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Santos
**GROUNDWATER
MONITORING BORE**
ROM_BXGGWG04_BORE_W

TOTAL DEPTH: 456.7 m

SCREEN INTERVAL: 443.7-455.7 m

LONGITUDE: 149°23'35.0"E

LATITUDE: -26°36'12.0"S

TOP OF CASING RL: 301.57 mASL

COMPLETION DATE: 1 MARCH 2012

Santos GLNG

GLNG Gas Field Development Project Groundwater Technical Report

31 October 2014

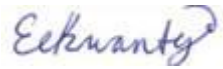


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Glossary

Alkaline	Having the properties of any of various bases, the hydroxides of the alkali metals and of ammonium, which neutralise acids to form salts.
Alluvial	Sediments deposited by flowing water.
Alluvium	General term for unconsolidated deposits of inorganic materials (clay, silt, sand, gravel, boulders) deposited by flowing water.
Alluvium aquifer	An aquifer formed within alluvium. See <i>Alluvium</i> .
ANZECC guidelines	<i>Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000)</i>
Aquaculture	Cultivation of the food resources of the sea or of inland waters.
Aquatic ecosystems	The physical and chemical environment that contains a community of organisms (plants, animals, and microbes), and ecological processes within rivers and their riparian zones and reservoirs, lakes, wetlands and their fringing vegetation.
Aquifer	Rock or sediment in a formation, group of formations or part of a formation that is saturated and sufficiently permeable to transmit economic quantities of water to wells and springs.
Aquifer testing	The process where an aquifer is subjected to pumping to assess the hydraulic parameters of the aquifer.
Aquitard	Saturated geological unit with a relatively low permeability that can store large volumes of water but does not readily transmit or yield significant quantities of water to bores or springs. An aquitard can sometimes, if completely impermeable, be called an aquiclude.
Artesian aquifer	A confined aquifer whose water is pressurised i.e. if tapped by a bore, would flow naturally to the surface.
Artesian bore	A term commonly used to describe a bore which is completed into an artesian aquifer.
Artesian storage	The component of aquifer storage that is due to the compressibility of the aquifer material and water itself when the aquifer remains fully saturated. Artesian storage (also known as confined or elastic storage) is expressed as the volume of water released from or taken into storage by a unit change in water level. Confined storage is typically several orders of magnitude less than the total or unconfined storage.
Australian Height Datum (AHD)	A level datum, uniform throughout Australia, that generally approximates mean sea level.
Authority to prospect (ATP)	A petroleum tenure granted under the <i>Petroleum Gas (Production and Safety) Act 2004</i> (Qld) allowing the holder to undertake petroleum

	exploration activities and studies to evaluate the development potential of a defined resource.
Basalt	The dark, fine-grained igneous rock of a lava flow, composed essentially of plagioclase and pyroxene, and sometimes displaying a columnar structure.
Baseflow	The component of river or stream flow that is derived from groundwater discharge to the river or stream.
Baseline	A basic standard or level, usually regarded as a reference point for comparison.
Beneficial use	An alternative reuse for a material such as coal seam water or salt residues that changes the status of the material from a waste to a resource that can be used for a beneficial purpose.
Biodiversity	The number and variety of organisms found within a specified geographic region or within a given ecosystem.
Bore	Artificially constructed or improved groundwater cavity used for the purpose of accessing or recharging water from an aquifer. Interchangeable with borehole, piezometer.
Borehole	Includes a well, excavation, or other artificially constructed or improved groundwater cavity which can be used for the purpose of intercepting, collecting or storing water from an aquifer; observing or collecting data and information on water in an aquifer; or recharging an aquifer. Interchangeable with bores, wells, piezometers.
Brackish	Water that contains between 500 and 10,000 milligrams per litre of dissolved solids according to National Water Commission.
Brine	Concentrated wastewater produced by desalination (e.g. reverse osmosis) treatment that typically contains more than 35,000 milligrams per litre of dissolved solids.
Buffer	An area of land separating adjacent land uses that is managed for the purpose of mitigating impacts of one use on another. A buffer area consists of a separation distance and one or more buffer elements.
Cainozoic	Relating to the geological era of rocks of most Recent age (65.5 million years ago to present).
Catchment	The area of land that collects and transfers rainwater into a waterway.
Category A environmentally sensitive area	Means any environmentally sensitive area listed in Section 25 of the Environmental Protection Regulation 2008 (Qld).
Clay	Deposit of particles with a diameter less than 0.002 mm, typically contain variable amounts of water within the mineral structure, and exhibit high plasticity.
Coal	Carbon-based sedimentary rock formed by the accumulation and decomposition of plant material in layers, which can be used as a combustible fuel. Main types, in order of highest rank to lowest rank, are

	black coal (anthracite, bituminous, sub-bituminous), brown coal (lignite) and peat (considered to be a precursor of coal).
Coal seam gas (CSG)	Natural gas extracted from coal seams.
Coal seam water	Groundwater produced at the surface by the depressurisation of coal seams during gas production.
Coal seam water dams	Types of dam (storage or evaporation) used to contain coal seam water that is necessarily or unavoidably brought to the surface in the process of natural gas from coal seams extraction.
Colluvium	General term applied to loose, heterogeneous and incoherent sediment such as soil material and/or rock fragments transported by gravity and deposited or built up at the bottom of a low-grade slope.
Condamine	River in south eastern Queensland, rising on the western side of the Great Dividing Range and flowing west to join Dogwood Creek to form the Balonne River.
Confined aquifer	An aquifer bounded above and below by impervious (confining) layers. In a confined aquifer, the water is under sufficient pressure so that when wells are drilled into the aquifer, measured water levels rise above the top of the aquifer.
Confining layer	Layer of low permeability material underlying or overlying an aquifer, which restricts the vertical movement of water.
Conglomerate	Consolidated gravel consisting of rounded and waterworn pebbles etc. embedded in a finer cementing material.
Consolidated aquifer	Water bearing rock aquifer such as sandstone, coal, limestone, granite, etc.
Contour plot	Graphical technique for representing a three-dimensional surface by plotting contours, on a two-dimensional format.
Cretaceous	Relating to the third period within the Mesozoic era beginning approximately 145.6 million years ago and ending approximately 65 million years ago.
Cultural significance	The meaning or value ascribed to the cultural landscape. It normally stems from a combination of association and integrity.
Cumulative impact	The combined impact to one or more environmental values delivered by multiple projects being undertaken simultaneously within the same sphere of physical influence.
Dam	An engineered land-based structure that is designed to contain, divert or control liquid. A dam does not mean a fabricated or manufactured tank or container, designed and constructed to an Australian Standard that deals with strength and structural integrity of that tank or container.
Deep groundwater	Groundwater resources associated with aquifers and resources at depths >100 m.

