed based upon the broad crested weir formulation:

$$Q = C_d L H^{1.5}$$

Equation 13

where **Q** is the flow rate, m^3/s, equal to peak flow rate
C_d is the release coefficient = 1.4
L is the width of the weir, m
H is the water depth above the crest of the weir, m.

The tailwater, i.e. water level downstream of the weir, must be considered. A weir may be assumed to release freely if the tailwater is lower than 0.8 H above the weir crest (Henderson, 1966)[32].

Once the outflow structure has been sized, a daily water balance, using the historical rainfall record, may be undertaken for selected pits to validate the hydraulic performance of the containment system within the pit and the likelihood (risks) of overflows.

4.5 Estimate of the Annual Soil Loss within the Pit

4.5.1 RUSLE Method

The Revised Universal Soil Loss Equation (RUSLE) is designed to predict the long term, average, annual soil loss from sheet and rill flow at nominated sites under specified management conditions. Key features of the method, as applied to the Alcoa's mining operation, have been outlined below, following IECA (2008)[33].

The RUSLE Equation is represented by:

$$A = R \times K \times LS \times P \times C$$

Equation 14

where **A** is the computed soil loss, tonnes/ha/year
R is the rainfall erosivity factor
K is the soil erodibility factor

[31] ANCOLD (2012). Guidelines on the Consequence Categories for Dams. Australian National Committee on Large Dams (ANCOLD) October 2012.
[32] Henderson, FM, Open Channel Flow, 1966
[33] International Erosion Control Association (IECA), Australasia, 2008. *Best Practice Erosion and Sediment Control*.

LS is the slope length/gradient factor
P is the erosion control practice factor
C is the ground cover and management factor.

4.5.2 Rainfall Erosivity Factor – R

The rainfall erosivity factor, R, is a measure of the ability of rainfall to cause erosion. It is the product of two components: total energy (E) and maximum 30-minute intensity for each storm (I30). So, the total of EI for a year is equal to the R-factor. Table 4-4 presents rainfall erosivity factor for several locations within WA (IECA, 2008).

Table 4-4: Annual rainfall erosivity factor for locations in WA (IECA, 2008)

Location in WA	Annual rainfall erosivity factor
Broome	2293
Geraldton	3485
Perth	2820
Albany	1620

4.5.3 Soil Erodibility Factor – K

The soil erodibility factor, K, is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. Soil texture is the principal component affecting K, but soil structure, organic matter and profile permeability also contribute. In the RUSLE, it is a quantitative value experimentally determined.

K should be derived for each particular site and based on laboratory analysis, particularly at sensitive sites. The method for estimating the K-factor is described by Rosewell and Loch (2002)[34]. Table 4-5 presents typical K factors based on unified soil classification system.

Table 4-5: Typical K factors based on unified soil classification system (IECA, 2008)

Brief Description	Code	Typical values	Default[1]
Silty gravels, poorly graded gravel-sand-silt	GM	0.00 – 0.06	0.053
Clayey gravels, poorly graded gravel-sand-clay	GC	0.00 – 0.05	0.042
Well graded sands, gravelly sands, little fines	SW	0.00 – 0.04	0.036
Poorly graded sands, gravelly sands, few fines	SP	0.00 – 0.03	0.027
Silty sands, poorly graded sand-clay mixtures	SM	0.01 – 0.05	0.043
Clayey sands, poorly graded sand-clay mixtures	SC	0.02 – 0.05	0.044
Inorganic silts, clayey sands with slight plasticity	ML	0.03 – 0.07	0.062
Inorganic clays of low to medium plasticity	CL	0.02 – 0.06	0.058
Organic silts and organic silt-clay of low plasticity	OL	0.01 – 0.04	0.033
Inorganic silts, fine sands or silty soils, elastic silts	MH	0.02 – 0.07	0.066
Inorganic clays of high plasticity, elastic soils	CH	0.00 – 0.05	0.047

Note: [1] Default values should be adopted in absence of local site data. The default values have been developed from a statistical analysis of NSW soil data (Landcom, 2004)[35] and represent the statistical average plus one standard deviation for each soil type.

[34] Rosewell, CJ and Loch, RJ (2002). Estimation of the RUSLE Soil Erodibility factor, in NJ McKenzie, KJ Coughlan and HP Cresswell (eds.), “Soil Physical Measurements and interpretation for land Evaluation”, CSIRO.
[35] Landcom (2004). Soils and Construction. Managing Urban Stormwater. NSW Government.

4.5.4 Slope Length/Gradient Factor – LS (IECA)

The slope length–gradient factor, LS, describes the combined effect of slope length and slope gradient on soil loss. It is the ratio of soil loss per unit area at any particular site to the corresponding loss from a specific experimental plot of known length and gradient. Table 4-6 presents LS factors for disturbed land (IECA, 2008)[36].

Table 4-6: Typical LS factors for disturbed land (IECA, 2008)

Slope gradient (%)	Slope length (m)												
	5	10	20	30	40	50	60	70	80	90	100	150	200
1	0.09	0.11	0.13	0.15	0.16	0.17	0.18	0.19	0.19	0.20	0.20	0.23	0.24
2	0.14	0.18	0.24	0.28	0.31	0.34	0.36	0.39	0.41	0.43	0.44	0.52	0.58
3	0.17	0.24	0.34	0.41	0.27	0.52	0.57	0.61	0.65	0.69	0.72	0.87	1.00
4	0.21	0.39	0.44	0.54	0.63	0.71	0.78	0.85	0.91	0.97	1.03	1.26	1.47
5	0.24	0.36	0.54	0.68	0.80	0.91	1.01	1.10	1.19	1.27	1.35	1.70	2.00
6	0.28	0.42	0.64	0.81	0.97	1.11	1.24	1.36	1.47	1.58	1.68	2.14	2.54
8	0.34	0.53	0.83	1.08	1.31	1.51	1.70	1.88	2.05	2.21	2.37	3.07	3.70
10	0.42	0.68	1.09	1.44	1.75	2.04	2.31	2.56	2.81	3.04	3.27	4.06	4.94
12	0.52	0.85	1.39	1.85	2.27	2.66	3.02	3.37	3.70	4.02	4.33	5.77	7.07
14	0.62	1.02	1.69	2.26	2.79	3.28	3.74	4.18	4.61	5.02	5.42	7.27	8.95
16	0.71	1.19	1.98	2.67	3.31	3.90	4.46	5.00	5.52	6.02	6.51	8.78	
18	0.80	1.35	2.27	3.07	3.82	4.51	5.17	5.81	6.42	7.02	7.59		
20	0.89	1.50	2.55	3.47	4.32	5.12	5.88	6.61	7.32	8.01	8.68		
25	1.09	1.88	3.23	4.43	5.54	6.59	7.60	8.57	9.51				
30	1.28	2.23	3.86	5.32	6.69	7.99	9.23						
40	1.61	2.83	4.98	6.92	8.74								
50	1.88	3.33	5.89	8.22									

The slope and length are defined along the drainage line of "sheet" flow from its point of origin to either a location where:

- The gradient is so flat that sediment deposition will occur
- The sheet flow enters the backwaters of a sediment trap/basin
- The sheet flow enters the drain, channel or valley floor containing concentrated flow.

4.5.5 Erosion Control Practice Factor – P

The erosion control practice factor, P, is the ratio of soil loss with a nominated surface condition ploughed up and down the slope.

Table 4-7 below suggests appropriate values for P.

[36] International Erosion Control Association (IECA), Australasia, 2008. *Best Practice Erosion and Sediment Control*.

While changing the surface condition does not greatly affect P, roughening of the surface greatly increases the chances of establishment of a vegetative cover that does substantially reduce soil loss.

Table 4-7: Surface condition P-factor (IECA, 2008)[37]

Surface conditions	Value of P factor
Compacted and smooth	1.3
Track-walked along the contour	1.2
Track-walked up and down the slope	0.9
Punched straw	0.9
Loose to 0.3 metres depth	0.8

4.5.6 Cover Factor – C

The cover factor, C, is the ratio of soil loss from land under specified crop or mulch conditions to the corresponding loss from continuously tilled, bare soil. The values of cover factor for bare soil, typical for a mine site, is 1.0 (IECA, 2008).

4.6 Drainage Protection Slots

Drainage Protection Slots (DPS) are installed at the clearing stage and remain in place until mining commences. DPS must be executed with the upslope edge on contour to maximise runoff capture. DPS are installed by a shallow drill and blast pattern of closely spaced drill holes. The objective is to create a zone with a very high permeability, and accordingly high infiltration, which could effectively capture the runoff from the upstream catchment, as shown schematically in Figure 4-7.

[37] International Erosion Control Association (IECA), Australasia, 2008. *Best Practice Erosion and Sediment Control*.

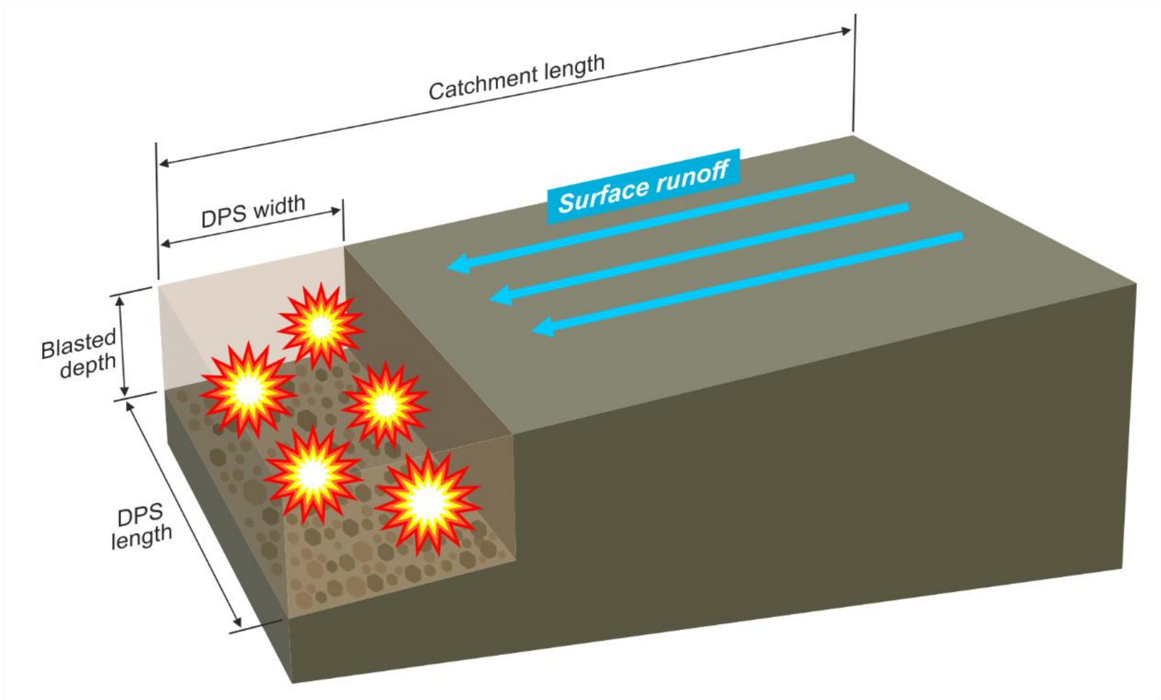


Figure 4-7: Drainage protection slot (DPS) schematic

Volume of voids after the blasting is equal to product of blasted volume and its porosity, i.e.

$$V_{DPS.voids} = depth_{DPS} \times width_{DPS} \times length_{DPS} \times porosity_{DPS}$$

Equation 15

where ***depth***$_{DPS}$ is the depth of DPS, m
width$_{DPS}$ is the width of DPS, m
length$_{DPS}$ is the length of DPS, m
prosotiy$_{DPS}$ is the porosity of DPS, assumed to be 50% based on site experience.

Accordingly, the length of the catchment whose runoff, for a design event, could be stored in these voids is equal to:

$$Catchment_{length.voids} = \frac{V_{DPS.voids}}{length_{DPS} \times Runoff_{coef} \times Rainfall_{design.depth}}$$

Equation 16

where ***Runoff***$_{coef}$ is the runoff coefficient for the catchment
Rainfall$_{design.depth}$ is the design rainfall depth, m.

Infiltration from the DPS void takes place in both vertical and horizontal direction, the magnitude of which depends on the proximity to the groundwater. Total infiltration volume can be evaluated as:

$$V_{infiltration} = depth_{DPS} \times width_{DPS} \times K_{lateral} + length_{DPS} \times width_{DPS} \times K_{vertical}$$

Equation 17

where $K_{lateral}$ is the lateral infiltration rate, m/day
$K_{vertical}$ is the vertical infiltration rate, m/day.

These infiltration rates are subject to further field testing, however, based on site experience to date it can be assumed that $K_{lateral}$ = 2.5 (m/day) and $K_{vertical}$ = 0.5 (m/day).

Similar to above evaluation of the catchment length in relation to the voids volume of the DPS above, the catchment length can be evaluated in relation to the infiltration as:

$$Catchment_{length.infiltration} = \frac{V_{infiltration}}{length_{DPS} \times Runoff_{coeff} \times Rainfall_{design.depth}}$$

Equation 18

By combining these two aspects catchment length is equal to:

$$Catchment_{length.DPS} = Catchment_{length.infiltration} + Catchment_{length.voids}$$

Equation 19

The time, in days, required for the water in the DPS voids to drain out is equal to:

$$Time_{draining.voids} = \frac{V_{DPS.voids}}{V_{infiltration}}$$

Equation 20

For installation aspects of the DPS the reader is referred to Design, Install and Maintain Drainage Protection Slots - AUACDS-2056-381.

Drainage protection slot maintenance must be scheduled at regular intervals to ensure the capacity and infiltration is maintained.

5 HAUL ROADS

Alcoa utilises two basic sump types as part of the haul road water management design process, Sedimentation (Detention) and Infiltration (Retention) sumps. The haul road sump design process maps are included in Appendix A. The process maps covers:

- Hydrology (for Sedimentation Sump Design)
- Sedimentation Sump Design
- Infiltration Sump Design

A Sump Design Tool (SDT) has been prepared to undertake the calculations for sizing of Sedimentation and Infiltration sumps with respect to the design criteria. The calculations are outlined in this section. Once design criteria are meet, sump sizes must then be converted into design drawings.

All sumps must have an engineered overflow to account for circumstances where the design storage capacity (and freeboard) are exceeded. Without a controlled overflow point, an uncontrolled breach is possible with embankment erosion and associated high rates of sediment transport.

The sediment holding volume is designed as a function of both the estimated annual sediment load in captured runoff water and the expected frequency of maintenance clean outs. The design frequency of maintenance clean-out is identified in Section 5.4.4 of this document. While the nominal clean-out frequency is every two years, this can be varied in design to suit individual sumps.

5.1 Sump Selection

Selection of Sump Type is defined in Table 5-1, based upon the considerations associated with the sedimentation and infiltration. Note that, depending on location, depth to groundwater should be considered as well. It is recommended that all sumps which could discharge to a natural stream within a defined buffer distance from the sump overflow or outlet shall be designed as a sedimentation sump with forebay. Soil hydraulic properties are presented in Section 3.2.

Table 5-1. Sump type selection

Sump type	Design Condition
Infiltration	• Discharge distance to a natural stream is greater than the defined buffer distance (>50 m); and • Not a stream crossing; and • Low risk of groundwater interception (>50 m from nearest stream zone vegetation).
Sedimentation	• Discharge distance to natural stream <50 m; or • Located at a stream crossing; or • High risk of groundwater interception (<50 m to nearest stream zone vegetation)

5.2 Sump Location

Sumps must be located in consideration of the surrounding environment, in particular, proximity to stream, location of dieback free areas in relations to discharge and location in relation to the PDWSAs.

All sumps be designed with the sump base above the inferred ground water level. If, upon construction, a sump intercepts groundwater it must be relocated, or redesigned to provide the required storage without intercepting groundwater.

The Groundwater interception assessment detail in Section 3.1 shall be used to identify the likelihood of groundwater interception.

5.3 Haul Road Catchments

For the purpose of estimating haul road catchment area:

- For a road in cut, width is measured from the top of batter to the crown of the road, or if superelevated to the opposite top of batter.
- For a road in fill width is measured from the top of the safety bund to the crown of the road, or if superelevated to the opposite top of bund.

A haul road catchment's outlet is generally at a chute into a drop box or sump. The road catchment length is measured from its outlet up to the outlet of the next adjacent catchment, if on grade, or to the road crest if there is no other interposing catchment. For roads in sag, the contributing length is the sum of the measured lengths in both directions.

5.4 Sedimentation Sump Design

The main purpose of a sedimentation sump is to capture the particulate matter carried in the bed load and in suspension in collected runoff water. The effectiveness of sedimentation is dependent on the residence time of water passing through the sump, which is a function of the sump's detention storage volume and the surface hydraulic loading rate applied to the sump. A review of best practice indicated that while such sumps are potentially effective at trapping the bulk of sediments typically found in storm runoff, they have low effectiveness at trapping fine sediment particles, which may be defined as contaminant particles smaller than 0.062 mm, i.e. 62 micron (CSIRO, 1999)[38].

If fine sediments are a significant source of turbidity affecting downstream water users, then supplementary treatment methods may be required to reduce the concentration of fine particles in the discharged water. Sedimentation sumps can capture settleable particles but may have limited effect on discharged turbidity due to fines in suspension.

5.4.1 Sump Storage Terminology

The total volume of a sediment sump consists of three parts, shown in Figure 5-1:

1. The permanent pool volume (PPV) which detains the water on its passage through the sump and allows the sediment to settle out
2. The flowthrough volume (FTV), or surcharge volume, also contributes to detaining the water on its passage through the sump allowing settlement of sediment

[38] CSIRO, 1999. Chapter 7 – Structural Treatment Measures, from *Urban Stormwater: Best Practice Environmental Guidelines*

3. The sediment holding volume (SHV) required to hold the collected sediment.

The SHV is the portion of the sump volume which is allocated to collect and store the settled sediments until they can be cleaned out. The SHV is logically located at the bottom of the sump. The PPV represents the volume of the sump, lying above the SHV, which will not drain out via an overflow or outlet pipe. It represents the volume of water which can be contained within the sump. The FTV is the topmost portion of water that exists only when there is flow passing out of the sump through an outlet pipe or over a weir.

A sedimentation sump consists of three main parts:

1. **The inlet**, which typically comprises an offshoot channel from the road gutter, a lined inlet chute to protect the sump wall at the inlet and a lined apron to protect the sump floor from scour and undermining of the chute
2. **The sump storage** comprising the forebay, sediment holding volume (SHV), the permanent pool volume (PPV) and the flowthrough volume (FTV) as described in section 0
3. **The outlet** which at the Alcoa Minesites is typically a broad-crested weir formed in the earth embankment to discharge at the external ground level into a shallow outlet swale or channel which either disperses flows into the forest or directs it to a nearby stream. The weirs generally are lined to reduce risk of scour at the outlet.

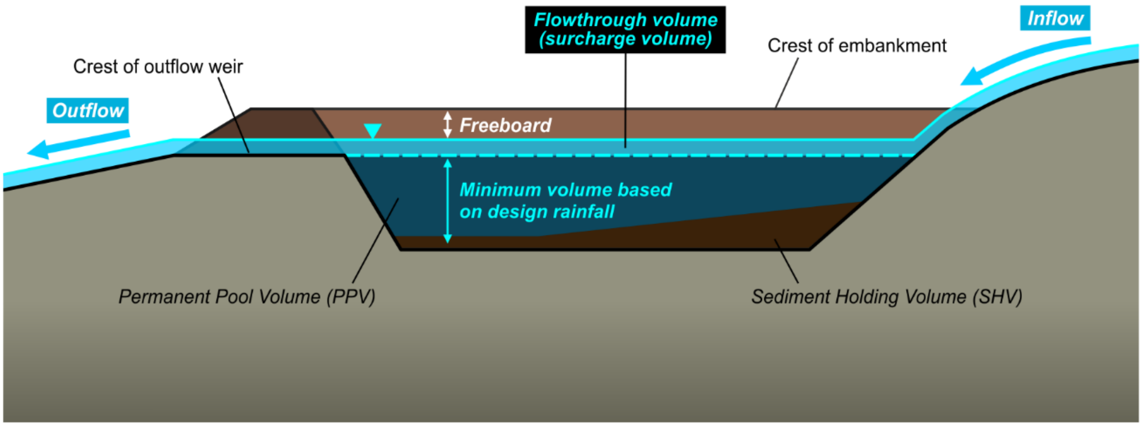


Figure 5-1. Sump storage terminology

Due to differences in catchment characteristics, sump water loads and sediment retention efficiencies, the PPV and SHV must be calculated separately and added, together with the estimated surcharge volume, to arrive at the total design volume of the sump.

5.4.2 Sump Forebay

The purpose of the forebay is to trap (through sedimentation) the coarser fraction of sediments carried in runoff. These tend to form the major proportion of sediment volumes which are readily settleable, leaving the main sump to treat the finer particles which take longer to settle and are more easily resuspended by through flows. The use of a forebay also enables better control of flows entering the main sump, thereby improving its hydraulic efficiency. The forebay area and volume are typically much smaller than for the main sump. With the greater volume of sediment being concentrated in the forebay, cleanout is a simpler process, with the larger area of the main sump requiring cleanout less frequently.

The hydraulic design of the forebay follows the same process as for the main sump, but with different design target parameters. That is, the target particle size for the forebay is much greater than for the main sump, typically 125 micron or larger for the forebay, while the main sump target may be 16 micron or even lower. The proportion of sediment volume settling in the forebay compared to the main sump will be dependent on many parameters, the most significant being:

- The surface hydraulic loading applied to forebay and to the main sump (which affects their respective sedimentation effectiveness)
- The concentrations of total suspended solids (TSS) in the influent runoff water
- The particle size distributions of the particles entering the sumps.

An indication of these parameters and the proposed cleanout regime may then guide the design of the proportion of the required sediment holding volume (SHV) to be allocated to the forebay, with the balance attributed to the main sump.

A forebay should be designed and used for all but the smaller sedimentation sumps. As a guide, forebays can be excluded when the catchment area is smaller than 2,600 m^2.

A typical arrangement of a forebay sump is provided in Appendix E.

5.4.3 Catchment Sediment Yield

The MDB[39] defined sediment yield from mine site haul roads under four classes:

A. Roads constructed from material with a good particle size grading and low usage by ore trucks. These roads could be expected to generate relatively low levels of sediments from wear and wash-off.

B. Roads constructed from material with a poor particle size grading but with low usage by ore trucks. These roads could be expected to generate greater rates sediments from wearing of the less competent pavement materials.

C. Roads constructed from material with a good particle size grading but with heavy usage by ore trucks. These could be expected to generate relatively high levels of sediments from road traffic wear.

D. Roads constructed from material with a poor particle size grading and with heavy usage by ore trucks. The combination of heavy usage on the less competent pavement materials is undesirable as elevated levels of wear will occur generating much higher rates of mobile sediments available for wash-off by rainfall runoff.

[39] Croton , J. T., 1990 *Minesite Drainage Book*. Water and Environmental Consultants for Alcoa of Australia.

The estimated catchment sediment yields are based on the data presented in the MDB. For slopes from 2% to 12%, the following equations apply for the four haul road classes:

A. $$Y_S = 10 \times S_R + 1.8$$

Equation 21

B. $$Y_S = 40 \times S_R + 1.2$$

Equation 22

C. $$Y_S = 50 \times S_R + 2.0$$

Equation 23

D. $$Y_S = 100 \times S_R + 8.0$$

Equation 24

where Y_S is the annual sediment yield rate, mm/year/m^2
S_R is the longitudinal slope of the road segment, m/m.

For compacted areas, such as mined areas, which are not heavily trafficked, an annual sediment yield of 3 mm/year/m^2 is assumed, per the MDB.

If field data indicates consistently higher sediment yield rates than those indicated above, the design rates presented above should be updated to conform with the observed information.

Sediment yield from forested catchments will be at background levels, significantly lower than the rates generated from disturbed surfaces and trafficked areas. For the purposes of sump design, the sediment yield from forested areas contributing runoff is assumed to be zero.

5.4.4 Required Holding Volume (Sediment Storage)

The SHV of a sump is a function of the annual sediment load rate and the cleanout frequency. The annual sediment load rate to a sump may be estimated by multiplying the sumps contributing catchment area by the applicable sediment yield rate. The SHV is then calculated by multiplying the annual sediment load rate by the average time in years between cleanouts. Thus, the sediment holding volume (for 100% capture);

$$SHV = A(total) \times \frac{Y_S}{1000} \times T_S \times F_B$$

Equation 25

where ***SHV*** is the sediment holding volume, m^3
A(total) is the catchment area contributing runoff and sediment to the sump, m^2
Y_S is the sediment yield rate, mm/year/m^2
T_S is the average time in years between sump sediment cleanouts
F_B is a bulking factor applied to the deposited sediments, 1.3 is assumed.

From the longitudinal slope of the road, the degree of usage by ore trucks and the quality of the road surface material, the sediment yield rate, Y_S, can be estimated from the equations in Section 5.4.3.

For haul roads, Figure 5-2, along with the runoff contributing width, may be used to estimate the lineal sediment yield in millimetres depth per year per metre length of the road. By applying Equation 25 above the required SHV can be estimated directly (bypassing the need to use Figure 5-2).

Complex catchments can be broken into components for the calculation of SHV in the same way as they are divided for the estimation of runoff. To obtain the total SHV for a particular sump, add together the SHVs for each sub catchment contributing flow to the sump.

Generally, it is assumed that each sump will have sediment cleaned out at least every two years. The expected clean out frequency of a sump may be adjusted at the design stage by increasing the SHV, to extend the period between clean outs, or by reducing the SHV for more frequent clean out. If it is intended to clean the sump less often than this, then Equation 25 for SHV above makes allowance for the cleaning interval. In cases where a sump has a design life of less than 5 years it may be feasible to size the SHV to hold all the sediment so that cleaning within the sump's design life is unlikely to be necessary.

For a compacted catchment area, Figure 5-3 shows the estimated SHV, based on 3 mm/year/m² sediment yield and clean out every two years.

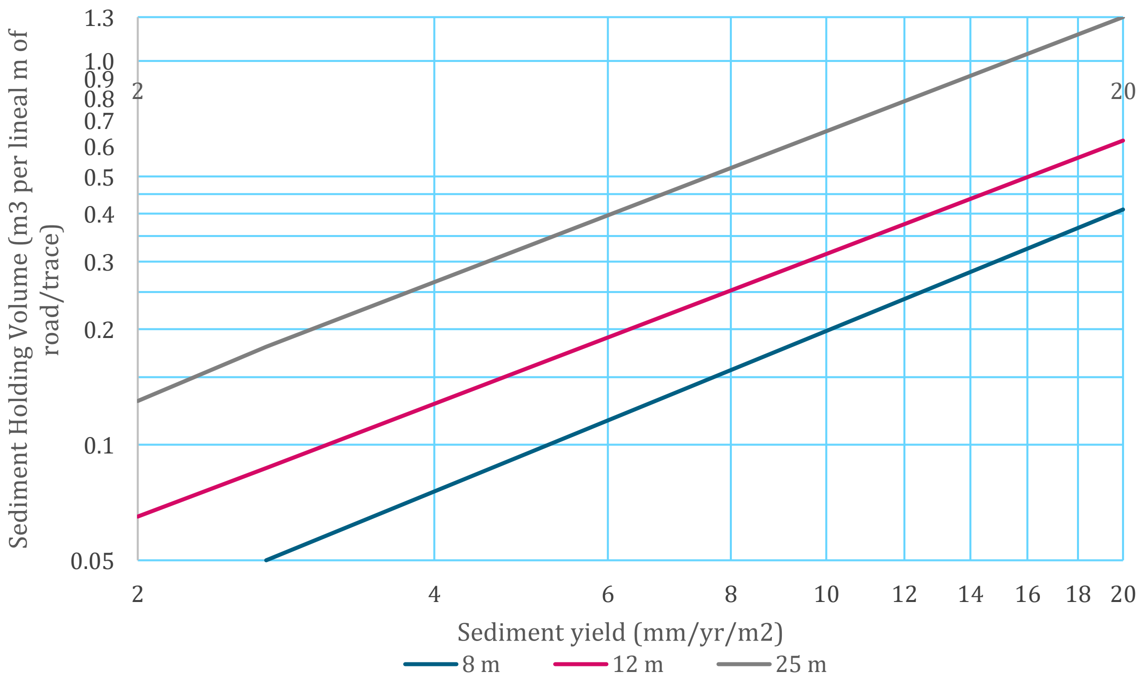


Figure 5-2. Relationship between Sediment Yield and required SHV per metre length of road/track.

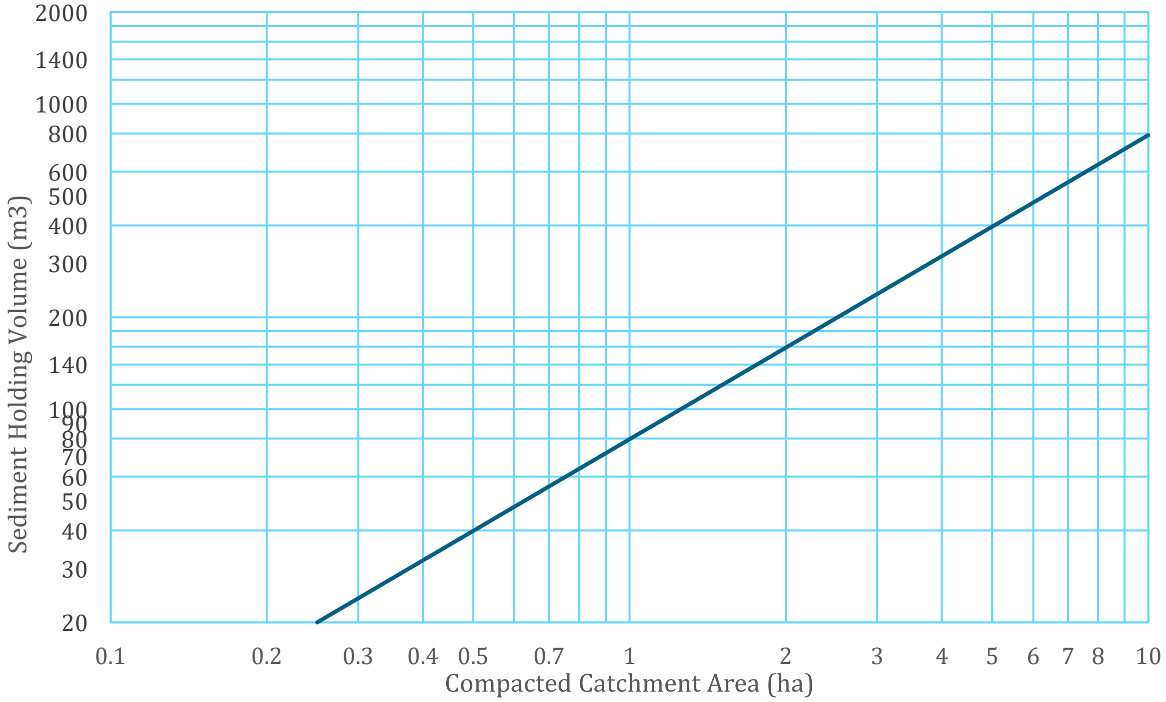


Figure 5-3. Relationship between compacted catchment area and required SHV, based on an estimated 3mm/year sedimentation rated

5.4.5 Sump Efficiency

Sump efficiency (SE) is a measure of how uniform the flow conditions are within the sump pond. If all the flow through the sump was on a broad even front, uniformly distributed both horizontally and vertically, with no short circuiting, the SE would be 1.00 (100%). Actual sumps always fall short of this ideal.

Sediment settling basins are considered of high to moderate efficiency at trapping coarse sediments, of moderate efficiency at trapping medium sediments and low efficiency at trapping fine sediments (CSIRO, 1999[40]). It is likely that it is the fine sediments which contribute to most of the turbidity seen in the haul road sedimentation pond discharges.

Sedimentation sump dimensions should be arranged such that the flow velocities in the sump provide sufficient detention time for the suspended particles to settle to the bottom of the sump. Chapter 12 of Australian Runoff Quality (ARQ)[41] suggests that the sump specification can be based on the expression by Fair and Geyer[42], which was developed for wastewater sedimentation design.

[40] CSIRO, 1999. Chapter 7 – Structural Treatment Measures, from *Urban Stormwater: Best Practice Environmental Guidelines*
[41] Wong, T. H. F. (ed), 2006. *Australian Runoff Quality*, Engineers Australia.
[42]Fair G.M. and Geyer J.C., 1954, Water Supply and Waste Disposal, John Wiley and Sons, New York, Vol. 2

$$R = 1 - \left(1 + \frac{1}{n} \times \frac{V_s}{Q/A_s}\right)^{-n}$$

Equation 26

With sump geometry known, this can be modified to account for the additional effect of permanent pool storage, as follows:

$$R = 1 - \left(1 + \frac{1}{n} \times \frac{V_s(S_p + S_e)}{Q \times d}\right)^{-n}$$

Equation 27

where **V_S** is the settling velocity of particles, m/s

R is the fraction of initial solids removed
Q/A_S is the surface hydraulic loading rate, m/s
Q is the design peak flow-through rate, m^3/s
A_S **i**s the sump design water surface area, m^2
S_P is the volume of the permanent pool (PPV), m^3
S_E is the volume of the extended detention (FTV), m^3
d is the depth of the extended storage, m
n is the turbulence parameter.

Note that the term extended detention has been used above for the consistency with the referenced technical document; the term used in the remainder of this manual, consistent with MDB[43], is surcharge volume.

Table 5-2 lists typical settling velocities of sediment particles.

Table 5-2. Particle settling velocities under ideal conditions (from ARQ[44] after Maryland Department of Environment, 1987[45])

Classification of particle size range	Particle diameter (µm)	Settling velocities (mm/s)
Very coarse sand	2000	200
Coarse sand	1000	100
Medium sand	500	53
Fine sand	250	26
Very fine sand	125	11
Coarse silt	62	2.3
Medium silt	31	0.66
Fine silt	16	0.18
Very fine silt	8	0.04
Clay	4	0.011

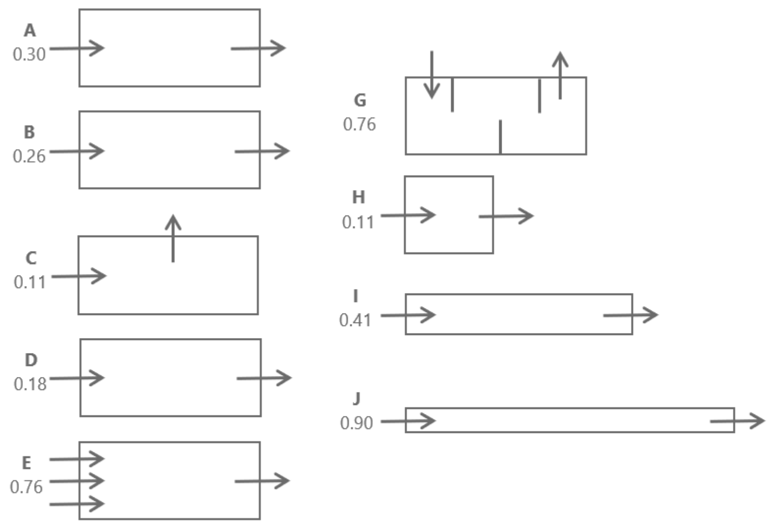
[43] Croton , J. T., 1990 *Minesite Drainage Book*. Water and Environmental Consultants for Alcoa of Australia.
[44] Wong, T. H. F. (ed), 2006. *Australian Runoff Quality*, Engineers Australia.
[45] Maryland Department of Environment, (1987), *Design Procedures for Stormwater Management Extended Detention Structures*, Baltimore, USA.

The turbulence parameter, n, may be related to the hydraulic efficiency, λ, of the sump as described by Persson et al[46] and referenced in both ARQ and the Stormwater Management Manual for Western Australia[47].

$$n = \frac{1}{1 - \lambda}$$

Equation 28

The allowable values of λ vary from 0 to 1, where values above 0.7 may be classed as good, values between 0.5 and 0.7 as satisfactory and values below 0.5 as poor hydraulic efficiency. Figure 5-4, outlines hydraulic efficiency values for various pond surface shapes. In this figure, the "O" symbols in items "O" and "P" represent an island or similar structure which will obstruct or spread the flow; the double lines in item "Q" represents a subsurface berm, a structure to distribute the flow evenly across the section.



Hydraulic Efficiency (λ) is a quantitative measurement of flow hydrodynamic conditions in constructed wetlands and basins. λ ranges from 0 to 1, with 1 representing the best hydrodynamic conditions for stormwater treatment (Engineers Australia, 2006). Note:

- good hydraulic efficiency where $\lambda > 0.70$
- satisfactory hydraulic efficiency where $0.50 < \lambda < 0.70$
- poor hydraulic efficiency where $\lambda \le 0.50$

Figure 5-4. Hydraulic efficiency (λ) for various pond surface configurations (from Stormwater Management Manual for WA, 2007)[48].

Figure 5-4 demonstrates the effects that distributed vs concentrated inlet and the ratio of pond width to length have on SE. In general, wide level sill inlets (with compatible entry chutes) distribute flows into the sump more evenly than narrow deep ones, enabling more of the sump volume to be effective in promoting

[46] Persson, Somes and Wong, 1999. *Hydraulics efficiency of constructed wetlands and ponds.* Wat. Sci. Tech. Vol. 40, No. 3.
[47] Department of Water and Swan River Trust 2007, *Structural controls, Stormwater Management Manual for Western Australia*, Department of Water and Swan River Trust, Perth, Western Australia.
[48] Department of Water and Swan River Trust 2007. Structural controls from *Stormwater Management Manual for Western Australia*, Department of Water and Swan River Trust, Perth, Western Australia.

sedimentation. Long thin sumps tend to be better than short broad ones as they reduce risk of short-circuiting through the sump, ensuring improved detention times which enhance sedimentation. Sumps should not become so long and thin however, that flow velocities become excessive, say greater than 0.1 m/sec (per MDB[49]) which may resuspend sediments and reduce detention times. Regarding the case for a distributed outlet, Persson et al. (1999)[50] suggested that a single outlet point would not affect the hydraulic efficiency significantly. While the location of the outlet, relative to the inlet is important, its width is of less consequence.

Layouts “H”, “B”, “I” and “J” from Figure 5-4 represent basic rectangular ponds with water surfaces of varying length to width ratio., Persson (2000)[51] indicated that these L:W ratios were 1:1 (H), 2:1 (A, B, C, D, E, G, O, P, Q), 4:1 (I) and 12:1 (J). From this information a relationship may be derived to estimate the hydraulic efficiency of sumps with water surface areas of intermediate aspect ratio (Figure 5-5).

Layout “E” is closely aligned to the layout of the second stage of a sedimentation sump.

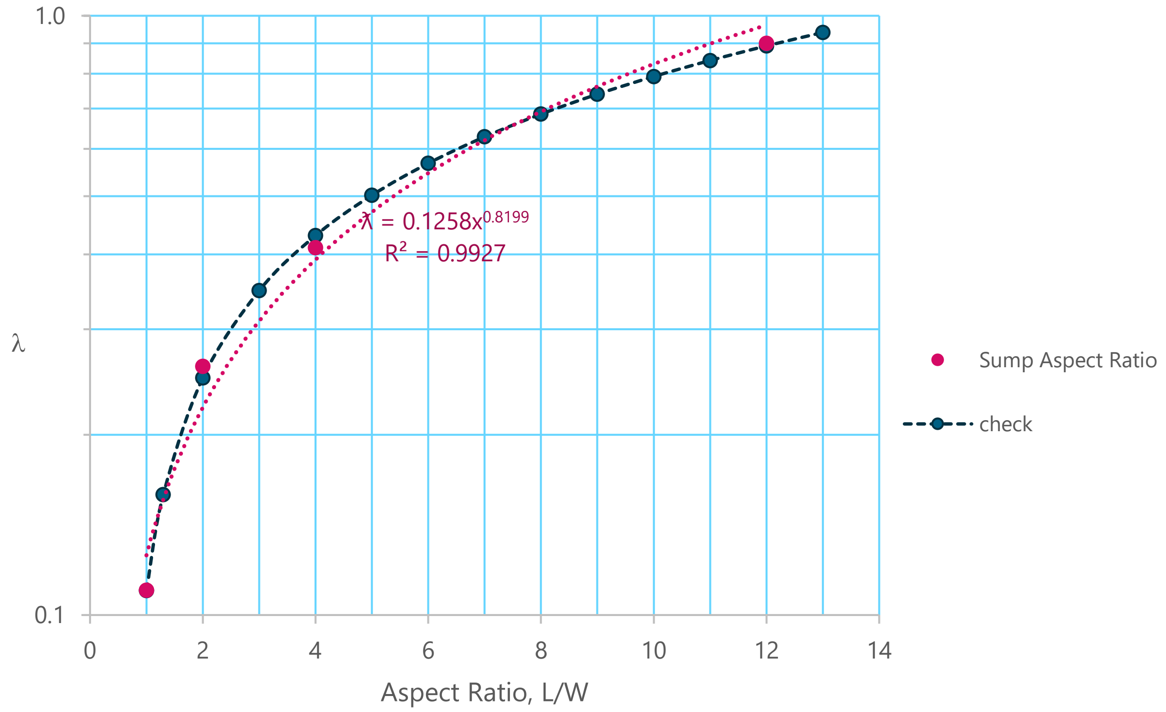


Figure 5-5. Relationship between sump water surface ratio L/W and hydraulic efficiency, λ.

From the basic rectangular sump shape, proportional adjustments may then be made to the estimated efficiency to account for sump characteristics including distributed inlet, baffles, submerged spreader bund, offset inlet and outlet and short-circuiting due to adverse inlet and outlet positions.

[49] Croton , J. T., 1990 *Minesite Drainage Book*. Water and Environmental Consultants for Alcoa of Australia.
[50] Persson, Somes and Wong, 1999. *Hydraulics efficiency of constructed wetlands and ponds*. Wat. Sci. Tech. Vol. 40, No. 3.
[51] Persson, J. (2000) *The Hydraulic Performance of Ponds of Various Layouts*. Urban Water. Volume: 2 Number: 3, pp 243-250.

5.4.6 Design Surface Hydraulic Loading

CSIRO (1999)[52] suggests that sediment traps can be effective for capturing fine sediments but require low surface hydraulic loading, typically 50 m/year or less. With mean annual rainfall of 1,229 mm (based on 80 years of data at Dwellingup) and an assumed runoff coefficient from roads of 0.9, 1 hectare of road area would require a minimum sump surface area of 221 m^2. This appears consistent with existing Alcoa sedimentation sumps.

This approach for design is based on averages however, not extremes, and is more appropriate for waterways which sustain more consistent flows. Where focus is on the less frequent rainfall events, as is the case at the Alcoa mines, design must be based on design peak flow.

On a design storm event basis, the surface hydraulic loading rate is computed from the design peak flow Q, (m^3/s) divided by the pond surface area, A_s (m^2). That is,

$$\text{Surface Hydraulic Loading} = \frac{Q_i}{A_S}$$

Equation 29

5.4.7 Required Pond Volume

Stahre and Urbonas (1990)[53] suggest a pond sizing procedure based on the particle size and distribution found typically in a site's sampled stormwater. Adapting that procedure for Alcoa's mine sites suggests the following approach, which is replicated in the SDT:

1. Determine the particle size and particle volume distribution associated with the pollutants (in this case sediments) found in the stormwater runoff.
2. Based on the sediment data decide how much of the various particle sizes need to be removed to achieve the desired discharge quality. Acknowledge that the greater the removal rate adopted, the larger are the facilities that will be required. Also acknowledge that sedimentation alone may not achieve those goals.
3. Based on a target particle size (or sizes) make a **preliminary** estimate of the design surface loading rate required to achieve a desired removal rate. Figure 5-6 shows a relationship between surface loading and sedimentation effect for particles of 16 micron size. A figure in the reference (on which Figure 5-6 was based) covers particle sizes from 4 to 250 micron.
4. Determine settling velocities for all the representative particle sizes. Table 5-2, adopted from ARQ[54], presents settling velocities for particles sizes from 2 mm down to 4 micron.
5. From the above information, calculate the sedimentation retention effectiveness (fraction of solids removed) for all the representative particle sizes using Equation 27 or Equation 27. From the adopted PSD, estimate the mass of each representative particle size removed.

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[52] CSIRO, 1999. Chapter 7 – Structural Treatment Measures, from *Urban Stormwater: Best Practice Environmental Guidelines*

[53] Peter Stahre and Ben Urbonas, 1990. *Stormwater Detention for Drainage, Water Quality, and CSO Management*. Prentice Hall, New Jersey.

[54] Wong, T. H. F. (ed), 2006. *Australian Runoff Quality*, Engineers Australia.