Depressurisation	Reduction in groundwater pore pressure (pressure head) in a confined groundwater system due to extraction of groundwater.
Dewatering	Draining, permanently or temporarily, a wet area of land or an aquifer.
Dissolved oxygen (DO)	The amount of oxygen dissolved in water.
Dissolved solids	Minerals and organic matter dissolved in water; a measure of salinity.
Drawdown	The change in groundwater level in a bore, or the change in water table elevation in an unconfined groundwater system, due to the extraction of groundwater.
Ecosystem	An organic community of plants, animals and bacteria and the physical and chemical environment they inhabit.
Environmental authority (EA)	A licence to operate, issued in accordance with the <i>Environmental Protection Act 1994</i> (Qld), that imposes conditions on authorised activities to reduce or avoid potential environmental impacts; used by Queensland Department of Environment and Heritage Protection to assess and administer regulatory environmental compliance of the project.
Environmental impact statement (EIS)	A document prepared to identify, describe and assess the potential impacts of a proposed action on the environment, and document ways to mitigate such impacts; it should provide sufficient detail to inform a decision on the proposal.
Environmental management plan (EMP)	Document that provides operational detail of how environmental management measures identified in the environmental impact statement will be implemented.
Environmental values	Desirable characteristics, properties and behaviours or an aspect of the environment.
EPBC threshold criteria	The rules or principles used to measure the significance of a plant, animal or ecosystem against the requirements of the <i>Environment Protection and Biodiversity Conservation Act 1999</i> (Cth).
Ephemeral	Relates to the amount of time that surface water persists in a watercourse or wetland; ephemeral watercourses flow only during significant rainfall events and for a short-time following rainfall events.
Erosion	Wearing away of rock or soil caused by physical or chemical processes
Fault	Zone of displacement in rock formations resulting from forces of tension or compression in the earth's crust.
Formation	General term used to describe a sequence of rock layers.
Fracture	Break in a rock including cracks, joints, and faults.
Groundwater	Water found in the subsurface in the saturated zone below the water table or piezometric surface i.e. the water table marks the upper surface of groundwater systems.

Groundwater flow	The movement of water through openings and pore spaces in rocks below the water table i.e. in the saturated zone.
Groundwater resource	Groundwater available for beneficial use, including human usage, aquatic ecosystems and the greater environment.
Hydraulic conductivity	Measure of the ease with which water will pass through earth material; defined as the rate of flow through a cross-section of one square metre under a unit hydraulic gradient at right angles to the direction of flow (metres per day).
Hydraulic fracturing	Hydraulic fracturing involves pumping a fluid under pressure into a coal seam to open up and connect fractures within the coal, increasing the opportunity for gas to move within the coal seam and flow toward the well.
Hydraulic gradient	Change in the hydraulic head over a certain distance.
Hydraulic head	Elevation to which water will rise in a borehole connected to a point in an aquifer.
Hydrogeology	The study of the interrelationships of geological materials and processes with water, especially groundwater.
Hydrograph	Graph that shows groundwater or surface water properties as a function of time.
Igneous rock	Rock formed from magma that has cooled and solidified either at the earth's surface (volcanic rock) or deep within the earth's crust (plutonic rock).
Impact	An event that disrupts ecosystem, community, or population structure and alters the physical environment, directly or indirectly.
Infiltration	The downward movement of water from the atmosphere into the ground; not to be confused with percolation.
Intrusion	The solidified remnants of an igneous flow of rock into sedimentary strata.
Jurassic	The geologic period that extends from ~200 million to ~145 million years ago. The period occurred within the Mesozoic era, following the Triassic and preceding the Cretaceous periods.
Landholder	The owner, occupier, manager, or controller of land or water, including anyone acting on their behalf.
Liquefied natural gas	Gas consisting primarily of methane, liquefied to facilitate transport and storage.
Lithology	The physical character of rocks.
Matters of national environmental significance (MNES)	Listed under the <i>Environment Protection and Biodiversity Conservation Act 1999</i> (Cth); includes listed threatened species and ecological communities, migratory species protected under international agreements, Ramsar wetlands of international importance, the Commonwealth marine environment, World Heritage properties, National

Heritage places, the Great Barrier Reef Marine Park, nuclear actions and a water resource, in relation to coal seam gas development and large coal mining development

Mesozoic	The geological era from ~250 million to ~65 million years ago. It is the era between Palaeozoic and Cainozoic.
Meteorological	Relating to meteorology or to phenomena of the atmosphere or weather.
Mitigation	To appropriately protect and maintain the existing environment in accordance with relevant legislation and best-management principles; taken to have the same meaning as management.
Modelling	The creation of a computerised model that simulates natural environment, allows simulations to project future outcomes.
Monitoring bore	A bore used to monitor groundwater levels or quality.
Mudstone	A clayey rock of nearly uniform texture throughout, with little or no lamination.
Natural resource	Resource that occurs naturally, such as sunlight, wind, soil, or water.
Palaeochannel	Buried stream channel.
Percolation	The movement and filtering of fluids through porous materials.
Permeability	The ease with which a fluid can pass through a porous medium and is defined as the volume of fluid discharged from a unit area of an aquifer under unit hydraulic gradient in unit time (metres per day).
Permian	Geological period from approximately ~300 million years ago to ~251 million years ago. The Permian period occurred between the Carboniferous period and Triassic period.
pH	Absolute value of the decimal logarithm of the hydrogen-ion concentration (activity). Used as an indicator of acidity ($\text{pH} < 7$) or alkalinity ($\text{pH} > 7$).
Piezometer	Hydraulic structure within a borehole which, when properly designed and constructed, facilitates the measurement of groundwater levels and the collection of representative groundwater samples.
Piezometric level	The elevation to which groundwater levels rise in boreholes that penetrate confined or semi-confined aquifers.
Pleistocene	A time epoch of the Quaternary period. It began ~2-3 million years ago and extended to the commencement of the Holocene epoch ~10,000 years ago.
Production wells	A well that is designed to extract gas from one or more natural underground reservoirs.
Project	Gas Field Development Project, involving construction, operation and decommissioning of gas field and associated infrastructure to supply gas to market; the subject of this environmental impact statement.

Project area	The Gas Field Development Project area, comprising 10, 676 square kilometres in the Surat and Bowen basins made up of 35 petroleum tenures: - Arcadia gas field – PL 233, PL 234, PL 235, PL 236, PLA 420, PLA 421, PLA 440, ATP 526P (5 parts), ATP 653P (1 part), ATP 745P (2 parts), ATP 804P (1 part) (2,726 km²) - Fairview gas field – PL 90, PL 91, PL 92, PL 99, PL 100, PL 232, ATP 655P (2 parts) (1,962 km²) - Roma gas field – PL 3 (313), PL 6 (316), PL 7 (317), PL 8 (318), PL 9 (319), PL 10 (320), PL 11 (321), PL 13 (322), PL 93 (323), PL 309, PL 310, PL 314, PL 315, PLA 281, PLA 282, ATP 336P (2 parts), ATP 631P (2 parts), ATP 665P (2 parts), ATP 708P (1 part) (4,383 km²) - Scotia gas field – PL 176, ATP 803P (1 part), ATP 868P (1 part) (1, 605 km²). - Possible area for supporting infrastructure
Proponent	Santos GLNG, a Joint Venture between Santos Limited, PETRONAS, Total and KOGAS.
Qualitative	Relating to or concerned with quality or qualities, rather than quantity or measured value.
Quantitative	An assessment based on quantities or quantifiable data.
Quaternary	The geological time period beginning ~2 to ~3 million years ago and extending to present; encompasses the Pleistocene and Holocene time epochs.
Raw water	Untreated water from the environment.
Receptor	That part of the environment that may be the recipient of environmental harm; receptors may include houses, schools, hospitals, surface waters, groundwater, land, ecosystems etc.
Recharge	Recharge is defined as the process by which water is added from outside to the zone of saturation of an aquifer, either directly into a formation, or indirectly by way of another formation.
Recovery	Rise of the water level in a bore or an aquifer after the pumping rate has been reduced or the pump has been shut off or when mining has ceased. Also known as rebound.
Registered groundwater bore	Groundwater bore that is recorded in the Queensland Department of Natural Resources and Mines database.
Regulatory framework	System of regulations and the means to enforce them, usually established by a government to regulate a specific activity.
Remediation	Removal of pollution or contamination from the environment to restore to health; requires that impact is reduced to some acceptable level.
Riparian	Situated along or near the bank of a waterway.

Runoff	All surface and subsurface flow from a catchment, but in practice refers to the flow in a river i.e. excludes groundwater not discharged into a river.
Salinity	The concentration of dissolved salts in water, usually expressed in electrical conductivity (EC) units ($\mu\text{S}/\text{cm}$) or total dissolved solids (TDS) units (mg/L TDS).
Sandstone	Rock formed by the consolidation of sand, the grains being held together by a cement of silica, lime, gypsum, or iron salts.
Sediment	Particles derived from rocks or biological materials that have been transported by air or water.
Sedimentation	Deposition or accumulation of mineral or organic matter deposited by air or water.
Seep	A diffuse wetland area where interflow and groundwater emerges, usually at a slow rate or small volume, to become surface flow.
Semi-confined aquifer	An aquifer that is partly confined by layers of lower permeability material through which recharge and discharge may occur, also referred to as a leaky aquifer.
Sensitive place or sensitive receptor	Area or structure sensitive to a predicted environmental impact (usually from air emissions or noise) such as a dwelling, a library, childcare centre, kindergarten, school, college, university or other educational institution; a hospital, surgery or other medical institution; a protected area or an area identified under a conservation plan as a critical habitat or an area of major interest under the <i>Nature Conservation Act 1992</i> (Qld); a marine park under the <i>Marine Parks Act 2004</i> (Qld); or a park or garden that is open to the public.
Shallow groundwater	In the context of the study, shallow groundwater has been recognised as groundwater resources not deeper than 100 m below ground surface.
Siltstone	Consolidated silt; fine-grained sedimentary rock.
Spring	Natural discharges of groundwater at the surface or within stream beds. Spring vents are a single point in the landscape where groundwater is discharged at the surface. Recharge (reject) springs occur where rates of recharge are greater than rates of water infiltration; thus, 'rejection' of water causes seepage of water at the surface from exposed formations. Recharge springs are commonly an ephemeral feature in a local aquifer and not necessarily connected to the water table aquifer. Discharge springs occur where faulting or rapid thinning occur against basement highs disrupting lateral through-flow of groundwater or where water-bearing zones approach the ground surface and pressurised groundwater breaks through fractures in thin confining beds. Watercourse springs are a section of a watercourse where groundwater enters the stream from an aquifer through the streambed. These springs occur where an outcropping aquifer has been eroded to create a depression in the surface of sufficient depth to reach the water table.
Stakeholder	Person or group affected by or concerned with an issue or enterprise.

Statutory guideline	A document that provides direction for implementing the intent of legislation.
Storage capacity	The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.
Storativity	The volume of water that a saturated confined aquifer releases from storage per unit surface area of the aquifer per unit decline in the water table. Quantifies an aquifer's ability to release water.
Strata	Single bed of sedimentary rock, generally consisting of one kind of matter representing continuous deposition.
Stratigraphy	Branch of geology dealing with the classification, nomenclature, correlation, and interpretation of stratified rocks.
Terms of reference (ToR)	Written document developed by the regulatory authority (i.e. Queensland Coordinator-General) that provides the minimum expectations for the scope of an environmental impact statement.
Terrestrial	Relating to, consisting of, or representing the Earth; relating to the land as distinct from the water.
Tertiary	Relating to a geological period or a system of rocks that precedes the Quaternary and constitutes the earlier principal division of the Cainozoic era. ~65 ma to 2.6 ma.
Threatened species	Generic term for a plant or animal species listed as critically endangered, endangered, vulnerable or rare under either State or Commonwealth threatened species legislation. The terms 'threatened' and 'conservation significant' are interchangeable in this context.
Triassic	The geological time period extending from ~250 to ~200 million years ago. It is the earliest period of the Mesozoic era and occurred between the Permian and Jurassic periods.
Trigger level	The point at which some form of action is begun, such as exceedance of guidelines.
Unconfined aquifer	An aquifer with no confining layer between the water table and the ground surface where the water table is free to fluctuate.
Unconsolidated aquifer	Strata such as sand that has not been turned into rock.
Vulnerable	Designated as vulnerable under the <i>Environment Protection and Biodiversity Conservation Act 1999</i> (Cth) and/or <i>Nature Conservation Act 1999</i> (Qld). Refer to <i>Environment Protection and Biodiversity Conservation Act 1999</i> (Cth) conservation status and <i>Nature Conservation Act 1992</i> (Qld) conservation status for meaning of 'vulnerable' under these acts.
Water table	The surface in an unconfined aquifer or confining bed at which the pore water pressure is atmospheric; it can be measured by installing shallow wells extending a few feet into the zone of saturation and then measuring the water level in those wells.