6. Composite the total sedimentation effectiveness from the results of step 5 and determine the percentage of sediment mass removed, i.e. the retained mass fraction. The residual TSS flowing from the sump may then be estimated by reducing the influent TSS by the retained mass fraction.
7. If the total sedimentation effectiveness is considered inadequate, or the outflowing TSS is too high, then repeat the calculations using a lower hydraulic surface loading rate. That is, either increase the sump surface area (and volume) or reduce the runoff from the contributing catchment by diverting runoff to another destination for treatment.
8. Once satisfied with the adequacy of the hydraulic surface loading rate, determine the surface area of the sump and its geometric configuration. The hydraulic surface loading rate may be based on the average flow rate through the basin.

The sump volume (PPV) is computed from the design surface area, $\mathbf{A_s}$ (determined by the above procedure), the effective sedimentation depth, **d** and the sump geometry (shape and side slopes).

While target particle sizes may differ, this process applies equally to design of both the forebay sump and the main sedimentation sump.

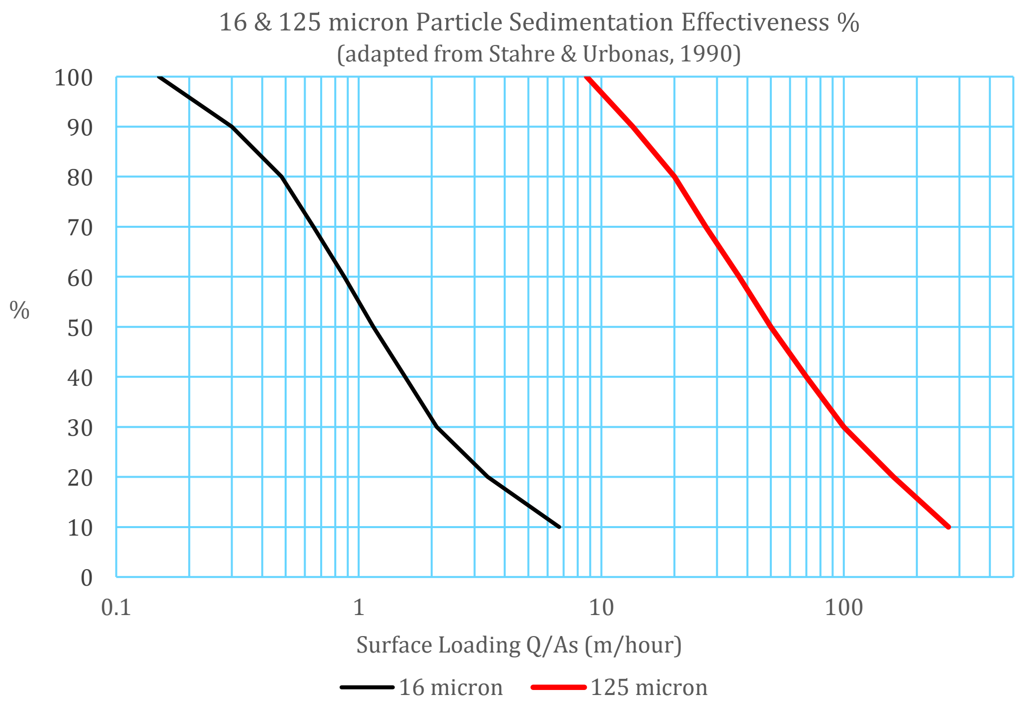

Figure 5-6. Sedimentation effectiveness for 16-and 125-micron particle sizes

5.4.8 Space Limited Design

Based on experience to date, these two cases may be implemented where limited space is available (i.e. when road is in a cut).

5.4.8.1 In/Out Sedimentation Ponds

In/Out sedimentation ponds reflect conditions where multiple smaller consecutive sedimentation ponds are constructed, with the aim that their cumulative volume provides the required storage. Accordingly the water is coming in and out from consecutive ponds, but ultimately complies with design criteria.

5.4.8.2 Drop Box solution

Drop boxes are installed to initially capture the road runoff. A culvert from the drop box conveys water into nearby storages of appropriate design capacity.

5.5 Infiltration Sump Design

Infiltration sumps are utilised to capture potentially turbid water and promote infiltration near sensitive environments. The effectiveness of an infiltration sump to discharge collected rainfall runoff will be fundamentally dependent on the characteristics of the soils forming the base and walls of the sump and the natural soil layers conducting water away from the sump. This effectiveness however may be compromised by:

- Clogging of the surface soils through a build-up of fines carried by the inflowing water
- Groundwater inflows into the sump or groundwater level rise underneath the sump both adversely affecting the infiltration discharge rate and augmenting the sump overflow
- Sump being constructed in naturally low hydraulic conductivity materials.

Infiltration sumps must be sited higher in the landscape, away from known wetlands, creeks and surface expressions of groundwater as described in Section 5.2. Should interception of groundwater be identified during construction or operation, the sump design capacity must be reviewed based on the likely reduced infiltration rate.

5.5.1 Sump Configuration

The configuration of infiltration sumps is shown in Figure 5-7. The sump three storage components; the minimal volume (determined through a water balance assessment), additional volume from the factor of safety depth, flowthrough volume as water discharges over the crest. The latter is contained within the sump freeboard that extends above the weir to the top of the sump embankment.

The sump receives catchment runoff and direct rainfall, disposing water through infiltration and evaporation. Infiltration within the sump occurs through the base area (A_b) of the sump and wall area (A_w) as function of the local groundwater conditions and hydraulic conductivity (Section 3.2). The sump volume is determined through a water balance assessment (Section 5.5.2).

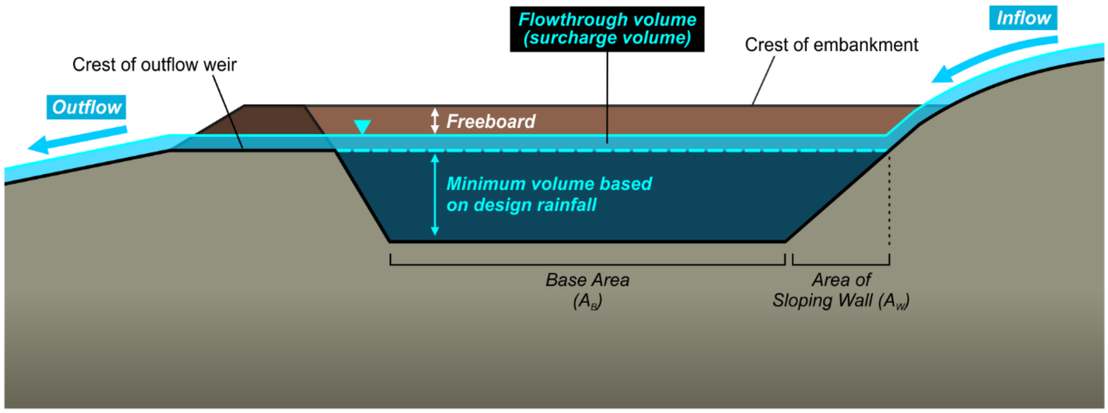

Figure 5-7: Infiltration sump configuration

5.5.2 Water Balance

Infiltration sump volume design is a balance between the time-dependent inflowing volume and the time-dependent outflowing volume. Infiltration sump design is undertaken in the SDT (presented in Appendix F), based on the calculations outlined below. A daily water balance, over a 40 year period, determines the volume of rainfall that falls in the catchment area and runs off into the sump. The volume of water lost to infiltration, evaporation, or to overflow from the sump (and discharge downstream) is determined, with the SDT returns the percentage of catchment inflow to the sump that is discharge downstream (overflow percentage).

The daily water balance that enables design of the infiltration sumps is a variation of the water balance provided in Appendix C for the mine pit sump design (Section 4.1.2).

Volume of storage with index k for a day t can be evaluated starting from the storage volume at the end of the previous day increased by the inputs and reduced by the outputs for that day, i.e.:

$$V_t^k = V_{t-1}^k + Input_t^k - Output_t^k$$

Equation 30

where ***Input*** is runoff from haul catchment + direct rainfall on storage
Output is storage infiltration + storage evaporation.

The following changes are made from the mine pit water balance (Section 4.1.2):

- Catchment inflow is limited to the connected haul road area and assumes there are no upstream storages that may overtop.
- There is no infiltration within the catchment, reflecting the compacted haul road conditions. A runoff coefficient of 0.9 is applied to account for losses associated with minor ponding on the haul road.

The haul road sump water balance is presented in Table 5-3 and Figure 5-8.

Table 5-3. Haul road sump water balance components (daily timestep)

Component	Equation	Reference
$\boldsymbol{Input_t^k}$		
Runoff volume	$\boldsymbol{Catchment\ Area^k\ x\ Rain_t\ x\ Runoff\ Coef^k}$	Daily rainfall data provided in Appendix B.
Direct rainfall	$\boldsymbol{Top\ Storage\ Area^k\ x\ Rain_t}$	
$\boldsymbol{Output_t^k}$		
Infiltration	$\boldsymbol{Water\ Area_t\ x\ K_{SAT}}$	As per Section 3.2, application of Darcy's Law; Infiltration is K_{Sat}
Evaporation	$\boldsymbol{Water\ Area_t\ x\ Evaporation_t}$	Evaporation data as outlined in Section 2.2

Water area for infiltration and evaporation outputs is calculated at each timestep by considering the volume of water in the sump from the previous timestep and corresponding surface area.

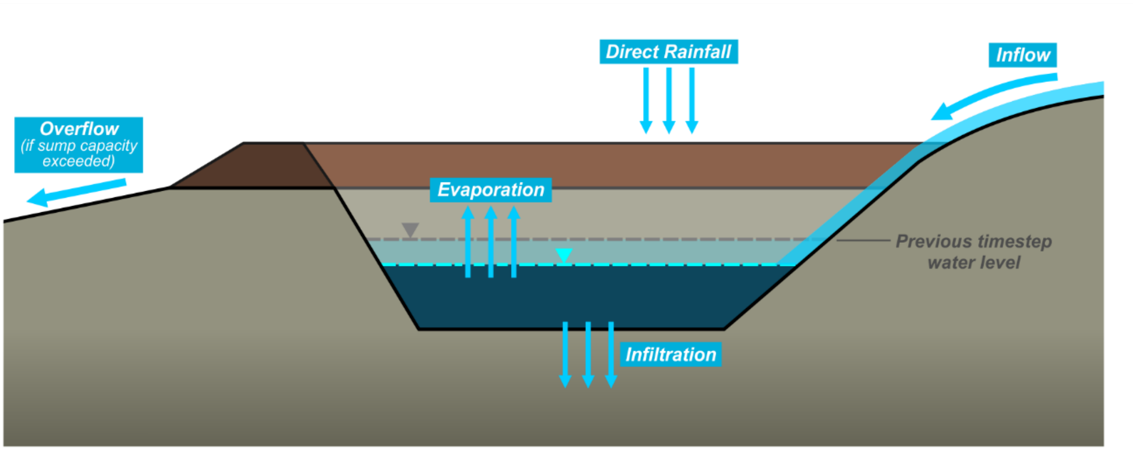

Figure 5-8. Haul road sump water balance

5.5.3 Infiltration Sump Design Process

The SDT facilitates the design of infiltration sumps, through a water balance assessment, consistent with drainage design process map (Appendix A). The initial step in the design process is establishing the catchment conditions and confirming local infiltration rates.

An iterative sump sizing approach follows:

1. Based on the assigned side slopes, sump depth and an initial rainfall design depth, a sump volume is generated and assessed in the water balance (assuming a square configuration). The SDT reports the percentage of inflow into that sump that discharges downstream as overflow (overflow percentage).
2. The sump volume can then be adjusted (increasing or decreasing the sump footprint) and reassessed in the SDT. This step again assumes a square basin footprint and returns the overflow percentage. The volume should be adjusted to meet the design criteria.
3. The final step in the SDT is to revise the sump dimensions to a rectangle configuration to fit the ground conditions. The rectangular sump is assessed in the water balance, returning the overflow percentage. The sump dimensions (length and width) can be adjusted to meet the design criteria.

An example SDT output is included within Appendix F, and a process flow map for the design of infiltration sumps is provided in Appendix A.

5.6 Sump Construction

5.6.1 Inlet Structure

The sump inlets comprise concentrated inflow points directly into the sumps. These inflows are lined chutes discharging from road gutters or culvert outlets from drop boxes. The inlet structure should decelerate the incoming water and spread it out onto a broad front.

The inlet must be protected from scour due to the higher water velocities expected to occur. Rock pitching is commonly used. Other options may include concrete, bitumen or suitably anchored polyethylene liners.

Where possible the inlet should distribute inflow across the full width of the sump to reduce inlet velocities and promote uniform flow to avoid flow short circuiting. Where inlet flows pass into a forebay, a wide weir connecting to the main sump provides opportunity to distribute flow into the main sump.

On superelevated roads, at road sags or at corners, a wider discharge from the gutter may be used to assist in removing water from a roadway. At these wider discharge locations, appropriate scour protection of the sump/road embankment is still required.

5.6.2 Forebay Construction

The purpose of the forebay is to accept runoff water from the roadway and provide opportunity for the heavier, coarser particles in the runoff water to drop out prior to distribution of flow into the main sump. The coarser particles will often fall out of suspension within seconds of the runoff flow entering the forebay. Evidence of this is shown in Figure 5-9. Commonly, it is these coarser particles which contribute the major portion of the sediment volume captured in the sump.

Figure 5-9: Sediment settling quickly near a sump inlet

The forebay may be formed by isolating the inlet portion of a sump with a weir bund, as shown conceptually in Appendix E. The weir bund also serves to distribute flows more evenly into the main portion of the sump.

The weir bund must have appropriate scour protection to retain its integrity. It must be protected for the full width of the weir opening from the upstream edge near the crest, across the crest, down the downstream bund embankment (main sump side) and terminating on the main sump floor, nominally 1 m from the toe of the weir bund.

If the weir crest is full width of the weir bund, then scour protection should extend onto the side embankments of the main sump to nominally 0.5 m from the weir bund. This is proposed to protect the main sump walls from water cascading over the weir bund.

If the weir crest is not full width of the weir bund, then scour protection should extend laterally, on the downstream side of the weir bund, to nominally 0.5 m wider on each side of the weir crest. This is proposed to protect the extended portion of weir bund from water cascading from the weir opening.

5.6.3 Sump Storage

Sump storage size is determined in the SDT, using water balance assessments for infiltration sumps, as outlined in Section 5.5.3.

Sediment sump storage comprises two main volume components: the PPV and the SHV. The sump's sedimentation effectiveness, and hence it's required volume, is dependent on the sump shape and its water surface area. This is discussed in further detail in Appendix H. The SHV portion of the storage volume is calculated from the method in Section 5.4.4. The PPV is determined from Sections 5.4.5 to 5.4.7. The length to width ratio of the water surface of the PPV, which affects the sump's hydraulic efficiency (SE) (from Figure 5-5) and the design surface hydraulic loading rate, generally will control the overall shape of the sump. The inclusion of a forebay the first stage of a two-stage sump will also affect the shape (and therefore the footprint) of the sump.

5.6.4 Sump Forebay

Forebay sizing is described in Section 5.4.2 and the general sump sizing methods of Sections 5.4.3 to 5.4.7. Refer also to the process map in Appendix A.

The (internal) weir structure from a forebay to a second stage sump should be constructed as a full width level sill outlet to reduce approach velocities and minimise risk of turbulent remixing of settled sediments.

Ensure that the dimensioning of the sump produces the correct total volume and shape below the water line.

5.6.5 Spillway Design

The design objective for the controlled release structures (spillway) is to minimise the likelihood of excessive sediment load in these releases which can occur if failure of the containment structure takes place. Outlet structures from Alcoa's Haul Road sumps generally comprise broad-crested weirs formed within the sump embankments and lined to minimise erosion. The engineered embankment, geometry and construction method, including compaction, must follow sound geotechnical principles to prevent failure and excessive mobilisation of sediment. Above ground discharge is to be via rock lined chute and include spreader apron.

Outlet weirs discharging to external channels, stream zones or forest should be at ground level to discharge on a broad front to the forest floor or led via a channel to flat ground at the edge of the stream zone and discharged also on a broad front into dense vegetation. If the discharged water is concentrated and flows across the forest floor it will likely develop an erosion channel.

The hydraulic design and geotechnical principles for the outlet weirs is consistent with the Mine Pits presented in Section 4.4.1 and broad crested weir formulation (Equation 13). The embankment crest level should be set at least at the spillway design flood peak level plus wave runup allowance for 10% AEP or 300mm freeboard as per ANCOLD (2012)[55]. In natural terrain, a freeboard of 100 mm to be allowed

5.6.6 Sump Wall Construction

The importance of avoiding a sump failure by over topping or slumping of the walls cannot be over emphasised. Both adequate freeboard and wall crest width must be provided to produce a stable and leak free wall under all conditions and to provide allowance for settlement after construction.

Table 5-4 gives freeboard amounts and wall crest widths recommended from the MDB. Widths for walls constructed from clay and silty gravel are recommended for two standards of soil compaction. Uncontrolled compaction assumes track rolling in 300 mm lifts. Controlled compaction is for 95% standard compaction to AS 1289.5.1.1:2017.

Note that sumps excavated into natural ground may not need compacting. Compacting is applicable to all constructed walls.

Table 5-4. Minimum freeboard and wall crest width

Soil Type	Controlled Compaction		Uncontrolled Compaction	
	Freeboard (m)	Wall Crest Width (m)	Freeboard (m)	Wall Crest Width (m)
Clay	0.5	0.6	0.8	1.0
Silty Gravel	0.5	0.9	0.6	1.5

Building walls as steep as theoretically possible should be avoided as, even with adequate crest width and freeboard, serious failures can still occur. Also check the material from which the walls are to be built and remove all large rocks and organic matter as they can be sources of pathways for leaks. All batters should be seeded. Woodchips and bitumen should also be used to stabilise the external surface of clay walls and their surrounds.

5.6.7 Sump Baffles

To increase the effective flow path length within a sump pond, baffles may be used. Baffles are dividing walls going part way across a sump to force the flowing water to follow a more tortuous or serpentine path

[55] ANCOLD (2012). Guidelines on the Consequence Categories for Dams. Australian National Committee on Large Dams (ANCOLD) October 2012.

(Figure 5-4). Baffles can be useful in certain situations where space along the main axis of the sump is limited, but they may make a sump difficult to clean. The single long baffle used to convert a sump into a U shape is the most useful but may not suit the relative locations of the inlet and outlet. If constructed as an earthen embankment, a baffle will reduce the sump of a considerable amount of its volume. To overcome this volume loss, a baffle structure constructed from marine plywood or a similar robust material and supported by timber posts may present a more effective approach for baffle construction.

Formed earth baffles are not recommended. Refer to Figure 5-4, Item G, as an example.

Where practicable, baffles should be used to improve sump hydraulic efficiencies which are otherwise lower than 0.5 (with reference to Figure 5-4). That would apply to all rectangular sumps with a water surface length to width ratio of less than 5 (Figure 5-5) and which do not have a distributed inlet (such as provided by a forebay distribution weir or by a submerged distribution berm at the inlet).

With two or more baffles installed, their alignments dividing the pond surface into roughly equal areas, the effective sump length would be the average path length of flows from the inlet to the outlet and the sump effective width would be the separation distance between the baffles (and between baffle and sump end embankment). Using those effective lengths to estimate the L/W ratio, Figure 5-5 then may be used to estimate the revised hydraulic efficiency with the baffles installed.

5.6.8 Sump Access

Suitable access for inspection and maintenance must be provided to all sumps. The purpose of a sedimentation sump is to remove particulate matter from runoff water and the accumulation of these sediments must be regularly monitored and periodically removed to refresh the sumps capacity and function.

5.6.9 Construction Drawings

Standard Alcoa drawings of sedimentation sumps showing full details of sump construction are available from Mines Engineering.

6 EXECUTION & QA/QC GENERAL COMMENTS

6.1 Construction Phase Drainage Management

Contractors undertaking construction of haul roads and associated drainage infrastructure shall prepare, for Alcoa's approval, their own Drainage Management Plan for construction. The Contractor's Drainage Management Plan shall be compliant with this manual (and other relevant standards and regulations). It shall identify roles, responsibilities, likely impacts of their works, risks, risk mitigation measures and a monitoring program to ensure compliance. Alcoa will undertake audits of this compliance.

The Victorian Branch of the Civil Contractors Federation published the "CCF Environmental Guidelines for Civil Construction"[56], outlining a broad variety of environmental controls including many drainage and sediment control measures for construction sites. Intended for use by the Victorian civil construction industry, most of the documented controls have more universal application, and may be referenced in the development of project or task specific Drainage Management Plans.

[56] Civil Contractors Federation, 2010. *CCF Environmental Guidelines for Civil Construction*.

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APPENDIX A - Drainage Design Process Map

Haul Roads

Catchment Hydrology

Catchment Hydrology Calculation

↓

Determine the contributing catchment, runoff coefficient and design event (based on risk profile).

↓

Determine the mainstream length and average gradient.

↓

Based on average gradient, estimate average velocity or gutter flow, and resulting travel time.

↓

Estimate the Time of Concentration (T_C) for peak inflow estimation.

↓

For design AEP, determine design rainfall intensities for durations of T_C minutes (for peak flow estimation).

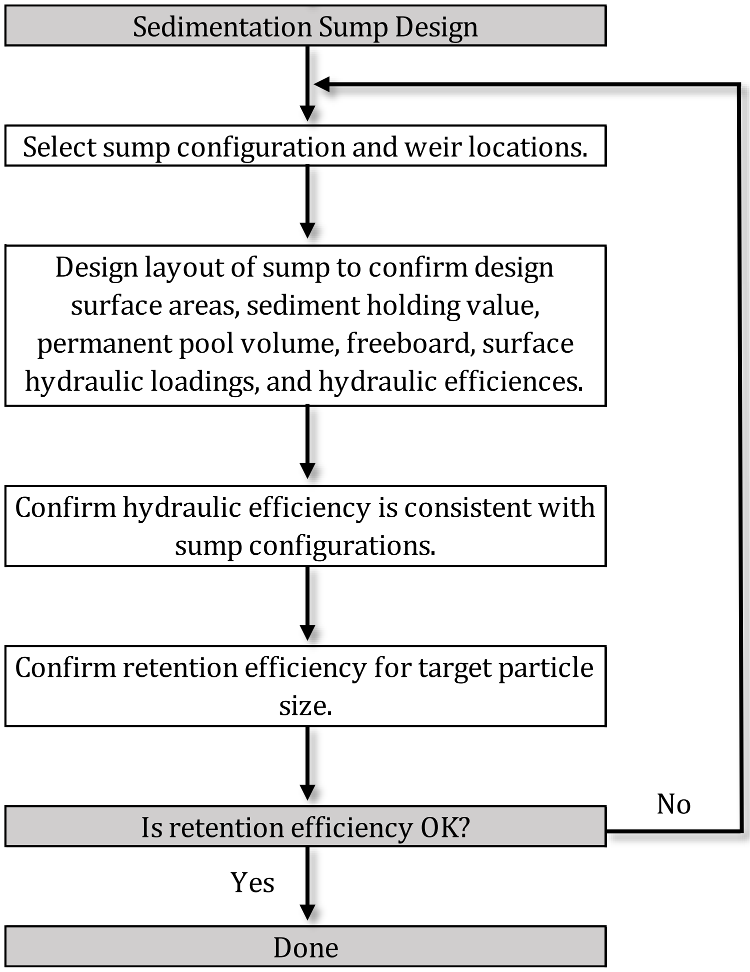
↓

Compute design peak inflows Q_C (for duration T_C).

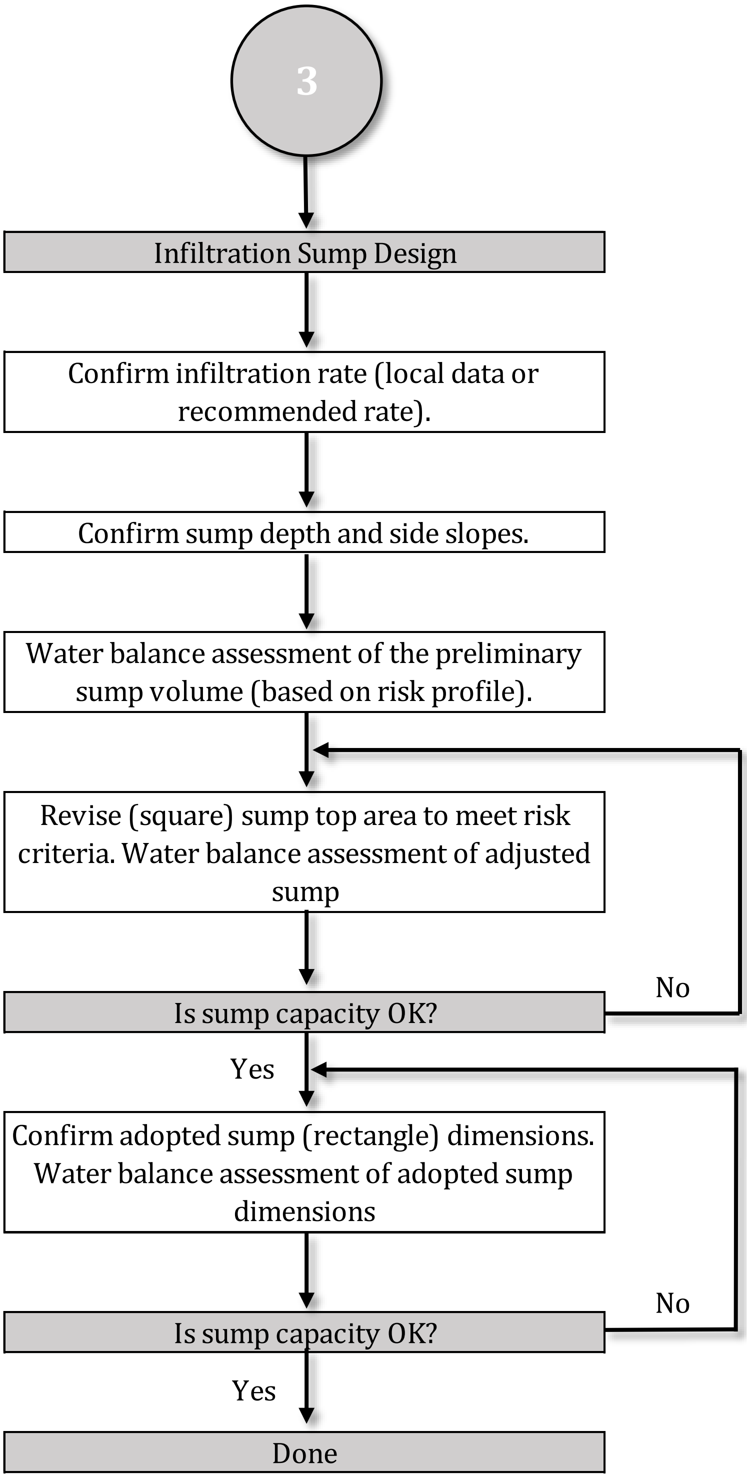
↓

Input into sediment sump assessment.

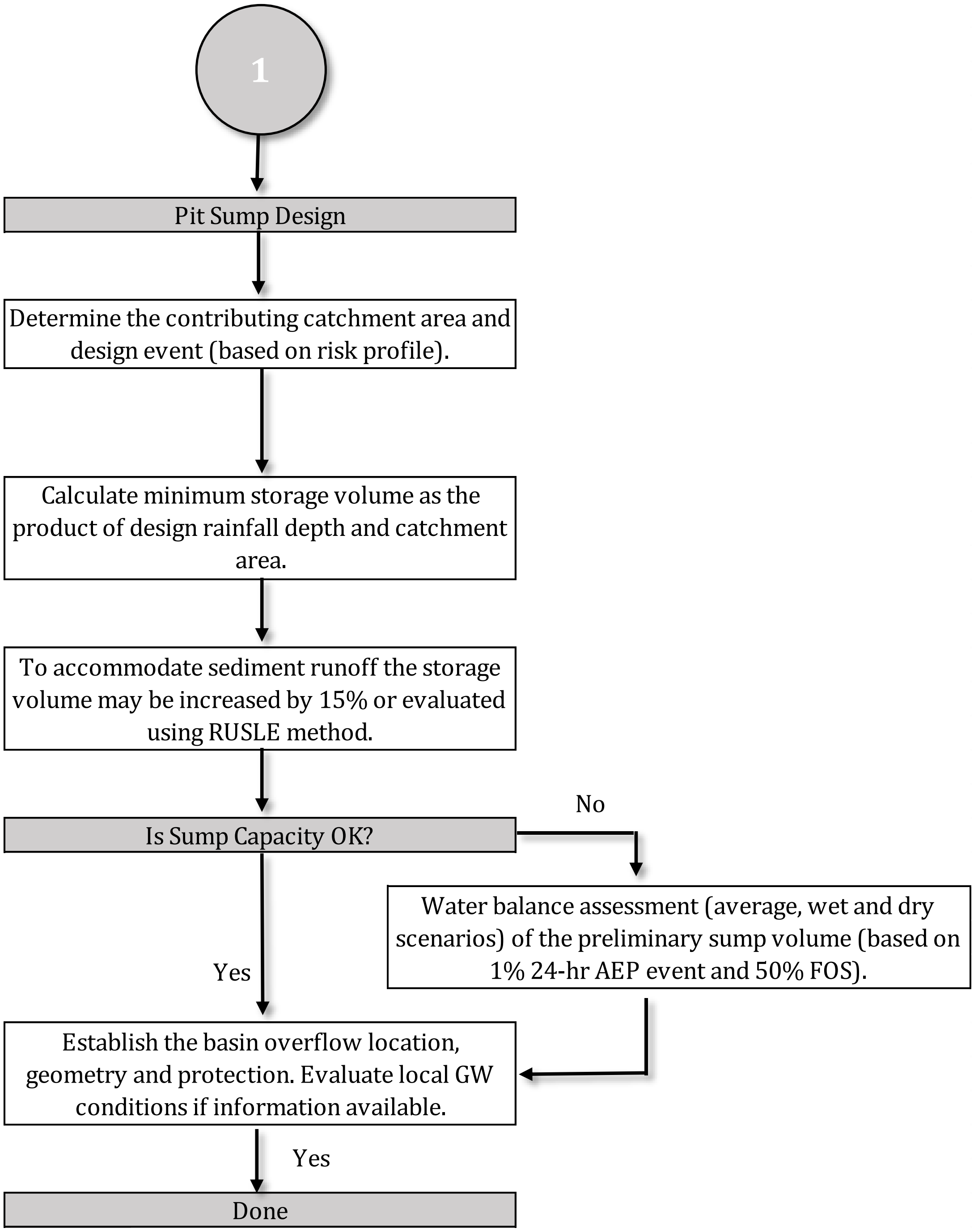
Sediment Sump Design



Infiltration Sump Design



Pits


1
Pit Sump Design
Determine the contributing catchment area and design event (based on risk profile).
Calculate minimum storage volume as the product of design rainfall depth and catchment area.
To accommodate sediment runoff the storage volume may be increased by 15% or evaluated using RUSLE method.
Is Sump Capacity OK?
No
Water balance assessment (average, wet and dry scenarios) of the preliminary sump volume (based on 1% 24-hr AEP event and 50% FOS).
Yes
Establish the basin overflow location, geometry and protection. Evaluate local GW conditions if information available.
Yes
Done

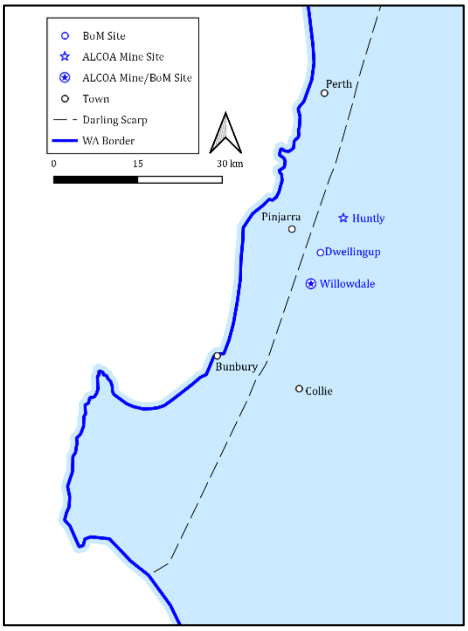
APPENDIX B - Design Rainfall

Design rainfall, intensity-frequency duration and daily rainfall data for the drainage manual was sourced from the Bureau of Meteorology. Two gauging stations were chosen due to their proximity to Alcoa's mining sites and amount of data available (shown in the figure to the right).

For the Willowdale mine site, BoM's Willowdale station (ID: 9893, Latitude: 32.92°S, Longitude: 116.01°E) was used as the data extends to 1982.

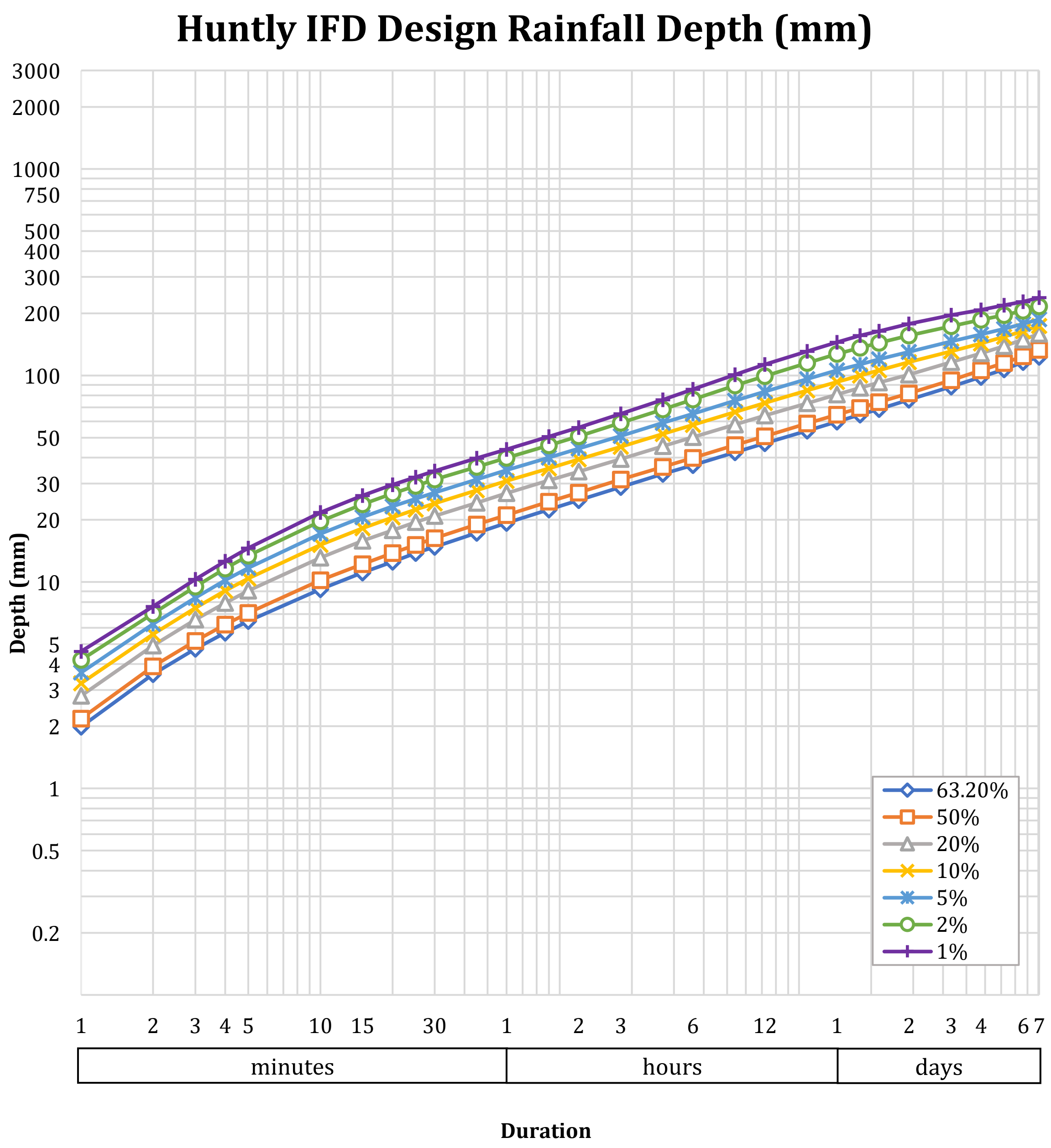
For the Huntly mine site, BoM's Dwellingup station (ID: 9538, Latitude: 32.71°S, Longitude: 116.06°E) was used as the data extends to 1934 (only data from 1980 was used). BoMs Huntly site only contains rainfall records back to 1990 so was not used for the drainage manual.

Data used has been summarised in the tables and figures below.

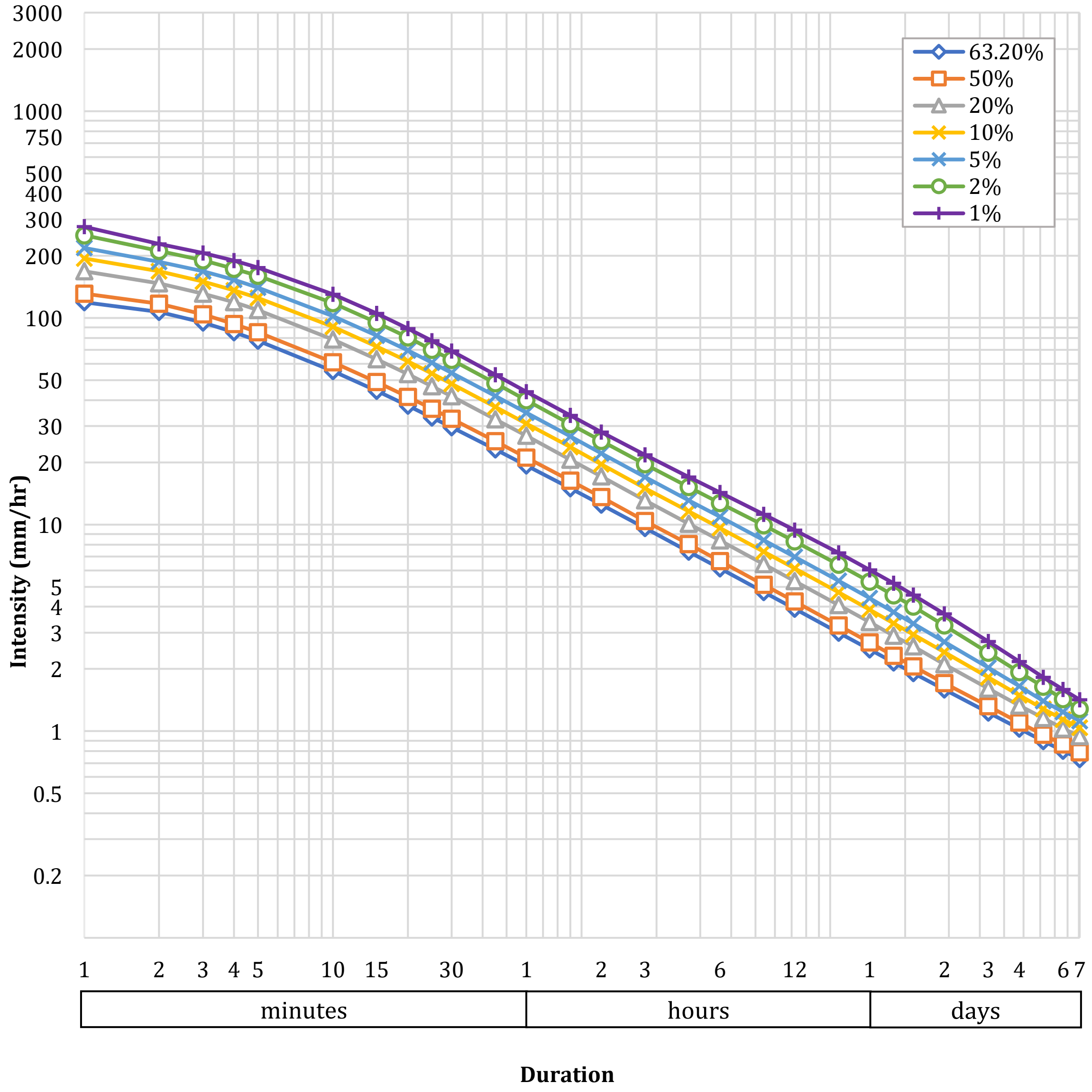


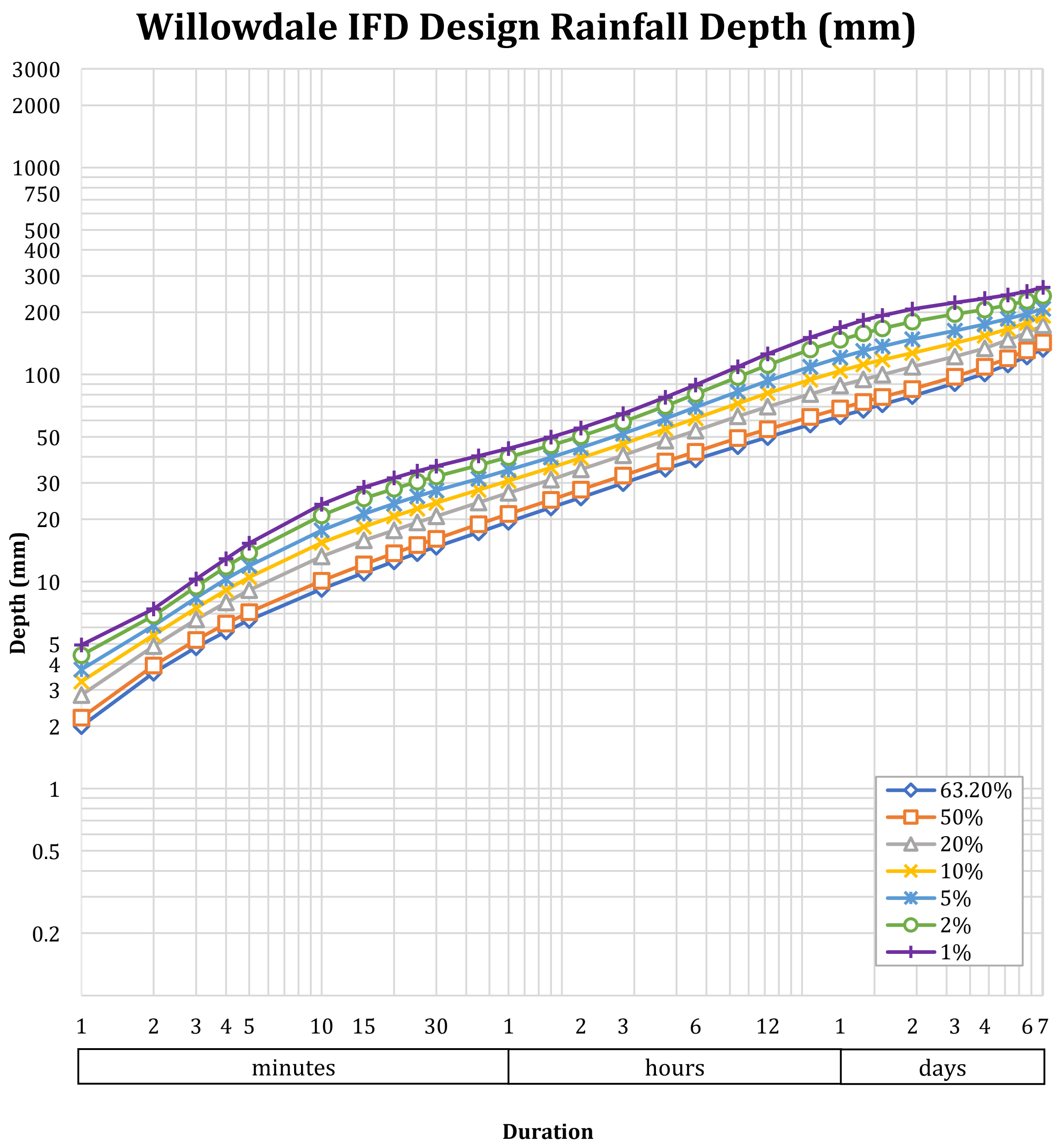
Map of BoM weather stations

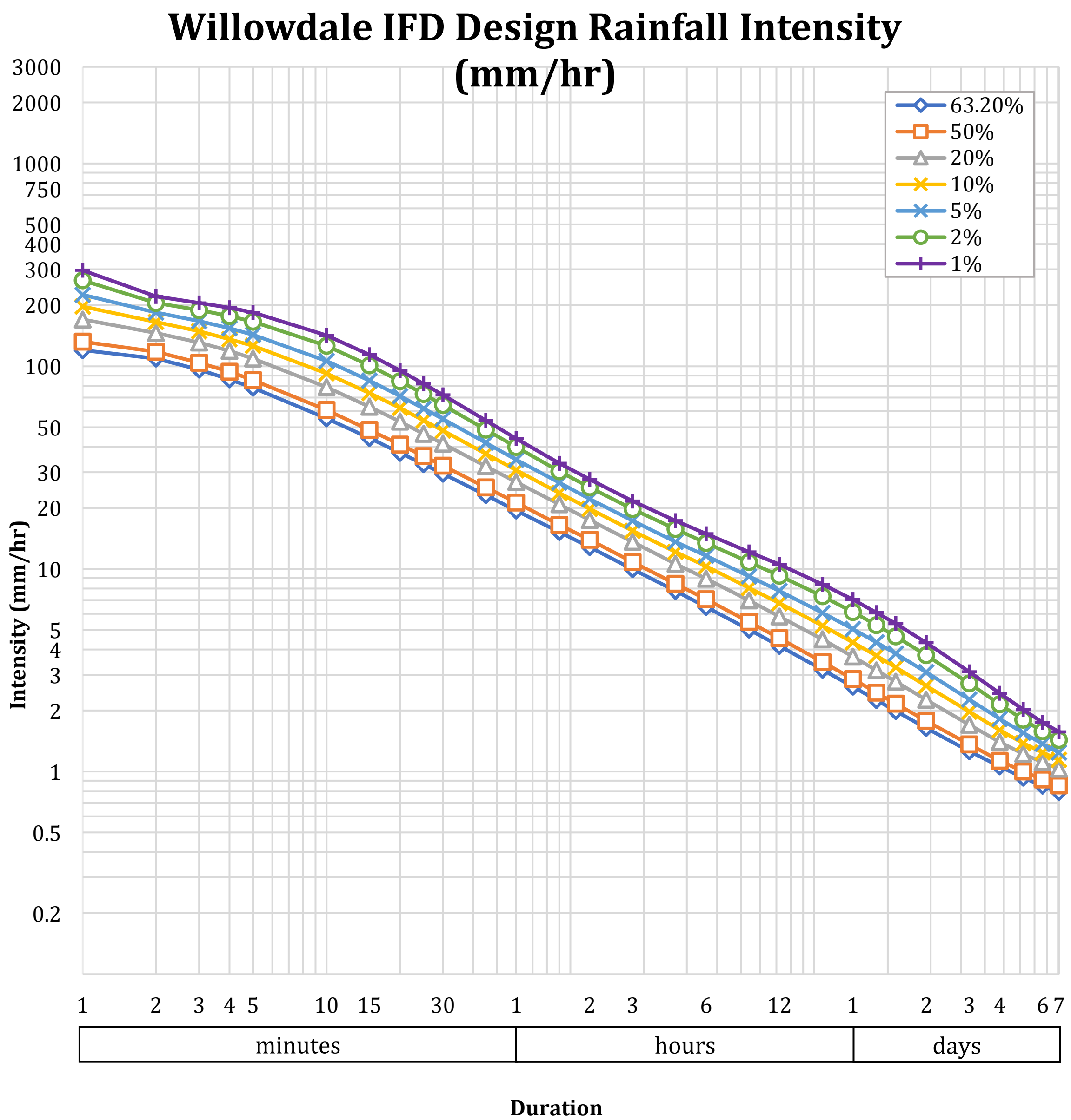
Design Rainfall Depth and Intensity-Frequency-Duration Data



Huntly IFD Design Rainfall Intensity (mm/hr)




Willowdale IFD Design Rainfall Depth (mm)
Depth (mm)
3000
2000
1000
750
500
400
300
200
100
50
30
20
10
5
4
3
2
1
0.5
0.2
63.20%
50%
20%
10%
5%
2%
1%
1
2
3
4
5
10
15
30
1
2
3
6
12
1
2
3
4
6
7
minutes
hours
days
Duration


Willowdale IFD Design Rainfall Intensity (mm/hr)
63.20%
50%
20%
10%
5%
2%
1%
Intensity (mm/hr)
3000
2000
1000
750
500
400
300
200
100
50
30
20
10
5
4
3
2
1
0.5
0.2
1 2 3 4 5 10 15 30 1 2 3 6 12 1 2 3 4 6 7
minutes
hours
days
Duration

IFD Design Rainfall Depths (mm) for Huntly Mine (based on data from Bureau of Meteorology 28/10/2022).

Annual Exceedance Probability (AEP)										
Duration	**Duration in min**	**63.20%**	**50%**	**20%**	**10%**	**5%**	**2%**	**1%**	**1 in 200**	**1 in 500**
1 min	1	1.99	2.18	2.81	3.23	3.64	4.19	4.61	5.5	6.62
2 min	2	3.57	3.9	4.91	5.59	6.25	7.03	7.61	8.84	10.5
3 min	3	4.74	5.18	6.56	7.49	8.39	9.48	10.3	12.1	14.4
4 min	4	5.68	6.22	7.91	9.06	10.2	11.6	12.6	14.9	17.8
5 min	5	6.46	7.09	9.06	10.4	11.7	13.4	14.6	17.3	20.8
10 min	10	9.22	10.2	13.1	15.1	17.1	19.7	21.7	26	31.4
15 min	15	11.1	12.2	15.8	18.2	20.6	23.8	26.2	31.4	38
20 min	20	12.5	13.8	17.8	20.5	23.2	26.8	29.6	35.4	42.7
25 min	25	13.8	15.1	19.5	22.4	25.3	29.2	32.2	38.5	46.4
30 min	30	14.8	16.3	20.9	24.0	27.1	31.3	34.5	41.1	49.5
45 min	45	17.3	19	24.2	27.8	31.4	36.1	39.8	47.2	56.7
1 hour	60	19.3	21.1	26.9	30.8	34.8	39.9	43.9	52	62.5
1.5 hour	90	22.4	24.5	31	35.5	40	45.9	50.6	59.9	71.9
2 hour	120	24.9	27.1	34.2	39.2	44.2	50.8	56	66.5	79.9
3 hour	180	28.8	31.3	39.4	45.1	51	58.9	65.2	77.7	93.6
4.5 hour	270	33.3	36.1	45.4	52.1	58.9	68.5	76.3	91.5	111
6 hour	360	36.8	39.9	50.2	57.7	65.3	76.5	85.6	103	125
9 hour	540	42.5	46	57.8	66.5	75.5	89.3	101	122	148
12 hour	720	46.9	50.8	63.9	73.5	83.6	99.4	113	136	165
18 hour	1080	54	58.5	73.4	84.5	96.1	115	131	158	191
24 hour	1440	59.7	64.5	80.8	92.9	106	127	145	173	208
30 hour	1800	64.5	69.7	87	99.8	113	136	156	183	218
36 hour	2160	68.8	74.2	92.4	106	120	144	164	190	226
48 hour	2880	76.2	82	101	116	130	156	178	202	237
72 hour	4320	88.3	94.8	116	131	146	173	196	218	252
96 hour	5760	98.4	106	128	143	158	186	208	230	264
120 hour	7200	107	115	139	154	168	196	219	242	275
144 hour	8640	116	124	149	164	178	206	228	252	285
168 hour	10080	123	133	159	174	187	216	238	262	295
1-Day Winter Factor			0.95	0.90	0.90	0.90	0.85	0.85	0.80	0.75
7-Day Winter Factor			1.00	1.00	1.00	0.95	0.95	0.95	0.90	0.90

IFD Design Rainfall Intensities (mm/hr) for Huntly Mine (based on data from Bureau of Meteorology 28/10/2022).

		Annual Exceedance Probability (AEP)								
Duration	**Duration in min**	**63.20%**	**50%**	**20%**	**10%**	**5%**	**2%**	**1%**	**1 in 200**	**1 in 500**
1 min	1	119	131	168	194	218	251	276	330	397
2 min	2	107	117	147	168	187	211	228	265	316
3 min	3	94.9	104	131	150	168	190	206	241	288
4 min	4	85.2	93.3	119	136	153	173	189	223	268
5 min	5	77.5	85.1	109	125	140	160	175	208	250
10 min	10	55.3	61	78.7	90.6	102	118	130	156	189
15 min	15	44.4	48.9	63.1	72.8	82.2	95.1	105	126	152
20 min	20	37.6	41.4	53.4	61.6	69.6	80.4	88.8	106	128
25 min	25	33	36.3	46.7	53.8	60.8	70.1	77.4	92.3	111
30 min	30	29.6	32.5	41.7	48	54.2	62.6	69	82.1	98.9
45 min	45	23.1	25.3	32.3	37.1	41.9	48.2	53.0	62.9	75.6
1 hour	60	19.3	21.1	26.9	30.8	34.8	39.9	43.9	52	62.5
1.5 hour	90	15	16.3	20.6	23.7	26.7	30.6	33.7	39.9	48
2 hour	120	12.5	13.6	17.1	19.6	22.1	25.4	28	33.3	40
3 hour	180	9.61	10.4	13.1	15	17	19.6	21.7	25.9	31.2
4.5 hour	270	7.4	8.03	10.1	11.6	13.1	15.2	17	20.3	24.6
6 hour	360	6.14	6.66	8.37	9.61	10.9	12.7	14.3	17.2	20.8
9 hour	540	4.72	5.11	6.43	7.39	8.39	9.92	11.2	13.5	16.4
12 hour	720	3.91	4.24	5.33	6.13	6.97	8.29	9.39	11.4	13.8
18 hour	1080	3	3.25	4.08	4.69	5.34	6.39	7.29	8.76	10.6
24 hour	1440	2.49	2.69	3.37	3.87	4.4	5.28	6.04	7.2	8.67
30 hour	1800	2.15	2.32	2.9	3.33	3.77	4.54	5.19	6.09	7.27
36 hour	2160	1.91	2.06	2.57	2.94	3.32	4	4.56	5.28	6.27
48 hour	2880	1.59	1.71	2.11	2.41	2.71	3.25	3.7	4.2	4.93
72 hour	4320	1.23	1.32	1.61	1.82	2.03	2.4	2.72	3.02	3.5
96 hour	5760	1.03	1.1	1.33	1.49	1.65	1.93	2.17	2.4	2.75
120 hour	7200	0.90	0.96	1.16	1.28	1.4	1.64	1.82	2.01	2.29
144 hour	8640	0.80	0.86	1.03	1.14	1.24	1.43	1.59	1.75	1.98
168 hour	10080	0.73	0.79	0.945	1.04	1.12	1.28	1.42	1.56	1.76

IFD Design Rainfall Depths (mm) for Willowdale Mine (based on data from Bureau of Meteorology 28/10/2022).

Annual Exceedance Probability (AEP)												
Duration	**Duration in min**	**63.20%**	**50%**	**20%**	**10%**	**5%**	**2%**	**1%**	**1 in 200**	**1 in 500**	**1 in 1000%**	**1 in 2000%**
1 min	1	2.00	2.20	2.83	3.29	3.76	4.41	4.94	5.77	6.96	8.01	9.19
2 min	2	3.62	3.93	4.87	5.51	6.12	6.85	7.38	8.54	10.3	11.9	13.5
3 min	3	4.81	5.22	6.55	7.45	8.34	9.44	10.3	11.9	14.3	16.5	18.9
4 min	4	5.74	6.26	7.93	9.09	10.3	11.8	12.9	15.1	18.1	20.9	23.9
5 min	5	6.52	7.12	9.1	10.5	11.9	13.8	15.3	17.9	21.5	24.8	28.4
10 min	10	9.22	10.1	13.2	15.4	17.7	20.9	23.6	27.6	33.3	38.3	44.0
15 min	15	11.0	12.1	15.8	18.4	21.2	25.2	28.5	33.3	40.1	46.2	53.1
20 min	20	12.5	13.7	17.7	20.7	23.8	28.1	31.7	37.1	44.7	51.4	59.1
25 min	25	13.7	15.0	19.3	22.5	25.8	30.4	34.1	39.9	48.0	55.3	63.5
30 min	30	14.7	16.1	20.7	24.0	27.5	32.2	36.1	42.1	50.7	58.4	67.0
45 min	45	17.3	18.9	24.1	27.7	31.4	36.5	40.5	47.2	56.9	65.4	75.0
1 hour	60	19.4	21.2	26.8	30.7	34.6	39.9	43.9	51.2	61.7	71.0	81.4
1.5 hour	90	22.8	24.8	31.1	35.5	39.8	45.5	49.8	58.1	69.9	80.5	92.3
2 hour	120	25.5	27.8	34.8	39.6	44.3	50.4	55.1	64.2	77.4	89.0	102
3 hour	180	29.9	32.5	40.7	46.3	51.8	59.1	64.7	75.5	91.0	105	120
4.5 hour	270	35.0	38.0	47.9	54.6	61.3	70.5	77.6	90.8	109	126	145
6 hour	360	38.9	42.4	53.6	61.5	69.4	80.4	89.2	104	126	145	167
9 hour	540	45.1	49.3	62.8	72.6	82.6	97.2	109	128	154	178	205
12 hour	720	49.9	54.5	69.9	81.3	93.2	111	126	147	178	205	236
18 hour	1080	57.3	62.5	80.6	94.4	109	132	151	177	213	246	282
24 hour	1440	62.9	68.6	88.4	104	121	147	169	198	238	274	315
30 hour	1800	67.6	73.6	94.7	112	130	158	183	215	259	295	338
36 hour	2160	71.7	77.9	99.9	118	137	167	193	226	272	309	353
48 hour	2880	78.8	85.2	109	127	148	180	207	239	287	325	370
72 hour	4320	90.7	97.6	122	142	163	196	223	252	298	339	383
96 hour	5760	101	109	134	154	175	206	233	261	304	345	388
120 hour	7200	112	120	147	166	186	217	242	269	310	349	392
144 hour	8640	122	131	159	178	197	227	252	279	318	353	396
168 hour	10080	133	143	173	192	208	240	264	290	326	358	401
1-Day Winter Factor			0.95	0.90	0.90	0.90	0.85	0.85	0.80	0.75	0.75	0.70
7-Day Winter Factor			1.00	1.00	1.00	0.95	0.95	0.95	0.90	0.90	0.90	0.85

IFD Design Rainfall Intensities (mm/hr) for Willowdale Mine
(based on data from Bureau of Meteorology).

Annual Exceedance Probability (AEP)										
Duration	**Duration in min**	**63.20%**	**50%**	**20%**	**10%**	**5%**	**2%**	**1%**	**1 in 200**	**1 in 500**
1 min	1	120	132	170	197	225	265	297	346	418
2 min	2	109	118	146	165	184	205	221	256	309
3 min	3	96.1	104	131	149	167	189	205	238	287
4 min	4	86.1	93.9	119	136	154	177	194	226	272
5 min	5	78.2	85.5	109	126	143	166	184	214	258
10 min	10	55.3	60.8	78.9	92.2	106	126	142	166	200
15 min	15	44.2	48.5	63.1	73.7	84.8	101	114	133	161
20 min	20	37.4	41.1	53.2	62.1	71.3	84.4	95.1	111	134
25 min	25	32.8	36.0	46.4	54.0	61.8	72.9	81.9	95.7	115
30 min	30	29.5	32.3	41.4	48.1	54.9	64.4	72.1	84.2	101
45 min	45	23.1	25.2	32.1	37.0	41.9	48.6	54.0	62.9	75.8
1 hour	60	19.4	21.2	26.8	30.7	34.6	39.9	43.9	51.2	61.7
1.5 hour	90	15.2	16.5	20.8	23.7	26.6	30.3	33.2	38.7	46.6
2 hour	120	12.8	13.9	17.4	19.8	22.1	25.2	27.6	32.1	38.7
3 hour	180	9.97	10.8	13.6	15.4	17.3	19.7	21.6	25.2	30.3
4.5 hour	270	7.77	8.45	10.6	12.1	13.6	15.7	17.3	20.2	24.3
6 hour	360	6.49	7.07	8.94	10.3	11.6	13.4	14.9	17.4	21.0
9 hour	540	5.02	5.47	6.98	8.06	9.18	10.8	12.1	14.2	17.1
12 hour	720	4.16	4.54	5.82	6.77	7.77	9.24	10.5	12.3	14.8
18 hour	1080	3.18	3.47	4.48	5.24	6.07	7.32	8.38	9.82	11.8
24 hour	1440	2.62	2.86	3.69	4.33	5.05	6.12	7.05	8.23	9.92
30 hour	1800	2.25	2.45	3.16	3.72	4.34	5.28	6.09	7.17	8.63
36 hour	2160	1.99	2.16	2.78	3.27	3.82	4.64	5.36	6.29	7.56
48 hour	2880	1.64	1.78	2.26	2.65	3.09	3.75	4.32	4.99	5.97
72 hour	4320	1.26	1.36	1.70	1.97	2.27	2.72	3.10	3.50	4.14
96 hour	5760	1.06	1.13	1.40	1.60	1.82	2.15	2.43	2.71	3.17
120 hour	7200	0.93	1.00	1.22	1.38	1.55	1.80	2.02	2.24	2.58
144 hour	8640	0.85	0.91	1.11	1.24	1.37	1.58	1.75	1.94	2.21
168 hour	10080	0.79	0.85	1.03	1.14	1.24	1.43	1.57	1.73	1.94

Design Rainfall Polynomials

The BoM has fitted curves to the design rainfall depth curves to facilitate estimation of design rainfall depths using spreadsheets and other computational means. The form of the equation is as follows:

$$D_p = e^{(C_0+C_1t+C_2t^2+C_3t^3+C_4t^4+C_5t^5+C_6t^6)}$$

where D_p is the Design rainfall depth for the specified probability and duration, mm,
p is probability,
C_i is the polynomial coefficient, i = 0 to 6,
t is Ln(T), and
T is the duration in minutes.

Or expressed in another form:

$$D_p = e^{\{\sum_{i=0}^{6} C_i[Ln(T)]^i\}}$$

This approach aids in computing design rainfall depths directly in a spreadsheet rather than needing to refer to the charts or tables.

The tables below present the polynomial coefficients for Huntly and Willowdale respectively, sourced from BoM. For the Rare design rainfalls (1 in 200 to 1 in 2000 AEP), there are separate curves (and therefore a separate set of coefficients in the tables) to estimate rare design rainfalls from 1 day to 7 days duration and for estimating rainfalls for sub-daily durations from 1 minute to 1 day. Further information on this aspect can be found on the BoM website at:

http://www.bom.gov.au/water/designRainfalls/revised-ifd/?content=help#displayCoefficients

Polynomial Coefficients for Design Rainfall Depths at Huntly (data from Bureau of Meteorology 28/10/2022).

Annual Exceedance Probability (AEP) Coefficients								
Coefficient	**63.20%**	**50%**	**20%**	**10%**	**5%**	**2%**	**1%**	
C0	0.68603	0.78115	1.03162	1.17176	1.29215	1.43230	1.52781	
C1	0.95994	0.92750	0.85216	0.81504	0.78523	0.70290	0.64267	
C2	-0.17957	-0.14066	-0.05100	-0.00739	0.02724	0.12424	0.19523	
C3	0.02699	0.01046	-0.02755	-0.04596	-0.06052	-0.10188	-0.13226	
C4	-0.00194	0.00123	0.00853	0.01207	0.01487	0.02293	0.02890	
C5	0.00003	-0.00025	-0.00090	-0.00122	-0.00146	-0.00219	-0.00273	
C6	0.00000	0.00001	0.00003	0.00004	0.00005	0.00008	0.00009	
Rare AEP >	**Coefficients for periods of 1 to 7 days**				**Coefficients for Sub-Daily Periods**			
	1 in 200	**1 in 500**	**1 in 1000**	**1 in 2000**	**1 in 200**	**1 in 500**	**1 in 1000**	**1 in 2000**
C0	-12.14468	-10.61891	-8.72292	-6.29435	1.70401	1.89050	2.02923	2.16631
C1	6.00076	5.57880	4.98939	4.20608	0.54037	0.49218	0.45450	0.41588
C2	-0.70592	-0.66014	-0.59286	-0.50217	0.32538	0.38618	0.43373	0.48251
C3	0.02858	0.02678	0.02410	0.02048	-0.19232	-0.22008	-0.24180	-0.26409
C4	0.00000	0.00000	0.00000	0.00000	0.04160	0.04738	0.05192	0.05657

C5	0.00000	0.00000	0.00000	0.00000	-0.00397	-0.00453	-0.00496	-0.00541
C6	0.00000	0.00000	0.00000	0.00000	0.00014	0.00016	0.00018	0.00019

Polynomial Coefficients for Design Rainfall Depths at Willowdale (data from Bureau of Meteorology 28/10/2022).

Annual Exceedance Probability (AEP) Coefficients								
Coefficient	**63.20%**	**50%**	**20%**	**10%**	**5%**	**2%**	**1%**	
C0	0.69485	0.78650	1.04009	1.18998	1.32354	1.48470	1.59827	
C1	0.96864	0.92495	0.78211	0.68084	0.57910	0.39622	0.25167	
C2	-0.17796	-0.12371	0.04940	0.16957	0.28898	0.50694	0.67884	
C3	0.01783	-0.00631	-0.08108	-0.13163	-0.18114	-0.27373	-0.34659	
C4	0.00175	0.00663	0.02121	0.03073	0.03989	0.05763	0.07156	
C5	-0.00047	-0.00093	-0.00224	-0.00306	-0.00383	-0.00540	-0.00662	
C6	0.00002	0.00004	0.00009	0.00011	0.00014	0.00019	0.00023	
Rare AEP >	**Coefficients for periods of 1 to 7 days**				**Coefficients for Sub-Daily Periods**			
	1 in 200	**1 in 500**	**1 in 1000**	**1 in 2000**	**1 in 200**	**1 in 500**	**1 in 1000**	**1 in 2000**
C0	-46.64907	-46.71431	-29.65789	-30.03461	1.75331	1.93995	2.08027	2.21859
C1	18.42271	18.40159	12.14152	12.36241	0.21773	0.21563	0.22112	0.20133
C2	-2.18078	-2.16105	-1.39034	-1.42010	0.72103	0.72262	0.71586	0.74081
C3	0.08656	0.08491	0.05331	0.05457	-0.36555	-0.36566	-0.36254	-0.37393
C4	0.00000	0.00000	0.00000	0.00000	0.07544	0.07530	0.07461	0.07699
C5	0.00000	0.00000	0.00000	0.00000	-0.00699	-0.00695	-0.00688	-0.00711
C6	0.00000	0.00000	0.00000	0.00000	0.00024	0.00024	0.00023	0.00024

Daily Rainfall Data

Daily Rainfall (mm) at Huntly since 1980 (data from Bureau of Meteorology).

Year	Month	Day																														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1980	1	0.1	0	0	0	0	0	0	0	0.6	0	0	0	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	4.2	43.8	1.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	3	0	0	0.4	0	0	0	0	0	0	0	3.2	0.2	0.1	0	0	0.3	0	0	0	8.1	0.4	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	26	0	0	0	0.3	1.8	0.8	0	0	0	3.2	0.4	0	11.4	8.6	4.8	16.8	42.8	6.6	9	0.2	0.1	0	0	0.1	0	0	
	5	0.1	0	0	0	10.2	18.6	3.8	1.2	6.8	0	0	1.4	0	0	0.4	0.2	0	0	0.1	0	0	1.8	1.6	1.8	1.4	0.2	0	54.2	19.6	12.8	4
	6	0.2	27.2	10.8	8.6	18.8	0	0.2	0	0	0	0	0	0	4.6	7	6.6	0.1	0	0	1.1	4.8	51	3.4	11.8	19.2	3.2	6	0	19.4	12	
	7	4	1.6	0.6	0	0	0	0	0	0.1	40.2	26.8	12	6	1.2	1.8	27.9	1.5	0.2	0	0	0	0.1	0	4.6	15.6	21.4	18	5.1	0.4	0.1	18.4
	8	15.4	0	0	2.6	10.2	5.6	0	1	51.6	3	0.6	0.1	0	0.2	0	0	0.8	24.8	0.1	0.2	27.1	5	1.6	0.8	0	39.2	0.8	1.6	8.2	18.6	0
	9	3.8	0	12.8	0	0	11.2	0	4.2	0	0.1	0	0	0	26.4	0.1	10.8	2.2	1	0.4	0	0	21	14.6	11	0.1	0	0	0	16.6	3.2	
	10	1.8	2	0	9.6	5.6	0	0	0	1.4	0.2	0	0	0	0	0	7.6	0	0	0	0.3	12.4	14	0	0.1	5	3.2	0.9	0.1	0	0	0
	11	0	0	0.8	0	1.2	0.1	0	0	0	0	0	0	0.2	0	1.8	0	4.6	6	0	0	0	0	0	0	11.6	13.6	0.4	0.1	1	0.3	
	12	0	0	0	0	0	0	0	0	0	0.6	0	0	0	0	0	0	0	0	0	0	5.2	0.1	0	0	0	0	0	0	0	7.2	46
1981	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	18.6	0.4	0.1	0	0	0	0	0	0	0	0			
	3	0	0	0	0	0	24.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	14	52.8	0	0	0	1.6	0.1	0.4	7.6	2.8	0.1	0.1	0	0	0	1	0.2	0	0	0	0.1	0	0	0.6	0	0.6	1.2	0	
	5	0.2	0	0	0.1	0	0	0	0	0	0	0	0	0	17.4	2.6	0	0	0	0	0	23.4	1.4	0	0	42	30.4	14.2	24.2	0.8	36.3	0.2
	6	0	10.6	9.8	0	0	0	28.6	38.6	5	0.8	0.4	14.4	0.2	0.1	0.1	5.4	6.6	0	16	17.2	2.8	0.2	0.2	2.2	9.6	9.2	18.6	8.4	19	12	
	7	3.8	0.6	0	0	0	0.1	0	0.4	0.8	2.8	0.4	4.2	0	0.8	10.6	0.4	19.4	2.4	1.6	0.1	2.6	68.2	23.2	3.4	21.6	0	23.4	0	2.6	27.2	0.4
	8	12.4	3	2.6	10.4	4.8	0.4	17	3.4	0	33	18.6	6.2	4.2	12.8	33.3	13	3.8	5.6	16.2	4.8	0	0	1.2	0.2	5.4	0	0	3.2	0.4	0	0
	9	0	0	0	0.4	4.2	0	0.4	56.2	0.4	1.6	0	0	0	0	0	5.2	18.4	0.4	2	23.8	2.4	11	0.1	0	0	2.2	0	0	10.2	1.2	
	10	40.6	7.8	0.2	0	0	3.8	0.1	1.8	0.2	0	0	0.1	0.4	0	0	0	0	4.2	0	0	0	0.2	0	0	0	24.4	5	0	0.1	0	0
	11	10.8	7.6	2.6	0	0	0	0.6	0	0	0	0	15.4	0	0	0	0	0	0	0	0	0	2.6	0	0	4.2	26.2	6.6	0.8	0	0	
	12	1.2	0.8	0	1.2	1.4	0.8	0	0	0	10.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.6	0
1982	1	0	0	1.4	0	6.6	0.2	0	0	0	0	0	0	0	0	0	0	1.2	0	0	0.2	159.8	58.2	9.8	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0.6	0	0	0	0	0	0	0	0	0	1	0	0	0			
	3	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12.4	0.1	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	5	10.4	6.2	1.4	0.4	0	0	0	12.8	0.5	0.2	0	1.4	0.1	0	0	0	3.2	0	0	0	0	0.4	0.1	2.8	0.2	1.8	11.6	8.8	8.4	6.6	0.1
	6	0.2	0	27.6	1.2	0.2	0	0	19.6	14.9	8	15.8	1.6	6.4	8	13.6	27.4	3.4	14.8	4.2	0	0.2	0.2	0.2	9	10.2	2.8	0	0.1	3.3	0.2	
	7	13.1	0	2.2	17.9	5	15.4	0.5	0.8	0.8	4.8	0	0	6.1	0.4	39	36	3.4	0.2	11.2	13.6	5	16.6	6.8	3.6	3.4	3	21.6	1.6	0	0.1	0
	8	0.8	28.4	0.2	0	0	0	14.4	24	0.8	0.2	0.2	0.2	0.4	2.1	0	0.1	0	1.8	22.6	3.6	0	0	31.8	0.6	0	0	0.2	1.2	5.8	0.4	2
	9	0.8	2	0.4	0	0.2	0	0	0	0	0	0	0	0	0.4	66.8	28.2	1.6	1	0.2	0.8	8.6	15	1.2	20.4	6	0.2	0	0	0	0.1	
	10	0	0.2	0.4	15.6	24.4	4.2	0.2	2.3	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	2.8	13.6	0	0	0.6	0	0	0
	11	0	0	0	1.8	0.8	1.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	2.6	0	0	0	
	12	0	0	0	0	0	0	0	0	0.1	2.6	11.6	9	0.1	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6
1983	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	2.2
	2	0.1	0	0	0	20	35	11.6	5.4	0	0	0	0	0	0.2	15.6	15.6	0.2	0	0	0	0	0	0	0	8.4	0	0.5	0			
	3	0	0	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	3.8	1.6
	4	10.7	0.8	0.2	0	0.9	0.2	2	6.4	2.2	0	0	0	0	0	0	0	0	0	0	0	1.8	0	0	0	0	0	0	2.4	0	0	

	5	0	6.2	30.2	0.2	0	7.4	0.4	0	0.4	0	0	6.4	3.6	0.2	0	0	0.8	1.6	0	0	0	0	0	0	0	0	6.8	0.4	0	0.2	0
	6	39	45.8	2.2	9.6	2.8	4	0.2	0	0	0	0	0	0	0	0	1.2	11	41.8	12.8	4	0.2	7.2	0.4	0.2	11.4	10.2	9.6	65.4	33.6	10.6	
	7	1.2	0	0	0.6	0.1	0.1	0	18.2	25	7.2	0.2	0.2	0	0	0.1	0	0	1	3.4	0.2	3.6	0.1	0	43.6	47.4	22	0.6	0.2	0.2	19.4	0.5
	8	0	1	4.2	8	57.4	6.4	0	2	0.2	0	0	29.2	10.2	19.4	0.2	0	0	7.8	0	5	0.2	3.4	39.6	19.2	36.6	4.6	14.4	18.6	15.6	1	0.4
	9	24.2	18.2	14.7	19.8	2	12.4	16.2	0.2	0.2	0.2	6	24.6	14.4	0.6	7	2.4	2	0.2	0.1	0	0	2.6	0.4	4.7	0	0	2.2	0	1.6	0	
	10	0	0	0	0	0	0	0.4	0	0	0	0	0	14.4	0.3	0	0	6.2	0	0	0	0.2	0	0	0	0	0.2	0	0	0	0	0
	11	0	0	0	0	0.5	3.4	20.2	1.6	0	0	0	1.8	5.4	0	0	0	11.8	0.8	1.6	0	0	0	0	0	0	0	0	0	0	0	
	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0	2.1	0.1	8.2	0	22
1984	1	0.2	0	0	0	0.8	0	0	0	0	0	0	0	0	0	1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	4.2	0	0	0	0.4	0	0	0		
	3	0	0	0	3.2	0	0	0	2.2	4.2	0	0	0	0	0	0	9.6	0.4	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0
	4	0	0	0	0	0	0	0	0	0	0	16.2	1	6.2	0	0	0	5.6	0.8	0.1	0	0	4.2	0	0	0	0	0	0	0	93.4	
	5	4	1.4	0.1	0	0	2.2	36.4	31.6	9.8	10.8	10.2	0.4	0.1	0.2	9.6	9.8	22.4	11.4	6.2	38.6	11	0.3	0	0	4.6	26.2	39.2	25.4	4.8	7.8	0.8
	6	0.2	2.2	7.8	0	46.2	12.8	0.2	0	0	1.6	0	8.2	39.4	0.2	3	0.2	0.2	0	0	0.2	62.8	13.4	0.2	0	0.4	0	0.1	0	0	1.5	
	7	0.8	0	0.8	14.8	23	20.4	3.8	8.6	0.2	0	0	0	0	0	2	10.8	0.8	0	0	1.6	0	0	0.2	0.1	0	17.2	1.2	0	0	4.2	0.3
	8	0.1	14.2	11.4	0.8	7.6	19.6	13.2	19.2	6.2	0.2	0	0.2	4	0.4	9.6	2.4	8.2	0.8	19.2	9.4	4.2	1.4	6	1	0	0.6	0	1.8	0	9.2	0
	9	1.4	7.4	19.8	0.4	29.2	0	0	0.6	25	0	0	0	0.6	66	12.6	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	
	10	4.2	1.6	0	0.6	0	0	6.4	7.4	1	0.2	0.1	2.4	0	0	0	0	0	0	0	0	0	0	0.2	0.1	0	0	0	0	0.4	11.2	3.6
	11	3	0.6	1.6	0	4	12.2	3.4	27.2	13	0	0	0	0	0	0	9	30.2	10.4	0	0	0	0	3.5	0	0	0.8	0.2	0	0	0	
	12	0	0	0	0	0	0	0.6	0	3.8	0	0	0	0	2.8	0	0	0	0	0	0	0	0	0	0	0	0	0	28.4	2.8	0	0.4
1985	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.2	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	36.8	0	0	0	1	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0			
	3	0.4	0	0	0	0	0	0	27.4	0.4	0	0.1	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	3.1	58.4	40.8	6.4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0.6	4	5	0.6	
	5	0	0	4	3.6	0	0	0	0	0	0	0	15.6	10.4	0.1	0	0	0.1	0	0	0	0	0	0	0	0	22	11.6	4	5.2	0	0
	6	0	0	0	0	10.8	4.1	30.2	14	6.8	8	6.8	1.2	13.3	2	1.4	20	16.4	0.1	0.1	0	0.2	11	1.2	1.8	16.2	0.8	4.6	0.1	41.2	10.8	
	7	70	3.4	2.4	0	0	0	0	0	4.2	0	19.8	1.6	51.6	21.8	0	0	0	5.8	4	8	0	0	0	20	0.6	2.6	26.6	6.2	0.4	0	0
	8	0.2	0	38.4	12	13	1	0	0	10	0.6	1.6	13.8	0	0	0	0	0	24.5	33	20.8	0	0	0.6	20.2	22.8	1.2	30	0	0	8.2	19
	9	0	0	0	0	0	0	0	0	10.2	0.6	0	0	0	4.2	0.3	0	4.8	13.2	0	0	5.8	21	1.2	0	0	0	0	0	3.2	3.6	
	10	0	0	0.6	1.2	9	0	0	0	0	0	0	7.8	2.8	0	0	0	0	0	0	0	4.2	0	0	0	0	9.2	4.6	13.2	0.8	0	0
	11	0	0	7.8	0	0	0	1.4	23.4	13.4	0	0	0	0	0	0	0	0	0	0	0	1.4	4	0.6	0	0	0	0	0	0	1.3	
	12	1	0	0	0	1	0	0	0	0	0	0	0	0	3	0	0	0	5.8	0.8	1.8	0	0	0	3	0	0	0	0	0	0	0
1986	1	0	0	0	0	0	0	0	0	6	1.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	4.4	0	0	0	3.4	0	5.2	0.2	0	0	0	0	2.6	5	65	0.2	0	0	9.6	12.8	0			
	3	0	0	0	0	0	0.2	0	0	3.6	2	13.2	0.8	0	0	0	0	0	0	6.6	10.8	0.2	0	0	0	0	0	0	0.4	10.2	0	0
	4	3.2	0	3.6	0.2	0	0	0	0	0	2.2	0	0	0	3.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	5	0	0	0	0	13.6	0.8	2.6	9.2	0	3.2	0	1.2	5.6	11	0	1	0	0.6	12.6	17.6	37.6	17.6	0	0	0	20	10	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0.4	6.2	10	8	0.4	0	0	0	0.4	5.2	7	29.8	16.2	5.4	29	7.4	0.2	
	7	0.1	8.2	22.2	4.6	6.2	5.2	0.2	0	0	0	0.1	0	23.8	20	17.6	0.2	0.1	1.2	1.4	0	8.8	11.6	8.2	0.4	0.2	0.2	0	0	0	22.2	15
	8	19.2	0	0	0	0	5.6	4.2	11.2	6	0	5.4	1.4	0.2	0.2	11.6	0	0	16.4	6.6	1.8	3.6	20.6	11.2	8	12.2	0	0.2	18.6	1.2	7.4	4.2
	9	0.2	0.1	0.6	8.8	0	0	0	0.6	0	2	2	0	0	1.6	33.2	0.6	0	11.8	7.8	2	2	3	0.8	0	1.4	0.8	0	0	1.4	0.2	
	10	0	0	0	0	0	7.4	0	0.4	0	0.4	0	24.6	19.2	1.4	2.4	0.4	19.2	2	4.8	0	0	0	0	0	0	0	6.6	0.2	0.4	1	0
	11	0	0	0	8	1.8	0.2	0	10.4	27.2	0	0	0	0	0.8	0	0.4	1.8	0	0	0	0	0	0	0	0	0	0.2	0	0	5.8	
	12	0	0	0	0	0	1	0	0	0	0	0	0	0	0.8	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

1987	1	0	0	0	0	0	0	0	0	0	3.8	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0	2	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0.6	0	0	7	4.2	18.6	0.2	0	0	0	0	0	2.8	1.8	0	0	0	0	0.4	5.2
	4	0.4	0	0	1.8	0	0	1.2	89.6	6.4	0.2	8	1.2	0	0	0	0	0	0	0	0	0.4	0.8	0.1	0	21	15.8	1.4	0	0	1.4	
	5	23.4	1.4	0	0	0	0	0	2.8	7.2	17.8	0.6	0	0	2.8	0.1	0	0	0	0	0	0	0	2.6	0.4	0	0	0	0	0	0	0
	6	0	0	0	4.2	0	6	13.2	0.8	11.8	6	0	0.6	0	0	8.2	4.2	19.8	16.6	56	21.8	9.4	7.2	1	3.4	8.8	4.2	1.4	3.6	8.2	0	
	7	0.6	4.6	10.8	10.8	0	0	0	38.6	0	0.4	0	3.8	4	8	4	5.6	0	0.2	0	0	0	5	16.2	13.4	0	0	0	0	87.2	27.8	26.8
	8	3	0	0	0	0	0	0	0	0	0	0	4.8	47	0	0	0	0	0	0	2.8	6.2	2.4	0	1	24.4	0	0	0	0.4	0	0
	9	0.1	0	0	0	0	1.2	0	0	0	0	0	0	0	0	0	0	0	9.2	7	0	0.2	0	35.4	9.6	0.4	22	3.6	0.2	0	0	
	10	0	0	6.2	0.4	0	0	0	0	0	0	0	0	0.4	10.8	7.6	0	0.8	0	0	0	0.2	0	0	0	0	0	0	0	0	6.6	3.6
	11	7.8	2.6	0	0	0	0	0	0	0	0	0	0	0	0.1	0.4	3.4	0.6	5.4	0.4	3.6	0.2	0	1	0.2	0	0	0	4	11.2	6.8	
	12	0	0	0	0	0	0	7.2	0	0	0	0	0	0	0	0	0	0	0	0.6	0	0	0	0	26.4	1	7.4	0.8	0	0	5.2	0.2
1988	1	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	2.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0	0	0	0	0		
	3	0	0.6	0	0	0	0.1	0.2	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	5.2	1	0.8	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	10.2	0	0	1	2.6	0.1	3.8	31.2	42.6	0.2	
	5	0	0.1	0	0	0.1	0	0	0	0	0	0	7.6	54.2	45	18.2	7.2	3.2	11	0.2	12.4	12.4	4.2	1.6	0.4	2.6	3.2	3.2	0	0	1.6	10.6
	6	57.4	39.8	15.4	0	0	8.8	6	13.6	1.2	19	2.6	10	34	21	1.4	32.2	1.6	7.8	2.2	12.8	0.2	0	0	0	30	16.8	0.2	0	0	0	
	7	0	0	0	0.4	8.6	1.4	29	11	4	0.6	0	0.4	23.4	4.4	22.4	0.4	2.8	13.8	1.4	0	0	3.2	17.6	60.2	12.2	0	0	6.2	0	0	0
	8	0	0	0	0	0	0	0	0	0	8	0.2	34.6	10	10.8	19	9.8	0.8	0.2	0.4	8.2	0.4	0	0	0	39.6	3	0	0	21.4	11.4	0
	9	0	0	0	0	0	28.8	10.4	2	3.2	6.6	1	0.2	0	0.6	12.4	1.4	4.4	0.4	6.4	5	5.2	26.8	5.2	1.6	1.2	7.4	6	17.2	24.8	6.8	
	10	5.6	0.8	7.6	6.6	9.4	11	11.2	0	3	0	0.4	0.8	0.2	0	0	0	0	0.8	4	18	5.1	0.2	0	0	0	0.5	0	0	0	0	0
	11	22.8	9.4	3.2	0.2	0	5.2	28.6	1.8	0	0	0	22.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	12	0	0	0.4	0	0	0	0	0	0	2.4	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	1	0	0	0	0	0	6.4	0.6	0	0	0	0	2	0	0	5	0	0	0	0	0	0	0	0	0	8.4	7	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0.6	0	0.4	0	1.4	0	0	0	0	0	0	0	0	5.2	21	25	17.2			
	3	2.2	3.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	6.6	18	19	0.8	0	0	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29.2	0.1	0.2	0.1	0.1	0	0	
	5	1.2	0.1	0	0	0	0	0	0.1	0	0	0.1	0	0	0	1.6	61.8	0.6	0.1	0	0.2	79.6	0.1	13.8	1.8	0.1	0.1	32.6	16.2	0.3	9.4	7.8
	6	0.2	0.8	4.4	0.2	0.2	3.2	6	0.8	0.1	0	3.8	12.2	6.8	1.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0	0.1	0	0.1	0	0	28.8	2.2	41.8	
	7	2.8	14	5.8	0.1	0	0	3.4	10.8	0.2	0	0	10	6.6	18.2	0.2	0.4	0	0	0.6	41.4	34.2	1.6	5.6	20.6	9	0.1	7.8	22.8	11.8	1.4	0.1
	8	0	5.4	9.6	0.1	0	0.8	0.1	0.2	0.1	0.1	0	0	5.2	0.8	0.2	0	0	69.3	5.4	1.2	2.2	0	0	3.4	0.1	0	1	4.8	7.2	26.4	0.4
	9	4.8	18.2	0.4	0.1	1.2	0.1	13.2	6.4	0.4	3.4	0.1	0.1	0.1	0.1	16.4	0.2	0.1	14	6.4	9.2	7.6	2	5.8	8.6	0.2	0.1	0.1	14.6	2.8	2.9	
	10	3.8	26.8	16	3.4	1	18	13.8	1	5.2	0.2	1.4	0.6	12	4.4	8	0.1	26.6	11	4.6	0	0.8	0	0.1	0.1	4	0.3	0	0	6.6	1.4	0.1
	11	0.1	0	0	0	0	0	0	0	0	0	6.2	4.8	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	
	12	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0.9	0	0	0	0	0	0	1	11.4	1.1	0	0	4	0	0	0
1990	1	0	0	0	0	0	0	0	0	2.2	7.2	0	0	0	0	0.4	0.1	0	0	0	0	1.4	0.8	5.4	0	0	0	0	2.8	18.2	0.1	0
	2	0	0	0	0	0	0	0	0	0	2.8	1.8	0	37.2	4.4	14	1.1	0.2	0	0	0	0	0	0	0	0	0	0	0			
	3	1.2	0	0	1	0.2	0	6.6	0	0	0	0	4.6	3.6	0	0	0	0	0	0	0	0	0.1	0	0	0	28.4	0	0.1	0	0	0
	4	0	9.8	4.4	0.3	0	0	0	0	0	12	3.2	0	0	0	0	0	0	0	0.2	45.2	0	14	14	10.4	0.3	0.6	6.8	3.2	0.1	0.2	
	5	6	0.2	0.2	11.2	0.2	0	0.1	2.2	1	0.1	0.1	0.1	11	13.6	1.2	0.1	0	8.6	1.8	0	0	0.1	0.1	0.1	0	2.2	15.4	28	6.6	0.2	0.1
	6	0	0.1	0.1	0	0	30.4	0.2	22.8	8.2	4.8	22.8	1.8	12.2	10.6	1.2	0.2	0.2	0	0.2	0.1	0.2	0.2	4.2	0.6	0	0.1	0	0.2	0	2.8	
	7	0.2	0.1	0	0	0	0.1	0.1	0	0	13	6.8	23	39.8	16.2	36.2	22.8	15.4	1	3.2	9.6	28	14	19.4	12.2	9.6	0.1	0.1	0.1	2.8	0.2	0.1
	8	0	26.6	28.4	16.4	1.4	0.6	0.6	0.1	0.1	12	5.2	1.2	4.6	4.4	0.1	0	0.1	11.4	25.4	3.2	0.6	0	0	0.2	0.1	0	2.2	11.8	3.8	2.2	0.1