Watercourse	A river, creek or other stream, including a stream in the form of an anabranch or a tributary, in which water flows permanently or intermittently, regardless of the frequency of flow events: • In a natural channel, whether artificially modified or not • In an artificial channel that has changed the course of the stream • It also includes weirs, lakes and dams.
Well	A structure that is designed to bore through the earth's surface in order to extract resources.
Wellhead	The component at the surface of an oil or gas well that provides the interface for drilling and production equipment.
Wetland	Numerous definitions of wetland exist. Under the Queensland Wetland Strategy, wetland is defined as 'areas of permanent or periodic/ intermittent inundation, whether natural or artificial, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed 6 m'. Three types of freshwater wetland (excluding aquifers) are recognised: Riverine wetlands, which are analogous to 'watercourses' used in this report. Palustrine wetlands, which are vegetated swamps. Many springs are also considered to be similar to palustrine wetlands. Lacustrine wetlands, which are areas of relatively deep, non-flowing water. Lakes, farm dams and large billabongs on floodplains are examples of lacustrine wetlands. As 'watercourse' is used to refer to 'riverine wetlands', use of the term 'wetland' more specifically refers to palustrine and lacustrine wetlands.
Yield	The quantity of water removed from a water resource e.g. yield of a borehole.

Abbreviations

AHD	Australian Height Datum
ANZECC	Australian and New Zealand Environment and Conservation Council
ATP	Authority to Prospect
BOM	Bureau of Meteorology
CMA	Cumulative Management Area
CSG	Coal seam gas
DNRM	Department of Natural Resources and Mines
DOTE	Commonwealth Department of the Environment
EC	Electrical conductivity
EHP	Department of Environment and Heritage Protection
EPBC Act	<i>Environment Protection and Biodiversity Conservation Act 1999</i> (Cth)
EVs	Environmental values
EWMI	Early Warning Monitoring Installations
EWS	Early Warning System
GFDA	Gas Field Development Area
GQAL	Good Quality Agricultural Land
InSAR	Interferometric synthetic aperture radar
JIP	Joint Industry Plan
LPG	Liquefied petroleum gas
MNES	Matters of National Environmental Significance
OGIA	Office of Groundwater Impact Assessment
PL	Petroleum lease
QDEX	Queensland Digital Exploration Reports system
TDS	Total dissolved solids
TMP	Trigger Monitoring Points
ToR	Terms of Reference
UWIR	Underground Water Impact Report
WMS	Water Management System
WQOs	Water quality objectives

Units

g/L	Grams per litre
m	Metres
ma	Million years ago
mAHD	Metres Australian Height Datum
mbgl	Metres below ground level
m/day	Metres per day
m/year	Metres per year
µS/cm	Microsiemens per centimetre
mg/L	Milligrams per litre
ML/year	Megalitres per year
mm/yr	Millimetres per year

Executive summary

Santos GLNG has existing approvals for the exploration and production of gas from the Arcadia, Fairview, Roma and Scotia gas fields. The Santos GLNG Gas Field Development (GFD) Project may expand the approved gas fields from 6,887 km² to 10,676 km² and develop up to an additional 6,100 production wells beyond the currently authorised 2,650 wells. The GFD Project is scheduled to commence in 2016 and will involve the construction, operation, decommissioning and rehabilitation of wells and associated supporting infrastructure to supply gas over the next 30 years.

Parsons Brinckerhoff was engaged by Santos GLNG to complete an assessment of the potential impacts of the proposed GFD Project on groundwater resources. This groundwater technical report has been prepared to inform the environmental impact statement (EIS) process for approval of the GFD Project and is aligned with the requirements in the Terms of Reference supplied by the Office of the Queensland Coordinator-General. The methodology used in the assessment follows a similar approach to that used by the Queensland Government for the Underground Water Impact Report (UWIR) for the Surat Cumulative Management Area (CMA) in 2012.

Assessment framework

The UWIR for the Surat CMA is part of the Queensland Government's framework to ensure the petroleum and gas industry develops in a responsible way in respect of impacts to groundwater. Petroleum tenure holders have the right to extract groundwater in the process of petroleum and gas production, but are required to monitor and manage the impacts on water supplies and springs. The Surat CMA is an area where gas fields are being developed by multiple companies and the impacts of groundwater extraction overlap. The UWIR was developed by the Queensland Government to assess cumulative groundwater impacts in this area and assign responsibility for monitoring and management to petroleum tenure holders.

In preparing the UWIR in 2012, the Queensland Government undertook numerical groundwater flow modelling to predict potential impacts of petroleum and gas production on groundwater pressure. The assessment included Santos GLNG's currently approved operations as well as development by other companies, but did not include the GFD Project. In mid-2013 the Queensland Government re-ran the regional groundwater flow model for the Surat CMA to simulate the additional production associated with the GFD Project and another proponent's development plans (the EIS Scenario). The EIS Scenario has been used to assess potential impacts of the GFD Project on groundwater pressure. Other potential groundwater-related impacts have been assessed using a qualitative significance assessment approach.

Environmental values

The GFD Project tenures are underlain by a number of aquifers that provide water for stock and domestic supply and to a lesser extent for urban water supply, agriculture (including irrigation and intensive stock watering) and industrial purposes. The major aquifers are associated with the Great Artesian Basin, which comprises water bearing units of the Surat and upper Bowen geological basins, as well as water bearing zones within Tertiary rocks and alluvial deposits. There are 872 registered bores in GFD Project tenures that are estimated to take 6,856 ML per year. Most registered bores in GFD Project tenures take groundwater from either the Mooga Sandstone, Gubberamunda Sandstone or the Hutton Sandstone. There are approximately 21,000 water bores in the Surat CMA, which are used for stock, irrigation, industry and urban consumption and extract around 215,000 ML/year (including 85,000 ML/year from the Great Artesian Basin (GAB)) (QWC, 2012a). The aquifers underlying the GFD Project tenures also sustain springs, including spring vents (grouped into spring complexes) and watercourse springs which provide baseflow to streams. A spring vent is a single

point in the landscape where groundwater is discharged at the surface. A watercourse spring is a section of a watercourse where groundwater enters the stream from a Great Artesian Basin (GAB) aquifer through the streambed. There are 72 spring complexes in the Surat CMA, 11 of which are located in GFD Project tenures. There are 43 watercourse springs in the Surat CMA, 11 of which are located in GFD Project tenures. Some spring vents are of conservation value and are protected under the *Environment Protection Biodiversity Conservation Act 1999* (Cth) (EPBC Act). There are 13 EPBC Act listed spring vents located with the GFD Project tenures.

Potential impacts

The extraction of coal seam water is an integral part of the production of natural gas from coal seams and has the potential for long-term, regional scale aquifer depressurisation, drawdown and other impacts. Depressurisation is a reduction in groundwater pore pressure (pressure head) in a confined groundwater system due to extraction of groundwater. Drawdown is a reduction in groundwater level in a bore, or a reduction in water table elevation in an unconfined groundwater system, due to the extraction of groundwater.

Without adequate controls in place other GFD Project activities have the potential to increase the risk of short to long-term localised depressurisation of aquifers and localised changes in groundwater quality. These may include activities such as well construction and operation, hydraulic fracturing, shallow subsurface activities, management of coal seam water and fluids or brine generated through desalination of coal seam water and the storage and transportation of chemicals and fuels.