	9	0.4	0.2	0.2	0	0	0	10.6	0.1	2.4	13	0.2	0.1	0.1	0	0	0.8	17.2	22	4	4.4	0.1	0.6	8	38	7.6	0.8	0	0.1	0.1	0.1	
	10	0	0	0.1	0	0	0	0.2	0	8.8	18	0	0	20.6	1.6	0	0	4.6	0.1	0.1	0	0	0	0	0	0	3.4	0	0	18.4	6.2	0.2
	11	5.8	8.8	0	0	0.2	0	0	0	0.2	0	0	0	5.8	0	0	0	10.4	0.1	6.4	1.6	0	0	0	0	0	0	0	0	0	0	
	12	0	0	0	5.6	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.2	0	0	0	0	0	0	0	0	0
1991	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	8	25.8	8.6	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	3.2	1.4	0	0	0	2.4	0	0
	4	0	0	0	0	0	0	0	0	7.4	66	23.4	0.2	0	0	0.1	0	0	0	0	0	3.2	0.8	0.6	0.9	0.2	0	0.1	0.1	0.1	0.1	
	5	0	0	0	0.1	1.3	0	0	0	0	0.2	0	0	0	0	17	7	0.1	0.1	0.1	2.6	27.2	29.4	9.2	2	0.1	0	0	19.6	28.8	22	9.4
	6	3.2	0.2	0.1	35.6	4.2	1.2	0.2	0.1	0	1	9.8	3.4	3.4	23.5	25.8	29.8	3.4	1.2	0.1	0.4	0	2	73	1.4	16	2.2	21.4	15.4	0.4	1.8	
	7	0.1	36.6	28.8	6.4	6.8	10.4	0.2	0.2	3.6	5.4	0.4	0.1	7.6	0.5	0.2	17.6	32.6	9.2	12.2	1.4	0.9	1.8	0.2	29.8	2	32.4	6.4	0.4	11.6	11	4.6
	8	32.8	30.8	22.8	16	9.2	0.1	0.2	0	0	0.2	0.2	0.1	0	0.2	0.2	0	0.8	26	6	5.2	0.5	2.2	1.5	0.1	0.1	19	5.4	5.4	6.6	0.2	0.2
	9	2	0.1	4.4	3	0.1	1	13.8	13.4	22.2	0.2	0.1	10.4	4.6	32.8	14.2	1	2.4	8	7.6	0.2	0.1	0.1	0.1	0.1	0	0	0	0	0	14.4	
	10	1.4	0	0	0	19.6	0.1	0.1	0.1	0.1	0	0	0.1	0	0	1	0	0	0	28.5	16.6	0.2	0.1	0.1	0	0	0	0	0	2.4	1.4	0
	11	0.6	4	0.4	0	23.2	0.2	0	0	0	0	0	0	21.2	8.6	1.4	1	0.6	1.4	0	0	0	0	0	0	2.8	0.6	0	0	0	0	
	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.8	20	4	0	0	0	0	0
1992	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.2	0.6	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	9.2	0	23.9	0.2	0.1	0	5	4.8	0.8	0	0.3	0.2	0	0	0	0	0	0	0	0	0	0	0		
	3	0	0	0	0.2	0	0	0	0	0	3	0	0	0	0	0	0	3.4	21.1	10	9.2	2.6	6.2	0	0.1	0	1.2	0	0	0	0	0
	4	0	0	4.2	0.1	0	0	1.8	0.3	0	0	0	0	0	0	0	0	0	0	19.8	0.1	0	0	0	0	0	0	2	16.9	0.2	0.8	
	5	2.8	4.2	8.6	18.6	6.4	12.8	4.6	0.1	0	0	0	0	0	2.8	0	0	0	0	0.8	0	6.2	7	15.8	21.2	0.3	0.1	0	0.4	27	6.8	1.2
	6	0	0	0.5	0.4	0.8	0	0	0.2	0	0	14.2	45	30.4	3.6	37	31.4	12.2	9.2	0.8	6.1	32	3.6	0.2	13.6	0.4	14	16	61	14.2	25.2	
	7	12.2	23	6.6	2.4	10	0.1	0	1.8	0.1	25.8	3	5	35	6.8	0.2	0	33.8	0.2	7	0.2	0.2	0.2	0.2	0	8.2	4.6	3.8	14.2	3	0.9	0.1
	8	0.1	7.2	1	12	12.2	4.2	18.6	1.4	12.8	27	30	1.6	3.6	9	13.4	13.2	0.2	0.1	0.2	0.1	0.1	0.1	0.1	2	10.2	41.2	1.8	37	0.4	2.8	17.2
	9	11	0.2	41.4	4.4	5.2	1	4	1.6	19.4	3.4	0.1	0	5.8	0.6	0.2	0	0	0.8	0	0.4	0.1	15.4	4.6	0.2	0.1	0.2	4	0	0	0	
	10	0	1.6	2.6	2.6	9.4	1	2	0.2	0	0	0	0.2	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0
	11	0	0	0	0	0	1	16.4	1.4	0	0	0	0	0	6.2	0	1.2	0.6	6.8	30.8	6.6	4.2	0.3	1	0	0	0	0	0	0	19.2	
	12	1.4	0	0	0	0	0	0	0.2	6.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0
1993	1	0	2.4	0	0	0	0	0	0	0	0	0	0	0	0	1.8	1.4	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0
	2	0	0	0	0	0	56	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9.8	11.4	43	0.3	0.2	0	0	3.8	0	0	0	0	4.2	0
	4	0	0	18.2	0.5	0.8	0.2	0	0	0	1.2	0	3.8	0	0	0	0	0	0.9	1.8	0.2	0	0.1	1	0	0	0	0	0	0	0	
	5	8.6	0.6	0	1.4	0.4	0.2	0	0	0	0	0.1	0	0	0	0	0	0	34.2	12.2	7.6	0.2	0	0	2.8	0.2	0.1	0.1	36.8	4.3	0.2	0.1
	6	0	0.8	0.2	0.1	0.1	0.1	0.1	0	5.6	0.4	0	0	0	0	0	40.1	2.6	11	1.1	2.6	0.2	0.1	0.1	0.1	4.8	2.2	31.6	5	20	6	
	7	0.8	32	2	2.4	0.2	0.2	0.2	0.1	1.6	21.6	14	33	0.4	1.6	6	14	0.4	0.2	0	0.2	0	27	3.6	0.3	4.4	24.4	34	22.8	28.8	9	11.6
	8	0.1	0.1	0.2	18.4	0.4	28	4.4	6.4	14.4	0.1	0.4	33.4	0.8	0.2	4.2	18.4	0.3	0.1	0.2	0.1	0.1	0.1	0.1	0	24	1.4	0.1	0	17.8	11.2	0.9
	9	0.1	0.1	0	40	2.2	19	13	12.4	0.2	0.1	0	8.4	1	0.1	1	11	11.2	6.6	6.4	0.2	0	0	21	0.4	0.2	0.2	2.6	0	0.6	24	
	10	2	17.6	0.2	0.2	0.1	0	1	1.8	0.6	0	0	0	0	0	0	0	0	0.8	0	0	0	0	3.2	0.6	3	0	11.2	2.2	0	0	7.4
	11	2.4	0	0	0	0	0	0	0	29.6	29.8	0.1	1.4	5	0	0	0	0	0.4	4	0.2	0.2	0	0	0	0	1.4	0	0	0	0	
	12	0	0	0	0	0	0	0	0	0.4	1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.8	0	0	0
1994	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.4	0.2	0	0	0	0	0
	2	0	0.6	1.4	0	0.4	1.8	0.2	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	2.4	0	1.2	0	0	1	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0.4	0	0	0	0	0	0	0	1	5.6	0.7	0.1	0.1	0	0.1	

	5	0	0	0	0	0	0.1	0	0	0	0	0	0.1	0.7	0.6	0.1	1.4	0	0	0	0	15.2	11.6	37.2	48.8	12	0.4	2.6	1	35.6	42.8	1.8
	6	26	25.6	0.2	1.8	0.4	0.2	14.4	6.4	17.2	0.2	8.8	1.4	0.1	0	0	0	0.4	0.8	6	36.4	49	21.6	1.2	6.8	4.6	0.4	30.4	1.6	0.4	0.7	
	7	24	15.5	14.4	2.6	6.2	13	2	29	12.8	13.2	5	0.1	5.4	6.8	2.4	2	4.2	0.2	0.2	0.2	0.2	14.6	0	4.2	0.1	0	0.1	2.8	1	0	0
	8	0	0	0	60.8	2	0.4	0.2	0.1	0.6	13.1	3.4	3.8	0.1	0.1	0	0	0.1	0.1	0.1	0.1	0.1	4.2	0.1	0.1	0	0.2	4	0.6	0	1	0.3
	9	6.8	12.2	5	0.4	0.1	0.1	10.6	0.1	0	13.2	22.8	0.1	2	3.6	0.1	0.1	0.1	0	0	0	0.1	0	0	0	0	0	1.8	0	0	12.2	
	10	10.4	1.2	3.4	0	5.2	0	0	0	0	0.8	0	0	0	8.6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	1.8	11.4	20	5.2	0.2	0	0	
	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0	0	0
1995	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0
	2	0	0	0	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.2	0	0	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.8	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	2.3	0.1	0.2	0	0	7.8	0.5	0	1.4	0	0	0	0	0	0	0	0	0	5.2	0.5	0	0.1	
	5	0	0.1	0	0	0	0	0	0	0	21	18	24	13	0.4	0.2	0.1	0	21.8	0.4	0	2	24	67.4	2.2	3	0	0	2	0.2	0.1	0.1
	6	0.1	7.8	0.2	0	3.8	22.4	41.8	25.2	22	1.6	0.1	0	0.1	0.1	0.1	0	0	0	0	7.6	0.4	0.1	18.4	4.4	21	0.8	2.2	0.2	0	0	
	7	0	0	0	0.2	0.2	25	3	31	26.6	4	11.4	14.2	9.2	15	2.4	8.2	0	2.8	0.8	49	18.6	0.3	0	11.4	34.2	4.2	9.4	1.8	31.8	9.2	5
	8	0.8	0.1	0	0.1	0	0	0	0	29.6	3.8	5.8	5.4	23.4	0.1	0.1	0.4	12.6	0.3	1.6	23	1.8	11.4	3	17.4	4.8	19.4	0.2	0	0.3	2.8	0.4
	9	0	0	29	0.3	1	18.4	7.4	0.2	0.6	0	0	3.5	15.2	1.4	1.6	0	0	1.8	3.6	5	0.2	0	0	0	0	0	0.3	0	0	0	
	10	0	0	0	4.8	3.6	0.6	0	0	2.2	0.8	19.4	3	0	0	0	0	8	51.2	3.2	0	0	0	0	0	0	0	0	0	0	9.4	4.6
	11	8.2	2.7	0	0	0	1.8	0.1	10.6	4	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.2	1.8	8.6	2	0	1.2	
	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	4	0	0	0	2.8	3.6	0	0	0	2.6	1	0	2.6	12.2	0	0
1996	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.8	0	0	0	0	0	8.6	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3.6	1.6	0.4	0	0	0	0	0	0	2.2	0	0	0	0.2	4.6	0	0	0
	4	0	0	0	0.5	0	0	0	0	0	0	2.2	7.4	0.8	0	0	0	0	0	2.8	37.4	0.2	0	0.8	0	0.4	0	0	0	0	0	
	5	0	0	0	0.4	10.8	0	0	14.8	16.2	18	0.2	0	0	0	0.4	0.7	2.2	0	0	0	0	0	0	0.1	0	0	0	0	0.1	0	31.2
	6	3.4	0.1	2.4	0	0	0.1	0	0	1.4	17	0.2	1.4	5.8	0.1	0.2	41.2	5.4	38	30	39.2	19.4	17.4	7.4	0.1	0.1	0	16.6	25.6	2.2	35.4	
	7	11	10.8	24.2	8	1.2	0	0	23.6	0	0	0.1	0	5.2	0.1	0	23	21.6	21	9.4	0.4	15.2	13.2	14.6	19.6	7.6	0	12.6	28.4	7.6	28	9
	8	14.2	13.8	8.8	12.2	10	0.8	6.4	0.2	0.2	0.2	23.4	4.2	16.2	0.4	9	0.5	0.2	0	0	13	14.8	0.5	4.6	14.8	0.1	0	10	12.2	0.6	0.2	5.6
	9	0	0	10.2	0.2	1	9.4	1.4	4	0.6	16.8	12.8	1.8	0	9.6	36.2	10.6	1.4	28	4.2	0.2	0	35.2	1.4	1.4	0.1	0	35	1.4	0	3	
	10	0.2	0	0	0	0	0	0	0	2.6	13.5	2.8	0	0	0	0	0	0	0	0	0	4	18.4	21.2	7	0	0	0	0	0	3.4	0
	11	0	0	0	0	0	4.6	0.5	0	0	0	0	0	0	0	19.6	17.8	0	0	0	0	0	0	0	2.2	0	0	0	0	0	25.8	
	12	12.8	5	0.1	0	0	0	0	0	0	0	0	15.7	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1997	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.1	0.4	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	28	2.2	0	0	8	2.2	0	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.8	3.5	0	0	0	0	0	0	0	0	0	0.4	8	16.6	0
	4	0	0	0	0.2	0.6	0.6	0	0	0	0	2.7	0.5	0	0	0	0	0	0	0	0	4.4	0.2	0.1	0.1	0	0	6.4	3.9	2.4	5.6	
	5	14.4	0.1	6.6	0.2	0	0	0	0	0	0	0.2	3.6	4.4	0.2	0	0.1	0.1	13	18.2	0	0	0	27.2	7.2	13.6	11.4	6.3	1.7	0.2	0	42.6
	6	16.2	5	17.4	26.8	9.4	23.4	2.8	6.6	30	0.4	9.2	4.2	2.2	0.1	0	0	0	0	6	10.2	9	1.4	8.8	0.1	7.6	0.2	0.2	0.2	0	0	
	7	0.1	0	8.8	0.8	0.4	15.6	16.6	0.2	8.7	0.2	0	0	26.8	19.2	0.2	0	0.1	0	0	0	0.1	0.1	0	6.4	23	4.4	18	0.2	4.4	0.2	0.1
	8	0	0.2	0	28.6	16.8	8.8	6	3.8	32	15.4	0	0.2	0	7	30	10.2	0	0	0	0	0	0.2	0	0	0	0.1	9.2	20	2.4	0	0
	9	1.6	24.3	4.8	3.6	0.8	22	0.6	4.6	13.2	2.4	0	12.6	1.4	0.2	0	0.1	0	2.6	4.6	2.6	0	0	0.2	5	0	2.6	0.2	0	0	0	
	10	4	0.2	0	0	0	0	0	15.4	39.9	20	0.2	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0.1	0	0.2	1	0	0	0
	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.4	17.4	0.2	0	0	5	0.8	0	0	0	
	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

1998	1	0	0	0	0	0	0	0	0	0	0	0	0	0.6	2.2	0	5	6.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0			
	3	0	0	0	0	0	0	0	0	0	27.6	31.6	2.2	0.2	0	0	0	0	0	0	7.4	34.6	4	0.2	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	2.5	4.2	0.5	0	0	0	0	0	0.5	17.8	0.8	0	0	0.1	0.3	0.1	1.9	2.1	0	0.6	0.1	0	0.2	0.1	
	5	0	0	0	0	3.2	1	0	0	11.2	3	0.1	0.1	0.1	2	0.1	0.1	0.1	9.2	4.2	4	4.6	13.2	0.2	0.1	0.1	35.4	1.6	5.4	2.1	0.2	0
	6	0	1.6	0	5.8	17.6	2.6	0	54.2	6	51	16	0.2	21.2	0.4	0.2	0.1	14.2	3	0.2	0	0	0	0	0	0	14.8	12.2	16.6	0	0.2	
	7	1.8	0.2	0.2	11.4	19.2	22.2	4	0.6	0.2	0	0	0.2	0	0	0	0	0.4	15.2	4.6	0.2	4.8	10.4	0.4	0	0.1	6.4	0.4	0	0	0.2	1.4
	8	57.2	5.4	5.8	0	28.3	11.6	10.2	7.8	0.2	0.8	22.2	0.2	0	0	0	4.8	3	15.8	17.6	1	4.2	0	0	9	0.2	0.2	24	5.4	28	13	10.2
	9	21.6	34	14.8	6.8	0	0	0	0	0	1.4	0	0.4	7.8	0	0	0	5.4	6	0.2	13.6	13.6	32	0.2	0	16.8	3.6	16	1.2	8.6	4.8	
	10	19.2	4.4	0.1	0	0.5	0.4	0	0	0	3	1.2	2.2	9	7	0	4.4	19.6	0	0	0	0	0	0	0	0	0	1.2	1.6	0.2	0	0
	11	2.2	0.6	0	0	0	3	0.1	0	0	0	0	0	15.6	9.6	0	0	5	25.6	0	0	1.5	0.3	1.6	0	0	0	0	0	0	0	
	12	12.6	1.4	0	0	0	0	4	0	0	0	0	0	0	0	12.2	0	0	0	0	0	0	0	2.2	0	0	0	0	0	0	0	0
1999	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1.2	0	0	0	0	0	0	0	11.8	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	0	0	0	0	0	5	4	0	0	0	0	0	0	0	0	0	7	2	0.4	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	2	3	1	0	0	0	0	0	13	0.2	0	0	0	0	0	0	0	0	0	0	0	0	
	5	0	3.8	4.8	0.3	0	12.6	0.2	0.2	1.4	5.2	1.6	0	2.5	1.2	0.4	2.5	2.5	0	22.1	37.2	36.6	1.4	0.2	0.1	0.1	9.4	12.2	22	6.2	0	0.2
	6	5	0.4	27	0.2	0	0	0	11	10	0	21	7	0	8.6	1	9	1	34	10	8	0.2	0	49	0.2	0	33	4	9	7	0	
	7	0	0	0	11	43	0.8	0.6	0	0	0	0	0	12	36	34	31	11	0.8	2	0	0	0	0	0	0	15	11	10	7	0	0
	8	0	0	0	0	0	18	2	0	2	47	37	6	0	0	8	6	29	10.8	7	6.6	0	0	0	40	11	0.2	0	0	7	6	0
	9	0	0.2	38	4	0	0	0	2	0	0	51	0	0.8	32	22	0	0	0	0	0	5	5	0	0	0	5.2	24	7	0.6	0	
	10	10	0.2	0	0	0	0	24.4	38	5	0	0	0	2	33	1	17	0	0	0	0	0	0	0	1.8	0.1	0	0	0	0	0	0
	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	12	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	8.2	0	0	0	0	0	0	0	0	0	13	0
2000	1	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	25.4	0.7	35.6	0.2	0.1	0	0	14.2	17.4	0.2	0	0	0	0	0	0	7.4
	2	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0		
	3	0	0	0	0	0	0	0	0	0	49.5	0.2	0	0.2	0	0	0	1.4	0	0	0	0.8	10.6	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	1.8	0	0	1.2	0	0	0	0	0	0	0	0	0	7.2	8.4	21	19.4	0.2	
	5	0	0.2	0	0	0	0	0	3.6	0.4	0	16.4	10.4	0	0	0	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2
	6	3.4	0.2	0	0	0	0.2	0	0	0	6.2	3.2	0	0.2	70	20.6	0.2	0	0.2	31.6	20.4	8.2	7.2	1.6	3	26.2	15.2	6.2	0.5	0.2	0	
	7	25.92	25.92	25.92	25.92	25.92	6.4	10.6	7	7	7	7	0	30.1	7.2	21.5	21.5	21.5	25.2	15	8.8	2	0	0	0	1	0.2	0	7.4	4.7	4.7	4.7
	8	3.2	19.4	6.4	0.2	14.7	14.7	14.7	0	0.8	0.2	0.2	0	2.7	2.7	1	29.2	0.4	0	1.9	1.9	1.9	1.9	1.9	1.9	0	6.6	6.6	6.6	6.6	8.2	42.8
	9	9.3	6.2	6.2	6.2	0.4	19	19	6.2	0	0	0.2	0	17.1	4.8	4.8	4.9	4.9	0	0	0	0	0.4	0	0	0	0	3.4	6.6	7.6	4	
	10	0.2	0	0	0	1.4	0.4	4.15	4.15	0	0.1	0	0	0	0	0	0	0	0	0	0	1.2	0	0	0	0	0	0	0	0	4.6	0
	11	0	0	0.1	0	0	0	0	12.4	4	4.6	4.2	0	0	0	0	0	3	0.1	0	0	0	0	0	0	0	0	11.8	0.4	1.4	0	
	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.2	0	0
2001	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0	0	0	0	0	0	0	0	0	0
	2	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0.2	0	0	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	1	1	3	0.2	0	0	0	0	
	5	0	0	0	0	0	26.6	13	10.4	0	15.2	2.4	10	10	10	0	0.3	0	0	0	3.6	3.6	0.2	0	6.8	10.2	0.5	0.5	0	0.6	11.2	5.8
	6	1	5	0.2	2	0	0	0.2	8	3	7	1	0	0.2	0	0	0	5	0.2	1	0	0	0	0	5	0	0	0	0	0	6	
	7	5	9	10	7	0	0.2	4	25	10	0.2	0	9.8	0.2	0	0.2	0	0.2	0.2	0	0.2	8	0.2	0	0	0.2	0	0	8	1	41	8
	8	0	0	9	6	0	12	4	0	16	0.4	3	8	0.4	29	28	5	0	0	0.2	0	0.2	0	0.2	27	0.2	0	0	0.2	0	8.2	0

	9	0.8	1	0.6	0	0	18	6	0.8	20	3	0	1	4	0	2	2	0	0	0.8	0	0	27	13	0.2	0	0	0.2	1	33	18	
	10	1	0.2	0	0	0	0	0	0	3	0	0	1	0	0	0	0	0	0	0	0	15	12	0.2	0	0	0	0	0	0	0	0
	11	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	46	0.2	0	0	0	2	0	0	0	0	0	0	
	12	21	0.2	5	1	0	0.2	0.4	0	0	0	0	0	0	0	0	0	0	0	3	0.2	0	0	0	0	0	0	0	0	0	0	0
2002	1	0	0	0	0	0	0	0	0	0	4	0.2	0	0	3	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	1	0	0	0	1	0	0	0	0	0	0	0	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	2.8	0	0	0	0.6	0	0	0	0	0	0	0	0	1.2
	4	0	0	0	0	0	0	7	0.6	6	0	0	0.2	0	0	0	0.2	62	31	0	0	0	0	4	0.8	0.2	2	0	0.2	0	0	
	5	0	2	25	0.2	0.2	37	18	26	18	0.8	34	2	0.2	7	0.8	0.2	0	0	0.2	0	0.2	0	0.2	4	0	0.2	0	0	0.2	0	0.2
	6	0	16	28	44	14	7	4	0	0.2	0.2	3	0.2	14	19	10	0	0.2	2	25	0.2	0.2	0.2	0	2	9	4	3	0	22	0.2	
	7	33	8	0.4	2	18	0	12	5	0.6	10	22	27	4	16	18	0	0	3	27	0.2	2	0.6	1	8	12	15	22	0	0	0.8	5
	8	7	0.4	0	14	18	2	0	0	22	10	0.2	0.2	0	0	6	0	0	0	0	0	0	0.2	0	0	11	9	14	0.2	0	26	22
	9	51	14	13	0.2	2	0.6	0	0.2	0	0.2	0.2	1	2	3	42	0	0.2	0	0	2	0	0.2	7	5	0	2	0	0	0	0	
	10	0	0	0	0	6	46	6	0	0	0	2	0.2	0.2	0	0	0	8	27	0.2	0.2	0	0	0	2	0	0	0	8	1	0	0.2
	11	30	0.4	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	
	12	0	0	0	0	0	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0
2003	1	0	0	0	0	0	0	0	0	0	0	0	0.6	0.2	0	0	0	0	0	0	2	0.2	0	0	3	0.2	0	0	0	0	0	0
	2	0	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	2	0.2	0	0	0	0	0			
	3	0	0	0	0	0	0	0	0	33	0.8	0	0.2	0	0	0	0	0	3	0	0	3	0.2	0.8	1	0	0	0	0	0	0	29
	4	0.2	0	0	0	7	0	2	0	0	0	11	47	18	0.2	0	0	0	3	0.2	0.6	0.2	3	0	7	6	0.2	0.2	0.2	0	0	
	5	0	0	0	0	0	1	0	0	0.2	0	0.2	27	14.2	0.2	1	37	5	1	0.4	0	37	13	3	0	0.2	0.2	0	0	0	20	6
	6	8	6	3	0.8	2	5	0	0.2	0	4	0.8	0	0.2	0	0	0.2	0	0	0.2	0	0.2	0	13	5	17	36	44	24	8	7	
	7	1.2	0.6	18.8	42.6	29.2	6.4	0.4	0	7.8	21.4	29.4	1.2	0.2	27.2	3.2	0.2	0.1	0	0	13	0.6	10.1	0.1	0.2	0	0.3	8.1	0.6	0.1	40.8	1.4
	8	3	0	31	11	3	0	0.2	0	0.2	0	32	1	0	0	0.2	14	0.2	0.2	0	4	6	38	0.4	2	0.2	0	0.2	0	1	0	0
	9	0.2	0	0	17	1	0	0.2	2	19	20	18	4	6	0.6	0	0	0.2	0	0	20	7	19	23	15	12	0	0	0	0	5	
	10	1	0	0	0	0	0	0	0	0	0	0	0	35	4	1	0	2	0.2	0	0.2	0.4	0	0	0	0	0	3	0.8	0	0	0
	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.8	28	11.4	1.6	0	0	0	0.5	9.2	0	0	0	0	0	
	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0.2
2004	1	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	3.3	0	0	0	0	0	0	0	0	0	0	0		
	3	0	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	2	0.2	0	0	0	0	0	0	2	3	0.2	0	0	0.8	6	3	4	5.6	0	0	0	0	0	0	0	0	
	5	0	0	0	0	0	0	23	36	0	38	11	0	0.2	0	0.2	17	2	7	0	0.2	1	40	0	0	0	0.2	0	0	0	0	8
	6	0.2	0	0	0	23	8	16	47	8	8	57	21	3	0	0.2	0.2	28	0.2	0.2	0.2	0	25	3	2	2	0	2	25	3	3	
	7	4	31	7	9	1	0	21	24	3	0.2	0	0.2	0	0	0	0.2	0	0	0	0	14	43	0.4	0	3	0.2	0	0.2	0	24	6
	8	12	5	2	1	3	16	0.2	0	0.2	0	0	60	4	8	1	0.2	0	13	0	7	21	5	20	47	20	20	14	8	0.2	0	0
	9	0	0	0	0	5	23	2	0.4	6	0	0	0	0	0	0	0	0	0	5	0	2	0	0	0	0	0.6	0	0	0	0.2	
	10	5	0	0	0	0	16	1	0	0.2	4	2	31	1	0	0	2	0	0	0	0	14	0.2	0	0	0	0	0	0	0.4	0	0
	11	0	0	0	0	0	0	0	0	1	8	11	9	0.2	0	0	0	6	0.2	0	0	0	0	0	0	3	7	6	0	0	0	
	12	0	0	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	4	0.2	0	0
2005	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0.2	0.2	0	0	0	0	0	0	0.2	2	0	0	2	0.2	0	0	0	0	0	0	0	0	0	0			
	3	0	0	0	0	0	0	0.2	0	0	0.6	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	7	0.4	0	12
	4	29	7	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	2	3	0.2	0	0	0	0	0	

	5	3	107	11	0.4	0	0.2	0.2	0.2	0	0	0.6	17	11	0.6	0.2	47	3	0	58	1	0.2	14	0	0.2	0.2	0.2	0.2	0	0	0	0
	6	0	0	6	0	0.2	0	36	10	23	27	15	17	3	0.6	0.4	1	8	2	3	0	0.2	0	32	23	3	2	0.2	0.2	0	12	
	7	1	0.1	0	23.8	3.4	0	0	0	0.4	0	0	0	15.4	4.6	3.4	1.8	0	0	0.1	0	31.2	3.2	9.8	3	1.4	1.5	0	0	0.8	0	0
	8	0	6.8	10.2	0	1	1	3.4	0.3	0	1.6	0.6	0	28.8	15.6	0	4.6	21.6	25.4	0	0.2	0.2	0	0	2.8	1.8	0	0	15.8	3	6.2	0
	9	0	0	0.1	3	6	30	10	15	15	0.2	0	3.4	8.9	8.9	0	0	19.4	5.2	1	3.7	7	0	0	0	0	0	4.2	4.2	16.4	5.6	
	10	11.4	8	0.4	19	2	42.2	0	0.2	5	0.2	0	1	0	0	0	0	1.4	0	0	0	0	12.5	3.2	0	18.2	1.9	1.2	1.2	0.2	0.2	10.4
	11	0	0.4	0.2	0.2	17	0.8	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	
	12	0	0	0.2	1	2	3	0.2	0	1	0	11	1	2	0	0	0.2	0.2	0	0	0	0	0	5	0	0	0	0	0	0	0	0
2006	1	0	0	9.2	1.8	0	0	0	1	0	0	0	0	11.6	0.2	0	0	0	0	0	0	0	0	0	0	17.4	3.2	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	2	0.2	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.6	2.2	0	0	0	0	0	0	0
	4	9.4	0.8	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	8.2	1.8	0.4	4	16	0.2	0	0.2	0	
	5	0	0	0	0	0	5	0	0	0	0	0	0	0	0	34	0.2	0	0	0	0	0	0	2	4.8	0	0	0	0	4.2	1.8	0.6
	6	0	0	0	0	0	0.2	0.2	0.2	0	0	0	0	0	0	0	0	0	0	0	30.4	0	0	0	0	0	1.8	4.2	14	0	0.6	
	7	7.4	0.2	0.6	8.8	0.6	0	0	0	13.2	7	1	0	0	0.2	1.2	0	0	0	0	0	26	0.2	0	0	37.2	6.8	9.5	19.4	7.8	13.6	0.2
	8	5.4	14.8	2.6	0.2	8.8	0	17.6	14.4	1	0	0	23.5	9	2.8	28.5	6.2	0	0	13.2	18.1	0.2	50.6	19.8	0	0.3	0.5	0	0	0	0	25.7
	9	1.5	0	0	2.2	0.4	0	0	0	0.2	7.2	7.4	14.8	0	0	0	0	5.2	6.6	7.6	1.6	11.2	4.4	2	0	0	1	0	0	0	2.6	
	10	0	0	1.2	13.2	0	0	0	0	0	0	4.6	23.6	10.4	0.2	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0
	11	0	0	0	0	0	0	0	0	0	4.8	6.6	2.6	0	0	0	0	3.4	0	0	0.2	0	0	0	0	0	0	0	0	21.4	0.1	
	12	0	0	0	0	0	0	0	2.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2007	1	0	0	13.2	0	0	0	0	0	0	9	4	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.6	1.3	5	0	0	0	0	0	0	0	0	0	0.6			
	3	12	16.2	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.2	2.4	0.6	0	0	0.2	0	0	0	0	0	0	0	0
	4	0	0	0	0	0.2	0	0	0.2	3	0.2	0	0	0	0	0	68	0.2	0.6	0.2	0	0	0	3	0.7	9	0.2	0	0	2.4	25.2	
	5	31.4	5.6	3.2	1.6	5.4	0.4	0	0	0.1	0	0	4	0.4	0	0	0	0.1	5	0.1	5	0.2	0	1	0.9	4.6	13.6	12	44.8	0	0	0
	6	0.1	0.1	0	0	0.2	0	3.2	2.2	1.2	0.1	0.1	0	0	22.2	0.2	0.1	0.2	0	0	0.1	0	0	24.7	13.5	2.4	0.8	0.1	32.2	0.4	10	
	7	2.6	24.6	32.2	4	0.2	0.6	0.1	8	5.6	0.2	0.1	0	0	0	0	0	0.2	0.1	3.2	17.2	7.2	30	9.6	36.4	13.4	6.8	0.4	26.4	5.6	20.1	19.2
	8	26.5	1.6	0.1	0	0.1	22.6	14.2	5.4	0	19	11.4	0.2	0.1	0.8	0.2	0	0	0	0	1.8	0.2	0	24	0.1	3	21.4	12.6	7	6.2	39.6	0.2
	9	0	0	0	2.2	11	0	0.4	21	0.4	0	0	31.8	12.4	0.3	14	3	2.4	6.6	12.4	1.8	1.2	5.8	0.1	16.8	5.6	2	15.2	0.8	0.1	0.8	
	10	0.6	1.4	0.1	0	0	0	0	27.4	22.4	2	5	0.1	0	0.1	0	0	0	9.8	0	1	3.2	0	0	0	0	0.2	24.2	5.4	0	0	0
	11	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	1.2	0.2	0.2	0	0	0	0	0	0	0	0	0	6.4	
	12	6	0.2	0	0	0.1	3.4	0	0	0	0	0	0.5	0	0	0	0.8	5.4	10.8	0.2	0	0	0	0	0	0	0	0	0	0	0	0
2008	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	3.4	3.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	3	0	0	0	0	0	0	1.4	0	0.1	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	60.4	0.2	0	0	13.8	6	0	10.4	0	4.6	0	0	0	0	0	0	23	1.4	2	0.2	2	2.8	5.6	0.1	0	0	10.4	3	7.2	4.4	
	5	0.1	0	0	0.3	0	0	0.3	0	0.2	0.1	16.4	0.2	1.2	6	1.2	4.2	0.1	0	0	0	0	14.2	20.2	28.6	11.8	0.2	0.1	0	26	0.2	0.4
	6	66	0.3	0	0.1	0.1	0.1	0	0	23	9.8	7.6	4.4	0.2	0.1	8.4	37	7.4	1	0	0	0.1	0	0	0	18.4	0.1	0.2	32.4	16.5	1.5	
	7	0	0	0.2	12.8	16	0.3	0	0	3.2	12	12	2	0	0	0	50.4	3	27	19.8	0	0	0	0	45	0.3	2.6	5.6	10	6.4	14	19.4
	8	1.8	23.8	0.2	0	0	0	0.4	0	0.1	0	0	0	0.1	0	0	0	0	0	1	0.9	0	0	0	0	0	0	0	0	0.8	0	0.1
	9	9.6	0.2	0	0	0.2	0	0	0	0	0	7.4	8.2	14.6	2	0.8	0	7	8	18.2	5.4	10	1.4	0	0	36	5.4	0.1	1.4	1.2	4.2	
	10	1.6	7	0	4	4.2	0	0	0	0	0	0	1	0	0	0	0.1	0.6	0.5	0	0	0.1	0	2.2	10.2	33.6	0	0	0	5.6	1.6	0
	11	0	0	0	11	2.6	23.4	5.4	0.1	0	0	0	0	0	0	0	0	0	0	0	4.4	4.4	0	11.8	3.2	9.4	1	4.2	0.5	0	0	
	12	0	0	0	2.8	0.7	0	0	0	0.1	0	1.2	0	0	0	0	0	0	0	0	2.4	7.4	0	0	0	0	0	0	0	0	0	0

2009	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0.2	0.2	0	0	0	0	0	0.2	0	0
	2	0	3.2	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	22.2	0.1	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.2	0	0	3.4	0	0	0.6	2	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0.6	0	0.2	0	0	0	0	0	0	
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.2	2.2	12.8	29.2	25.2	0.1	0	0	0	0	0	0	0
	6	7.4	6.6	0	7.6	0	0	0	0	0	8.6	14	3	0	0	0	0	0	2.8	20.6	22	18.8	0	0	8.6	44	13.6	24.4	27	34.4	25.6	
	7	3	0.1	0	0	0	1.6	8.6	1	10.6	19.2	4.6	0.2	0	0	0.2	15.3	23	1.1	19.6	19	17.6	1.2	25.9	0.1	7.6	0.1	0	0	0	0	0
	8	0	0	0	0	0	17.8	0	5	2	0.2	9.2	19.6	9.2	49.8	43	8.6	11.2	2.2	4.4	3.6	8.2	9	6.6	2.6	0.6	0	0	4	0	0	0
	9	6	9	0.4	0	14.2	4	1.6	18.4	2.6	10.3	32.8	40	7	0.4	18.8	1.4	3	27.2	1	5.6	17.2	6.2	3.4	0.4	0.4	0	0	5.4	0.6	0.8	
	10	0	0	4.6	0	0	0	0	0	0	0.1	1.4	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	1.2	1.2	11.4	0.1	0
	11	0	0	0	0	0	7	0	1.2	0	0	0	1	5.6	0.2	0	0	0	13.4	34.8	5	0.1	0	0	0	0	0.4	0	0	0	0	
	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.2	0	0	0	0	0	0	0	0	0	0	0
2010	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0.8	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	2	28.8	0.1	0	0	0	0	0	0	0
	4	0	0.6	0	3.8	0.8	0.8	0.1	0	0	0	0	5.6	6.2	18.6	23.2	2.7	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	
	5	1.4	0	0	0	0	0	0	0	0	0	0	0	2.2	0.1	0	0	0.1	0	0	0	0	20.4	12.2	0	0	0	19.4	9.4	0.2	0	0
	6	1	0	0.2	0	0	0	0	0	0	0	0	0.3	0	10.6	23	31.6	0.8	2.4	3.6	0	0.1	0	24.2	0.6	0.1	0	0.1	0.1	0	0	
	7	0	5.2	0	0	0	0	0.1	0	58	10.8	1.4	29.4	14.6	0.4	0.1	2.2	2.6	0.2	0.1	0	0	0	0	0	0	11	8.2	10.4	20.8	0.3	1
	8	0	0	0	0	0	0.2	0	0	0	0	0	18.6	26.3	1.8	0.1	0	0	1	0	0.5	0.4	5.4	0	0.6	0	0	0	0	0	4	2.7
	9	0.8	0	0	0.5	0	0	0	18.4	9.8	0.1	0	6.8	0.4	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	10	0	0	0	0	0	0	0	0	0	2.4	7.2	0.1	0	0	0	0	0	0	0	0	20.4	0	0	0	0	0	0	2.6	0.2	0	0
	11	0	0	0	0	0.2	0	0	0	0	0.2	9.8	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	
	12	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	5.2	2	0	0	0	0	0	0	0	0	0	0
2011	1	0	0	0	0	0	27	0.8	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.4	12.2	4.2	0	0	0	1	9.2	1.2
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	2.1	1.8	0	0	6.8	1.2	0	0	0	0	0	0.2	0	0	0	0	0	7.7	7.7	0	10.2	10.8	0.3	0	
	5	0	0.1	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0.8	3.2	0.2	11.6	16	0.1	0	0	0	0	0	0	0	47	0.4
	6	5.8	36	0.2	0	0.1	0	0.2	0.2	0	0	0	0	0	8	13.2	7	0	4	8.2	1.6	2.8	0.1	1.6	11	65.4	0.8	0.1	42.2	25	0.6	
	7	22.8	7.6	8	0.3	0.1	0	0	0	0	0.1	4.4	4.8	0.2	0	5.4	19.4	0.2	0.1	0	1.2	13.6	1.4	7	0.2	0	9	0.2	21.6	11.2	22	24.6
	8	5.4	13.4	22.2	4.2	0.2	0	2.4	4.4	7	0.2	0	0	0.1	29	4	30.6	0.4	0	0	0	0.1	54.2	1.2	14	0.2	0	0	0.2	0	0	0
	9	0.2	23.8	9	6.4	0.2	0	0	0	0	0	0	0	0.9	0	1.6	9.8	5	29.8	4.4	3	6	8.6	0	0	0	5.6	9.8	12.8	0	0	
	10	0	0.4	1.8	0	0	0	0	0	0	0	3.2	0	2.8	2.4	0	0	0	4	1.2	0	0	0	8.2	0	12.2	1	0.2	0	0	0	0
	11	0	0	1.4	20.2	5.2	28.4	3.6	37.4	10.8	0.2	0	0	0.2	1.2	0.8	0	1	13.4	0	0	0	0	0	0	0	0	0	0	1.2	0	
	12	0	0	0	0	0.2	0.2	16	0.2	0	0	0	0	56.4	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36.2
2012	1	0	0	0	0.2	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	2	0	1.4	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0.4	0	0	0		
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0
	4	0	10.2	20	0.4	13	0	0	0	0	0	0	0	0	0	0	0	0	2.2	3.4	0	0	0.4	0	0	0	0	0	0.1	14	22	
	5	0.1	0	0	12	51.6	11	2	29	1.2	1.4	0	0	0	0.6	1	0.5	0	0.4	0	0	0	0	0	0	0.4	0	0	0	0.2	0	0.1
	6	7.4	0	0	0	0	0	16.6	14.4	0.6	6	35	20	41.6	0.2	5.4	0.4	1.4	0.2	23.8	10.8	9.6	0.2	0	0	0	0	17	3.4	0.2	0	
	7	0	0	0	0	0	0	8	0.8	0.2	3	5.4	0.2	0	0	0.4	10.2	3	0.2	0	0	0	0.2	0	4.2	0.2	0	0	0	0	0	14.4
	8	15.6	4.2	9.8	8.6	5	2.2	31.6	6	0.2	0	0	2.6	36.4	1.4	5.2	0.2	0	0.2	0	0	24.2	20	0.4	1	0.2	0	0.8	7.8	3	0.2	0

	9	15.4	1.2	3.6	54	10	12.4	0.4	0	0	0	0.8	1.4	0	0	0	0	0	13.8	6	6.4	1.4	34	0.1	0	17.9	17.9	29.6	5.6	0.1	0	
	10	0	0	12	1.8	0.2	0	0	0	0	0	0	0	1.2	15.6	4.8	0.4	0	0	0	3.2	0	16.2	0.6	0	0	0	0	0	0	0	0
	11	0	0.1	1.6	42.4	21.8	3.8	0.4	0	0	0	1.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10.2	27.2	6.4	
	12	0.8	0	0	0	1.2	0.8	3.4	1.8	0.2	0.6	0	25	14	0.1	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0.8	0.4	0
2013	1	0	0.8	0	0	0	0.2	13	0.4	0	0	0	0	0	0.6	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	4.4	1	1.8	0	0	0	0	0			
	3	0	0	0	2.4	0.6	0	0	0	0	0	3.6	0	0	0	17.4	0	0	0	0	0	0	0	0	0	0	37	0.2	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0.6	3.4	0	0	0	0.4	4.2	0.6	1.2	0	6	0.1	0	0	0	0	2.6	0	0	
	5	0	31.2	8	0	0	0	0	46	35	23.8	1.2	0	0	0	0.2	0	31	0.4	0	12.2	0.2	0	0	0	0.2	0	5	4	9.4	22.2	1
	6	0.2	0	0	0	1.4	0.4	0.2	0	7.4	27.6	0.2	0.2	0.2	0	0	0	1.4	0.2	0	0.4	0.2	0	0	14.8	20	2.2	0.4	0.4	0.2	0	
	7	0	0	1.6	1	0	0	0	0	0	25	0.2	16.4	0	0.4	1.6	18	14.6	0.4	0	0	0	0	0	29	7	31.4	49	2	0.6	4.6	14
	8	12.2	4.5	0	0	3	12.4	33	29	4.4	7.2	9.6	0.4	4	6	9.4	15	8	2.4	0	0	0.3	0	0	0	0	2.1	6.4	13.6	5.6	20.2	21.6
	9	3.6	1.1	0	18.2	0	0	0	0	0	0	15	34.3	1.2	15.4	6	0	37.2	1	9	7	6.6	20.2	26	13.4	4.2	0	7	0	1.4	14	
	10	0	0	0	0	3.4	6	0.2	0.2	10.6	0.2	0	3	0	0	0	7	0.2	0	6.8	10.8	0.4	0	0	0	0	0	0	0	0	0	0
	11	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.4	0	2	0	0	0	0	16.4	
	12	1.8	0.2	0	0	0	0.6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.4	0.4	0	0.2	0	0	0	7.4	2
	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0.2	0	7	14.6	0.6	0	
	5	0	0	0	0	3.2	0.1	1.6	55.1	17	12.6	1.3	1.1	2.6	0	1	0.1	1	1.6	7	2.5	35.2	3.8	44	26.4	24	9.2	2.4	10.6	1.2	0.2	0
	6	2	3.2	1.4	0	0	0	0	0	1.2	15.6	1.8	0	0	0	0	0	0	51.2	9.2	15.2	15	32	0.2	0	0	0.2	5	0	0	0	
	7	3.8	17	19	0.2	3	11.2	15.4	22.2	0.8	0	0	0.4	0	20.6	5.6	2	0	0	0	16.4	4	23	3.2	7.3	1.2	11	30	5	8	1.2	3.2
	8	0.2	0	0.2	0	0	0	2.4	7	0.4	0.2	0	0	0	0	0.4	0.2	0	20	23.4	1.4	14.8	3.4	0.2	0	0.3	6.6	0	0	17.6	48.8	1.4
	9	0	0	0	0	0	0.8	15.2	24	12	0.4	2.6	0	0.8	0	0	0	0	0	0	0	0	35	0	0	0	0	20.6	25.4	10	2	
	10	0.2	0.8	0	0	14.8	17	0	0	1.2	0	0	0	0	0	0	0	0	1.6	4	3	0.2	0	4.8	1	0	3.6	0.4	0	0	0	1.8
	11	0	0	2	0	0	0	6	1	0	3.6	0	0	0	0	0	0	0	0	0	0	1	0.2	0.8	0	0	0	17.4	4.8	0	0	
	12	0	2.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0
2015	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	9.6	2.4	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	15.4	6.2	0	0	15.8	1.4	0	0	0	0	0	0	0	2.4	0	0	0	0
	4	0	0	0	0	0	0	4.4	13.4	0.2	55.4	3.2	13	2	0	3.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	
	5	2.4	0	0	16.2	0	0	0	0	0	0	0	0	0	0	0	8.2	20.4	23	0.4	0	0	0.2	0	0	0	0.8	0	0	0	0	0
	6	0	14	9	5	0.2	2.4	0.6	0	0	0	0	1.6	0	0	0	0	0	3.8	39	6	24	13.2	0	0	0	0	0	0	0	0	
	7	0	0.8	13.2	0.8	4	1.2	7	10	0.2	2.4	0	0	0	0	0	0	0	2	0.8	17.6	19.6	1	9.4	0	0.8	0	0	2	1.6	3.6	9.8
	8	5	0	0	0	0	0	0.2	15.4	18.4	12.4	6	0	0.4	1	0.2	0	12	12.4	3	28.2	10.6	19	0.2	0.8	0	0	0	4	8.6	17.4	1
	9	9.2	0.2	0	0	6	0.4	0	0	0	0.2	17.4	28	6.4	0.4	1.6	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0	
	10	0	0	0	0	7	1.6	0	0	0	0	0	0	0	2.6	1.6	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	18.4
	11	0.6	5	7	0	0	0	0	0	0	0	0	0	0	0	2.8	0	0	2	2.4	0	0	0	0	0	0	0	0	0	0	0	
	12	0	0	0	0	11.2	12.4	2.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	1	0	0	0	0	0	0	0	0	5	0	0	1.4	0	0	0	0	0	0	0.6	17	0.2	0	0	2	0	0	0	0	0	2.2	14.2
	2	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.6	0.2	1	0	0	0	0	0		
	3	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	1.8	0	0	0	3.4	3	0	14.4	5.4	0.2	0	0	0
	4	0.4	0	0	0	0	0	0	0	0	0	6.4	2.8	4.4	0	0.6	0	1.2	8	10	0	0	0	0	0	5	16	4.6	2	7.6	7.4	

	5	0	0	1.4	0.2	0.2	0.2	26.4	0	0	0	0	0.4	0.2	12.4	0.4	2.2	0.2	1.6	0	0	36	21.4	25.6	45.6	1.8	19.4	0.2	12	2	0	0
	6	0	0	0	9	0.2	0	11.4	0	0	7.2	0.6	0	24.4	0.4	0.4	0	0	0.4	0	18.6	0.8	0.6	2.4	0	6.4	0.4	0	4.6	33.8	0.4	
	7	0	0	1	0.4	0	0	0	17.2	6.4	13	0.8	0	0	0	0.4	4	35	4	0	0	16.6	8.6	0.4	2.2	0	0.8	0	0	0.4	2	18.2
	8	6.6	0	0	16.4	1.4	0.4	21	26.4	9.6	11.6	0.4	10.8	0.2	0	0.4	6.6	8	30	0.6	11.6	0.4	7	0.4	0	0	0	49	6.6	0.4	0	9.8
	9	3	0	0.6	0	0	0	11.6	8.4	0.2	1.8	0.6	0	0	0	0	10	0.2	0	21	0	0	0	15	3	6	0	13.2	11.6	0	0	
	10	16.6	6.6	3	4.6	0.4	0.6	3	19	6.6	0.2	0	0	0	1.2	19	0.4	0	0	0	3.4	0	0	0	0	0	0	0	0	3	0.4	0
	11	0	0	0	0	0	0	0	0	0	0	3.8	0	0	0	0	0	9.6	0	0	0	0	0	0	0	0	0	0	0	0	0	
	12	0	0	0	1	0	0	1.2	0	0	0	0	11	12.4	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0.4	0	0	0
2017	1	0	0	0	0	0	0.2	0.2	0	0	0	0	1.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	111	22	1.2	0	0.6	0	0	0	0	0	0	2.8	0	0	0	0	0	0	0			
	3	0	0	3	0	0	0	0	0	0	0	0	0	6.6	6.8	8.4	0	0	2.2	0	0	0	1.2	3.6	1.2	0	6	0.2	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	5	0	0	0	0	8	0	0	0	10	0	0	0	0	0	38	5.6	0.2	0	36	2	31	4.4	3	0	0	6.2	0.4	0	0	0	0
	6	0	0	0.6	0	0	0	0	0	0	0	0	0	0	8.8	0	0	0	0	0	0	0	31	58	0	0	0	0	0	0	0	
	7	28	16.4	0	4.2	16	9	12.6	0.6	0	0	0	7.4	13.6	0.4	1	20	0	0	14.6	24	9	21.8	3	6.4	5	16	4.2	16.8	27	5.6	2.2
	8	53	0	1	8	0.4	0.2	0.4	12.8	52	15.4	1.5	25.9	25.3	28.8	17.4	8.8	7	10.6	4.4	0	0.4	0.4	0.2	0	0	0	0	0	0	0.7	5.8
	9	2.1	6.6	0	0	0	0	0	0.6	0.2	0	1.4	2	0	0	0	0	1.6	0	0	9.4	43	34	16	2.6	10	0.5	0.6	5	0.4	0	
	10	0	0	0	0	0	0	1.9	0.6	0	0	6.2	0	0	0	0	9.4	23.6	10.2	0	0	0	1	0.2	0	1.6	6.8	16.4	1.2	5	0	0
	11	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1.3	1.1	0	0	0	0	0	0	0	0	0	0	0	0	
	12	0	0	0	6.4	1.4	0	0	0	0	0	0	0	0	0	0	0	5	29.6	17.2	0	0	0	0	0	0	0	0	0	0	0	0
2018	1	0	0	0	0	0	0	0	0	0	0	2.8	0	0	0	0.2	128.6	0.2	2.4	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	6.7	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	4.6	0.5	0	0	0	0	0	0	0	0	0	0.1	1.6	9.2	2.4	0	0	0
	4	0	0	0	0	0	0	0	0	0	1.5	0.3	1.4	3.2	0	0	0	0	1	0	0.4	0.1	20	10.4	0.1	0	0	0	0	0	0	
	5	0	2.8	1.2	0	0	0.8	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	55.7	28.6	10.5	9.4	0	0	0
	6	4.8	0	0	0	10	21.6	11.2	2	4	59.1	11.8	2.3	3.2	0	0	0	0	24.4	8.4	9.4	0.5	0.8	0	0	0	0	40.7	2.8	0	0	
	7	0	3.4	43.6	25.8	24.4	0.4	0	0	0	0	0	0	11.8	1.2	19	11.4	3.8	3.6	1.4	0	4.8	31.8	16.2	4.8	3.4	38.6	0.8	1.2	0	8.4	0
	8	27.8	12	15.2	62.2	8.1	0	3.6	5.6	30	8.9	0	0	0	21.2	0.7	1.3	3.3	0	0	0	5.9	2.6	0	0	0	0	0	23.3	26.9	5.9	0
	9	0	0	0	3	10	1.6	4.4	10.2	0.8	1.7	9.4	0.2	1	5.8	0	0	0.4	0.2	0	0	0	0.2	0	0	0.8	0	0	0	0	9	
	10	0	0	0	6.6	0.5	1	0	0	0	3.2	1	2.2	1.2	28.4	4.2	0	0	10	9.9	0	7.6	2	0	0	0	0	0	0	0	0	0
	11	0	0	0	0	5.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11.4	0	0	7	0	0	0	0	
	12	0	0	0	0	0	3.1	0	0	0	0	0	1.4	0	0	0.4	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2019	1	0	0	3.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	7.4	0.1	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
	3	0.8	0	0	0	0	0	9.6	2.2	0.6	3.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	1	0	0	0	0	0	0	0	0.6	0	0	7.8	5.6	0.6	0	29.8	7	0	0	0	0	0	0	0	0	0	0	
	5	0	0	0	4.8	0.4	16.8	1.6	0	0	0	0	0	0	0	0	5.6	8.8	0	0	7.4	0	1	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	33.6	4.8	33.8	19.6	40.8	4	3	4	4.7	0.2	1.6	0	0	0	0	2.6	39.5	8	0	2.6	27.4	17.6	0	9.8	
	7	9.6	0.2	0	0	33	1.4	8.8	1.2	0.4	0.8	0.8	0	0	0	0	0	0	5	16.2	37.8	8	9.8	0	0	2.6	0	2	0	0	0	0
	8	0	0	0	3.2	4.4	13.2	2	0	0.4	0	0.2	0	4	2.6	6.4	0.2	43	0	0.2	0	0.2	0	26.4	1.4	0.2	0	0	0	0	35.6	17.4
	9	1.8	14.6	16.8	5.2	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0.4	17	0.1	0	0	0	0	0.2	0	0	0	0	0	
	10	1.4	0	0	1.8	20	0	0	0	0	0	0.2	5	0	1.7	0	0	0	0	0	0	0	0	0	1.4	0	0	0	0	0	0	25.2
	11	15	17	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.4	0.6	0	0	0	0	0	0	0	0	0	
	12	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0	8.4	0	0	0	0	0	0	0	0	0	0	0

2020	1	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.2	0
	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0.5	0	12.6	0	11.3	2	0.6		
	3	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	19	0	3.4	10.6	0	0	0	0.2	0	0	0	0	0.3	1.4	1.2	0	0
	4	0	0	0	0	1	0	0	0	0	0	0	0	0.2	0	0	1.2	0	0	11.6	1.2	0.8	2.4	1.6	0	2	0	0	0.3	0	0	
	5	0	0	0	0.2	21.1	32	5.6	5.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	29.2	10	1.6	7.8	22.4	24.4	12.4
	6	5.2	0	0	0	0	0	0.2	0	0	0	13.4	17.4	2.2	1	1	0.8	0	46.6	7.8	0	0	0	21	7.6	0.3	0.4	21.6	22.4	10.8	0	
	7	5.2	0	0	0	0	8.2	28.8	9	0	0	0	0	18.2	18.2	4.6	4.8	32.2	2.6	2	0	0	0	11.2	0	0	4.4	0	25	0	0	0.2
	8	0.4	0	5	3.4	0	0	0	0	4.7	26	38.8	3.3	0	0	1.2	20.4	15.4	3.8	0	0	0	0	0.4	2.4	0	0	0	0	3	0	0
	9	24	10	3.2	0.4	0.4	7.8	38.8	2.6	0.3	7	0	0	0	0	0	0	0	0	12.2	22.2	2	3.6	0	0	0	0	10.2	2.6	2	3.6	
	10	0	2.6	1.2	0	0	0	0	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.6	0	0	0
	11	20	4.8	6.2	0	0	0	0	0	5.8	47	0	0	7.4	1.6	15.6	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	7.4	
	12	1.4	0	0	0	0	0	0	0	0	0	0	0	1.8	4.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2021	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.7	0	0	0	0	0	0	0.4	0	0	0	0
	2	0	0	0	0	0	0	38.6	19	5.2	1	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0			
	3	1.2	20	7.8	11.8	15.6	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.4	0.3
	4	0.2	0	0	1.2	0	0	0	1.2	0	0	10.6	46.6	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	
	5	0	0	0	0	50	0.2	1	0	0	0	0	0	0	0	0	0	0	8.2	0	0	0	0	15.6	14.6	0	0	0	0	12.8	14.4	2.4
	6	0	0	0.2	0	0	1	0.8	0.2	0.2	16.4	3.4	0	0.6	8.4	4.6	0.2	0	0.2	0.2	28.4	17.2	0.2	0.6	0	0.2	0	0	8	18.2	0.6	
	7	2.2	0.8	0.2	7.2	41	11	16.4	5.8	2.6	38.6	0	17.8	29.8	22	17.8	4.4	1.2	5.8	3	2.6	30	2.6	1.8	11.4	1.4	0.4	69.2	4.6	33	14.2	13.8
	8	25	7	0	0.2	0	0	0.2	1.4	20	29.4	7.8	0.4	0	0	0	0.2	0.2	0	4.8	19	5.6	9.4	0	0	0	2.4	7	1.4	5.8	9.6	6.8
	9	4.8	25.8	2.8	0	0	0	0	0	23	15.4	3.2	0	0.2	0	0	26.2	9.6	0	11.4	0.2	0	0	0	0	0	0	1	4.6	1.8	0.4	
	10	6.6	15.2	11	0	9.2	0.2	0	4.2	0.2	0	0	18.4	0.2	0	0	0	0	0.2	18.4	29	15.8	0.4	0.2	0	6	2.2	26.8	0	0.4	0	0
	11	2.6	0.2	0.2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.4	0	0	0	0	0	0	0	0	
	12	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	2.4	0.4	6.6	0	0	0	0	0	0	0	0	0	0	0	0

Daily Rainfall (mm) at Willowdale since 1982 (data from Bureau of Meteorology).

Year	Month	Day																														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1982	1	0	0	1	0	6.6	0.8	0	0	0	0	0	0	0	0	0	0	0	2.4	0	0	160	93.2	1.6	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0.6	0	0	0	0	0	0	0	0	0	2.4	0	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.4	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	5	17.2	10.4	1	0.8	0	0	0	10.2	2.2	0	0.1	1.8	0	0	0	0	4.8	0	0	0	0	0.1	0	9	3	3	16.6	7.8	4.2	0	0
	6	0	0	28.4	0	0	0	0	18.6	17.8	16.2	10	1.4	9	11.4	17.6	41.2	3.8	11.6	5.2	0	0	0	0	15.6	17	2.2	0	0	3.8	0.1	
	7	16.6	0	2.6	19.8	4.6	20.6	0.4	0	9	0.2	0	0	4.4	0	34	25.2	1.6	0	6.2	33.3	2.2	18	9.6	0	9.2	7	28.4	0.8	0	0	0
	8	0.6	27	0	0	0	0	12.8	19.2	0.6	0	0	0	1	3.4	0	0	0	1.6	10	3.6	0	0	42.6	0.4	0	0	0	0	15.8	0	3
	9	1.9	5.9	0.4	0	0	0	0	0	0	0	0	0	0	8.4	46	20.6	0.4	1.1	0.1	1.3	7.4	8.1	26.3	31.2	5.8	0	0	0	0	0	
	10	0	0	0	30.2	14	2	2.8	0	0	0	1.6	0	0	0	0	0	0	0	0	0	0	0	3.6	4	19.6	0	0	0	0	0	0
	11	0	0	3.8	5.4	0.9	1.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.6	0	0	0	
	12	0	0	0	0	0	0	0	0	4.8	3.4	9.4	2	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.7
1983	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	5.2
	2	0	0	0	0	13.8	3.9	11.7	2	0	0	0	0	0	0	22.6	13.2	0	0	0	0	0	0	0	0	0	0	19.6	0			
	3	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
	4	26.2	0.3	0	0	0	4.8	1.2	11.6	0.3	1.4	0	0	0	0	0	0	0	0	0	0	5.2	0	0	0	0	0	0	0	0	0	
	5	3.2	1.6	37	0.7	0	7.8	1.8	0	0.6	0	0	13.4	1.8	0	0	0	0	2.4	5.4	0.3	0.1	0	0	0	0	0	8.4	0.2	0	0	0
	6	71.4	65.2	0.6	7.2	7.4	5.2	0	0	0	0	0	0	0	0	0	0	31.2	27.2	32.6	3.6	0.2	16	1	0	4.2	13	6.2	56.4	39.4	17.4	

	7	4.2	0.2	1	0.4	0	0	0	17.2	44.6	8.4	0	0	0.2	0	0	0	0	4.2	4.6	0.2	5.6	0.1	0	68	26.8	29	0.8	0	0	25	0.2
	8	0	0	2.8	9	44.4	5.8	1.6	0.2	0	0	0	25.6	14.6	16	0	0	0	8.8	0	13.2	0.8	0.2	50.4	27.6	29.8	0.8	19.2	19.6	17.2	1.2	0.2
	9	23.6	12.6	18	17.1	4.3	15.4	29.2	0.4	0	0	3.8	12.6	24.2	0.4	8.2	7.3	0.6	0	0	0	0	3	0	3.2	0	0	2.2	0.4	1.4	0	
	10	0	0	0	0	0	0	0	0	0	0	0	0	17.6	0.8	0	0.6	7.6	0	0	0	0.6	0	0	0	0	0.6	0	0	0	0	0
	11	0	0	0	0	2.6	2	24.2	0.1	0	0	0	0.8	4	0	0	0	13.2	0.2	0	0	0	0	0	0	0	0	0	0	0	0	
	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	12.2
1984	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3.4	0	0	0	0.4	0	0	0	0		
	3	0	0	0	0	0	0	1.6	9.4	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0
	4	0	0	0	0	0	0	0	0	0	14.4	2.4	2	0	0	0	4.6	2.8	0	0	0	5.2	0	0	0	0	0	0	0	50	16.2	
	5	2.2	0	0	0	3.2	25.6	42.6	17.4	11.2	8.6	1.8	0.4	0	0.4	17	17	11.4	3.6	32	17.2	0.1	0	0	7.8	10.8	16.6	27.6	0.4	18.2	1.6	1.5
	6	1.6	15.2	0	47	17.6	0	0	0	2.8	0	17.4	37.8	0.2	0	0	0	0	0	0.4	53.6	21.2	0.4	0	2.6	0.6	0	0	0	0	4.4	
	7	0	0.3	14	20	17.4	4.4	8.6	0.8	0	0	0	0	0	0	10	1.6	0	0	0	0	0	0	0	0	18	5.4	0	0	6.4	0	0.2
	8	12.4	6.8	2.2	4.6	27.8	11.2	20.7	7	0	0	0	1.2	0.6	14.4	8.8	10.4	0.3	25.4	8	5.4	1.8	3.2	1	0	0.3	0	2	0	14	0.2	3.2
	9	11.4	21.2	2.2	41.2	0.7	0.2	0.3	22.4	4	0	0	0.8	46.2	2.4	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	1.2	2	
	10	1.6	0	0.2	0.2	0	3.6	13.2	1	0.2	0	7.2	0	0	0	0	0	0	0	0	0	0	1.6	1.6	0	0.4	0	0.4	0	10	10.6	0.8
	11	0.3	1.8	0	4	32.8	5.4	31	17.8	0	0	0	0	0	0	0	37	13.6	0	0	0	0	9	4	0	3.6	0	0	0	0	0	
	12	0	0	0	0	0	1.6	0	5	0	0	0	0.6	4.4	0	0	0	0	0	0	0	0	0	0	0	0	0	26.4	1	0	0	0
1985	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0
	2	1.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8			
	3	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	4.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	7.2	50	46.2	0	2.2	0	0	0	0	0	0	0	0	0	0	0	0	4.6	0	4.8	9.6	5.6	3.2	
	5	0	0	0.4	0	0	0	0	0	0	0	0	6.8	1.6	0	0	0	0	0	0.6	0	0	0	0	0	0	49.2	23.4	4.2	5.6	0	0
	6	0	0	0.1	11	1.2	23.2	13.8	10	9.4	7.4	0.9	5	0.3	3.3	0	3.3	8.6	8.6	0	0	0.4	13	0.9	4	14.8	1.6	2.6	0.4	69.2	33	
	7	75	3	0.8	0.4	0	0	0	0	0	0.1	20	3	33.8	36.4	0	0	0	3.4	3.8	11.4	0.4	0.3	0	11.2	0.9	3.4	26.2	18.6	0.8	0	0
	8	0	0	18.2	12	8.4	2	0	0	13.4	0	2	8.4	0	0	0	0	0	12.8	49.2	21.8	0	0	0.4	20.2	21	4.6	34	0	0	0	14.2
	9	0	0	0	0	0	0	0	0	10	0	0	0	0	5.8	0	0	5	12.6	0	0	4.4	9.8	3.8	0	0	0	0	0	2.2	1.6	
	10	0	0	1.6	3.2	0	0	0	0	0	0	0	9.6	1.8	0	0	0	0.2	0	0	0	0	0	0	0	0	12	1.2	21.8	1	0	0
	11	0	0	10	0	0	0	2.4	25.2	9	0	0	0	0	0	0	0	0	0	0	0.6	8.4	0	0	0	0	0	0	0	0.6	0	
	12	5	0	0	0	4.2	0	0	0	0	0	0	0	0	2.2	0	0	0	5.4	5	2.6	0	0	1.6	0	0	0	0	0	0	0	0
1986	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	2.2	0	0	0	4.2	0	0	0	0	0	0	0	0.2	4	33.5	0	0	0	1.4	27.4	0			
	3	0	0	0	0	0	1.4	0	0	0	5.8	19.2	0	0	1.2	0	0	0	0	2	11.4	0	0	0	0	0	0	0	0	13	0	0
	4	0	0	6.8	0.4	0	0	0	0	0	3.2	0	0	0	9.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	5	0	0	0	0	14.4	3.8	0	16.2	0	5.2	0	0.2	0	8.4	0	0	0	1.2	21.8	13	29.4	22	0	0	4	24.4	9.7	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	1.2	0	0	0	0	2.8	8	10	0.1	0	0	0	0.2	14	12.6	39	13.6	5.8	23.2	19.8	0	
	7	0	24.4	11	0	9.2	8	0.5	0	0	0	0	0	31.2	26	16.2	0	0	0	2.5	6.6	0	16.6	1.8	0	0	0	0	0	0	28.6	15.6
	8	18	0	0	0	0	7	7.4	11.3	6	12	0.8	0	0	0	16.9	0	15.9	0	5.2	5.2	5	23.6	4.4	11.4	4.3	0	0	22	0	7.4	3.4
	9	0	0	0.4	7	0	0	0	0.8	1.4	0	3.8	0	0	4.2	26	0	0	10.6	7.6	2.8	4	0	4.2	0	3	1.7	0	0	2	0.4	
	10	0	0	0	0	0	6.8	0	0	0	0	3	14	14.4	0	5.2	3.4	0	0	6.8	0	0	0	0	0	0	6.2	0	0	0	1.4	0
	11	0	0	0	20.6	0	0	0	5.4	14	0	0	0	0.6	0	0	0	4.4	0	0	0	0	0	0	0	0	0	0	0	0	15.8	
	12	0	0	0	0	0	0.6	0	0	0	0	0	0	0	0	2.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	1	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	1.2	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.4	3.4	28.4	0	0	0	0	0	0	6.6	0	2.6	0	0	0	0.2	2
	4	1.2	0	0	3.2	0	0	1.2	70	14.4	0	7.8	0	0	0	0	0	0	0	0	0	2.6	0.6	0	0	12.4	18	0	0	0	0	
	5	26.4	0	0	0	0	0	0	0	7	15.2	0.4	0	0	3.8	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
	6	0	0	0	4	0	7.6	24	1.2	5.8	8.8	0	0.6	0	0	4	12	21.2	19	28	18.4	9.8	12.2	1.4	4.8	6.4	1.2	0	0	0	7.6	
	7	25.4	0	0	28	0	0	0	44.8	0	0	0	13	7.5	3.4	6.5	8.5	0	0	0	0	0	3.4	19	8	0	0	0	0	62.8	24.2	33.2
	8	1.4	0	0	0	0	0	0	0	0	0	0	0	46.5	0	0	0	0	0	0	7	0	14	0	0	29.6	0	0	0	0.6	0	0

	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10.4	8.2	0	0	0	28.8	14.8	0	36.4	0.8	0	0	0	
	10	0	0	7.4	0	0	0	0	0	0	0	0	11.2	0	12.4	5.4	0	7.8	0	0	0	0	0	0	0	0	0	0	0	0	0	11.4
	11	0	6.4	0	0	0	0	0	0	0	0	0	0	0	0	2.6	1.2	0.6	4	0	5.6	1.2	0.4	0	0	0	0	0	8.2	11.2	10.2	
	12	0	0	0	0	0	0.2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0	0	0	0	12	0
1988	1	0	0	0	0	0	0	0	0	0	0	0	0	1.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	2.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	3	0	0	0	0	0	3.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	6.6	0	1.4	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8.8	0	0	1.6	5.2	0	0	17	59	0	
	5	0	0	0	0	0	0	0	0	0	0	0	46	60	47	30	24.6	2.6	14.2	0	14.2	11.2	6.2	2.6	0.2	2.6	7.4	6.6	0	0	2	11.2
	6	42	43.6	13.4	0	0	8.4	5.2	18.8	3	36.2	9	5.8	56.2	32	0	42.6	0	6.2	6.4	13.4	0	0	0	0	39	10.6	0	0	0	0	
	7	0	0	0	8.8	0	4	39.4	8.8	1	0	0	0	13.8	5.8	16.4	1.8	7.2	21.4	3.8	0	0	0	18	73.8	18.8	0	14.4	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	14	0	37.2	10.2	17.3	13.2	4.8	0	0	0.9	8.2	0.2	0	0	0	24.3	1.4	0	0	23.7	0	10.2
	9	0	0	0	0	0	35	8	2.6	17	4.4	3.4	0	0.8	0	16.4	2	0.6	11.8	2.3	2.8	9.6	26	4.4	0	12	0	18.8	12	22.8	5.6	
	10	5.2	0	13.6	9	4.2	14	6.4	0	2.2	0.4	0	2	0	0	0	0	0	0	7.4	22	5.8	0.3	0	0	0	0	0	0	0	0	0.8
	11	28.8	3	0.8	0	0	0	26.2	3.4	0	0	0	16.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	12	0	0	5.4	0	0	0	0	0	0	4.4	0	0	0	0	1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	1	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	6.4	0	0	0	0	3	0	0	0	0	14.6	5	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.2	0	0	0	0	0	0	0	0	3.4	16	19.6	10.2			
	3	5.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	8.2	20	15	0	0	0	2.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33.2	0	0	0	0.4	0	0	
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	97	0	0	0	3	69.4	0	6.6	1.2	0	0	36.8	16	0	6	9.2
	6	0.6	0	1.4	0	0	14.6	2	0.5	0	0	0	13.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39.2	3	38.4	
	7	6.2	12	3	0	0	0	2.6	1.2	0	0	0	6.6	16.4	30.6	0.2	2	0	0	3.8	42.8	35.8	4.2	9	16.2	15.8	0.4	30.6	9	6	3	0
	8	0	0.2	8	0	0	0	0	3.4	0	0	0	0	4	1.1	0	0	0	74.4	5	3.2	0	0	0	5	0	0	6.2	0	0	31.2	0.8
	9	1.6	0	0	0	13.4	0	6	8	0	6.2	0	0	0	0	14.4	0	0	11.6	14	16.6	9.4	3.4	2.4	6.4	0	0	0	22	2.8	0	
	10	5.4	31.2	18.4	3.4	0	19.8	7.2	1.2	1.2	0	2.6	3.2	6.8	5.6	5.2	0	27.6	8.8	7.6	0	5	0	0	0	6.4	0	0.4	4	2	0	0
	11	0	0	0	0	0	0	0	0	0	0	4.6	7.2	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	12	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	1	0	0	0	0	0	0	0	0	10.8	1.4	0	0	0	0	0	0	0	0	0	0	2.9	1.2	8.8	0	0	0	0	0.2	15	0	0
	2	0	0	0	0	0	0	0	0	0	1	12.8	0	0	8	25	3.2	0	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	0	1.4	0	0	12	0	0	0	0	1.8	0	0	0	0	0	0	0	0	0	1	0	0	0	31.4	0	0	0	0	0
	4	1.4	16	4	0	0	0	0	0	0	13.6	13	0	0	0	0	0	0	0	0	37.4	0	9.2	9.8	16	0	1	0.8	4.8	0	1.4	
	5	4.8	0	0	0	0.1	0	7.6	0	3.2	0	0	0	9	18.2	0.2	0	10	0	0	0	0	0	0	0	0	0	24	26.8	11	0	0
	6	0	0	0	0	0	29	0	23.8	8.4	14.5	33.6	1.6	26	20	0.6	0	0	0	0	0	0	0	2	0	0	0	5.4	0	0	0	
	7	0	0	0	0	0	0	0	0	0.8	15	6	19.2	38	15.4	19.2	19.4	15.4	2.8	3.2	5.4	65.4	6.8	15	21.2	0	0	0	0	13	0	0
	8	0	27.6	16.8	0	1.6	0.2	0	0	0	0	13.6	2.2	3	2	0	0	0.2	10.1	27	2.2	0.4	0	0	0	0	0	2	0	18.4	2.8	0.2
	9	1.6	0	0	0	0	0	6.2	0	1.4	9.2	0.2	0	0	0	0	26	6.4	24.6	5.4	0	0	0	18.6	26.8	4.2	0	0	0	0	0	
	10	0	0	0	0	0	0	0	0	0	26.2	0.2	0	32.4	0.8	0	0	5	0	0	0	0	0	0	0	2.8	0	0	0	19.2	6.2	0
	11	9.8	8	0.6	1.2	0	0	0.2	0	0	0	0	0	0	0	0	0	20.6	0	13	3.6	0	0	0	0	0	0	0	0	0	0	
	12	0	0	0	3.6	1.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.6	0	0	0	0	0	0	0	0	0
1991	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3	3.4	26	5.8	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	7.6	0	0	0	0	3.2	0	0
	4	0	0	0	0	0	0	0	0	54.2	22.4	0.2	0	0	0	0	0	0	0	0	1.2	3.8	2.6	0	0	0	0	0	0	0	0	
	5	0	0	0.2	2.1	0	0	0	0	0	0	0	0	0	0	12.4	0	0	0	11.6	0	39.6	28.6	10.6	2.2	0	0	0	14.8	36	15.2	8.6
	6	5.6	0	0	34	5.8	1.2	0	0	0	9	6	0	14	23.7	15.2	15	1.8	5.8	0.6	0.8	0.1	8.6	46.6	0	10.4	6	29.4	15.6	0.4	4.6	
	7	0	31.2	16.4	10.2	7.6	4.2	0	0	7.8	0.3	0	0	8.6	0	25	36.4	9.6	8.1	0	2.6	0	0	3.2	17.8	0	21.6	6.3	0	8.1	11.8	14.9
	8	22	22	22.4	0	0	0	0	0	0	0	0	0	0	0	0	0	27	35	16	2.4	1.4	0	0	0	0	24.6	7	12.6	6.4	0	3
	9	0	3	6.8	0	0	0	10.8	22.5	37	0	0	14.8	1.2	0	51.6	0	0	8.2	7.4	0	0	0	0	0	0	0	0	0	0	0	
	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	42.6	19	0.8	0	0	0	0	0	0	0	2.8	0	0

	11	6	0	0	0	23.6	0	0	0	0	0	0	0	21.5	10	0	0	8	0	0	0	0	0	0	0	6	0	0	0	0	0	
	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	7	0	0	0
1992	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.5	0
	2	0	0	0	0	0	0	9.4	0	21.4	0	0	0	3.2	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	3	0	0	0	0	0	0	0	0	0	3.6	0	0	0	0	0	0	6	0	12.2	0	11.4	4.6	0	0	1.6	0	0	0	0	0	0
	4	0	0	9.4	0	0	0	0	2.6	0	0	0	0	0	0	0	0	0	0	21.8	0	0	0	0	0	0	2.2	4.4	20	0	0	
	5	3.4	1.9	9.2	16.2	8.8	18.2	3.2	0	0	0	0	0	0	8	0	0	0	0	0.2	0	12	3	22.2	11.8	1.3	0.1	0	0	21.2	5.2	0
	6	1.6	0.8	0	0	0	0	0	0	0	0	16.2	47.8	19.2	1.2	27.2	24.2	21.6	10.2	0.5	13.6	25.5	4.2	0	7.2	0	14.6	24.2	22.4	17.8	15.4	
	7	17	19.4	7.4	2.2	18.8	0	2.8	2.2	0	24	3.2	1	48.1	6.2	0.2	0	38.6	0	16.4	0.2	0.2	0	0	0	9	5.4	7	13.8	1.6	1.2	0
	8	0	1.8	7	10.4	14.9	8.6	12.8	1.5	16.6	18.5	21.2	1.6	3.2	28	11.2	10.4	0	0.4	0	0	0	1.5	0	1	16.8	20	4.6	43.2	0	4.5	11
	9	12	0	18.2	6.4	4	1.5	0	1.4	21.9	4.4	0	0	0	0	5	0	0	0	0	0.4	0.4	11.8	4	1.1	0	2.6	0	0	0	0	
	10	0	0.4	8	1.6	8.2	0	2	0	0	0	0.8	0	3.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	12	0	0	0	0	0	0	0	0	4.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.8	0	0
1993	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.4	3.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	19.8	53.2	0	0	0	0	7.2	0	0	0	0	3.4	0
	4	0	0	19	1.2	2.8	0	0	0	0.4	4	0	5.2	0.2	0	0	0	0	1	2.4	0	0	0.6	4.2	0	0	0	0	0	0	0	
	5	8	0.2	0	1.6	1.2	0	0	0	0	0	0	0	0	0	0	0	0	34	3.2	7.6	0	0	0	0	3.8	0	0	22.9	0.8	0.8	0
	6	0	0	0	0	0	0	0	0	0	3.2	0	0	0	0	0	27	6.2	15.8	0	2	0	0	0	0	5	14	35	5.2	19.2	0	
	7	2.2	31	2.2	3.8	0.4	0	0	0	4.4	40.4	20.6	25.4	0	2.6	5	21.4	0	0	0	0	0	34.8	0	2.8	7	26.2	14.8	25.9	32.6	11.6	17.4
	8	0	0	0	30.2	0.2	31.8	8.2	6	10.4	0	2.8	23	0.4	3.2	0	0	0	0	0	0	0	0	0	0	24	2.2	0	0	27.8	9.8	1
	9	0	0	0	23.6	0	16.4	22.2	8.8	0	0	0	23.6	0	0	3.4	6	12	8.2	6	1.4	0	0	5.8	0.2	0	0	3.8	0	0.8	16.4	
	10	2.8	12	0.2	0	0	0	2.6	5.8	0	0	0	0	0	0	0	3	0	0	0	0	0	0	4.2	5.3	0.5	0	13.8	1.2	0	0	9.8
	11	0.8	0	0	0	0	0	0	0	64	0	0	8	0	0	0	0.7	0	0	10.5	0	0	0	0	0	0	0.2	0	0	0	0	
	12	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8.2	0	0	0
1994	1	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	1.2	0	0	0	0	0	0	0	0	0	6.8	2.6	0	0	0	0	0
	2	0.1	3.2	1	0	1.4	0	5.2	5.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	3.8	0	3.8	0	0	0	3.8	0.6	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	3.8	3.2	0	0	0	0	0	0	0	0.4	1.8	0.8	0.6	0.4	0	0.4	0	
	5	0	0	0	0	0	0	0	0	0	0	0	4.4	2.4	0.4	0	5.8	0	0	0	0	20	14.4	38	36.8	30.4	0.4	0	11	31.8	32.4	3.6
	6	33.6	26	0	2.8	0	0	7.8	13.4	12.2	0.3	9	1.2	0.3	0	0	0	0	1	4.2	57	21	16.2	0.6	13.8	3.2	0.2	25.2	0	0.2	4.2	
	7	51	11.6	11.2	7.6	10	15	2.4	31	13.8	11.2	4.4	0	7.2	6	3.6	9.2	11.6	0.4	0	0	0	17.2	0	6.8	0	0	0	3.8	1.2	0	0
	8	0	0	0.2	80.4	2	1.8	0	0	0	8.6	5	2.4	0	0	0	0	0	0	0	0	0	4	0	0	0	0	6.2	0.4	0	0	0
	9	9.8	9.2	0.6	0	0	0	12.4	0	0	16	17.2	0	2.2	1.2	0	0	0	0	0	0	1	0	0	0	0	0	4.8	0	0	22.4	
	10	3.6	3	6.4	0	3.4	0	0	0	0	0	0	0	0	9.4	0	0	0	0	0	0	0	0	1.2	0.4	0	0	0	0	0	0	0
	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	1.2	11.2	11	9.6	0	0	0	
	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.6	0	0	0	0
1995	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14.8	
	5	0	0	0	0	0	0	0	0	0	10.2	24.9	20.4	15.7	0.4	0	0	0	22	0.2	0	2.1	24.3	45.6	1.7	0.8	0	0	6.8	3.6	0	0
	6	0	12.8	0	0	6.2	17.5	18.8	29.2	21.7	0.3	0	0	0	0	0	0	0	0	0	0	4	1.5	0	9.4	7.1	18	0.2	4	0	0	
	7	0	0	0	0	0	25.2	1.8	49.2	34	2.7	8.8	11	9.8	6.4	2.2	2	0	1	1.5	48	23.6	0	0	10.4	31.4	9.2	15.4	0	35	5	1.4
	8	0.5	0	0	0	0	0	0	0	36.4	8.2	4	7.8	15.6	0.2	0.4	0.2	17.2	0	0.8	10	4.5	9.2	9.6	18	2.4	0	0	0	0	3.9	0
	9	0	0	29	0	1.6	17.8	10.2	0	4.4	0	0	5	15.6	1.4	2.4	0	0	4.2	6	11.6	0	0	0	0	0	0	0	0	0	0	
	10	0	0	0	5	3	0	0	0	1	3.5	5.8	0	0	0	0	1	4.6	41.8	4.4	0	0	0	0	0	0	0	0	0	0	9.9	7.6
	11	16	3.8	0	0	0	0	6.6	8.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.2	4.8	6.6	2.6	2.4	0	
	12	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0.5	0	0	0	0	0	10.2	0	0	0	0	0	0	9.6	2.6	0	0

	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.2	0
	2	0	0	0	0	0	0	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	3	0	0	0	0	0	0	0	0	0	2	0	0	0	1.4	2.8	1	0	0	0	0	0	0	2.4	0	0	0	0.5	8.5	0	0	0
	4	0	0	0	1.8	0	0	0	0	0	0	1.2	4.5	0	0	0	0	0	0	4.8	23.4	0	0	0	3	1.4	0	0	0	0	0.1	
	5	0	0	0	0.2	12.6	0	0	18	10.8	18.2	0	0	0	1.6	0.8	0.4	0	1.8	0	0	0	0	0	0	0	0	0	0	0	0	62
1996	6	4.2	0	1.6	0	0	0	0	0	0.2	13.2	0	6.5	4	0	0	30	5.2	29	27.5	29.4	34.6	9.6	9.3	0	0	0	28.2	17.8	2	27.4	
	7	9.4	16	20	9.4	0	0	0	21.8	0	0	0	0	0	0	0	19	24.2	18.2	7.8	0.2	15.2	15.4	28.2	14.2	11.4	0.4	13.2	20.4	6	27.4	12.4
	8	39.4	15.4	6.8	13.8	18	1.4	4	0	0	0	37.2	7.5	20	0	8.9	0.8	0	0	0	10.2	15.4	1.2	7.6	42.2	0	0	19	10	1.4	0	4
	9	0	0	14.4	0.6	0	8.1	1.4	6.4	2.2	24	19.3	0.6	0	7	11.6	8.4	5.2	32	2.6	0	0.2	36.6	4	0	0	0	16.8	1.8	0	3.1	
	10	0	0	0	0	0	0	0	0	1.4	11.6	0	0	0	0	0	0	0	0	0	0	6.5	15.8	12	9.2	0	0	0	0	0	1.3	0
	11	0	0	0	0	0	7.6	2.8	0	0	0	0	0	0	0	23.5	17.8	0	0	0	0	0	0	0	4.8	0	4.9	0	0	0	15.8	
	12	12	7.4	0.5	0	0	0	0	0	0	0	0	14.8	0	0	0	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	6.6	0	0	7.2	1.2	0	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15.2	0	0	0	0	0	0	0	0	0	0	2.8	11	4.7	0.4
	4	0	0	0	0.2	0.8	1	0	0	0	0	0	1.4	0	0	0	0	0	0	0	4.5	0	0	0	0	0	0	4.1	0.4	3	3.5	
	5	19.8	0.8	0	0	0	0	0	0	0	0	0.5	1.8	1.2	0	0	0	0	18.6	13	0	0	0	32.2	0.6	14.8	8.4	12	1.2	0.2	0	31.8
1997	6	32.4	12.4	14.8	37.4	20.4	13.6	6	6.8	33	2.2	13.6	6	0.2	0	0	0	0	0	9.8	13.2	12.4	0.8	9.5	0	6.4	0	0.8	0	0	0	
	7	0	0	14.4	0	3.6	11.4	18.6	0	9.2	0	0	0.3	35.1	10.4	0	0	0	0	0	0	0	0	0	7	10	4	18.3	3	3	4.8	0
	8	0	0	0	19	21	6.6	2.1	4.9	27.4	14.6	0	0	0	3.8	30.4	11	0	0	0	0	0	0	0	0	0	0	9.3	22.2	8.4	0	0
	9	1	17.8	5.6	0.6	0	12	1.5	16.2	17.8	3.3	0	0	0.4	0	0	0	0	0	13.1	0	0	0	0	12.2	0	2	0.4	0	0	0	
	10	0	0	0	0	0	0	0	5	20.8	22.6	0	0	0	0	0	0	0	0	0	0	0	0	10.8	0	0	0	0.5	3	0	0	0
	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14.8	18.3	0	0	2.4	8.2	0	0	0	0	
	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.4	11.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0			
	3	0	0	0	0	0	0	0	0	0	34	23	0	0	0	0	0	0	0	0	8	21	2	0.8	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	3.2	18	0	0	0	0	0	0	0	11.6	0.5	0	0	0	0	0	3.8	2.2	0	0.4	0	0	0	0	
	5	0	0	0	0	3.8	0	0	0	13.2	0	0	0	0	0	0	0	0	17.6	4	4.2	16.8	17.8	0	0	0	27.8	4.2	7.6	4	0	0
1998	6	0	3.2	4.8	7	19.8	3.5	0	53.5	9.4	29.7	18	0	15.4	0	0	0	19	0	0	1	0	0	0	0	0	12.8	9.4	11.8	0	0	
	7	0	0	0	19.7	14.9	19.2	1.4	0	0	0	0	0	0	0	0	0	2.3	17.8	5.8	0	7.6	12.6	0	0	0	12.4	0.8	0	0	0	3
	8	19.8	2.9	7	0	19.4	19.7	3.6	10	2.2	15.7	14.8	0.2	0	0	0	7.2	6.6	30.6	13	0.6	2.6	0.5	0	14.5	0	0	24.5	8.4	24.4	19.2	6.6
	9	25.6	28.6	18.4	0.4	0	0	0	0	0	2	0	0.2	8.1	0	0	0	3.5	0	0	0	27.2	29	0	0	8.8	4.1	19.7	4	7.6	6.6	
	10	15.6	7	0	0	0.8	0	0	0	0	4.2	0	1.6	7	3.2	0	8	10.6	0	0	3.2	0	0	0	0	0	0	4.2	0.4	0	0	0
	11	3.2	2.2	0	0	0	4	0	0	0	0	0	0	7.8	11.8	0	0	2.8	9.2	0	0	0.4	2	0	0	0	0	0	0	0	0	
	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14.8	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0			
	3	0	0	0	0	0	0	0	1.5	7.8	0	0	0	0	0	0	0	0	0	5.2	3.4	1	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	2	0	0	0	0.8	0	0	0	1.8	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	
	5	0	10.4	7.6	0.4	0	11.4	0	0	2.8	4	0.8	0	1.6	1.4	1.2	3.6	1.2	0	18.4	25.4	27	1	0	0	0	9.2	13	31	0.4	0.6	0
1999	6	0	4.4	11	0.8	0	0	0	7.2	6.8	0	19.8	8.4	0	23.4	10	10.2	0	28.6	11	7.2	0	0	47.2	0	0	30.7	5	19.6	6.8	2	
	7	0	0	0	34.5	16.5	6.2	0	0	0	0	0	0	10.9	33.6	33	24.2	12.1	2.6	4.9	0	0	0	0	0	0	14	7.4	12.6	6	0	0
	8	0	0	0	0	0	0	24.2	0	0.8	36	13.8	3	0	0	5	4.4	18	11.4	9	0	0	0	0	22.6	13	0.6	0.8	0	12.2	2	0
	9	0	2.2	20	11	0	0	0	0	0	0	36	0	1.6	23.4	20.5	2.6	0	0	0	0	2.8	0.3	0	0	0	6	12.3	6.8	3	1	
	10	10	0	0	0	0	0	23.8	61.8	5.5	0.2	0	0	1.6	19.8	0	18.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	11	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	12	0	2	0	0	0	0	0	0	0	0	0	1.2	4.4	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0
2000	1	0	0	0	0	0	0	0	0	0	0	0	1.8	0	0	19.2	6	8.2	0	0	0	0	7.4	18.2	0	0	0	0	0	0	0	7
	2	0	0	0	8	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0		