Numerical groundwater modelling results indicate there will be no increase to the maximum predicted depressurisation in aquifers underlying the Surat CMA due to the proposed additional development compared to what was predicted in the UWIR in 2012. The “*area of impact*” (the area that will experience groundwater pressure reductions greater than 5 m for consolidated aquifers, or 2 m for unconsolidated aquifers) will increase due to the expansion of areas being developed. The largest increases in depressurisation impacted areas will occur within the two target coal formations (the Walloon Coal Measures and the Bandanna Formation). There will also be increases in the extent of the depressurisation impacted areas within the overlying Springbok Sandstone, the Hutton/Marburg Sandstone and the Gubberamunda Sandstone.

Maximum depressurisation in the coal formations as a result of the GFD Project is expected to occur between 2020 and 2030. There will be a lag in the time to maximum depressurisation in overlying and underlying formations, with the timeframes dependent on how directly connected the formation is to the target coal formations. Depressurisation effects on aquifers are expected to persist for prolonged periods after extraction of gas has ceased.

The UWIR in 2012 predicted that 528 landholder bores would potentially be cumulatively impacted due to petroleum and gas development in the Surat CMA. Under the EIS Scenario, an additional 73 landholder bores in the Surat CMA, 48 of which are in GFD Project tenures, are predicted to be impacted. Landholder bores have been identified as potentially impacted where a decline in groundwater pressure of 5 m or more for consolidated aquifers, or 2 m or more for unconsolidated aquifers, is predicted at some time in the future at the location of the bore (following the methodology applied for the UWIR in 2012).

The UWIR in 2012 predicted that 11 spring complexes (excluding complex 507 which has been destroyed by cattle and local practices and complex 506 which is most likely associated with a perched groundwater system) and 22 watercourse springs would potentially be cumulatively impacted due to petroleum and gas development in the Surat CMA. A risk-based methodology, similar to that applied for the UWIR in 2012, was employed to identify springs at risk of impacts under the EIS scenario. The results indicate that two additional spring complexes (302 and 339) and one additional watercourse springs (W141) are predicted to be cumulatively impacted due to petroleum and gas

development in the Surat CMA under the EIS scenario. These springs are located within or near GFD Project tenures.

Management measures

The management measures identified for mitigating the potential impacts on environmental values are consistent with the existing environmental management framework developed and implemented for the Santos GLNG Project. This framework includes: the GFD Project Environmental Protocol for Constraints Planning and Field Development which guides site selection and placement of infrastructure to avoid, minimise and mitigate impacts on environmental values; the Water Resource Management Plan which details how Santos GLNG manages and monitors potential adverse impacts to water resources in accordance with Commonwealth requirements; the Coal Seam Water Management Strategy and Draft Environmental Management Plan which ensure coal seam water is managed in an integrated and sustainable way in accordance with regulatory requirements; and the Hydraulic Fracturing Risk Assessment which outlines the controls to minimise the risks associated with hydraulic fracturing.

The management measures for the GFD Project will also be in accordance with the commitments made in 2012 under the UWIR for the Surat CMA, and additional commitments required by future updates to this report. These commitments include the completion of bore assessments and make good agreements with specified landholders, completion of baseline assessments of landholder bores, development of Spring Impact Mitigation Strategies and undertaking groundwater and spring monitoring. Santos GLNG will also implement the commitments of the Joint Industry Plan for the Monitoring and Protection of the EPBC Act Springs, which provides an Early Warning System and response plan for springs protected by the EPBC Act to ensure that adequate time is available for assessment and implementation of management measures prior to potential adverse impacts.

Monitoring and reporting

Monitoring and reporting for the GFD Project will be undertaken in accordance with the UWIR and EPBC Act approval conditions for the GLNG Project. In addition, specific requirements are contained in each publication of the UWIR for the Surat CMA. This will include requirements for groundwater level and quality monitoring, baseline assessments of landholder bores and springs monitoring. If required following future updates and publication of the UWIR, Santos GLNG's existing regional groundwater monitoring program will be adapted to ensure appropriate monitoring for the GFD Project activities. Targeted groundwater monitoring will also be undertaken in association with the GFD Project and may include:

- Monitoring of EPBC Act springs in accordance with the Joint Industry Plan
- Monitoring associated with coal seam water / fluid management and storage activities (including seepage monitoring) in accordance with Environmental Authority (EA) conditions
- Monitoring of subsidence in accordance with the Ground Deformation Monitoring and Management Plan
- Monitoring associated with hydraulic fracturing activities in accordance with the Stimulation Impact Monitoring Program and EA conditions
- Managed Aquifer Recharge activities in accordance with EA conditions.

1. Introduction

Parsons Brinckerhoff was engaged by Santos GLNG to complete an assessment of the potential impacts of the proposed GLNG Gas Field Development (GFD) Project on groundwater resources. This groundwater technical report has been prepared to inform the environmental impact statement (EIS) process for approval of the GFD Project. The assessment methodology is aligned with the requirements outlined in the Terms of Reference (ToR) for the GFD Project EIS, supplied by the Office of the Queensland Coordinator-General. The assessment methodology follows a similar approach to the Queensland Government's legislative framework for assessment and management of cumulative impacts to groundwater resources (Queensland Water Commission (QWC), 2012a).

The Queensland Government's legislative framework aims to ensure the petroleum and gas industry develops in a responsible way. Under the regime, petroleum tenure holders have the right to extract groundwater in the process of petroleum and gas production, but are required to monitor and manage the impacts on water supplies and springs. This includes a requirement to 'make good' the impairment of private bore supplies caused by the exercise of these rights.

In areas where gas fields are being developed by multiple companies, the impacts of water extraction on groundwater levels may overlap and a cumulative approach is required to assess and manage impacts. In 2011 the Queensland Government declared the Surat Cumulative Management Area (CMA) and the Office of Groundwater Impact Assessment (formerly the Queensland Water Commission) was made responsible for assessing cumulative impacts and establishing integrated management arrangements for this area through the preparation of an Underground Water Impact Report (UWIR). The UWIR for the Surat CMA was released in 2012 (QWC, 2012a).

In preparing the UWIR, the Office of Groundwater Impact Assessment (OGIA) undertook numerical groundwater modelling to predict potential impacts of petroleum and gas production on groundwater pressure. The assessment included the currently approved operations of Santos Limited, its subsidiaries and joint venture partners, as well as development by:

- Origin Energy, its subsidiaries and joint venture partners, such as Asia Pacific LNG (referred to as 'Origin' in this report)
- Queensland Gas Company, its subsidiaries and joint venture partners (referred to as 'QGC' in this report)
- Arrow Energy, its subsidiaries and joint venture partners (referred to as 'Arrow' in this report)
- Other petroleum tenure holders (as detailed in the UWIR).

The proposed GFD Project is located within the Surat CMA, however this development was not initially included in the assessment undertaken for the UWIR in 2012. The reason it was not included was because at the time the UWIR 2012 was produced, the GFD Project was not part of the Santos GLNG Project planning. This groundwater technical report assesses the impacts to groundwater resources associated with the GFD Project through the use of the same numerical groundwater model used for the UWIR and follows a methodology similar to that used in the UWIR.

This approach and modelling allowed for the potential impacts to groundwater resources, due to the proposed GFD Project, to be understood within the context of the potential cumulative impacts to groundwater resources associated with currently approved petroleum and gas development reported in the UWIR for the Surat CMA.

1.1 Project description

Santos GLNG intends to further develop its Queensland gas resources to augment supply of natural gas to its existing and previously approved Gladstone Liquefied Natural Gas (GLNG) Project.

The Santos GLNG Gas Field Development Project (the GFD Project) is an extension of the existing approved gas field development and will involve the construction, operation, decommissioning and rehabilitation of production wells and the associated supporting infrastructure needed to provide additional gas over a project life exceeding 30 years.

Specifically, the GFD Project seeks approval to expand the GLNG Project's gas fields tenure from 6,887 km² to 10,676 km² to develop up to 6,100 production wells beyond the currently authorised 2,650 wells; resulting in a maximum of up to 8,750 production wells. The GFD Project will continue to progressively develop the Arcadia, Fairview, Roma and Scotia gas fields across 35 Santos GLNG petroleum tenures in the Surat and Bowen basins, and associated supporting infrastructure in these tenures and adjacent areas. The location of the GFD Project area and primary infrastructure is shown on Figure 1.1.

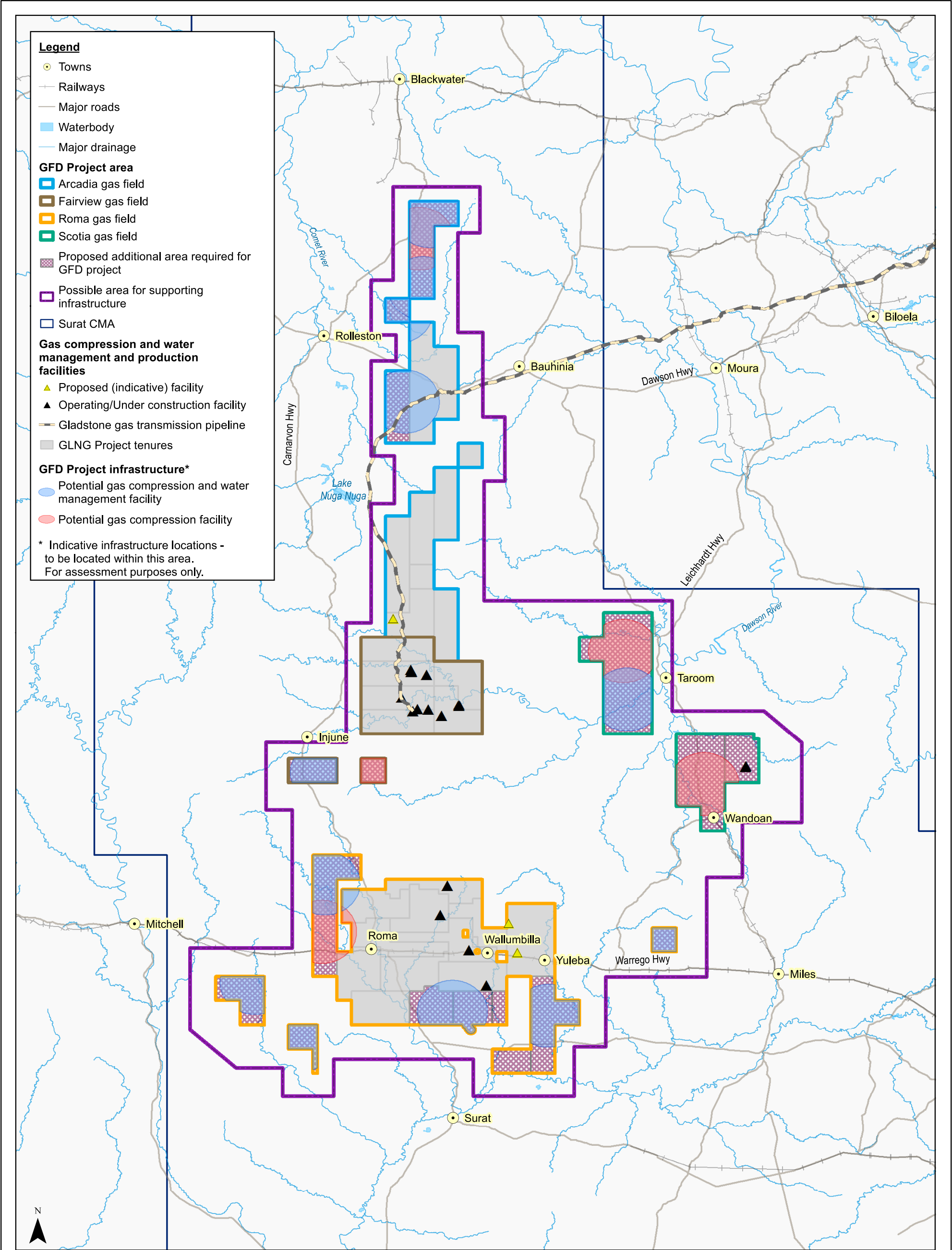
This GFD Project will include the following components:

- Production wells
- Fluid injection wells, monitoring bores and potentially underground gas storage wells
- Gas and water gathering lines
- Gas and water transmission pipelines
- Gas compression and treatment facilities
- Water storage and management facilities
- Access roads and tracks
- Accommodation facilities and associated services (e.g. sewage treatment)
- Maintenance facilities, workshops, construction support, warehousing and administration buildings
- Utilities such as water and power generation and supply (overhead and/or underground)
- Laydown, stockpile and storage areas
- Borrow pits and quarries
- Communications.

The final number, size and location of the components will be determined progressively over the GFD Project life and will be influenced by the location, size and quality of the gas resources identified through ongoing field development planning processes, which include consideration of land access agreements negotiated with landholders, and environmental and cultural heritage values.

Where practicable, the GFD Project will utilise existing or already approved infrastructure (e.g. accommodation camps, gas compression and water management facilities) from the GLNG Project or other separately approved developments. The GFD Project may also involve sourcing gas from third-party suppliers, as well as the sharing or co-location of gas field and associated facilities with third parties.

For the purposes of transparency this EIS shows an area off-tenure that may be used for infrastructure such as pipelines and temporary camps (supporting infrastructure area). While not assessed



specifically in this EIS, any infrastructure that may be located within this area would be subject to further approval processes separate to this EIS.