	3	0	0	0	0	0	0	0	0	0	27.8	0	0.5	0	0	0	0	2	0	0	0	1.2	10.4	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	1.6	0	0	0	0	0	0	0	0	0	0	0	1.2	11.8	10	19.4	11.9	1.2	
	5	0	0	0	0	0	0	0	3	0	0	19.6	9.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6	0	10.4	0	0	0	0	0	0	0	3.4	2.8	0	0.4	114.8	10.2	0	0.4	0	27.2	16.7	7.4	4.6	1	8.4	36	17	6.5	0	0	0	
	7	28.6	51	5.6	49.3	16	3.2	10.6	0	0	0	29.4	0	21.2	10.8	17.3	16.1	24.7	15.8	11.8	12.8	2.9	9.2	5.8	2.5	0	0	1.2	7.4	3.5	0.5	1
	8	8.2	24.7	2.2	0	9.2	35.2	22.8	0	2	0	0	0	3.9	0	1.6	37	1	0	2	3.6	0	0	0	23.8	0	15.4	0	5.5	21.6	15.2	27
	9	6.9	10.8	0.6	0	0	48.2	4	1.9	0	0.4	0	0	16.6	6.6	2.3	10.7	0	0	0.6	0	0	0	0	0	0	0	3.8	5.8	5.7	6	
	10	0	0	0	0	0.6	0.6	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	6	0
	11	0	0	1.4	0	0	0	0	20.5	5.8	4.2	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	14.6	1.4	0	0	
	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.4	0	0
2001	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0.6	0	0	0	0	0	0	1.6	2.2	0	0	0	0	0	0	0	0	0.6	5.5	0	0	0	0	0	
	5	0	0	0.7	0	0	21	5.4	11.6	0	9.8	0	15	8.4	0	0	0	0	0	0	3.4	5	0	0	12	10	0	0	0	1	11.8	0
	6	1.5	3.4	1	8.2	0	0	0	0	11.2	4.8	1	0	0	0	0	0	4.8	0	0	0	0	0	0	9.2	0	0	0	0	0	14	
	7	4.1	6	9	7.2	0	0	9.1	13	7.2	0	0	12	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	6.6	0	47.6	7.2
	8	0	0	16.4	9.2	0	10	3.2	1	18.8	0	7.6	0	0	29.4	14.8	0	0	0	0	0	0	0	0	24.3	0	0	0	0	0	11.4	0
	9	1.2	1	2	0	6.9	15.8	10.6	1	18	1.4	0	2.6	7	0	3.4	3.4	0	1	1	0	0	18.5	8.3	0	0	0	0	1.8	34.4	15	
	10	6.2	0	0	0	0	0	0	0	2.6	0	0	4.8	0	0	0	0	0	0	0	0	18.7	11	0	0	0	0	0	0	0	0	0
	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34.5	0	0	0	0	4.4	0	0	0	0	0	1.2	
	12	19.4	0	3.9	2.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.5	0	0	0	0	0	0	0	0	0	0	0	0
2002	1	0	0	0	0	0	0	0	0	0	4.8	0	0	0	0	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3.8	0	0	0	0	0	0	0	0	4.2
	4	0	0	0	0	0	0	4.6	1.2	7.8	0	0	0	0	0	0	0	38	7	0	0	0	2	8.8	0	0	14.4	0	0	0	1	
	5	1.9	1.8	44.1	0	0	23.5	12.8	12.4	6	1	24.4	9	0.6	2	1.4	0	0	0	0	0	0	0	0	3.2	0	0	0	0	0	0	0
	6	0	15	12.2	37.2	25	19.5	4	0	0	0	6.6	0	13.6	15.8	7.4	0	0	12	7.6	0	0	0	0	5.1	2.2	10.8	6.7	0	18.7	0	
	7	16.2	4.4	3	3	13.3	2.1	12.1	8.2	1	8.8	22.4	28	4.5	11.8	7.9	0	0	7.5	23.4	0	3	2	0	9	16.6	10.2	35	0	0	2	0.8
	8	6.8	0	0.8	8.4	24.8	1.6	0	0	24	15	3	0	0	0	13.4	0	0	0	0	0	0	1	0	0	11	5	14.6	0	1.2	19.2	26
	9	43	10	17.5	0.6	2.4	0	0.8	0	0	0	0	0	1.8	4.4	30.8	1.2	0	0	0	1.8	0	2.6	12.8	4.8	0	8	0	0	0	0	
	10	0	0	0	0	9.5	27	8	0	0	0	0	0	0	0	0	0	12	40	1	0	0	0	0	2.3	0	0	0	16.6	3.4	0	0
	11	33	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	
	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.6	0	0	0
2003	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	4	0	0	0	0	0	0	0
	2	0	5.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	3	0	0	0	0	0	0			
	3	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	3	4	0	0	0	0	0	0	16
	4	0	0	0	0	0	0	15	0	0	0	8	51.9	22	0	0	0	0	0	0	0	0	4.8	0	0	12	2	0	0	0	0	
	5	0	0	0	0	0	0	0	0	0	0	0	19.1	9.1	0	0	41	6.4	0	0	0	28.6	6.2	0	0	0	0	0	0	0	19.2	3
	6	7.4	6.2	5.6	1.2	1	0	0	0	0	11	1.2	0	0	0	0	0	0	0	0	0	0	0	6.2	2	56.6	33	40.4	19.2	13	4.8	
	7	0	2	26.4	9.1	0	0	35.2	1	7.5	26	28.8	0	4.5	31	1.4	0	0	0	0	16	2.2	5.4	0	0.4	0	1.2	0	6.8	0	29.8	3.4
	8	0	0	35.6	17	5.4	2.8	0	0	0	0	25	2	0	0	0	15	0	0.4	0	6	6.4	32	1	1	0	0	0	0	3.7	0	0
	9	0	0	0	20.6	0.8	0	1.6	6	15.8	16.8	13.8	8	8.2	0	0	0	0	0	0	9.5	12	17	25.8	0	11	0	0	0	0	3.2	
	10	1	0	0	0	0	0	0	0	0	0	0	0.6	18.6	6.5	3	0	3	0	0	0	0	0	0	0	0	0	2.2	0	0	0	0
	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	21.2	15.6	8.4	0	0	0	0	12.8	0	0	0	0	0	
	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.4	0
2004	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	3.8	4.2	0	8	10.8	0	0	0	0	0	0	0	0	

	5	0	0	0	0	0	0	15	2.6	0.4	33.8	16.5	0	0	0	0	13	2.1	17	0.8	1.6	6	39.8	0	0	0	0	0	0	0	0	6.5
	6	0	0	0	0	14	19.4	35.8	21	6.8	11.4	51.3	20	2.4	0	0	0	30	1	0	0	0	36	2	7.2	0.2	0	27	22	6	8	
	7	6	44	7.5	12	0.8	0	27	18.6	0	0	0	0	0	0	0	0	0	0	0	0	9	46.3	0.5	0	3.5	0	0	0	0	19	5.4
	8	16	6	4	2	3	0	0	0	0	0	0	53	6	13	1	0	0	7.4	0	12.8	20	4.6	16	40.6	31.4	21	8	3.4	0	0	0
	9	0	0	0	0	10	12.8	2.2	0	0	0	0	0	0	0	0	0	0	0	10.4	0	4	0	0	0	0	3.4	0	0	0	0	
	10	6.2	0	0	0	0	23	11.6	0	0	5.2	4	36.5	1.4	0	0	2.7	0	0	0	0	19.8	0	0	0	0	0	0	0	1.4	0	0
	11	0	0	0	0	0	0	0	0	1.2	8.2	6.3	8.8	0	0	0	0	9.4	0	0	0	0	0	0	0	2	11.6	16.8	0	0	0	
	12	0	0	1.4	0	3.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	5.6	0	0	2.6	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	0	0	0	0	0	0	0	4.8	5.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.6	0	0	19.5
	4	32.8	11.4	0	0	0	0	0	0	3.4	0	0	0	2.4	0	0	0	1.8	0	0	0	0	0	1.8	1.4	0	0	0	0	0	0	
	5	0.6	81.6	16.8	0.4	0	0	0	0	0	0	0.2	17	6	1.2	4.2	53.4	0.6	0	59	1.4	0	15.6	0	0	0	0	0	0	0	0	0
	6	0	0	15.8	0	0	0	52.4	7.4	37.1	20.4	21	36	0.4	0	1.8	0.8	11.8	11	3.7	0	0	0	18.5	30.8	4.6	0	0	0.9	0	15	
	7	1.8	0	0	33.9	6.6	0	0	0	0	0	0	0	15.8	11.6	4.8	0	0	0	0	0	22.6	4	8.2	2.4	4	2.2	2.5	4.6	0.2	1.2	0
	8	0	17	6.8	0	4.6	2.4	1.8	0	0	1.8	0.4	0	29.6	19.8	0.5	6.6	31.8	22.4	0.4	0	0.2	0	0	0.2	0	0.8	0	14.4	3.4	7.6	0
	9	0	0	2.2	1.2	2.4	22.8	25.3	21.8	15	0	0	8.6	2	15.8	0	0	22.4	3.4	0.4	4.6	9.4	0.6	0	0	0	0	10.4	2.9	13	8.9	
	10	15.2	7.8	1.2	20.4	0.4	39.9	0.4	0	5.3	0	0	3	0	0	0	0.4	8.4	0	0	0	0	14.6	3.2	0	17.6	6.1	1.2	0	0.8	2.6	15.8
	11	0	0	0	0	17.8	0.2	0	8	1.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50.8	0	0	0	
	12	0	0	0	1.2	3	2	0	0	0	0	22.8	1.6	2.6	0	0	0	0	0	0	3.4	0	0	6.9	0	0	0	0	0	0	0	0
2006	1	0	0	5.4	0	0	0	0	2.2	0	0	0	0	4.6	0	0	0	0	0	0	0	0	0	0	0	22.2	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.2	0	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9.2	0	4.2	0	0	0	0	0	0
	4	6.8	0.2	0	0	0	0	0	0	0	0	3.2	0	0	0	0	0.4	0	1.2	0	0	0	0	3.9	0.4	8.8	15.6	0	0	0	0	
	5	0	0	0	0	2.8	7.8	0	0	0	0	0	0	0	0	7.6	2.2	0	0	0	0	0	0	4	0	0	0	0	0	3.6	1.8	0
	6	0	0	0	0	0	0	3.8	0	0	0	0	0	0	0	0	0	0	0	0	22	2	0	0	0	0	4.4	10.7	28	0	0.2	
	7	8.9	0	1.2	2.4	0	0	0	0	14	8.4	0.4	0	0	1.2	0	0	0	0	0	0	25.2	0.2	0	0	31	5.3	21	20.2	17.4	14.3	0.3
	8	6.4	11.8	3.9	0.5	1	0	19	14.9	0	0	0	13	9	0	45	8.2	0	0	31	17.6	0.2	28.9	24.9	0.2	0	4.4	0	0	0	0	17.2
	9	9.7	2	0	4.2	0	0	0	0	0	4.8	13.3	19.2	0.2	0	0	0	0	11.4	3	2	6	6	2.2	0	0	0	0	0	0	0	
	10	0	0	0	17.8	0.2	0	0	0	0	0	0	34.6	7.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	11	0	0	0	0	0	0	0	2.2	0	5.6	9.5	2.2	0	0	0	0	1	0	0	0.9	0	0	0	0	0	0	0	0	19.8	3.4	
	12	0	0	0	0	0	0	0	4.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2007	1	0	0.6	18.2	0	0	0	0	0	0	4	2.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	4	5.4	0	0	0	0	0	0	0	0	0	1.8	2.6			
	3	10.8	28.2	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9.8	0	0	0	0.4	0	0	0	2.8	0	0	0	0
	4	0	0	0	0	0	0	0	4.6	0	0	0	0	0	0	0	74	0	1.8	0	0	0	0	4.3	0.2	9.2	0	0	0	2.2	39	
	5	28.2	10.6	6.2	3	1	2.3	0	0	0	0	0	6.6	0.6	0	0	0	0	5.6	0	8.1	0.2	0	2.2	2	10	20.8	12	23.6	0.2	0	0
	6	0	0	0	0	0	0	2.8	5.3	1.2	0	0	0	0	21	0	0	0	0	0	0	0	0	34.2	9.8	6.8	0.8	0.8	38	1.8	10.6	
	7	5.2	19.6	28.8	5.4	0.2	2.9	0.6	12.2	4.2	0	0	0.4	0	0	0	0	0.6	0	4	23	7.4	32.8	9.4	30.2	13.6	10.8	2	32.4	3.6	1.6	29.6
	8	11.6	2.2	0	0	0	19.2	14.2	8	0.2	29.2	9.4	0	0.4	3.2	0	0.2	0	0	0	4.4	0	0	34.4	0	9.8	18.2	11.2	10	10.8	36.4	0.4
	9	0.2	0	0	0.6	11.3	0	1.4	18.6	2.4	0	0	40.6	15.2	0	11.8	4.2	5	6	7.4	1.2	5.8	9.2	0	20	7.4	7.8	18.3	2.6	0.2	2.2	
	10	1.4	0	0	0	0	0	0	22.8	17.4	4.2	8.2	0	0	0	0	0	0	12.4	0	0	5	0	0	0	0	0	27	2.8	0	1.1	0
	11	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	4.2	
	12	4.8	1.8	0	0	0	11.6	0	0	0	0	0	0	0	0	0	0	5.6	10.8	0	0	0	0	0	0	0	0	0	0	0	0	0
2008	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	3	0	0	0	0	0	0	0.6	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	59.6	0	0	0	8.2	1.5	0	7	0	6.2	0.8	0	0	0	0	0	24	0	5.2	0	1.8	4.8	13.4	0	0	0	12	5	5.6	8	
	5	0	0	0	0.8	0	0	0	0	0	0	23	1.2	0.8	9.6	5.2	13	0.2	0	0.2	0	0	23.4	36.4	24.2	9.8	0	0.4	3.4	23	0	0.6
	6	33.6	0.8	0	0	0	0	0	0	36.8	11.4	7.8	0	0	0	5.6	37.8	11.6	0	0	0	0	0	0	0	13.8	0	0	32	22	2.8	

	7	0.4	0	0	12.6	12.2	2	0	0	6.6	0	26.8	1.4	0	0	0.4	50	2	22.8	13.2	0	0	0	0	47.2	2.4	1.2	4	10.8	11.1	14.8	15.4
	8	1.4	15.8	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	7.8	1	0	0	0	0	0	0	0	0	2.8	2.2	0.8
	9	14	1.2	0	0	0	0	0	0	0	0	6.2	8.4	0	0	0	0	24.2	0	22.8	7.8	5.8	4.6	0	0	27	6.7	0	4.4	5	4	
	10	2.4	9.4	0	4.2	6	0	0	0	0	0	0	2.2	0	0	0	0	0	0.8	0	0	1	0.6	6	4.8	28.6	0.2	0	0	1.2	0.6	0
	11	0	0	0	11.8	0.6	21.4	0.6	0	0	0	0	0	0	0	0	0	0	0	0	3.2	3.2	0	7.3	1.8	8.6	0	0	7.8	0	0	
	12	0	0	0	1.6	2.2	0	0	0	0	1.8	1.8	0	0	0	0	0	0	0	0	0	55.4	0	0	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.1	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	33.4	0	0			
	3	0.2	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	8.8	0	0.4	0.2	1.8	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.6	0.2	7	44.2	17.8	0.2	0	0	0	0	0	0	0
2009	6	3.4	1.6	0.2	10.2	0.6	0	0	0	0	7.4	15.4	3.2	0	0	0	0.4	0	14.8	34.4	31.2	16.4	0	0	6	30.6	2.8	17.6	40.8	37	31	
	7	3.4	0	0	0	0	0.2	11	2	8.8	28.4	9.4	0	0	0	0	21.4	30	8.4	24.6	20	17	3.4	33.2	0	7.8	0	0.8	0	0	0	0
	8	0	0	0	0	1.4	18.4	0	3.2	0.4	0.6	15.8	10.2	8	14.4	46	11.4	15.2	0	26.8	4.6	6.8	8.2	10	2.6	0	0	0	1	1.4	0	0.2
	9	5.4	17	1	0	16.4	6	3.4	25.4	5.6	6.4	31.4	31.6	9.8	2.2	14.8	1.4	4	28.2	2	3.6	41	2.5	4	0.8	0.4	0	0	8	0.4	2.2	
	10	0	0	5.2	0	0	0	0	0	0	0	0.5	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.4	0	10	0	0
	11	0	0	0	0	0	5.6	0.2	9.2	0	0	0	3.6	9.2	0	0	0	0	24.6	33.2	0.6	0	0	0	0	0	1.6	0	0	0	0	
	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	4.8	18.8	0	0	0	0	0	0	0	0
	4	0	0.4	0	3.4	2.2	0.4	0	0	0	0	0	8.4	5	14.8	13.2	2	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0	
	5	5.6	0	0	0	0	0	0	0	0	0	0	0	4.2	0	0	0.8	1.4	0.2	0	0	0	14	18	0	0	0	20	4	0	0	0
2010	6	1.2	0	0	0	0	0.2	0	0	0	0	0	0	0	13.4	26	19	2.2	5.6	5	0	0	0.4	27.2	0	0.5	0	1.8	0	0.2	0	
	7	0	7.2	0.2	0	0	0	0	0	68.2	10	7.4	24.8	12.4	0	0	0	5	0.2	0	0	0	0	0	0	0	14.2	22	17.6	16.8	0.8	2.2
	8	0	0	0.4	0	0	0.6	0	0	0	0	0	17.4	27.4	1.8	0	0	0	2	0	1.2	2.8	6.2	0	2.8	0	0	0	0	0	7	2.4
	9	0	0	0	0.6	0	0	3.2	21.8	9.6	0	0	11.6	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	10	0	0.2	0	0	0	0	0	0	0	1.4	8.4	0	0	0	0	0	0	0	0	0	14.6	0	0	0	0	0	0	4	0.4	0	0
	11	0	0	0	0	0.3	0	0	0	0.6	0.8	8.4	0.4	0	0	0	0	0	0	0	0	1.6	0.4	0	0	0	0	0	0	0	0	
	12	0	0	0	0	0	0	0	1.8	0	0	0	0	0	0	0	0	0	0	0	4	1.8	0	0.2	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	27.2	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	5.4	10.2	10.6	0	0	0	4	2.6	1.4
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	1.8	1	0	0	5.2	4.2	0	0	0	0	0	0	0	0	0	0	0	10	14.6	0	32	11.4	2.2	0	
	5	0	0	0	0	0	11.2	0	0	0	0	0	0	0	0	0	0	0.4	4	0	30	18.6	0	0	0.4	0	0	0	0	0	37.2	5.6
2011	6	0	73.2	0	0	0	0	0	0	0	0	0	0	0	8.5	13	10.4	0	9.2	3.2	5.6	4	0	4.2	6.4	53.8	1.4	0	34.8	18.6	2.6	
	7	32.2	17.2	10.4	0.2	0	0	0	0	0	0	2.8	5.2	0	0	4.8	31.2	0	0	0	1	13.4	3	3.4	0	0	7	0	29.6	13.2	12.4	21.2
	8	10.6	7	19.8	10.6	0	0	1.8	6.8	5.2	0	0	0	0	29.2	6	31	1.8	0	0	0	0	56.2	5	12.8	0	0	0.4	0.4	0	0	0
	9	0.2	20.6	12.4	5	1.2	0.2	0	0	0	0	0	0	2.8	0	0.2	15	7.4	38.4	16.8	6.4	18.8	3	0	0	0.2	7.8	11.6	12	0	0	
	10	0	0	12.6	1	0	0	0	0.8	0	0	1.4	0	7.4	1	0	0	0	7.6	0	0	0	0	7.4	0	9	2.8	0	0	0	0	0
	11	0	0	1.4	6.8	10	25	9.2	34	4.6	0	0	0	0	0.6	0	0	0	16.8	0	0	0	0	0	0	0	0	0	0	0	0	
	12	0	0	0	0	4.8	0	11	9	0	0	0	0	40.4	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8.6
	1	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	3.5	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.6	0	0	0		
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0
2012	4	0.6	5.4	19.4	2.6	19.6	0.2	0	0	0	0	0	0	0	0	0	0	0	3	4	0	0	0.2	0	0	0	0	0.7	0.3	14	18.8	
	5	0	0.2	0.2	20	42	12.2	1	18.4	5.4	5.4	0.2	0	0	2.8	0.8	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	2.4
	6	5.8	0	0	0	0	0	19.6	11	0	0	46	37	35	3.3	0	9.6	2	0.8	26.4	21.7	17.2	0.2	0	0	0	0	16	1.2	0	0	
	7	0	0.6	0	0	0	0	14	0.8	0	0.6	10	0	0	0.6	0	9	0.4	0	0	0	0	0	0	1.2	0	0	0	0.6	0	0	19.2
	8	12.4	7	15	11.8	2.2	1	18.4	7	0	0	0	5.6	39	1.5	5	0	0	0	0	0.4	14	11.2	0.8	1.5	0	0	3.5	6.4	6.4	0.2	0

	9	19.8	2	8	59	16	4.4	0	0	0	0	3	0.8	0	0	0	0	0	17	0	10.2	3	20.6	0	0	11	19.2	22.4	11.4	0	0	
	10	0	0	10.6	0.8	0	0	0	0	0	0	0	0	0.4	17	3.4	0	0	0.4	0.6	0	0	10.8	4	0	0	0	0	0	0	0	0
	11	0	0.4	0	32	16	5.2	1	0	0	0	1.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	31.6	10.4	
	12	4	0	0	0	0	0.8	1.4	1.6	0	0	0	41.8	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
2013	1	0	1.8	0	0	0	0	0	7.6	0	0	0	0	0	0.4	0	0	6.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1.6	0	0	0	0	0	0			
	3	0	0	0	2.6	1.4	0	0	0	0	0	0.8	0	0	0.2	35.2	0	0	0	0	0	0	0	0	0	0	15.8	1.8	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	5.2	0.2	0	0	0	0	0	0.8	0	8.6	0.2	0	0	0	0	3	0	0	
	5	0	56	13	2.2	0	0	0	24.4	31.6	42.8	10	0	0	0	0	0	34.2	1.6	0	10.8	0	0	0	0	0	0	0	4.4	0.8	25.2	3.8
	6	0	0	0	0	4.8	0.6	0	0	6.8	6.7	0	0	0	0	0	0	2.6	0	0	1	0	0	0	15	14.8	0	1.8	1.4	2.4	0.2	
	7	0	0	3.8	1.4	0	0	0	0	0	18.4	0	25.6	0.4	0.6	14.4	13.4	9.4	0.6	0	0	0	0	0	57	4.4	32.4	55.2	4.6	4.8	2.2	11.2
	8	4.6	4	0	0	3	25.6	34	36	5.6	15.8	9.8	0.2	5	2.4	5.4	17.4	9.2	3.2	0	0.4	1	0	0	0	0	4	22.2	19	9.2	30.4	22
	9	5.4	4	2.2	19	0	0	0	0	0	0.2	25.8	26.8	0.6	9.4	9	0.4	22.6	1.8	8	13.2	37.6	21.2	28.4	18.8	3.8	0.2	8.4	0	3.2	13.4	
	10	0.2	0.2	0	0	4.3	9.6	0	0	10.4	1	0.4	4	0	0	0	6.4	0	0	3.6	10.4	0.2	0	0	0	0	0	0	0	0	0	0
	11	0	0	0	0	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.4	2.4	0	0	0	0	22.2	
	12	2.6	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0.8	0	0	0	4.4	3.2
	4	1.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3.2	16	1.6	0	
	5	0	0	0	0	2	0	4.6	31	23.4	15.2	0.4	0.6	4.4	0.8	2.6	0.6	2.2	4	9.8	5.6	54.4	2	53.4	25.8	17	15.8	6.2	2.4	1	0.4	0
	6	2	2.4	1	0	0	0	0	0	1	25.6	3	0.6	0	0	0	0	0	46	13.4	11	4.4	33	1.8	0.4	0	0.4	13.4	0	0	0	
	7	3	23.4	26.2	0	6	8.8	24	28.5	0.2	0	0.6	0.8	0	18.2	4.8	7.2	0	0	0	8.8	1.8	21	1	7.4	0.8	10	20.2	2.8	5.2	2.4	2.8
	8	0	0.4	0	0	0	0	8	2.6	0	0	0	0	0.6	0	1	0	0	15.2	16.4	0.4	20	13	0	0	0	6	0	0	33	53.2	0.6
	9	0	0	0	0	0	3.4	20	31.4	17.6	0.8	2	0	1.2	0	0	0	0	0	0	0	0	28.6	0	0	0	0.6	19.2	28.2	17.6	5.8	
	10	0	0.6	0	5.8	12	14	0	0	2.2	0	0	0	0	0	0	0	0	0.4	2.2	0	0	0	0.2	3	0	3	0	0	0	0	2.4
	11	0	0	3	0	0	0	7.2	0	0	0	0	0	0	0	0	0	0	0	0	0	2.4	3	1.4	0	0	0	9.6	19.8	0	0	
	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	12	18.6	0.8	0	12	3	0	0	0	0	0	0	0	5	0	0	0	0
	4	0	0	0	0	0	0	2	9.8	2.6	40.2	5.4	21.2	5.2	0.2	2.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	5	4	0	0	31.2	0	0	0	0	0	0	0	0	0	0	0	10.4	18.8	0	3.6	0	0	1.4	0	1.4	0	1	0.2	0	0	0	0
	6	0	13.2	8.4	1.4	0.2	4	1.8	0	0	0	0	2.4	0.4	0	0	0	0	3.4	6.4	5.8	13.6	16.8	0.4	0	0	1	0.4	0	0	0	
	7	0	0.8	0.8	1	3.6	0	6.8	4.4	0	2.2	0.2	0	0	0	0	0	0	7.2	0.4	23	35	1	14	0	0.4	0	0	1.6	1.8	3.6	8.4
	8	13.4	0	0	0	0	0	1.8	14	8.2	16.6	8	0	1.2	0.8	0	0	5.8	18.4	4	18.2	2.4	19.8	0	0.4	0	0	0	9.2	0.2	16.8	0.6
	9	14.6	0	0	0	11.2	0	0	0	0	0	0	44.6	10.4	0.8	3	0	0	0	1.4	0	0	0	0	0	0	0	0	0	0	0	
	10	0	0	0	0	9.2	4	0	0	0	0	0	0	0	4.2	1.6	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	31
	11	0.8	10.2	3.2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2.9	5	0	0	0	0	0	0	0	0	0	0	0	
	12	0	0	0	0	4.4	7.2	3.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.4	7.6	32	4.1	0	0	0	0	0	0	0	0	1.4	11
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	5	0	0	1	0	1.4	0.2	0	0	0	0.2	0	0	0	16.8	0.4	7.2	0.6	2	0	0	33.2	15.2	15	47	0.8	8.4	0	23.2	2	0.2	0
	6	0	0	0	7.5	0	0	13.8	0.6	0	11.2	0.2	0	24	0.4	0.2	0	0	0	0	23.4	2	3.4	3.3	0	5.4	0.2	0	4.3	13.1	0.2	
	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	19.6	3	0.2	18	27.6	13.4	8.2	1.2	13.6	0.2	0	0.4	16	21	21.6	0	9.4	0	11	0	0	0	0	42	9.2	0.8	0	15.2
	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	10	12.2	6.2	5.2	3	0	0	7.6	19.2	11.6	0.6	0	0	0	5	15.2	0	0	0	0	3.2	0	0	0	0	0	0	0	0	3.2	0	0

	11	0	0	0	0	0	0	0	0	0	0	8.8	0	0	0	0	0	6.2	0	0	0	0	0	0	0	0	0	0	0	0	0	
	12	0	0	0	1	0	0	0	0.8	0	0	0	7.5	14.5	0	0	0	0	0	0	0	0	0	0	0	0	0	8.2	0	0	0	0
2017	1	0	0	0	0	0	1.2	0	0	0	0	0	1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0
	2	0	0	0	0	0	0	0	0	0	67	12.4	1	0	0	0	0	0	0	0	0	5.8	0.2	0	0	0	0	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	5.8	9.6	7.5	0	0	0	3	0	0	4.4	2	0.4	0	5.2	0.2	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	5	0	0	0	0	2.6	0.2	0	0	9.2	0	0	0	0	0	25.5	4.8	0.4	0	37.4	13.4	21.8	4.2	4.4	2	0	5.2	0	0	0	0	0
	6	0	0	2.8	0.8	0	0	0	0	0	0	0	0	0	0.6	0	0	0	0	0	0	3.2	19	48	0	0	0	0.4	0	0	0	
	7	27	7.5	0	2.5	18.5	3.5	17	0	0	0	2	9	8.2	0.5	2	21	0	0	19	23.5	14.5	19.8	3.5	18	13.5	7	6.5	21.5	20.5	19	0.4
	8	26.4	0	4	9	0.8	0	2.5	13.5	59.5	20	2	21	14.5	26	12.5	8.5	7	5.5	4	1.6	1.5	2	0.5	0	0	0	0	0	0	20.5	10.8
	9	2	11	0	0	0	0	0	0	0	0	0	4	0	0	0	0	1.2	0	0.5	8.3	88	31.5	11.3	2.5	11	0.5	1	2	3.2	0	
	10	0	0	0	0	0	0	3	3.5	0	0.4	4.5	0	0	0	0	9.5	12.5	9	0	0	0	0.5	0	0	0	5	9	3	3	0	0
	11	0	0	0	0	0	0	0	0	0	0	0	9.5	0	0	0	0	0.4	2	17	0.5	0	0	0	0	0	0	0	0	0	0	
	12	0	0	0	5	1	0	0	0	0	0	0	0	0	0	0	0	9.5	33	13.5	0	0	0	0	0	0	0	0	0	0	0	0
2018	1	0	0	0	0	0	0	0	0	0	0	1.2	0	0	0	0	83	0	4.2	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15.5	0	0			
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	1.6	0	0.5	0	0	0	0	0	0	0	0	0	3	9	0	0	0	0
	4	0	0	0	0	0	0	0	0.5	0	4.2	0.4	0.2	1.5	0	0	0	0	1.5	0	1.5	0.4	20.5	6.2	0	0	0.2	0	0	0	0	
	5	0	3.3	0.2	0	0	1.2	10.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	44.5	29.5	15.2	10.2	0.5	0	5.4
	6	13.5	0	0	0	10.2	34.5	0	0	0	42.5	15.4	5	3	0	0	0	0	23.5	12.5	13	0	0	0	0	0	0	49	6.2	0	0	
	7	0	8	29	24	12	0.5	0	0.4	0	0	0	0	12.5	3	29	9.4	4.8	0	0	0	0	77	11	8	1.5	39.5	1	2	0	13.5	0
	8	24	15	18	40	1.5	0	6.5	11	0	32.5	0	0	0	21.5	1.8	3	9.5	0	0	0	8	3.5	0	0	0.5	0	0	16.5	24	8	0
	9	0	0	0	6.5	7	0.2	8	7.5	4.5	2.5	4.6	0	3	7	0	0	1	0	0	0	0	0	0	0	0.8	0	0	0	0	7.5	
	10	0	0.5	0	8.2	0.5	1	0	0	0	0.4	0.8	0.5	9.5	33	8.5	0	0	9	3	1	6	4	0	0	0.5	0	0	0	0	0	0
	11	0	0	0	0	6	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	2.5	0	0	0	0	
	12	0	0	0	0	0	4	1.5	0	0	0	0	3	0	0	0.5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2019	1	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.5	11.5	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
	3	1	0	0	0	0	0	6	4.5	0.5	4.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0.6	0	0	0	0	0	0	0	0.5	0	0	5.5	3	2	0	25	4	0	0	0	0	0	0	0	0	0	0	
	5	0	0	0	3.5	1	16	0	0	0	0	0	0	0	0	0	14.2	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	26.5	8	31.5	17.4	37.5	10.5	5.5	8.5	5.5	0.5	5	0	0	0	0	2.5	34.5	4.5	0.8	7	32	22	0.2	8	
	7	5.8	0	0	0	37.5	6	15.5	4.5	4	1.5	0.8	0	0.6	0	0	0	0	4.8	13.8	24	8	7	1	0	4	0	1	0	0	0	0
	8	0	0	0	3.5	7	11.5	0	0	0.8	0	0	0	5.5	15.5	6.5	0.2	29.5	0	0	1	0	0	34	1	0	0	0	0	0	47	17
	9	1.5	12	27	3	0	0	0	0	0	0	0	0	0.5	0	0	0	0.8	24	0	0.2	0	0	0	0	0.5	0.4	0	0	0	0	
	10	1.5	0	0	4.5	18	0.2	0	0	0	0	0	1.5	2	0	5	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	31.5
	11	11.6	17.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3	0	0	0	0	0	0	0	0	0	0	
	12	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	8.5	0.3	0	0	0	0	0	0	0	0	0	0	0
2020	1	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0.5	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0		
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	1	0.5	16	0	0	0	0	0	0	0	0	0	7	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	10.5	0.8	2.4	6	1.5	0	4	0	0	0	0	0	
	5	0	0	0	1.8	17.6	19.6	3.2	22.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32.5	14.5	3.5	4.6	19.2	36	15.5
	6	2	0.2	0	0	0	0	0.4	0	0	0	13.2	28	3	2	2	1.5	28	24	0.5	0	0	0	25	7	0.2	0	19.5	33	10	5	
	7	2.5	0	0	0	0	8	13	9	0	0	0	0	14	14.4	4	17	26	1.2	0.2	0	0	0	10.5	0	0	5.5	0	22	0	0	1.5
	8	0	0	6.6	0	2	0	0	0	15	20	27.5	0.8	0.5	0.5	2	20.4	16.2	4	0	0	0	0	0.5	0	0	0	0	0	3.5	0	0
	9	22	16	0.2	0	3	10	32.5	2	0	17.5	0	0	0	0	0	0	0	0	13	15.5	1	9	0	0	0	0	13.4	1.5	0	0	
	10	0.5	3	0	0	0	0	0	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
	11	20.5	4	2	0	0	0	0	0	0	57	0	0	9	5	10	0	0	1	2.5	0	0	0	0	0	0.5	0	0	0	0	11	
	12	0.2	0	0	0	0	0	0	0	0	0	0	0	2.5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2021	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0.8	0	0	0	0
	2	0	0	0	0	0	0	33	15	5.4	0.6	0	0	0	0	0	0	0	4.5	0	0	0	0	0	0	0	0	0	0			
	3	0	13.5	11	0	25.5	4	0	0	0	0	0	5.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	5	0	0	0	0	47	6.5	0	0	0	0	0	0	0	0	0	8	0	7.5	0	0	0	0.4	33	19.6	0	0	0	0	15.5	32	4
	6	0.2	0	0	0	0	1.2	7	0	0	16	4.6	0	0	10	6.5	0	0.5	0	0	27.4	14	0	0	0	0	0	0	23	0	0	
	7	6	0.5	0.2	4.6	39.4	19	24	7	3	44	0	4	13.5	25.4	17.5	4	1.4	3.4	2.4	2.5	19	2	1.4	12	2	0.5	69.6	4.2	26	20	9.2
	8	25	4.5	0.5	0	0	0	0	5	9	17.6	5.8	2	0	0	0.4	0	0	0	18.5	4.4	0	14	0	0	0	5	1.5	0.6	2.6	9	8
	9	9	17.2	3.5	0	0	0	0	0	23	3	4	0	0	0	0	34.6	0.8	9	7.5	0	0	0	0	0	0	0	0.6	0	0	3.4	
	10	2	24	0	0	18.8	0	0	0	4.5	0	12.4	5	0	0	0	0	0	0	14.4	25.6	7	0	0	0	5.5	0	0	0	0	0	0
	11	4	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	
	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	6	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX C - Daily Water Balance

Daily water balance evaluation can be undertaken for selected pits or storages based upon the following assumptions:

- Provide the link between the storages as defined in the pit design
- The evaporation losses have been assumed as negligible from the catchment, compared to the infiltration losses
- Daily precipitation from BOM, representative for the site
- Infiltration losses can be considered constant during the year
- Assume daily infiltration rate for the storage/pit; note that this may be subject of further refinement/calibration, as a function of future data collection
- Data from the Wokalup research station can be used to represent the site evaporation

Volume of storage with index k for a day t can be evaluated starting from the storage volume at the end of the previous day increased by the inputs and reduced by the outputs for that day, i.e.:

$$V_t^k = V_{t-1}^k + Input_t^k - Output_t^k$$

where $Input_t^k$ is the Runoff from catchment + Direct rainfall on storage + Discharge from upstream storage(s)
$Output_t^k$ is the Catchment Infiltration + Storage Infiltration + Storage Evaporation

Or, in more details:

$$V_t^k = V_{t-1}^k + RnfCatch_t^k + DirRain_t^k + \sum FlowUpst_t^k - InfCatch_t^k - InfStor_t^k - EvapStor_t^k$$

where V_t^k is the Volume in storage k on day t, m³,
V_{t-1}^k is the Volume in storage k on a previous day t-1, m³,
$RnfCatch_t^k$ is the Catchment Runoff for storage k on day t, m³,
$DirRain_t^k$ is the Direct rainfall on storage k on day t, m³,
$\sum FlowUpst_t^k$ is the Sum of discharges from storages upstream of storage k for day t, m³,
$InfCatch_t^k$ is the Catchment Infiltration for storage k on day t, m³,
$InfStor_t^k$ is the Infiltration from the floor of storage k on day t, m³, and
$EvapStor_t^k$ is the Evaporation from water surface of storage k on day t, m³.

Additional formulations are as follows:

$$RnfCatch_t^k = CatchArea^k \ x \ rain_t \ x \ RnfCoeff^k$$

$$InfCatch_t^k = max(CatchArea^k \ x \ inf_t, RnfCatch_t^k)$$

$$DirRain_t^k = StorAreaTop^k \ x \ Rain_t$$

$$InfStor_t^k = StorAreaBase^k \ x \ Inf_t$$

$$EvapStor_t^k = StorAreaTop^k \ x \ Evap_t$$

$$Overflow_t^k = max\,(0, V_t^k - Vcap^k)$$

where $CatchArea^k$ is the Catchment area for storage k, m²,
$Rain_t$ is the Rainfall for day t, m,
$RnfCoeff^k$ is the Volumetric Runoff Coefficient for storage k,
$StorAreaTop^k$ is the Top water surface area of storage k, m²,
Inf_t is the Infiltration for day t, m,
$StorAreaBase^k$ is the Bottom surface area of storage k, m²,
$Evap_t$ is the Evaporation for day t, m, and
$Vcap^k$ is the Storage capacity for storage k, m³.

If the storage volume exceeds the storage capacity the outflow will take place and the storage volume for the day is set to the storage capacity.

Sample water balances have been developed in EXCEL, EPA-SWMM and Matlab.

APPENDIX D - Assessment of Pit Design Criteria

The assessment was undertaken to establish whether the current design criteria used to evaluate the volume of storages in pit water containment design is appropriate, i.e. if by using the current criteria most of the historical rainfalls would be captured.

The daily water balance tool, developed as part of the pit water management design, was used to address this question.

Methodology

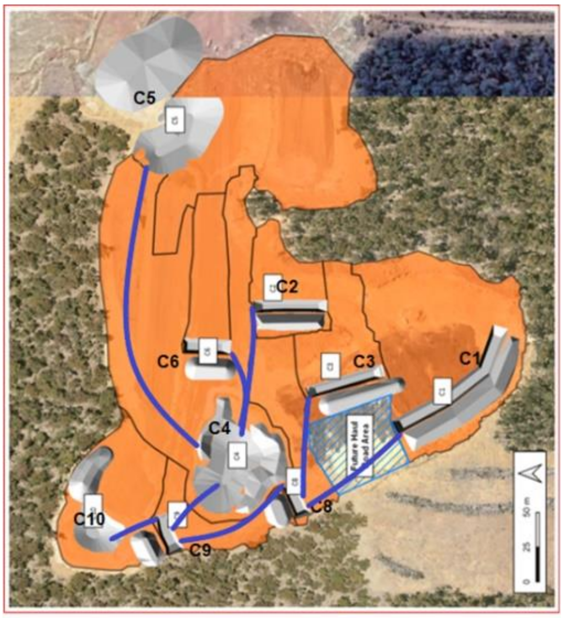
Undertake daily water balance at Kisler 5 pit under several scenarios and over the longer period:

a) Storage volumes evaluated based upon 24 hrs 1% AEP and 72 hrs 1% AEP as rainfall design criteria
b) Undertake sensitivity analysis of results on the assumed infiltration for each of the rainfall design criteria, using infiltration equal to 24 mm/day (currently used in the design), 12 mm/day (half current design) and 48 mm/day (double current design)
c) Identify the year with largest outflows and identify the storage design criteria which would prevent outflows
d) Evaluate the likely impact of groundwater levels on the design criteria

Pit geometry

The figure below shows the storages and the water path for the Kisler 5 pit, with geometrical details provided in the table below. Note that grey shapes in the figure below represent storages and the associated spoil, each of them located at the downstream end of the sub-catchment marked with a solid line. Blue lines illustrate the water path from the storage to storage, eventually reporting to the downstream most storage, marked as C10.

Note that, for the purpose of this analysis, the storage volumes presented in the table below do not have an additional storage provided as a factor of safety beyond the stated design criteria. In reality, through design (rounding off to larger than required volumes) and construction (building bigger rather than smaller storage volumes than required), a factor of safety does exist.

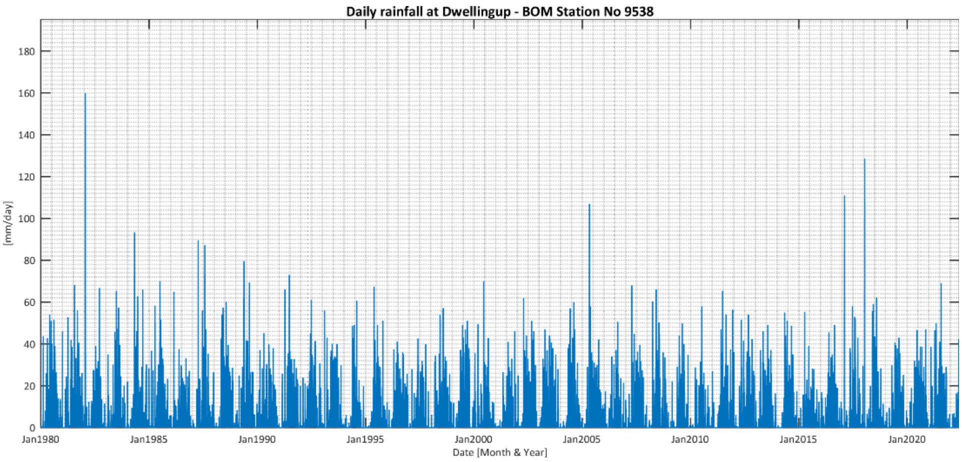


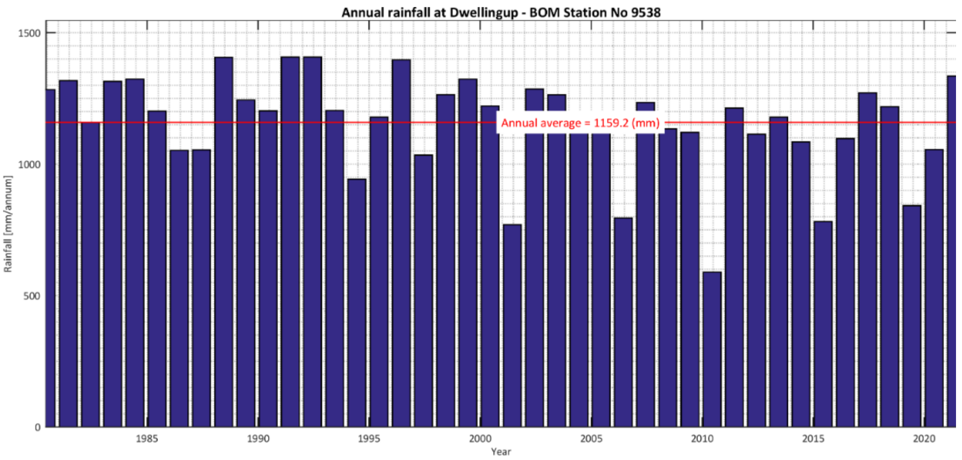
Mine	Huntly			V tot	9,080.5	m^3			
Pit name	Kisler 5			Catch tot	7.2	ha			
No of trenches & sumps	9				0.0715				
Storage Index	1	2	3	4	5	6	7	8	9
Storage Name	C5	C6	C2	C3	C1	C8	C4	C9	C10
Storage Volume (m3)	1981.2	393.7	431.8	520.7	1638.3	469.9	2489.2	368.3	787.4
Depth - base to overflow (m)	4	2.5	3	2.5	3	3.8	4	3.2	2.9
Storage cacthment area (ha)	1.56	0.31	0.34	0.41	1.29	0.37	1.96	0.29	0.62
Vol rnf coeff [-]	1	1	1	1	1	1	1	1	1

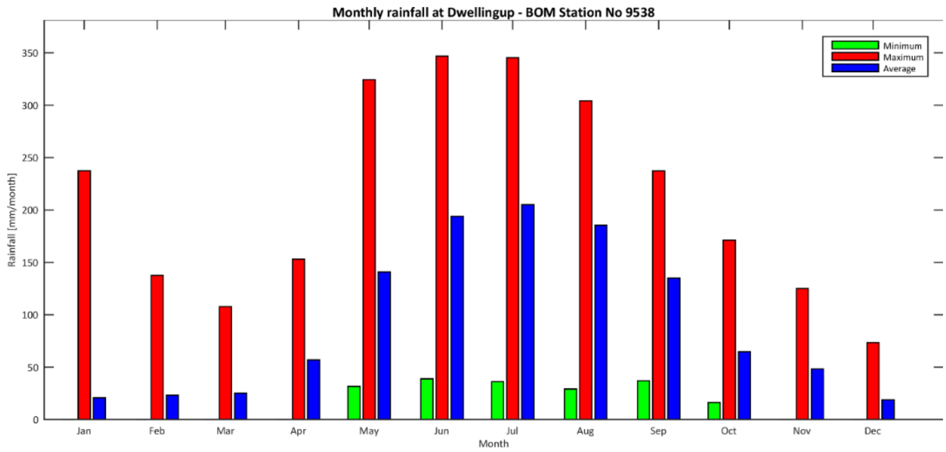
Rainfall

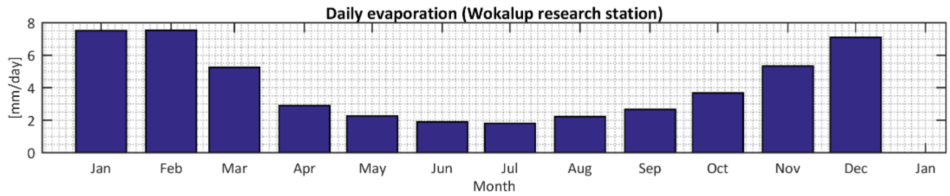
The rainfall record is identical to that used in Sump Design Tool (SDT), starting from 1980, and presented in the figures below, showing daily, annual and monthly rainfalls, respectively.