Approved exploration and appraisal activities are currently underway across the GFD Project's petroleum tenures to improve understanding of the available gas resources. As the understanding of gas resources increases, investment decisions will be made about the scale, location and timing of the next stages of field development.

For the purposes of this EIS, a scenario based on the maximum development case was developed at the approval of the ToR. This scenario assumed that production from the wells and upgrading of the gas compression facilities in the Scotia gas field would commence in 2016, followed by the GFD Project wells in the Roma, Arcadia and Fairview gas fields in mid-2019. This schedule is indicative only and was used for the purpose of the impact assessment in this EIS.

The potential GFD Project schedule is outlined in Figure 1.2. This schedule provides an overall field development scenario for the purposes of assessment in this EIS.

Figure 1.2 Proposed GFD Project development schedule

		PROJECT YEAR																													
GAS FIELD	INFRASTRUCTURE	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
SCOTIA	Production wells																														
	Facilities																														
ROMA	Production wells																														
	Facilities																														
FAIRVIEW	Production wells																														
	Facilities																														
ARCADIA	Production wells																														
	Facilities																														

Decommissioning and rehabilitation will occur progressively throughout the life of the GFD Project as construction activities cease and exhausted gas wells are decommissioned. Final decommissioning and rehabilitation will occur at the end of gas production in accordance with relevant approvals and regulatory requirements.

1.2 Project location

The GFD Project will be located across an area covering 10,676 km² within the Bowen Basin and Surat Basin. The GFD Project is located in the Banana Shire Council and Central Highlands, Maranoa and Western Downs Regional Council areas. The nearest towns include Roma, Surat, Wallumbilla, Miles, Taroom, Wandoan, Injune and Rolleston.

The land tenures in the GFD Project area include freehold, leasehold, and Crown land (including various reserves, national parks and State forests), with the predominant tenure being freehold.

Santos GLNG has obtained the necessary petroleum tenures to authorise gas field development activities in Queensland: an authority to prospect (ATP) for exploration and appraisal activities, succeeded by a petroleum lease (PL) for advanced appraisal and production activities. Petroleum

tenures allow certain petroleum activities (i.e. gas production) to occur over other existing land tenures.

The GFD Project comprises 35 petroleum tenures including 11 ATPs and 24 PLs as listed in Table 1.1. For operational purposes, Santos GLNG has divided the petroleum tenures into four separate gas fields – Arcadia, Fairview, Roma and Scotia gas fields, shown on Figure 1.1.

Table 1.1 Petroleum tenures forming the GFD Project

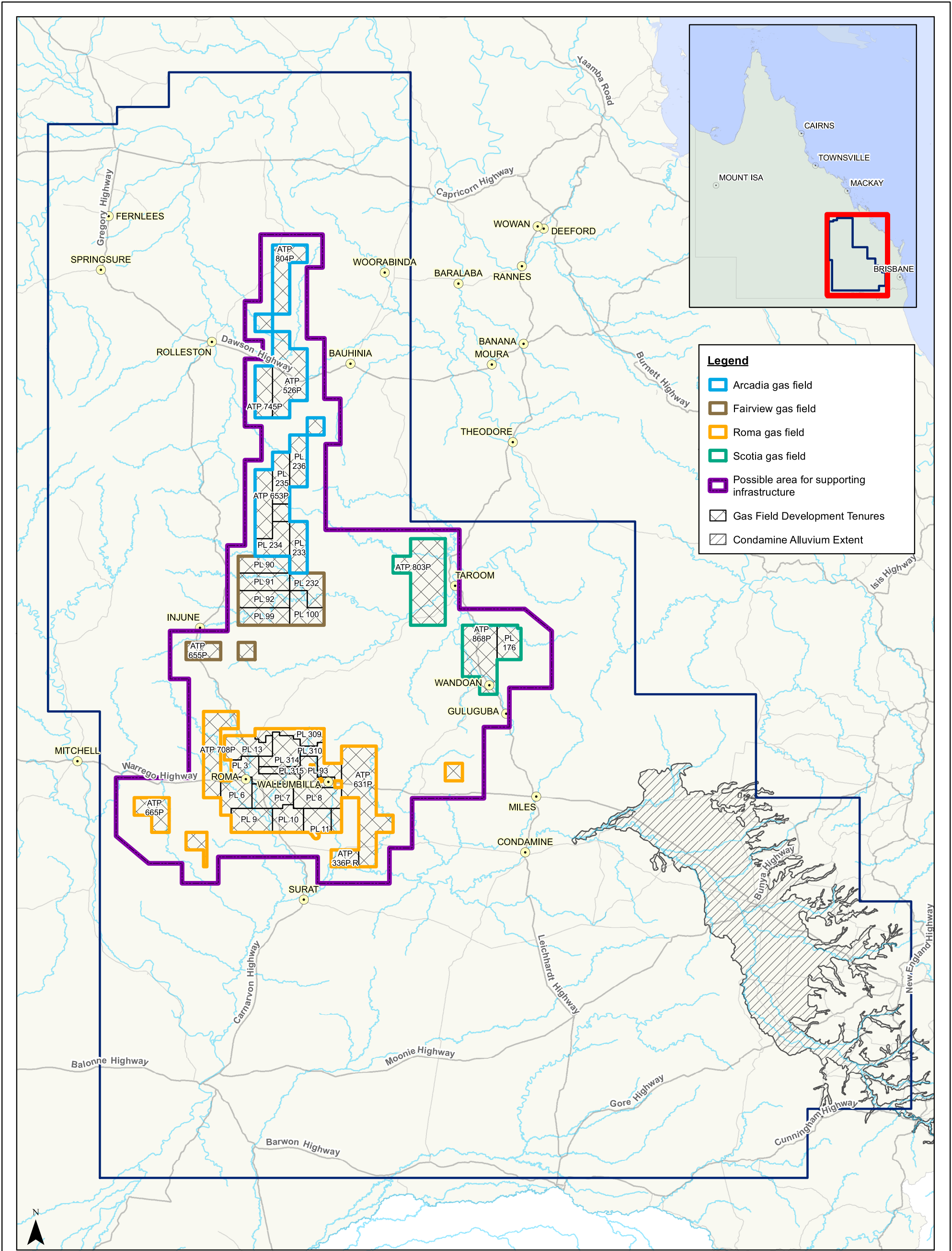
Gas field (number of tenures)	Tenure				Area (km ²)
	Petroleum lease (PL) / Petroleum lease application (PLA)		Authority to prospect (ATP)		
	GLNG Project	Additional for GFD Project	GLNG Project	Additional for GFD Project	
Arcadia (8 tenures)	PL 233 PL 234 PL 235 PL 236	PLA 420 PLA 421 PLA 440	ATP (5 parts) ATP 653P (1 part)	ATP 745P (2 parts) ATP 804P (1 part)	2,726
Fairview (7 tenures)	PL 90 PL 91 PL 92 PL 99 PL 100 PL 232			ATP 655P (2 parts)	1,962
Roma (17 tenures)	PL 3 (313) PL 6 (316) PL 7 (317) PL 8 (318) PL 9 (319) PL 13 (322) PL 93 (323) PL 309 PL 310 PL 314 PL 315	PL 10 (320) PL 11 (321) PLA 281 PLA 282		ATP 336P (2 parts) ATP 631P (2 parts) ATP 665P (2 parts) ATP 708P (1 part)	4,383
Scotia (3 tenures)		PL 176		ATP 803P (1 part) ATP 868P (1 part)	1,605
Total (35 tenures)	21 PLs	3 PLs	2 ATPs	9 ATPs	10,676

1.3 Scope of works

The GFD Project area for the groundwater assessment includes the hydrogeological units underlying GFD Project tenures and the Surat CMA (Figure 1.3).