Note that this rainfall period includes the significant rainfall event in 1982, cyclone Bruno, with a daily rainfall of 160 mm.









Daily water balance formulation as applicable for multiple storages is presented in Appendix C.

Simulation results

In what follows the results are presented for two alternatives in relation to the potential impact of the groundwater:

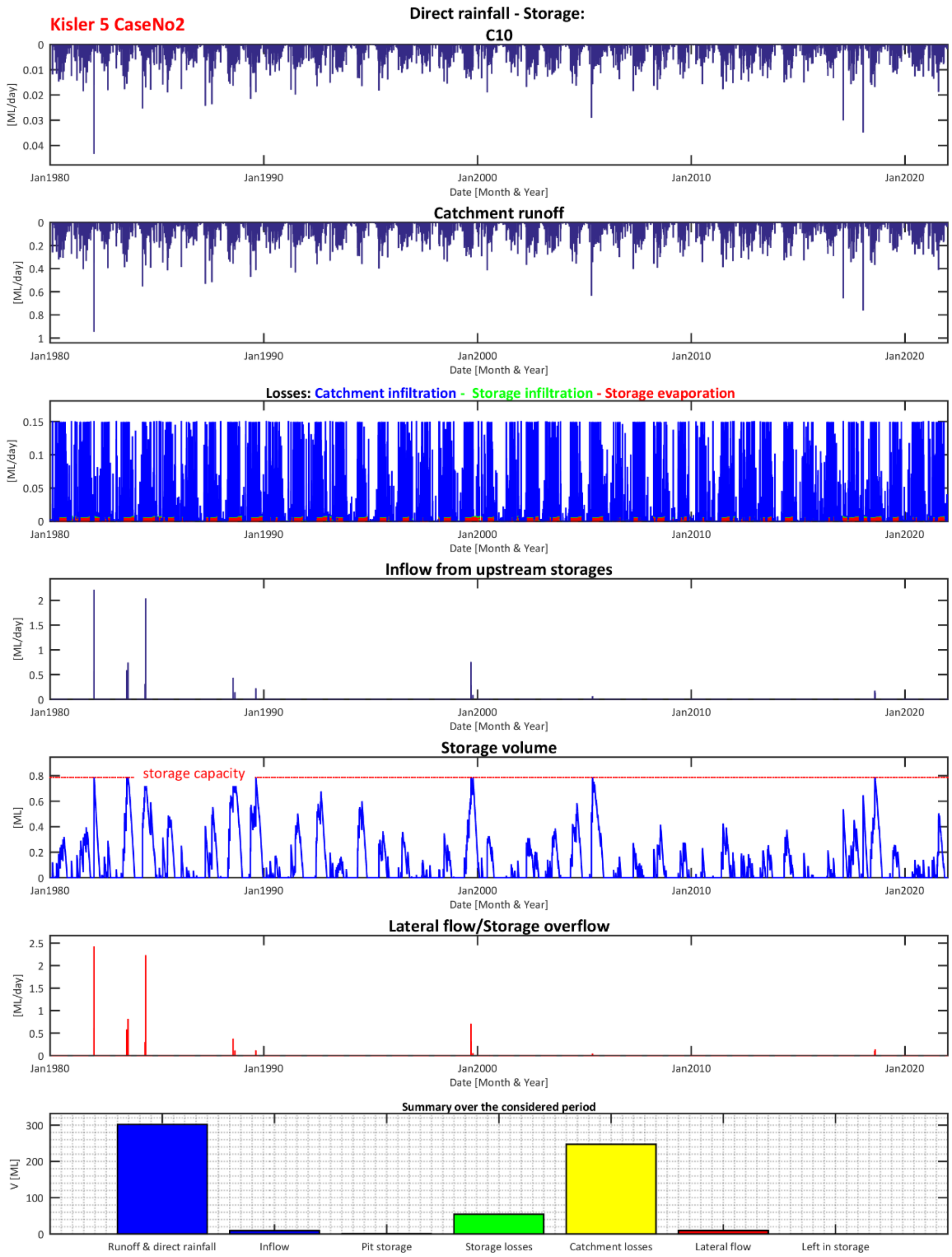
a) No adverse impact of the groundwater
b) Potential impact by the groundwater

A) Case with no adverse impact from the groundwater

Considered cases are summarised in the table below.

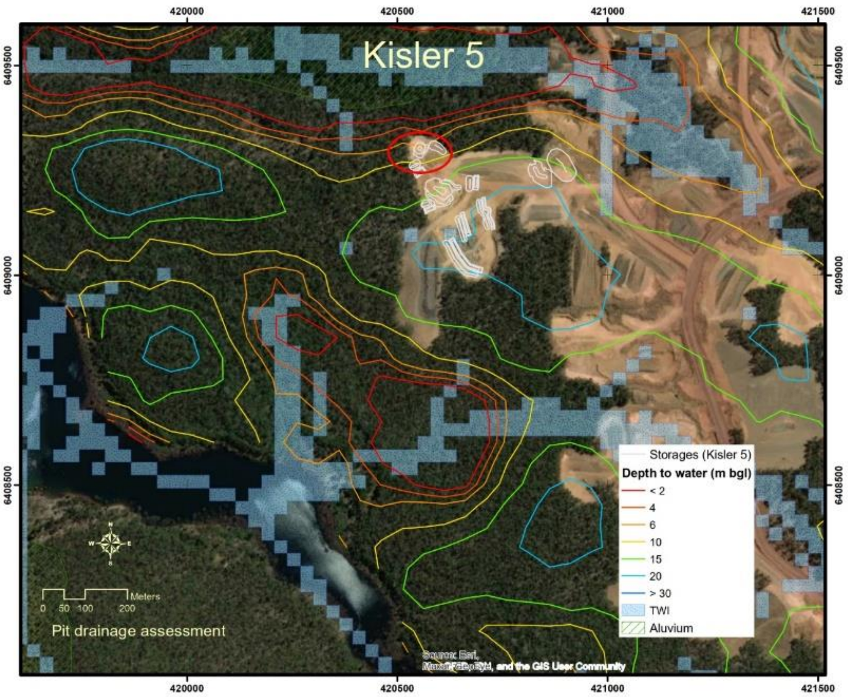
Case No	Storage Design rainfall criteria	Daily infiltration [mm]
1	24 hrs 1% AEP	12
2	24 hrs 1% AEP	24
3	24 hrs 1% AEP	36
4	24 hrs 1% AEP	48
5	72 hrs 1% AEP	12
6	72 hrs 1% AEP	24
7	72 hrs 1% AEP	36
8	72 hrs 1% AEP	48

Model results for Case 2 are presented in the figure below, detailing the selected water balance components for the downstream most storage of the Kisler 5 pit, storage marked as C10.



B) Case with inclusion of possible adverse impact from the groundwater

The recent estimates of the likely groundwater levels in proximity of the Kisler 5 pit (shown in the figure below) were used to refine the estimate of the likely spatial distribution of infiltration.



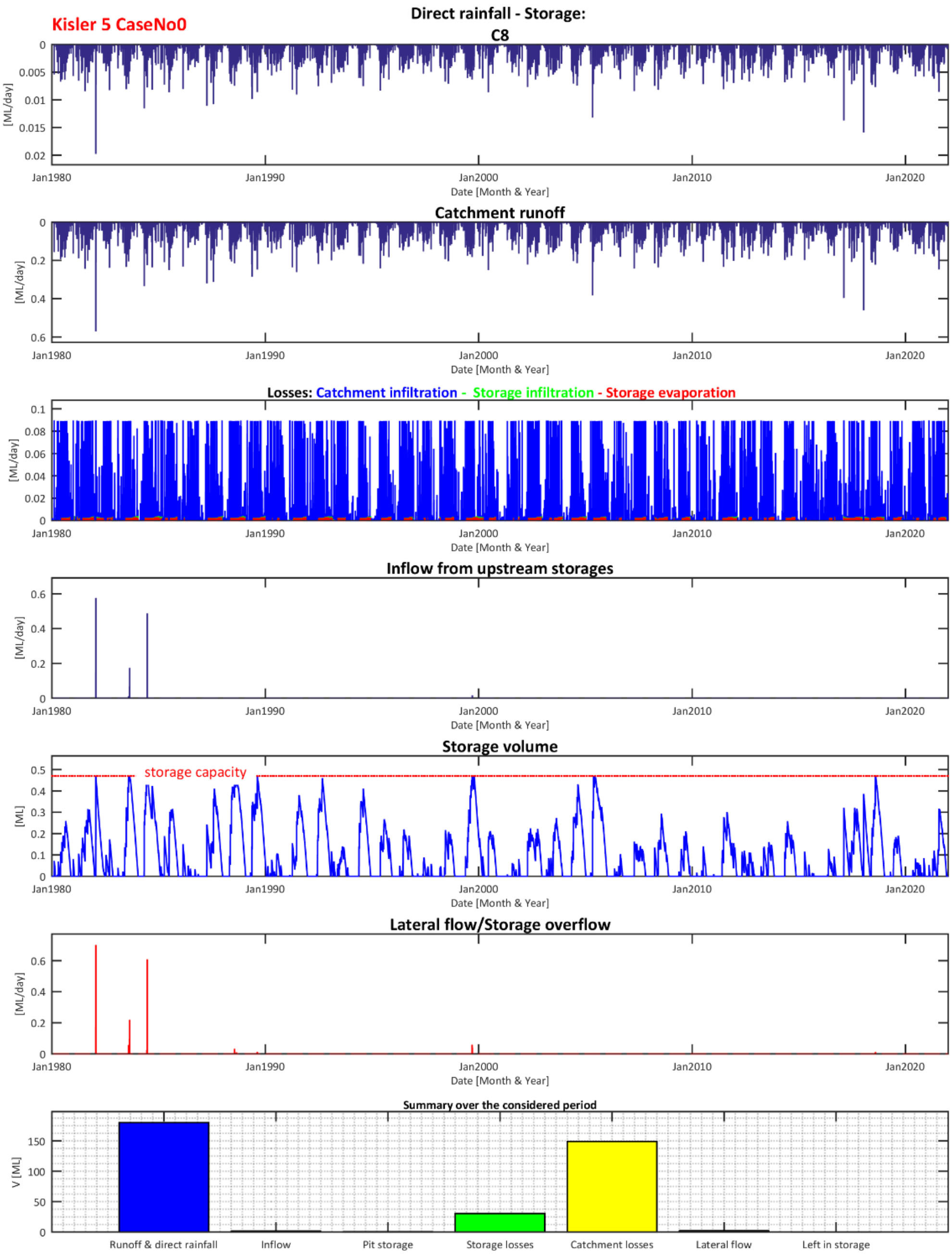
The inspection of GW levels led to the decision to undertake the water balance simulations with a reduced infiltration rate at storages C9 and C10 due to their location in proximity of higher groundwater levels (marked with a red circle).

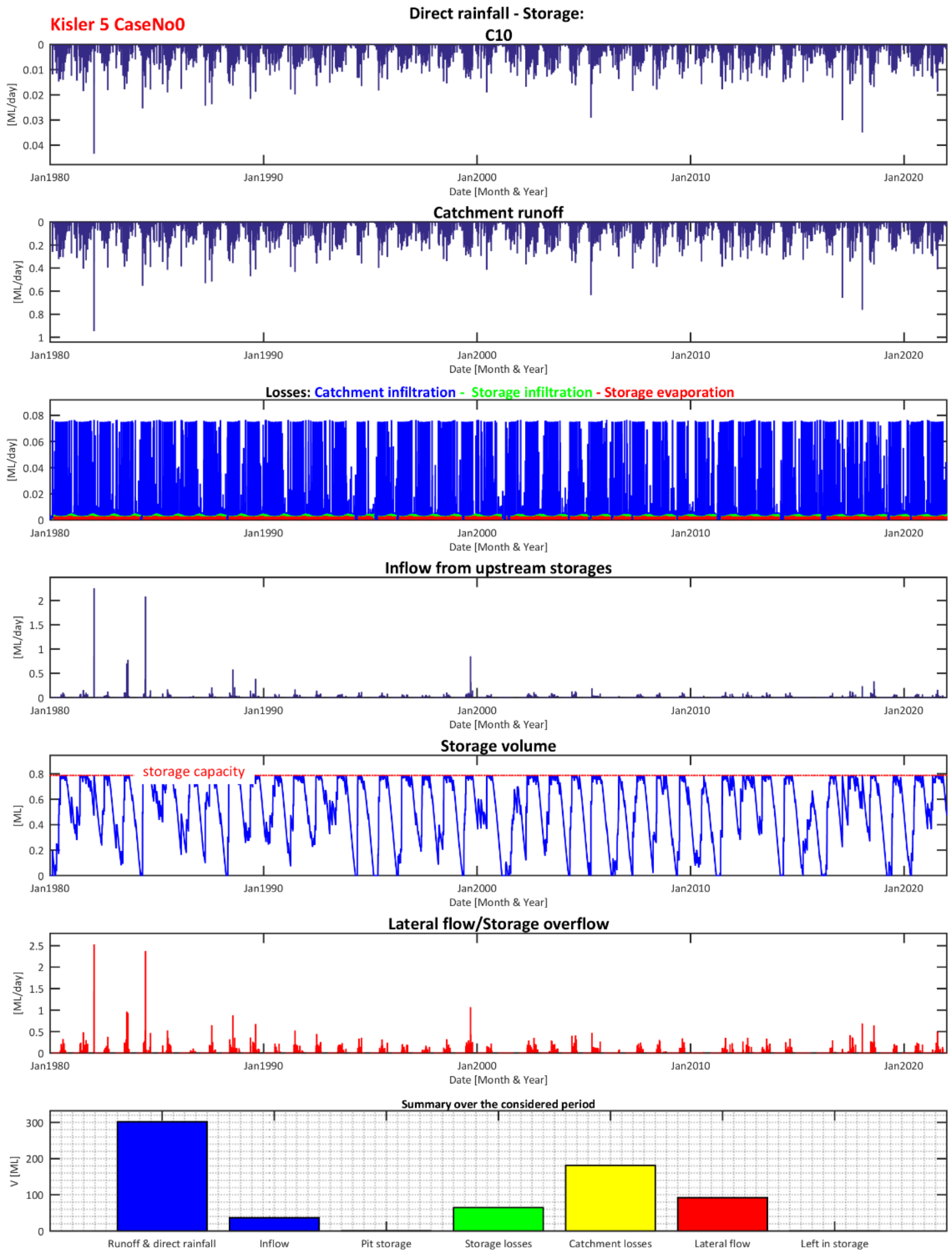
The daily water balance tool was used to address this question, under following conditions:

a) Storage volumes were evaluated based upon 24 hrs 1% AEP as rainfall design criteria
b) Infiltration rate equal to 24 mm/day (currently used in the design) was used outside of the zone with higher GW levels and 12 mm/day (half current design) within the zone with higher GW levels (storages C9 and C10)
c) All the other geometrical and model parameters were kept the same as in the original sensitivity analysis of the water balance for the Kisler 5 pit (Advisian 2022)

Simulation results

Model results are presented in the figures below, detailing the selected water balance components for one storage where infiltration rate was assumed to be 24 mm/day (**C8**) and the downstream most storage of the Kisler 5 pit, storage **C10.**


Kisler 5 CaseNo0
Direct rainfall - Storage:
C8
[ML/day]
Date [Month & Year]
Catchment runoff
Losses: Catchment infiltration - Storage infiltration - Storage evaporation
Inflow from upstream storages
Storage volume
storage capacity
[ML]
Lateral flow/Storage overflow
Summary over the considered period
V [ML]
Runoff & direct rainfall
Inflow
Pit storage
Storage losses
Catchment losses
Lateral flow
Left in storage
Jan1980
Jan1990
Jan2000
Jan2010
Jan2020



Summary of results for A and B

The table below presents the selected model results, including the outflow from the downstream most storage within the pit, both as the volumes (in ML) and as a percentage of the catchment runoff and direct rainfall onto storages over the entire pit.

Model results for the entire pits and outflows from the downstream most storage over the entire simulation period – Case 9 reflects the simulations addressing the potential adverse impact of the groundwater

Case No	Storage Design rainfall criteria: 1% AEP & duration	Daily infiltration	Catchment runoff and direct rainfall over entire pit	Catchment losses over entire pit	Storage Losses over entire pit	Outflow from last storage in the pit	Outflow as fraction of rainfall runoff & direct precipitation

		[mm]	[ML]	[ML]	[ML]	[ML]	[%]
1	24 hrs	12	3,481.1	2,103.6	649.1	722.4	20.75
2	24 hrs	24	3,481.1	2,869.8	601.9	9.4	**0.27**
3	24 hrs	36	3,481.1	3,165.4	314.4	1.3	0.04
4	24 hrs	48	3,481.1	3,272.6	208.5	0.0	0.00
5	72 hrs	12	3,481.1	2,074.9	862.1	536.1	15.40
6	72 hrs 1	24	3,481.1	2,830.6	650.5	0.0	0.00
7	72 hrs	36	3,481.1	3,122.2	358.9	0.0	0.00
8	72 hrs	48	3,481.1	3,228.0	253.2	0.0	0.00
9	24 hrs	24 & 12	3,481.1	2,772.8	615.6	92.1	**2.65**

The currently used design criteria have been marked in grey.

It can be observed that:

- For the current design criteria and without the adverse impact from the groundwater, only a very small fraction (0.3%) of the catchment rainfall runoff and direct precipitation on the storages resulted as outflow from the pit.
- Once the adverse impact of the groundwater is considered and compared to the design conditions marked in gray, the overflow is somewhat higher, but still quite small, equal to some 3% of the of the catchment runoff and direct rainfall onto storages over the entire pit and over the entire considered period.

Conclusions

The results indicate that the suggested design criteria of 24 hrs 1% AEP rainfall to evaluate the volume of the storages within the pit, together with the assumed infiltration of 24 mm/day, constant during the year, can capture most of the rainfall runoff and direct precipitation on storages, considering the historical rainfall period from 1980-2021. Note that this rainfall period includes the significant rainfall event in 1982, cyclone Bruno, with a daily rainfall of 160 mm recorded at Dwellingup.

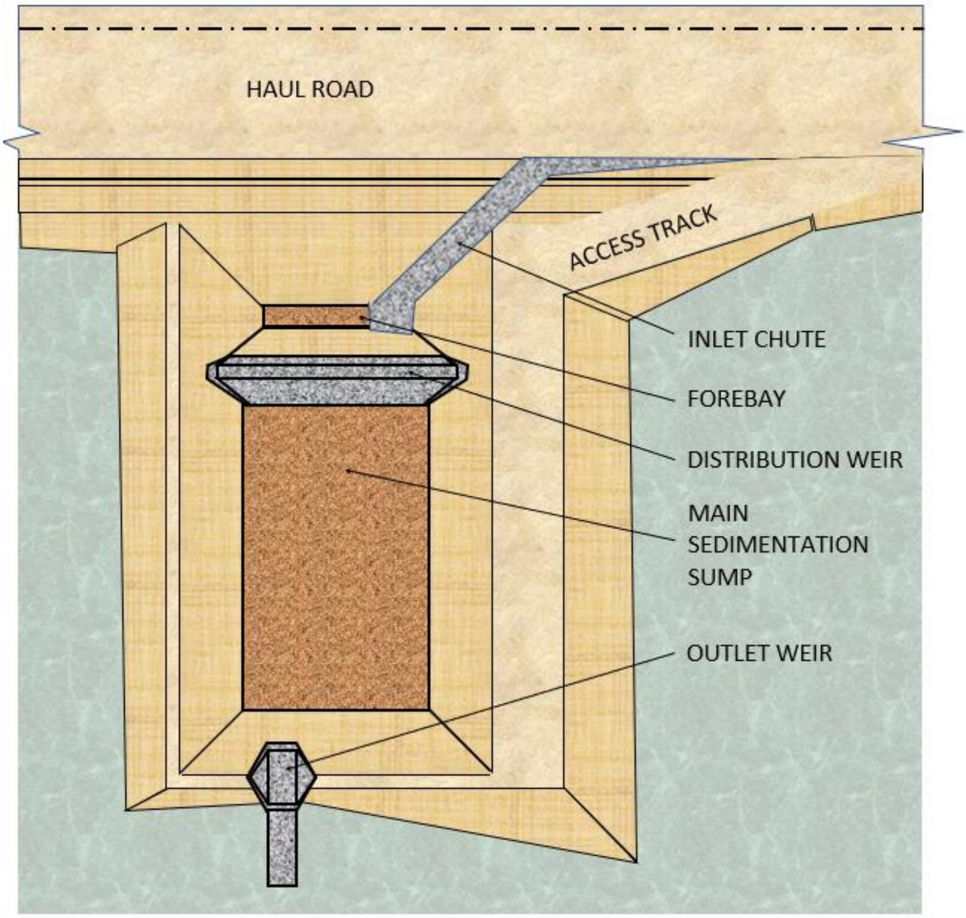
Even when the impact of the groundwater was considered, the suggested design criteria are suitable.

It can be concluded that the current design criteria, if the infiltration of 24 mm/day can be justified with the field data, is appropriate for the water management design of the pit.

References

Advisian, 2022. Basis of Design for Winterisation.

APPENDIX E - Typical Forebay Layout



APPENDIX F - Infiltration Sump Performance Assessment Example

ALCOA Sump Design Tool

Version 1.8 2/11/2022

Hydrology (Sediment Sump)
Sediment Sump Assessment
Infiltration Sump Assessment

Project Details

Project Title	**Test Spreadsheet**
Site	**Huntly**
Stage	**Test**
No of Sumps	**15**

Design Team

Designer #1		
Designer #2		
Designer #3		
Reviewer		
Authoriser		

Sump Type

Sump Type	Design Condition
Infiltration Sump	° Discharge distance to a natural stream is greater than the defined buffer distance (>50 m) ° Not a stream crossing ° Low risk of groundwater interception (>50 m from nearest stream zone vegetation)
Sedimentation Sump	° Discharge distance to a natural stream <50 m ° Located at a stream crossing ° High risk of groundwater interception (<50 m from nearest stream zone vegetation)

Sump Details

ID	Design Date	Designer	Sump Chainage (m)	Left or Right	Road Name	Reference Name	Asset Life (yrs)	Distance to Streamzone Vegetation	Discharge Distance to Natural Stream	Stream Crossing (Y/N)	Recommended Structure Type	Adopted Structure Type	Road Type
1	30/09/2022	RP	11275	Right	MacQuarrie	**MacQuarrie_11275_R**	>10	>50 m	>50 m	No	Infiltration Sump	Infiltration Sump	Good material, heavy usage
2	30/09/2022	RP	11875	Right	MacQuarrie	**MacQuarrie_11875_R**	>10	>50 m	>50 m	No	Infiltration Sump	Infiltration Sump	Good material, heavy usage
3	30/09/2022	RP	2374	right	Rhodes 1	**Rhodes 1_2374_r**	>10	>50 m	>50 m	No	Infiltration Sump	Infiltration Sump	Good material, heavy usage
4	30/09/2022	RP	4709	Right	Jankata	**Jankata_4709_R**	>10	>50 m	>50 m	No	Infiltration Sump	Infiltration Sump	Good material, heavy usage
5	30/09/2022	RP	13025	Right	Cable 4	**Cable 4_13025_R**	>10	>50 m	>50 m	No	Infiltration Sump	Infiltration Sump	Good material, heavy usage
6	30/09/2022	RP	13625	Right	Elliot Road	**Elliot Road_13625_R**	>10	>50 m	>50 m	No	Infiltration Sump	Infiltration Sump	Good material, heavy usage
7	30/09/2022	RP	11966	Right	Martin 9	**Martin 9 _11966_R**	>10	>50 m	>50 m	No	Infiltration Sump	Infiltration Sump	Good material, heavy usage
8	30/09/2022	RP	9650	Right	Parker B	**Parker B_9650_R**	>10	>50 m	>50 m	No	Infiltration Sump	Infiltration Sump	Good material, heavy usage
9	30/09/2022	RP	2750	Right	Rhodes 2	**Rhodes 2_2750_R**	>10	>50 m	>50 m	No	Infiltration Sump	Infiltration Sump	Good material, heavy usage
10	30/09/2022	RP	16000	Right	Wittwer 5	**Wittwer 5_16000_R**	>10	>50 m	>50 m	No	Infiltration Sump	Infiltration Sump	Good material, heavy usage
11	30/09/2022	RP	450	Right	Lloyd 5	**Lloyd 5_450_R**	>10	≤50 m	≤50 m	Yes	Sediment Sump	Sediment Sump	Good material, heavy usage
12	30/09/2022	RP	500	Left	Demarte 2C	**Demarte 2C_500_L**	>10	≤50 m	≤50 m	Yes	Sediment Sump	Sediment Sump	Good material, heavy usage
13	30/09/2022	RP	20	Right	Simpson-Downes	**Simpson-Downes_20_R**	>10	≤50 m	≤50 m	Yes	Sediment Sump	Sediment Sump	Good material, heavy usage
14	30/09/2022	RP	30	Left	McCarthy 4	**McCarthy 4_30_L**	>10	≤50 m	≤50 m	Yes	Sediment Sump	Sediment Sump	Good material, heavy usage
15	30/09/2022	RP	40	Right	Stone 13 Link	**Stone 13 Link_40_R**	>10	≤50 m	≤50 m	Yes	Sediment Sump	Sediment Sump	Good material, heavy usage

ID	Recommended Runoff Coefficient	Adopted Runoff Coefficient	CH1 (m)	CH2 (m)	Road Width (m)	Road Length (m)	Catchment Area (m^2)	Grade (%)	Sump Soil Type	Catchment Soil Type	Overtopping Risk Profile	Design Event (AEP)	Comments
1	0.9	0.9	11275	11375	26	100	2600	8%	Coarse silt	Coarse silt	High	1% AEP	
2	0.9	0.9	11875	12004	26	129	3354	8%	Coarse silt	Coarse silt	High	1% AEP	
3	0.9	0.9	0	550	26	550	14300	8%	Coarse silt	Coarse silt	High	1% AEP	
4	0.9	0.9	4460	4709	26	249	6474	8%	Coarse silt	Coarse silt	High	1% AEP	
5	0.9	0.9	12875	13025	26	150	3900	8%	Coarse silt	Coarse silt	High	1% AEP	
6	0.9	0.9	13625	13850	26	225	5850	8%	Coarse silt	Coarse silt	High	1% AEP	
7	0.9	0.9	11900	11966	26	66	1716	8%	Medium sand	Very fine sand	High	1% AEP	
8	0.9	0.9	9550	9650	26	100	2600	8%	Very fine sand	Medium sand	High	1% AEP	
9	0.9	0.9	2700	2750	13	50	650	8%	Medium sand	Medium silt	High	1% AEP	
10	0.9	0.9	16000	16187	26	187	4862	8%	Medium silt	Very coarse sand	High	1% AEP	
11	0.9	0.9	350	450	26	100	2600	2%	Very coarse sand	Medium sand	High	1% AEP	
12	0.9	0.9	400	500	26	100	2600	2%	Medium sand	Very fine sand	High	1% AEP	
13	0.9	0.9	20	50	26	30	780	2%	Very fine sand	Medium sand	High	1% AEP	
14	0.9	0.9	30	40	13	10	130	2%	Medium sand	Fine sand	High	1% AEP	
15	0.9	0.9	40	100	13	60	780	2%	Medium silt	Very fine sand	High	1% AEP	

Infiltration Basin

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Hydrology (Sediment Sump)
Sediment Sump Assessment

Water balance calculation

Infiltration Basin Flow Chart					A						B			
ID	Sump Chainage (m)	Overtopping Risk Profile	Basin Soil Type	Recommended Infiltration Rate K_{SAT} (m/day)	Adopted Infiltration Rate K_{SAT} (m/day)	Catchment Area (m^2)	Runoff Coefficient	Sump Depth (m)	Side Slope (1V:xH)	Freeboard (m)	Indicative Volume (m^3)	Indicative Top Area (m^2)	Percentage of Overflow
MacQuarrie_11275_R	11275	High	Coarse silt	0.01	0.05	2600	0.9	2	1.5	0.5	565.5	346.0	4.17%
MacQuarrie_11875_R	11875	High	Coarse silt	0.01	0.05	3354	0.9	2	1.5	0.5	729.5	424.4	4.75%
Rhodes 1_2374_r	2374	High	Coarse silt	0.01	0.05	14300	0.9	2	1.5	0.5	3110.3	1513.2	6.95%
Jankata_4709_R	4709	High	Coarse silt	0.01	0.05	6474	0.9	2	1.5	0.5	1408.1	745.3	5.88%
Cable 4_13025_R	13025	High	Coarse silt	0.01	0.05	3900	0.9	2	1.5	0.5	848.3	484.0	4.98%
Elliot Road_13625_R	13625	High	Coarse silt	0.01	0.05	5850	0.9	2	1.5	0.5	1272.4	686.4	5.64%
Martin 9 _11966_R	11966	High	Medium sand	0.5	0.05	1716	0.9	2	1.5	0.5	373.2	246.5	3.29%
Parker B_9650_R	9650	High	Very fine sand	0.05	0.05	2600	0.9	2	1.5	0.5	565.5	346.0	4.17%
Rhodes 2_2750_R	2750	High	Medium sand	0.5	0.05	650	0.9	2	1.5	0.5	141.4	118.8	1.21%
Wittwer 5_16000_R	16000	High	Medium silt	0.01	0.05	4862	0.9	2	1.5	0.5	1057.5	585.6	5.33%

	C				D							
ID	Adjusted Top Area (m^2)	Adjusted Base Length (m)	Adjusted Volume (m^3)	Percentage of Overflow	Adopted Base Length (m)	Adopted Base Width (m)	Adopted Base Area (m^2)	Adopted Top Length (m)	Adopted Top Width (m)	Adopted Top Area (m^2)	Adopted Volume (m^2)	Percentage of Overflow
MacQuarrie_11275_R	316.8	10.3	505.1	6.73%	16	7	112	23.5	14.5	340.8	542.5	4.96%
MacQuarrie_11875_R	392	12.3	655.6	7.47%	18	12	216	25.5	19.5	497.3	868.1	1.49%
Rhodes 1_2374_r	1376.4	29.6	2792.3	10.80%	36	28	1008	43.5	35.5	1544.3	3166.9	6.30%
Jankata_4709_R	681.2	18.6	1260.5	9.33%	24	20	480	31.5	27.5	866.3	1659.4	2.16%
Cable 4_13025_R	445.2	13.6	764.3	7.82%	18	12	216	25.5	19.5	497.3	868.1	4.33%
Elliot Road_13625_R	625	17.5	1140.6	9.04%	20	12	240	27.5	19.5	536.3	946.9	15.77%
Martin 9 _11966_R	228	7.6	333.8	5.57%	12	6	72	19.5	13.5	263.3	395.6	2.22%
Parker B_9650_R	316.8	10.3	505.1	6.89%	16	7	112	23.5	14.5	340.8	542.5	4.93%
Rhodes 2_2750_R	110.3	3.0	125.7	2.46%	4	2	8	11.5	9.5	109.3	123.1	2.76%
Wittwer 5_16000_R	533.6	15.6	947.8	8.57%	18	12	216	25.5	19.5	497.3	868.1	11.55%

Hydrology

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Sediment Sump Assessment
Infiltration Sump Assessment

Peak Flow calculation for sediment basin assessment

Hydrology Flow Chart | A | B | C | D

ID	Sump Chainage (m)	Catchment Area (m^2)	Adopted Runoff Coefficient	Equivalent Impervious Area (m^2)	Design Event (AEP)	Length (m)	Grade (%)	$V_{average}$ (m/s)	T_{travel} (minutes)	T_{min} (minutes)	T_C (minutes)	I_{TC} (mm/hr)	Q (m^3/s)
Lloyd 5_450_R	450	2600	0.9	2340	1% AEP	100	2%	0.88	1.90	3.0	4.90	184	0.120
Demarte 2C_500_L	500	2600	0.9	2340	1% AEP	100	2%	0.88	1.90	3.0	4.90	184	0.120
Simpson-Downes_20_R	20	780	0.9	702	1% AEP	30	2%	0.88	0.57	3.0	3.57	194	0.038
McCarthy 4_30_L	30	130	0.9	117	1% AEP	10	2%	0.88	0.19	3.0	3.19	206	0.007
Stone 13 Link_40_R	40	780	0.9	702	1% AEP	60	2%	0.88	1.14	3.0	4.14	194	0.038

Sediment Basin Assessment

Cover Page
Hydrology (Sediment Sump)
Infiltration Sump Assessment

Sediment Basin Sizing (Efficiency Testing)

Sediment Sump Flow Chart | A | B | C | D

ID	Sump Chainage (m)	Design Flow (m^3/s)	Catchment Soil Type	Target Particle Size d_S (micron)	Adopted Particle Specific Gravity	Particle Settling Velocity V_S (mm/s)	Estimated Maximum Surface Loading (m/hr)	Minimum Water Surface Area Required (m^2)	Sump Basic Configuration	Distance from inlet to side outlet (m)	Enter number of equal-spaced baffles	Base Width B_b (m)	Base Length L_b (m)	Base Areas A_b (m^2)	Side Slope (1V:xH)	Effective Sedimentation Depth D (m)	Nominal Sediment Holding Depth D_H (m)	Nominal Areas of Sediment Storage (m^2)
Lloyd 5_450_R	450	0.120	Medium sand	500	2.65	53	4.5	95.31	B	3	1	2	4	8	1.5	2	3	143
Demarte 2C_500_L	500	0.120	Very fine sand	125	2.65	11	4.5	95.31	C	2	1	1	1	1	1.5	2	2	49
Simpson-Downes_20_R	20	0.038	Medium sand	500	2.65	53	4.5	30.15	H	4	1	4	4	16	1.5	2	3	169
McCarthy 4_30_L	30	0.007	Fine sand	250	2.65	26	4.5	5.34	E	2.5	1	4	12	48	1.5	2	3	273
Stone 13 Link_40_R	40	0.038	Very fine sand	125	2.65	11	4.5	30.15	G	2	3	6	12	72	1.5	2	3	315

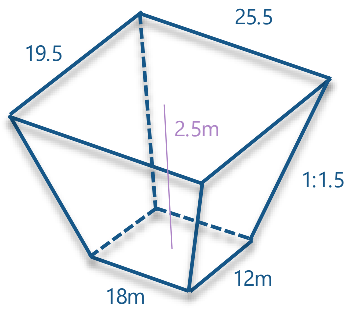
ID	Sediment Holding Volume V_H (m^3)	Permanent Pool Surface Width W_p (m)	Permanent Pool Surface Length L_p (m)	Permanent Pool Area A_p (m^2)	Permanent Pool Storage Volume V_p (m^3)	Permanent Pool Surface Aspect Ration R_{pp}	Surface Hydraulic Loading (m/hr)	Outlet Weir Crest Width B_W (m)	Nominal Surcharge Depth (h)	TWL Surface Width W_s (m)	TWL Surface Length L_s (m)	TWL Area A_s (m^2)	Surcharge storage volume V_s (m^3)	Adjusted (Effective) R	Estimated Hydraulic Efficiency λ	Adopted Hydraulic Efficiency λ	Turbulence / short-circuiting parameter *n*	Fraction of solids removed of target particle size d_s	Target Particle Size d_S (micron)
Lloyd 5_450_R	184.82	17	19	323.0	453.9	1.1	1.3	0.5	0.27	17.8	19.8	352.9	91.4	1.12	0.13	0.5	2.00	100.0%	500
Demarte 2C_500_L	38.00	13	13	169.0	206.0	1.0	2.5	0.5	0.27	13.8	13.8	190.8	48.6	0.15	-0.17	0.5	2.00	99.9%	125
Simpson-Downes_20_R	237.00	19	19	361.0	518.0	1.0	0.4	0.5	0.13	19.4	19.4	375.5	46.2	1.00	0.11	0.5	2.00	100.0%	500
McCarthy 4_30_L	435.47	19	27	513.0	773.5	1.4	0.0	0.5	0.04	19.1	27.1	518.5	20.4	9.25	0.75	0.75	4.00	100.0%	250
Stone 13 Link_40_R	537.60	21	27	567.0	869.7	1.3	0.2	0.5	0.13	21.4	27.4	585.2	72.3	5.91	0.56	0.56	2.27	100.0%	125

Infiltration Sump Report

Sump	**Cable 4_13025_R**

Project Title	**Test Spreadsheet**	Designer	
Site	Huntly	Date	2/11/2022
Stage	Test		

Sump Chainage (m)	13025
Left or Right	Right
Road Name	Cable 4
Type	Infiltration Sump
Road Width (m)	26
Road Length (m)	150
Catchment Area (m^2)	3900
Sump Soil Type	Coarse silt
Infiltration Rate (m/day)	0.05
Sump Depth (m)	2
Freeboard (m)	0.5
Side Slope (1:x)	1.5
Sump Base Width (m)	12
Sump Base Length (m)	18
Base Area (m^2)	216
Top Area (m^2)	497.25
Volume (m^3)	868



Comments

Risk Profile	High
Percentage of overflow	4.33%

Sediment Sump Report

Alcoa

Sump	**McCarthy 4_30_L**
Project Title	**Test Spreadsheet**
Site	Huntly
Stage	Test
Sump Chainage (m)	13025
Left or Right	Right
Road Name	Cable 4
Type	Infiltration Sump
Road Width (m)	26
Road Length (m)	150
Catchment Area (m^2)	3900
Road Type	Good material, heavy usage
Runoff Coefficent	90%
Grade	2%
Design Flow (m^3/s)	0.007
Catchment Soil Type	Fine sand
Target Particle Size dS (micron)	250

Designer

Date 2/11/2022

Reference: ALCOA Haul Road Drianage Manual

Sump Configuration **E**

Base Width (m)	4.0
Base Length (m)	12.0
Side Slope (1V:xH)	1.5
Effective Sedimentation Depth (m)	2.0
Nominal Sediment Holding Depth (m)	3.0
Permanent Pool Storage Volume (m^3)	773.5
Outlet Weir Crest (m)	0.5
Top Water Level Area (m^2)	518.5
Estimated Hydraulic Efficiency	0.75
Adopted Hydraulic Efficiency	0.75
Fraction of Solids Removed	**100.0%** (target particle size)

Comments

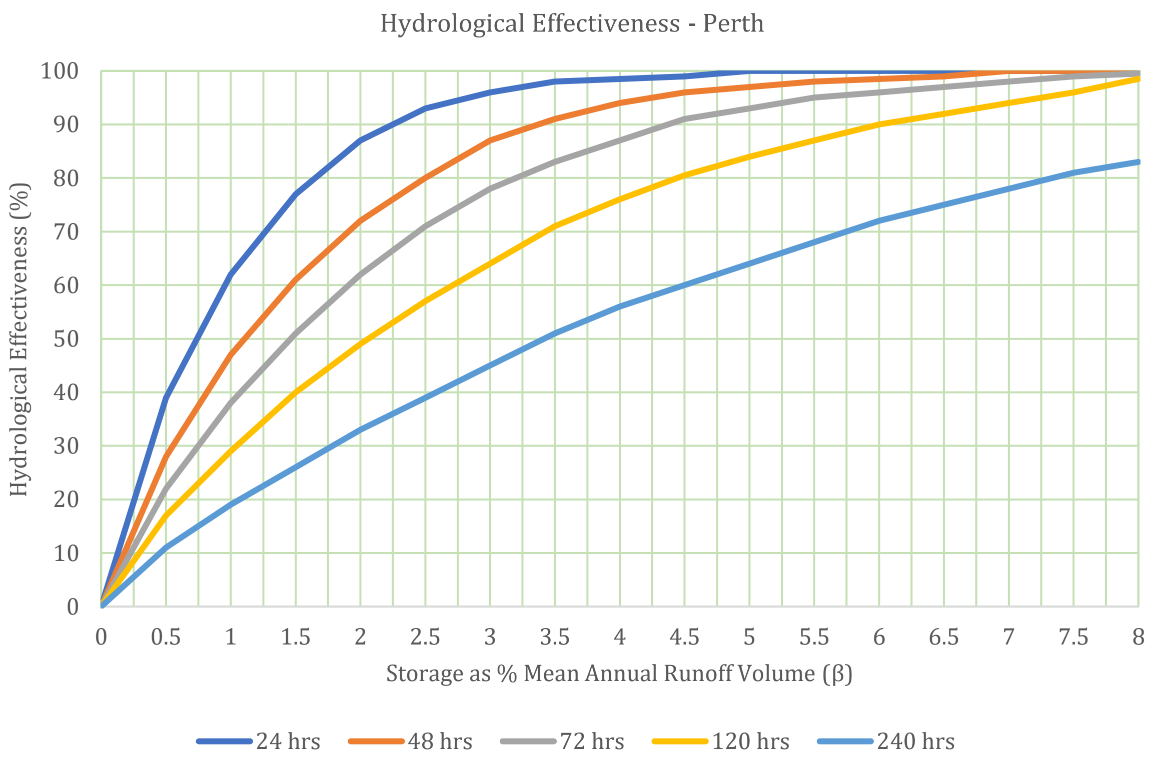
APPENDIX G - Drainage Design Aspects and Drainage Manual References

DRAINAGE DESIGN ASPECTS (SEE FIGURE)	FAILURE MODE	RATIONALE	IMPACT OF FAILURE	CONTROL	DRAINAGE MANUAL REFERENCE
Rainfall prediction **Water balance**	Design rainfall basis without water balance	Winter rainfall series accumulated storage	Accumulated water storage exceeds single design event storage increasing frequency of release	Winter rainfall series developed based on: a) 40 years actual rainfall (1980 onwards including TC Bobby 1982) b) dry, wet, average years grouping	*Appendix B – Design Rainfall* *Appendix C - Daily water balance (for pit)* *Appendix D – Assessment of pit design criteria*
Rainfall prediction **Storage sump/trench sizing** **Spillway design** **Embankment structure integrity**	Design rainfall basis exceeded	Rainfall volume > exceeds storage design	No controlled release structure or controlled release structure in place and turbid water conveyance	Risk factor dependent Initial design criteria is 1% AEP 24-hour with rainfall sequences overlay to assess performance, if risk assessment deems necessary. Risk factor considerations include (amongst others): - consider mining exposure duration - greater design events impact on the broader catchment - dilution of the possible sediment plume with clean flow from the undisturbed catchment	*Chapter 2. Design criteria* *Chapter 3. Design aspects* *Chapter 4. Spillway Design* *Appendix C - Daily water balance* *Appendix H supports decision on design rainfall*
Storage sump/trench sizing **Infiltration prediction**	Storage feature infiltration rate	Volume > containment	Insufficient containment volume increasing frequency of release	Infiltration rates are challenging to determine without detailed site-specific investigations and measurements. When site-specific data is not available, estimate infiltration rate by characterisation of typical soil properties. Infiltration rates are estimated based upon literature and current experience for common soil types. Development of site Investigation and data evaluation is in progress.	*Chapter 3 (Current Infiltration Estimates)* *Chapter 4 (Pit storage design)* *Chapter 5 (Infiltration and Sedimentation sump design)*
Erosion potential **Infiltration**	Mining surface runoff coefficient	Volume > sedimentation > containment	Assumption lower than actual underestimates storage feature containment volume required	Conservative values of runoff coefficient applied.	*Chapter 2. Design criteria* *Chapter 3. Design aspects* *Chapter 4. (Estimate of soil loss)*
Catchment calculations **Erosion potential** **Storage sump/trench sizing** **Water balance**	Surface flow model area	Area > volume > sedimentation > containment	Assumption lower than actual (incorrect mining area calculation, failing to consider adjoining mining areas) underestimates storage feature containment volume required	QA/QC of design work Audits of performance of constructed systems	*Chapter 4. (Estimate of soil loss)* *Chapter 5. (Infiltration and Sedimentation sump design)* *Appendix C - Daily water balance* *Alcoa internal QA/QC*
Mining area steepness **Erosion potential**	Mining surface slope gradient and material type	Slope > velocity > shear stress > sedimentation > containment loss	Underestimated sedimentation accumulation within storage feature contributing to lower than design basis storage	RUSLE method to be used to evaluate the soil loss Collect field data on sediment build-up Testing on erosion of local soils	*Chapter 4. (Estimate of soil loss)* *Chapter 4. (Storage Volume)*
Groundwater interaction **Storage sump/trench sizing** **Infiltration prediction**	Groundwater rise	Inundation > containment loss	Unexpected groundwater rise, potentially reaching the surface within lower slope storage features, resulting in containment loss and infiltration over-estimation	Assessment of groundwater interaction with surface water management structures, by combining topography and currently available groundwater monitoring data.	*Chapter 3. Design aspects* *Alcoa groundwater stewardship strategy development to improve groundwater interaction risk assessment*
Execution of drainage design **Storage sump/trench sizing**	Execution QAQC	Design > execution > QAQC check > containment	Storage feature not built to design	QA/QC Dedicated Alcoa 'drainage management' team	*Alcoa water planning practitioners and dedicated drainage management team to manage, supervise, QAQC*

APPENDIX H - Hydrological Effectiveness

Hydrological Effectiveness

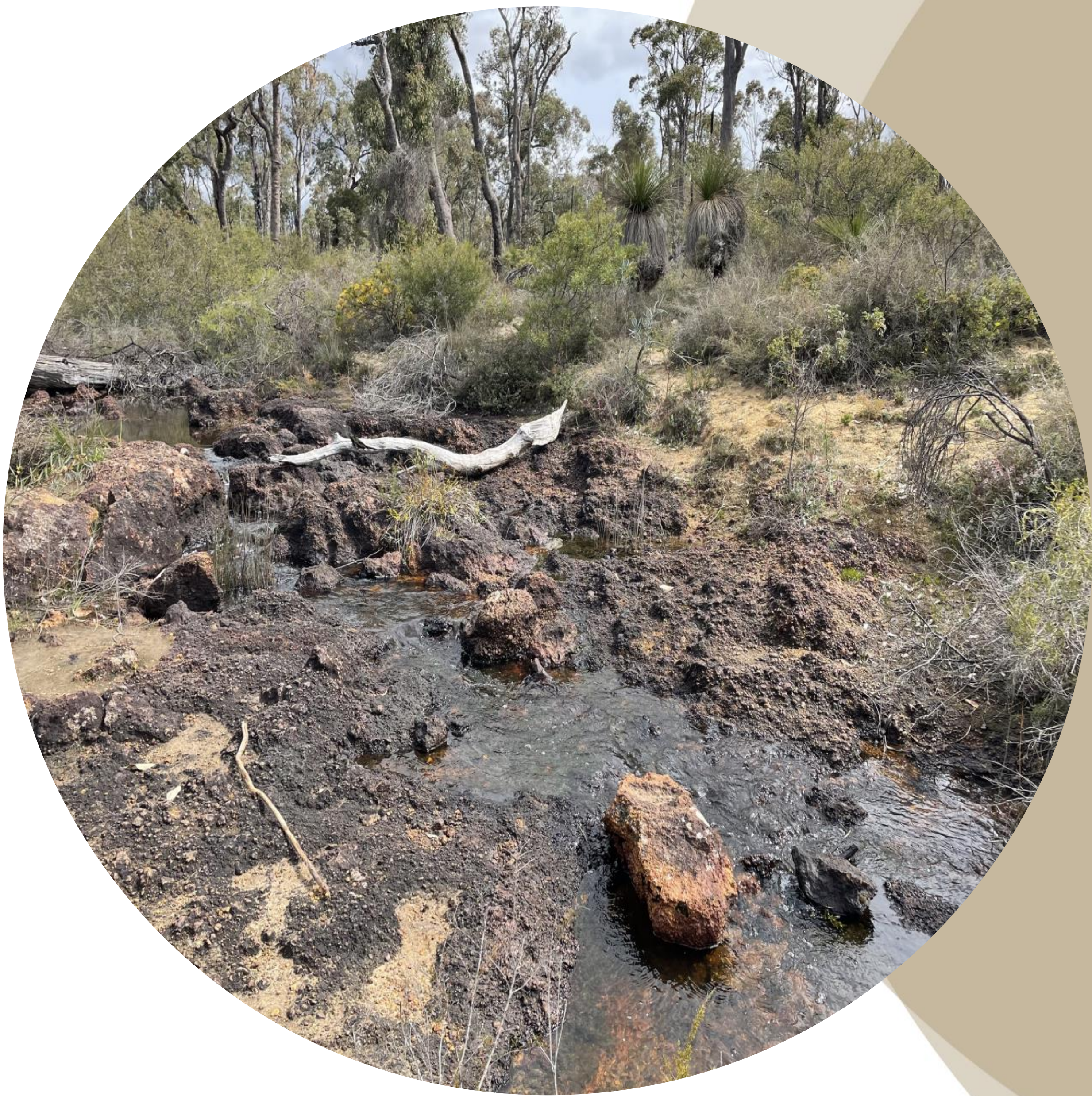
For assessment of wetland (and sump) performance, ARQ (2006) defines hydrological effectiveness curves for the major cities of Australia to reflect the diversity of climatic conditions across the continent. Of those that are available, the curves for Perth are considered most appropriate for the conditions at the Huntly and Willowdale mine sites. The curves in the figure below, adapted from Figure 12.15 of ARQ, relate hydrological effectiveness to sump storage volume as a percentage of mean annual runoff volume.



Based on figure above, storage volumes required to achieve 90% hydrological effectiveness for various durations, are shown in the table below.

Detention Time (hours)	24	48	72	120	240
Detention storage required to achieve 90% hydrological effectiveness as % of Mean Annual Runoff Volume	2.2%	3.3%	4.4%	5%	>9%
Estimated sump storage per hectare of EIA for Huntly/Willowdale, m^3/ha.	270	405	540	614	1105

These parameters reflect the proportion of all rainfall runoff events that the designated storage volume can detain (not retain) for the indicated residence time.



Field Infiltration Rate Testing

Program Approach

Alcoa

24/11/2022

311002-00171

Advisian
Worley Group

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PROJECT 311002-00171 - : Field Infiltration Rate Testing - Program Approach

Rev	Description	Author	Review	Advisian approval	Revision date	Client approval	Approval date
A	Progress draft	M. Simonic	D. Royal	D. Royal	21.11.22	B. Smith	Approval date
B	Updated draft	M. Simonic	K. Zic	D. Royal	24.11.22	B. Smith	

-

Table of contents

Table list

Acronyms and abbreviations

Acronym/abbreviation	Definition
b	Empirical constant in Campbell equation
BGL	Below ground level
DEM	Digital elevation model
DRI	Double ring infiltrometer
DWER	Department of Water and Environmental Regulation
EC	Electrical conductance
K	Hydraulic conductivity
K_{sat}	Saturated hydraulic conductivity
Lidar	Light detection and ranging (a form of DEM)
NTU	Nephelometric turbidity unit
PDWSA	Public drinking water source area
RL	Reduced level
SRTM	Shuttle radar topography mission
TDS	Total dissolved solids
TSS	Total suspended solids
Θ_{sat}	Porosity (dimensionless)
Ψ_e	Air entry value (mm)

1 Introduction

1.1 Background

Alcoa's mining operations on the Darling Plateau, Western Australia, are located within jarrah forest and water catchments which include Priority 1 public drinking water source areas (PDWSA's) associated with water supply reservoirs managed and operated by the Water Corporation. Minimising turbid water runoff from Alcoa's operations is important in complying with Alcoa's commitments under the Water Working Arrangements between Alcoa World Alumina, the Department of Water and Environmental Regulation and the Water Corporation.

1.2 Program context

Advisian is currently involved in mining & haul road surface drainage control. This work has identified the importance of infiltration rate for mine pit and haul road drainage assessment and design of drainage measures.

The program outline in this document has originated from the need for Alcoa to compile and manage a comprehensive infiltration rate dataset to inform drainage assessments and designs.

1.3 Objectives

The objective is to compile a comprehensive field infiltration dataset both spatially and temporarily (ie seasonal) to inform the drainage designs. This program outline provides an overview of how one could design and execute such a field program.

Targeted monitoring, review of data and progressive refinement of deployed techniques are the aspects to be addressed within this component of work; which will lead to a local and defendable knowledge base of key parameters for site water management.

Key uncertainties have been progressively identified in operation and design to date, with infiltration's interaction with the local and regional groundwater being one of the most important aspects for the successful site excess water management.

The uncertainty aspects are associated with the spatial variability of soil, runoff and groundwater conditions, stages of mining development as well as the meteorological conditions. It is suggested, with some of these uncertainties already addressed in design of calculations tools and evaluation of the local infiltration rates, that the uncertainties are clearly identified, and a guidance provided to the future users of these tools and documents on the likely ranges and provide advice on the impact on design and operation.

These guidelines will be periodically expanded and refined in the future, with appropriate documentation to ensure transparency, QA/QC.

It is envisaged that the water balance assessment of selected storages/pits is likely to be one of the tools assisting in quantification of uncertainties and progressive reduction in it, via collection and appropriate processing of the field data.

1.4 Focus areas

Infiltration, as one of the key parameters for excess water management and control, is important (and further evaluated) for the following focus areas (in terms of mining infrastructure):

Table 1-1 Focus areas

Element/feature	Description	Comment
Mining pit surfaces	Cleared area of what is originally jarrah forest in the Darling Range. Clearing involves removal of vegetation, topsoil, and bauxite ore, usually about four, occasionally up to six metres of vertical soil profile	May be rather heterogeneous, with parts of the cleared areas having different properties due to textural or weathering differences
Haul road sumps	Temporary roads used to haul ore from mining pits – sumps, sumps used for drainage management	Typically, small areas compared to surfaces cleared for mining
Rehabilitated area surfaces	Reprofiled, formerly mined areas, with reworked soil and re-established vegetation	

2 Overview of hydrological processes with focus on infiltration

2.1 Hydrological context

Successful mine site water management includes:

- effectively and responsibly managing rainfall, runoff and groundwater seepage affecting mining operations,
- diverting, capturing, storing, infiltrating, transporting, treating, re-using and disposing it in a manner that facilitates mine development and operation and ensures adequate protection of adjacent forests and downstream environments,
- preventing transmission of dieback into dieback-free forest, and
- preventing excessive sediments or other contaminants passing into the watercourses of the Public Drinking Water Source Areas.

2.2 Role of infiltration

2.2.1 Hydrological effects of mining

The geology of the majority of the mined areas comprises granitic basement of the Archaean Yilgarn Block, which is interwoven by numerous dolerite dykes of various thickness. Substantial regolith has developed because of chemical weathering, with a thickness of up to 40 metres.

The typical regolith profile comprises several distinct layers, including bauxite:

Table 2-1 Regolith profile in the Darling Range

Layer/material	Average thickness (m)	Description
Topsoil	0.4	Sands, gravels, loamy sand; alluvial sediments in valley floors
Duricrust	1.5	Brown, pisolitic gravelly sand, massive to unconsolidated in mid- to upper slopes, usually where bauxite is found; typically missing in and along valley floors, but not everywhere
Friable zone	2.5	Alumina rich, sandy loam, includes bauxite
Mottled zone	4	Saprolite clay, typically most clayey part of the weathering profile
Pallid zone	3	Sandy clay
Saprock, weathered zone	1	Weathered basement at the base of regolith, relatively thin, often with increased permeability
Fresh basement		Fresh granite or dolerite

Of hydrological significance are the root channels which penetrate vertically via fissures and discontinuities in the cemented layer(s) and deep into clayey zones. They are reportedly consistent in lateritic profiles and form preferential flowpaths of bypass recharge contributing to large vertical fluxes into groundwater systems (Grigg, 2017; McFarlane and Williamson, 2002; Turner and Johnson, 1987).

This lateritic and saprolite weathering profile is sometimes missing. Approximately 10% of the area represents basement outcrops, with probably at least similar proportion of subcrops.

The mining operation starts with vegetation clearing and salvage of timber and is followed by topsoil and overburden removal. Blasting of caprock and ore material prepares it for site removal. Mining usually results in removal of 4 to 6 m of the soil profile. Mining is followed by rehabilitation to jarrah forest (surface recontouring, soil return, seeding and planting).

Bauxite forms a horizontal ore body typically 3.5 m thick.

This bauxite mining process results in potentially higher infiltration through the exposed pit floor and removal of evapotranspiration due to the temporarily removed vegetation. The following hydrological effects typically occur:

- Disruption of surface runoff (and interflow where present),
- Increased groundwater recharge through the pit floor and associated mounding of groundwater underneath pits,
- Increase of groundwater discharge (baseflow) into streams – i.e. alterations to flow regime, and
- Increase in stream salinity due to higher proportion of baseflow (which is marginally more saline than surface water).

Infiltration rates are key to understanding and quantifying losses in the water balance estimation, and consequently for management and control of excess water. These rates are challenging to quantify without detailed site-specific investigations and measurements.

2.2.2 Effects of material properties

Aquifer or soil material properties directly influence the rate and duration of infiltration. Due to the nature of saprolitic weathering of the underlying granitoid basement, pit floors are often made of a clayey saprolite material, occasionally with coarser fraction where saprolite weathering is relatively shallow. Vertical hydraulic conductivity of these materials, which controls the infiltration rate, may be relatively small if dominated by clay fraction.

Soil antecedent conditions, ie. the wetted status of soil subject to infiltration, are important in the early stages of infiltration.

Vertical zonation typically present in soil properties may not be fully captured by field testing. More information on typical infiltration properties is provided in the next section.

2.2.3 Effects of groundwater depth

Depth to groundwater has a direct effect on infiltration capacity, in that it limits the space/volume available for storage and/or transmission of infiltrated water. Depth to groundwater varies, based on topography. In the Darling Range region, with substantial relief differences, depth to groundwater typically reduces from 10 to 30 m below ground level in elevated areas to several metres close to valley floors and drainage lines, where it can enter surface in form of seepages and springs.

Groundwater was a key factor of lateritisation process which formed the duricrust (ferruginous cap) at the surface.

In addition, winter rainfalls typically raise groundwater levels (and reduce depth to groundwater) by several metres, before they return to their dry season levels. The Darling Range region is also subject to general regional fall of groundwater levels, observed in the south-west of Western Australia for the last few decades, however that fall is less prominent along the 1100 mm isohyet.

Depth to groundwater is controlled by a number of geological and hydrological factors which contribute to the lack of accurate predictability of groundwater levels. The presence of local features such as rock outcrops, which obstruct the groundwater flow, often causes shallow, near surface groundwater conditions.

Evapotranspiration removes groundwater in forested areas where groundwater is within the reach of the root system and substantially contributes to control its depth. Removal of forest cover leads to elimination of this evapotranspiration control (and reduction of depth to groundwater).

Depth to groundwater and its seasonal variations are measured by a network of monitoring bores which are typically installed around cleared areas in transects from elevated areas to valley floors or drainages, and around pit perimeters in downgradient positions. Direct measurements from these monitoring locations are used to inform the drainage assessment. Where these are not available, depth to groundwater has to be estimated.

Groundwater flow in the Darling Range is topographically controlled. This allows for estimation groundwater levels, to a reasonable degree of accuracy, in absence of direct measurements.

2.3 Available infiltration rates from the region

Existing investigation sources reviewed to assist with estimation of infiltration rates – with direct relevance to bauxite mining in the Darling Range. They include Croton and Bari (1997), Croton and Tierney (1996), Raper and Croton (1996), and Sharma and Barron (1987).

Croton and Bari (1997) established reduction of saturated hydraulic conductivity (K_{sat}) from pre-mining 11 m/d to 1 to 2 m/d for rehabilitated sites (using a well permeameter). This reduction was considered not to be sufficient enough to explain ponding in rehabilitated area after rainfall events 100 mm or less.

These authors refer to findings of other studies, focused on the clayey zone of a freshly exposed saprolite profile (i.e. not, for example, rehabilitated areas). For a typical hillslope transect Croton and Tierney (1996) established K_{sat} = 0.07 m/d and Raper and Croton (1996) determined a K_{sat} geometric mean for the mottled zone = 0.052 m/d.

The exposed base of the mining pits most closely relates to mottled or pallid zones (K_{sat} 0.01 to 0.05 m/d) for which K_{sat} values can be drawn from a table compiled by Croton and Tierney (1985):

Table 2-2 Parameter values for Darling Range soils (after Raper and Croton, 1996)

Soil	Θ_{sat}	K_{sat} (mm/d)	Ψ_e (mm)	b
Sandy topsoil	0.24	6,800	-150	2.8
Upper slope topsoil	0.15	500	-150	4.4
Grey sand	0.44	1,570	-150	1.8
Clay layer	0.39	3	-1,500	20
Bauxite	0.46	470	-50	3.3
Western mottled zone	0.39	50	-400	12
Eastern mottled zone	0.31	50	-400	13
Western pallid zone	0.48	10	-400	11
Eastern pallid zone	0.31	10	-400	8
Doleritic pallid zone	0.55	10	-400	22
Weathering zone	0.42	225	-250	13

The dataset from double ring infiltrometer testing undertaken by Croton and Barri (1997) is relevant mostly to tops of rehabilitated profiles, not to cleared areas, and show higher values of saturated hydraulic conductivity (compared to data from mottle zone), reflective of two statistical populations, one with a mean of 5 m/d and the other of 30 m/d.

These authors commented that infiltration rates on the mining and rehabilitated areas are lower possibly due to reduced thickness of topsoil cover, they however concede that while they "improved our understanding hydraulic properties of near-surface rehabilitated mine pit soils, they have not defined the infiltration capacity of the control for runoff generation in rehabilitated mine pits." The conclusion from a review of other published data for the mottled zone is that it controls infiltration in rehabilitated mine pits and is at least two orders magnitude lower that the hydraulic conductivity of the topsoil.

In studying ponding in rehabilitated mine pits during rainfall of 100 mm or less, Croton and Tierney (1985) defined a relationship for infiltration rate to vary between 45 mm/d to 70 mm/d. Raper and Croton (1996) determined a geometric mean of 52 mm/d for the mottled zone.

The infiltration rates applied to mining pits at the regional scale were modelled for Myara North impact assessment study (GHD, 2021). When scaled to days during winter season with more substantial rainfall (typically 20 to 30 days) the infiltration rate would be 20 to 30 mm/d similar to the 24 mm/d value adopted by Alcoa. If infiltration was constrained to days which are preceded by some rainfall – about 10 to 12 days in total – the infiltration rate would be 50 to 60 mm, similar to values associated with mottled zone in Table 2-1.

GHD (2021) conducted slug tests on approximately 20 monitoring bores that typically penetrated the entire thickness of the regolith (installed in Myara North) which were screened typically at the base of regolith, the saprock, or transition zone between the regolith and fresh basement. The average value of hydraulic conductivity for this zone was found 0.6 m/d, within a range of <0.05 to 1.2 m/d.

Of important note is duricrust description provided by Raper and Croton (1996) indicating it as not highly permeable on its own, but with vertical holes of higher permeability. They are suggested as constituting 15% of the areas of the duricrust layer, with friable layer underneath having K of 0.2 to 1 m/d.

The infiltration rate needs to consider the effect of the available storage available between the surface and the watertable. Storage capacity generally increases upslope, where the thickness of the unsaturated zone is progressively larger. On the other hand, next to the valley floors, the unsaturated thickness is small and the capacity to accept water will exhaust quickly. Cleared areas higher up in relation to the valley floors would generally be more suitable for storing excess water.

Site specific yield or effective porosity values are not typically obtained during bauxite exploration, but can be estimated from pumping tests when these are designed to obtain this parameter. Regional groundwater modelling for impact assessment in Myara North part of Huntly Mine (GHD, 2021) suggested the range of specific yield values of 0.005 to 0.05, which are considered appropriate for the aquifer systems found in the Darling Range.

The average storativity values reported by Raper and Croton (1996) is 0.013, within a range of values between 0.0037 to 0.1.

3 Datasets

3.1 Spatial and temporal datasets

The previous section described how ground conditions within the Darling Range influence the infiltration capacity needed for drainage control. While there are general similarities, site-specific information is often needed to characterise infiltration properties. This information is spatial in its nature and it has been or it is being collated by various parties, including Alcoa technical and operational services.

Spatial information datasets, that typically inform infiltration assessments and drainage control engineering, can be broadly listed as follows:

- Ground elevation
- Geology
- Exploration drilling
- Groundwater levels/depths
- Groundwater quality
- Climate (rainfall, evapotranspiration)
- Soils and land systems
- Vegetation
- Natural surface drainage

The datasets available from various public sources and from Alcoa's programs are described in Table 3-1:

Table 3-1 Spatial information availability

Dataset	Types and availability	Improvement	Other comments
Ground elevation	SRTM (30 m accuracy) from public sources; local Lidar generated by Alcoa for individual pits	Ideally a Lidar dataset would be available at the (subregional) catchment scale	
Soils and land systems	Broad public mapping of soils (at national scale); land systems mapping		Typically coarse, only useful at a regional scale evaluations/planning
Natural surface drainage	DWER mapping, plus derived datasets from the terrain elevation models		Informs surface water drainage and excess water control planning. The DEM-derived datasets are considered more relevant
Vegetation cover	Alcoa-commissioned vegetation mapping		May assist in designating areas of groundwater dependent ecosystems (GDEs), evaluation

Dataset	Types and availability	Improvement	Other comments
			of impacts of mining interventions on vegetation health
Geology, regolith	Public mapping available, 1:500,000 (bedrock); 1:250,000 and 1:100,000 (surface geology). Regolith depth and description (national scale). Exploration drilling data, typically shallow and not crossing the full regolith thickness. Hydrogeological drilling, mostly spanning through the regolith		Due to the relative monotonous geological structure, the public mapping datasets are useful for identification of outcrop and subcrop areas. Exploration drilling data provides an up to date information on regolith not commonly available from public mapping. Depth of regolith is however only rarely captured, apart from installed hydrogeological monitoring bores.
Groundwater levels	Alcoa-commissioned groundwater level monitoring	Installation of automatic recording water level loggers would be useful in capturing the groundwater mounding peaks that are not captured by infrequent manual monitoring.	Large coverage of historical mining (and research catchment) areas, however lags in currently mined areas. There is a need for installation before mining starts.
Groundwater (and surface water) quality	Alcoa-commissioned groundwater and surface water sampling	Formulate and execute a targeted monitoring program, with annually based review	
Aquifer hydraulic properties	Several published studies and investigations from the region, currently no regular testing program in place	In line with previous research activities, restart and continue collection of site-specific data	

3.2 Operational phase datasets

Although operational datasets are also spatial and/or temporal in their nature, they are specifically associated with mining operation. They include:

- the site infrastructure (roads, pits, water storages/sumps, residual material storages), and
- temporal changes to area's land use and morphology which include clearing of the native vegetation, changes to the terrain morphology.

The site infrastructure datasets primarily define the changes to the terrain morphology which influence the natural drainage and affect the recharge and discharge processes for groundwater.

The operational datasets also include information on volumes of water (most often excess water) handled on site, when such an information is collected and recorded. Information on groundwater levels in the monitoring bores (if they have been installed and monitored) and changes of the water level in excess water storage pits also fall into this category.

4 Review of infiltration rate estimation methods

4.1 Hydraulic conductivity estimation from sieve tests

Estimates of hydraulic conductivity (K) and effective porosity can be made from the results of sieve tests - grain size analysis that quantifies clastic fractions found in soils (ie. the proportions of gravel, sand, loam/silt, clay). Under certain assumptions or conditions, analytically derived equations can be used to provide estimates of hydraulic conductivity. The classical analytical models, such as Hazen, Beyer and Carman-Kozeny models are based around the grain diameter 10% passing (d_{10}), in some cases also 60% (d_{60}).

Several other methods or refinements are also available in addition to these classical methods, tackling some of the particular assumptions. A spreadsheet tool, such as, for example, HydrogeoSieveXL (Devlin, 2016), calculates K from grain-size distribution curves using 15 different methods.

This method of obtaining site-specific K estimates is relatively cheap and can be used on a number of locations laterally and vertically within the pit perimeter, to characterise its permeability variations. An important drawback is that it can be applied on unconsolidated soils samples only (since such a sample is needed for a sieve test).

4.2 Ring infiltrometer testing

Ring infiltrometers are simple devices used for measuring soil surface infiltration capacity. A steel ring of known diameter is driven into the soil and water supplied from a graduated tank. The depth of water inside the ring is maintained at a constant level by a controlled feed from the tank. The level of water in the supply tank is recorded at regular intervals to allow calculation of the volume of infiltrated water as a function of time.

Since water infiltrating from the ring will tend to diverge laterally as well a vertically it creates the major source of experimental error in the use of this device. This is addressed by the use of a large diameter ring and by keeping the depth of water in the ring to a minimum. This then forms what is referred to as double ring infiltrometer (DRI) test.

Disturbance of the surface when the ring is driven into the soil is also a source of experimental error that can be minimised with the use of an additional large diameter ring. The rings are pushed into the soil to a depth of approximately 0.05 to 0.1 m, depending on soil refusal.

The presence of soil/regolith layering invalidates the assumption of a deep and homogeneous soil profile. Under natural conditions these measurements would be describing the topsoil overlying the duricrust at best. Under cleared mined conditions when four to six metres of material is removed from the soil/regolith profile and, for example, the mottled zone is exposed and the DRI test is applied, the assumption of homogeneity could be valid for that particular regolith segment, if for example, water storage sumps were to be constructed in this material.

For rehabilitation phase, the DRI tests may be suitable for testing the rehab material used for refilling of the cleared areas. Previous uses of the DRI testing (e.g. Croton and Bari, 1997) were almost exclusively focused on rehabilitated areas.

4.3 Pit infiltration tests

The pit infiltration test is a relatively large-scale infiltration test to better and more realistically approximate infiltration rates, which reduces some of the scale errors associated with relatively small-scale DRI test. There are numerous potential variations of how to conduct such a test. One of the potential applications that is considered suitable for Alcoa applications can be set up as follows:

- Excavate the test pit and lay back the slopes sufficiently to avoid caving and erosion during the test The base of the pit could be 2 m by 0.5 m or similar, at least one metre deep.
- Accurately document the size and geometry of the test pit and install a vertical measuring rod (peg), marked in centimetre increments in the centre of the pit
- Use a pipe with a splash plate on the bottom to convey water to the pit and reduce erosion or excessive disturbance of the pit bottom.
- Add a water to the pit that will maintain a water level 5 or 10 cm below the top of the pit (eg. 90 cm of water in 100 cm deep pit)
- Record the cumulative volumes and/or instantaneous rate necessary to maintain the water level at the same point on the measuring peg.
- Add water to the pit until one hour after the flow rate has stabilised, while maintaining the same pond level.
- After the flow rate has stabilised, cease water delivery and record the rate of infiltration in cm/hr until the pit is empty.

The subsequent analysis will then relate the infiltrated volume to infiltration rate. Since this test can take longer time in more permeable materials other variations of this method are possible, similar to a falling head test.

This test is considered to provide the best indication for the design of storage sumps in the cleared pits and haul road sumps.

4.4 Pumping tests

Properly designed and executed pumping tests of sufficient duration provide the best information on the aquifer system behaviour in response to hydraulic stresses, however they do not necessarily yield useful information on infiltration parameters (unless combined with some other infiltration methods).

Application of pumping tests will be potentially appropriate if groundwater extraction is deemed important for drainage control. This could include the cases with relatively shallow groundwater levels, close to natural drainage lines of valley floors, or where basement or dolerite outcrops are encountered causing rise in groundwater levels. These cases will be typically exacerbated by winter rainfalls during which groundwater levels rise by several metres.

A pumping test requires a test hole with a larger installed screen diameter (150 to 250 mm) with at least one or more monitoring bores with small installed diameter (50 mm). All bores need to be well developed and free of residues from the drilling and installation process. The pumping test would then consist of a sequence of a step-discharge test, constant rate test and recovery test, the duration of which varies with the view of site-specific conditions. A pumping test will provide site-specific estimates of hydraulic conductivity and storage parameters (specific storage, specific yield).

A special category in this section includes slug tests, a relatively quick method of obtaining near-bore hydraulic conductivity measurements. They comprise a quick insertion of a 'slug' into the bore hole, usually a solid body or water, design to produce a sudden change in water level. This is then followed by monitoring the groundwater level dissipation and analysis of water level changes against time.

Although this is a quick and relatively cheap method, its accuracy is influenced by the quality of the bore development. Any residues of drilling and installation process may mask the true aquifer permeability. If these limitations are properly addressed this method can provide useful measurements also in materials of low permeability.

4.5 Water balance methods

Water balance methods are applicable to cases when good quality groundwater level timeseries are available together with site-specific estimates of specific yield. In those cases, the measured groundwater level rise during winter rainfall events can provide the basis of recharge rate estimation during that event. The recharge rate will afford an indirect measure of infiltration properties.

This method can therefore be applied to sites with good quality groundwater level timeseries records (from pre-existing groundwater monitoring bores) and where specific yield was ideally obtained from pumping tests. This typically is not common for the new Alcoa sites, but highlights the need for forward installation of the groundwater level monitoring bores in areas which are planned to be mined in the near future.

5 Proposed investigation framework

5.1 General

Alcoa has a long history, that spans over several decades, of initiating and executing valuable studies and investigations of hydrological aspects of mining on the jarrah forest of the Darling Range. New challenges brought by the generally drying climate and the need to protect water resources of the Serpentine Dam catchment and its environmental assets necessitate the need to intensify some of the investigation and monitoring activities.

Alcoa's past and present investigation activities include several hundred monitoring bores in the previously mined areas, for which water levels are available from various time periods and with variable frequency of monitoring.

Alcoa and its consultants also collected data on some of the hydraulic properties as outlined in section 2.2 in particular.

Infiltration testing is generally required across the following key surfaces:

1. **Mine pits** - will involve field infiltration rate testing on identified exposed mine floor surfaces across range of different material types, including material characterisation
2. **Rehabilitated pits** - will involve near surface soil infiltration rates for several year old rehabilitation. Additionally, it will include infiltration at depth within the rehabilitation tillage zone across temporal scales
3. **Haul roads** - will involve infiltration rate testing on a range of exposed sump surfaces with material characterisation and depth to groundwater to enable correlation to drill holes in future sump locations

Infiltration testing methods will be applied across all three key surfaces and an example proposed surface-focused program is presented in Section 5.7

The proposed activities are subdivided into phases associated with the mining cycle, i.e. pre-mining, operational and rehabilitation phases, although some of the activities will span over more than a single phase.

5.2 Pre-mining phase

Investigations in the pre-mining phase are completed to ideally secure relevant and targeted information on the key hydrological aspects of planned mining (and associated infrastructure) activities.

In terms of excess water control and management, these secure information on depth to groundwater and how it varies in response to seasonal rainfall; surface water drainage definition (mapping of contributing catchments and drainages, measurements of streamflows, where appropriate, mapping of seepage and springs); sampling of groundwater and surface water quality; mapping of vegetation communities and identification of groundwater dependent ecosystems.

The proposed investigation activities during the pre-mining phase are outlined and described in Table 5-1:

Table 5-1 Proposed investigation activities during the pre-mining phase

Activity	Description	Comments
Natural drainage and catchment definition, streamflows and stream water quality	Delineate the natural drainage line network and catchment boundaries (using the best DEM available), encompassing the mined areas. Identify any permanent streams if they occur in the areas and collect flow measurements during dry and wet seasons. In case of the latter, it is recommended that a gauge be installed with an automatic data logger that includes measurements of water level and electrical conductance (EC), that would allow to continuously measure variations in flows and water quality. In addition to EC measurements, it is recommended that water quality samples for laboratory analysis (including turbidity) are taken before and after the rainy season and two or three samples are taken during or immediately following the peak rainfall events. An analysis of recent rainfall data shows that there are at least 10 to 12 days within a typical rainfall season which qualify as larger rainfall event. Consideration may be also given to automated turbidity monitoring during the wet season in areas identified with turbidity risk. Spot flow measurements are recommended for non-perennial streams, to be undertaken during the height of the wet season (typically August). During the flow measurement it is also recommended to obtain a sample for water quality analysis. All activities to be summarised in a flow and water quality sampling plan to be prepared before the onset of a wet season.	There are very perennial streams in the region.
Groundwater level and quality monitoring	Groundwater monitoring bores to be installed in areas of the imminent mining developments to monitor groundwater levels and quality. The siting of monitoring bores will ideally be informed by a risk assessment of the potentially shallow groundwater. Five to six monitoring bores are recommended per pit with shallow groundwater risks. Depending on the regolith depth and the position of the watertable, some the monitoring locations may require dual installation, a shallow and deep section. The installations at the downgradient site of the mining pits will often be shallow, while installations at the upper part of the pit will target deeper groundwater - and the shallow section will be dry. The location of monitoring points will be ideally designed by a hydrogeologist and would consider the likely infrastructure constraints and any environmental requirements.	
Slug tests conducted on	Slug tests are considered a relatively cheap method of collecting aquifer permeability information and	

Activity	Description	Comments
hydrogeological (monitoring) bores	recommended to be undertaken following the bore installation.	
Vegetation mapping	To be undertaken to provide the baseline and delineation of groundwater dependent ecosystems.	

In addition (or sometimes as an alternative) to pit-specific investigation activities, it will be beneficial to target several investigation profiles within the catchment to be mined, in an approach similar to previous research investigations in research and mined catchments.

5.3 Operational phase (during mining)

Most of the proposed investigation and monitoring activities from the pre-mining phase (if and when undertaken) will continue into the operational phase. In addition to these activities, data on hydraulic properties are likely to be required to improve the design of drainage control. In this case a combination of DRI and pit infiltration tests will be beneficial.

Table 5-2 Proposed investigation activities during the operational phase

Activity	Description	Comments
Obtain and analyse samples for sieve analysis from unconsolidated materials	In areas where bauxite and waste materials has been removed and there is a need for excess groundwater control, collect samples for sieve analysis from profiles of unconsolidated materials (friable, mottle zones or alluvium if close to natural drainage). It is recommended that two or three samples are taken from a metre-long profile. If the profile is fairly homogeneous a single sample may be sufficient. Laterally, the sampling plan should cover the texture variations that can be visually observed or inferred from exploration drilling. Typically, five to eight locations may be sufficient.	
Carry out infiltration testing using DRI and/or pit infiltration test	In pits requiring drainage control, undertake DRI or pit infiltration testing on areas likely to be developed into excess water storages, especially if these areas have a relatively high clay content. Ideally each water storage area will be tested before confirming the design and construction of storage sumps.	
Streamflows and stream water quality	As specified in the pre-mining phase	
Groundwater level and quality monitoring	Groundwater monitoring bores to be installed in areas of the imminent mining developments to monitor groundwater levels and quality (if not installed during the pre-mining phase). The siting of monitoring bores will ideally be informed by a risk assessment of the potentially shallow groundwater.	

Activity	Description	Comments
	Five to six monitoring bores are recommended per pit with risk of shallow groundwater. Depending on the regolith depth and the position of the watertable, some the monitoring locations may require dual installation, with both the shallow and deep sections. The installations at the downgradient site of the mining pits are likely to be shallow, while installations at the upper part of the pit will target deeper groundwater (up to 30 m deep). The locations of monitoring points should be designed by a hydrogeologist and would consider the likely infrastructure constraints and any environmental requirements. Install and continue measuring water levels using loggers, at least during the wet season. Manual monitoring will be sufficient during the dry season. Collect samples for water quality analysis before and after the wets season (for example in April and October/November).	
Slug tests on hydrogeological bores	Slug tests are to be considered and employed as a relatively cheap method of collecting aquifer permeability information (if not obtained during the pre-mining phase).	
Pumping tests	Pumping tests should be considered only in circumstances when active groundwater pumping is to be considered as a viable and required water control measure and the site conditions are favourable to such measures. The relatively low permeability of regolith's materials is likely to require application of, for example a spear rather than production bore setup, to tackle the relatively small and limited zone of influence of pumping in the low permeability environment. The pumping test(s) should be designed and supervised by a qualified hydrogeologist.	
Storage sump level/volume monitoring	Any storage sumps used for drainage control are to be equipped with pegs measuring the water level in the pit against the volumes of water deposited in the pit. The simple pit sizing tool developed by Advisian in Excel can then be used to 'calibrate' the infiltration rate parameter used for the pit design.	
Vegetation health monitoring	Vegetation health monitoring should be conducted periodically during mining to ensure compliance with vegetation health targets, including detection and monitoring of any potential adverse effects on the neighbouring vegetation communities. For example, groundwater mounding associated with clearing can be associated with waterlogging of soils downgradient of the mining pit with potentially unfavourable effects. A vegetation health survey is recommended at the height of the wet season (e.g. in August).	

As with all investigations, a proper planning design is necessary to address the specific needs, circumstances and constraints of each mining pit or other mining infrastructure element.

5.4 Rehabilitation phase

Monitoring activities from the mining phase will continue into the rehabilitation phase until full rehabilitation is accomplished to pre-defined criteria. These include monitoring of groundwater levels and quality and vegetation health monitoring.

Groundwater level monitoring may be reduced to quarterly intervals during the rehabilitation phase. Vegetation health monitoring is recommended to be conducted twice a year or as per site-specific recommendations of a qualified botanist/ecologist.

DRI testing is recommended to be applied on the rehab material, at a nominal sample size of five to seven tested sites per rehabilitated pit.

5.5 Efficiency measures / correlation-focused studies

A more wide-scale application of site investigation proposed above will result in provision of large dataset of site-specific values that may nevertheless offer insights in correlation between observed parameters and some of the morphological, geological and hydrological features. A targeted identification of such correlations and relationships, once properly understood, may lead to reduction of required investigation activities. It is therefore recommended that once a sizeable database of site-specific data is generated a correlation-focused study is to be undertaken.

The question of 'sizeable database' is of course subjective, however it is assumed that if the proposed investigation techniques are fully applied to a sample of five to ten pits in varying site conditions, this would constitute a potentially sufficient sample for seeking and identifying (or ruling out) likely correlations.

5.6 Uncertainty

Earth sciences investigations almost exclusively rely on point data and interpolation between them to characterise material properties (soil, aquifer materials). One of the major difficulties in site characterisation is associated with the estimation of the appropriate amount and extent of works, such as lateral or vertical spacing and/or sampling frequency.

The amount and extent of works are generally selected based on experience which may be subjective. There are also inherent difficulties in the interpretation of observations and parameter values derived from site characterisation.

In evaluation of site characterisation uncertainty, it has been pointed out that the natural soil (and aquifer material) variability dominates over other sources of uncertainty such as measurement errors and statistical uncertainty.

We therefore must accept that with a site characterisation program with finite resources available there will always be some residual uncertainty about estimated parameters. Numerical modelling techniques allow for exploring uncertainty and sensitivity of parameters to establish to what degree the parameter variations can affect the predictions associated with that parameter. It is then possible to focus on parameters with high sensitivity.

Prediction of infiltration do show they are sensitive to the infiltration rate parameter; in this case it is possible to explore how vertical changes in infiltration rate may affect the design of a sump. The saprolite weathering profile underlying the cleared surface of the mining pits is prone to vertical changes which would not necessarily be captured by tests such as DRI test or sieve tests or even pit infiltration tests.

Sensitivity-focused modelling, using, for example, the HYDRUS platform, can offer insights on site-specific impacts of vertical anisotropy and could be considered beneficial for wider Alcoa applications, for sensitivity-based examination, especially if any relationships can be identified with apparent soil textures (identifiable visually.

5.7 Investigation plan development

The proposed investigation framework provides suggested investigation approaches for different focus areas, the extent of which may differ or vary for different sites or developments or developmental phases.

We recommend that a specific investigation plan be developed iteratively, and in consultation with Alcoa personnel for larger development areas, that could be organised spatially within the surface catchment areas, in order to plan and streamline the resources.

Such a plan will be based on the framework provided in Section 5 and applied proportionally, in its content, to focus areas. It would always be desirable to start with the pre-mining phase of investigations, but it is likely to be not possible as this framework would be applied also to currently mined areas or rehabilitated areas. The framework makes provision for it in specifying which investigations are applied, what is their likely spatial count or measurement/sampling frequency.

An annual investigation planning needs to take into account the actual development plans, for example:

- How many pits will become operational
- How many pits will enter the rehabilitation phase
- How many haul road sumps will be installed
- The need to expand and explore new areas for planning purposes
- Additional compliance requirements from regulatory agencies or to address concerns of third parties

If, for example, five new operational pits and five pits that enter rehabilitation phase the investigation program could include the following scopes in Table 5-3:

Table 5-3 Example annual investigation program outline for areas with new and rehabilitated pits and haul road sumps (focused infiltration rate characterisation)

Investigation type	Likely quantities	Comment
New pits – possible quantities		
Groundwater monitoring bores	25 to 30	Assume 5 to 6 at each pit
DRI tests	25 to 30	Assume 5 to 6 at each pit
Sieve analyses	50 to 90	May be omitted if DRI testing undertaken, otherwise 5 to 6 locations with 2 to 3 vertical horizons
Monitoring loggers	10 to 15	Equip 2 to 3 bores at each cleared pit
Pit infiltration tests	10 to 15	Assume 2 to 3 tests at each pit, for design of infiltration/storage sumps
Vegetation health, GDE survey	Twice a year	At each site
Streamflow measurements and samples	3 to 4 times a year	Any permanent streams and/or non-perennial streams when they flow
Groundwater sampling and analysis	30 samples	Assume 2 to 3 sampled bores per pit twice a year
Pumping tests	0 to 2	Only if active groundwater extraction will be likely
Rehabilitated areas		
DRI tests	25 to 30	Assume 5 to 6 at each pit (to be repeated each year or year 3 and 5 of rehabilitation)
Sieve analyses	50 to 90	May be omitted if DRI testing undertaken, otherwise 5 to 6 locations with 2 to 3 vertical horizons (to be repeated each year or year 3 and 5 of rehabilitation)
Groundwater level monitoring	25 to 30 bores	Assume monitoring bores are installed
Vegetation health, GDE monitoring	Twice a year	Repeated in year 3 and 5
Water quality sampling and analysis	20 from bores Streamflows and quality, 3 times a year	Assume 10 bores, twice a year
Haul road sumps		
DRI tests	Dependent on number of sumps	Assume 2 per sump (to be repeated each year during operation)
Sieve analyses	Dependent on number of sumps	May be omitted if DRI testing undertaken, otherwise 2 to 3 locations with 2 to 3 vertical

Investigation type	Likely quantities	Comment
		horizons (to be repeated each year or year 3 and 5 of rehabilitation)
Pit infiltration tests	Dependent on number of sumps	Assume an initial test prior to sump installation
Vegetation health, GDE monitoring	Twice a year	Where vegetation health may be adversely influenced by sump operation
Water quality sampling from sump	Three times a year per sump	
Groundwater level monitoring	1 to 2 observation bores per sump	Only where vegetation health may be adversely influenced by water level fluctuations

The actual quantities and frequencies will be adjusted to site-specific and operational conditions and compliance requirements – and agreed with Alcoa's water team.

It is also recommended that each annual program is reviewed in depth to evaluate its benefits and drawbacks and draw learnings that could be used for other sites. Consideration may be given, after the data review, to identify any numerical modelling needs that would add value to the dataset and information base obtained from this data package.

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