To meet the requirements of the ToR for the GFD Project EIS and the Independent Expert Scientific Committee (IESC) Information Guidelines for Proposals Relating to the Development of Coal Seam Gas and Large Coal Mines where there is a Significant Impact on Water Resources (IESC, 2013), the scope of work for the groundwater technical report included:

- Acquisition of data from Santos GLNG, the Queensland Department of Natural Resources and Mines (DNRM) and from reports in the public domain.
- Data analysis:
 - Examination of climate data, the geology, water levels and water quality records, hydrochemistry and drilling records
 - Description of hydrogeological units, groundwater levels, flow directions, yield and assessment of critical dependencies and interconnectivity of the aquifers and coal sequences
 - Development of hydrogeological cross-sections and hydrogeological maps
 - Identification of groundwater users and groundwater dependent ecosystems, including springs
 - Description of groundwater-surface water interaction, interaction with saline water, possible sources of recharge and vulnerability to contamination.
- Assessment of potential impacts to groundwater resources:
 - Identification and evaluation of the environmental values that are relevant to the GFD Project, in accordance with published guidelines in relevant Queensland and Federal regulations
 - Numerical modelling using the UWIR model (QWC, 2012c) to predict aquifer depressurisation and to assess potential impacts on bores and springs using the criteria in the *Water Act 2000* (Qld)
 - Assessment of other potential groundwater-related impacts using a qualitative significance assessment approach
 - Identification of mitigation measures and requirements for ongoing monitoring and management including environmental baseline and impact reporting.



2. Regulatory and policy framework

This section outlines the key regulatory requirements at the State and Commonwealth level that are applicable to the GFD Project, including relevant policies.

Santos GLNG's corporate policy framework is also described in this section. The GFD Project activities will be undertaken in accordance with this framework.

2.1 Commonwealth legislation and policies

2.1.1 Environment Protection and Biodiversity Conservation Act 1999

Actions that are likely to have a significant impact on a matter of national environmental significance (MNES) are subject to the assessment and approval process under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act).

Amendments to the EPBC Act enacted on 22 June 2013 made water resources a MNES in relation to coal seam gas and large coal mining development (commonly known as the "water trigger"). This means that coal seam gas developments that have potential for significant impact on water resources must be referred to the Commonwealth Department of the Environment (DOE) (formerly the Department of Sustainability, Environment, Water, Population and Communities (SEWPaC)) for assessment under the EPBC Act. Developments that have potential for significant impact on nationally threatened plants and animals, including Great Artesian Basin (GAB) spring communities, must also be referred for assessment.

Santos GLNG referred the GFD Project to DOE on 5 November 2012 to determine if the GFD Project required assessment as a controlled action under Section 8 of the EPBC Act.

On 3 December 2012, the Minister for DOE determined the GFD Project to be a controlled action for which an EIS is required. The controlling provisions are:

- Wetlands of international importance (Ramsar wetlands) (sections 16 and 17B)
- Listed threatened species and ecological communities (sections 18 and 18A)
- Listed migratory species (sections 20 and 20A).

On 17 October 2013, the Minister further determined the controlling provisions related to the impacts of coal seam gas and large coal mining development on water resources (sections 24D and 24E) are controlling provisions for the proposed GFD Project.

Santos GLNG also received confirmation from DOE that the GFD Project would be assessed under the bilateral agreement between the Commonwealth and Queensland governments. As such, the preparation of this EIS in accordance with Part 4 of Queensland's *State Development and Public Works Organisation Act 1971* (Qld) is accredited as one of the accepted assessment pathways satisfying Section 8 of the EPBC Act.

The bilateral arrangement includes a decision process requiring review and support of the GFD Project's EIS by both levels of government before the GFD Project can proceed. The ToR for the GFD Project EIS, issued by the Office of the Queensland Coordinator-General in March 2013, includes both the State and Commonwealth requirements for groundwater impact assessment.

Independent Expert Scientific Committee

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) is a statutory committee established in 2012 under the EPBC Act.

The IESC provides scientific advice to DOTE on the impact that coal seam gas and large coal mining development may have on water resources. State regulators can also seek the IESC's advice in accordance with the terms of the National Partnership Agreement on Coal Seam Gas and Large Coal Mining Development.

2.2 Queensland legislation and policies

2.2.1 Petroleum Act 1923 and Petroleum and Gas (Production and Safety) Act 2004

The *Petroleum Act 1923* (Qld) (Petroleum Act) and the *Petroleum and Gas (Production and Safety) Act 2004* (Qld) (P&G Act) provide the rights to tenure holders to take or interfere with groundwater and to use the water for carrying out authorised activities.

The Petroleum Act and P&G Act provide the right to supply coal seam water to a landholder on the tenure (or adjacent land if common owner) for a domestic garden and stock watering purposes. Otherwise, a water licence under the *Water Act 2000* (Qld) (Water Act) is required.

2.2.2 Water Act 2000

The Water Act is administered by the DNRM and its purpose is to provide a framework for the sustainable management of Queensland's surface and groundwater resources. The Water Act regulates taking, supplying or interfering with water unless authorised under the Petroleum Act or the P&G Act.

The purpose of the Water Act is to provide for the sustainable management and efficient use of water and other resources, a regulatory framework for providing water services and the establishment and operation of water authorities.

The Water Act regulates groundwater impacts caused by petroleum tenure holders by setting out monitoring and reporting requirements, groundwater drawdown trigger threshold levels, and make good obligations if the extraction of coal seam water adversely affects groundwater supply to a third-party water bore or a natural spring.

The monitoring requirements include petroleum tenure holders undertaking baseline assessments of private water bores in areas where gas production testing or production has commenced. Baseline assessments are required to assist with proposed make good agreements and involve obtaining information about bores, including:

- The level and quality of groundwater in the bore
- How the bore is constructed
- The type of infrastructure used to pump water from the bore.

The groundwater drawdown trigger thresholds in the Water Act include:

- Bore trigger thresholds, where there is a decline in the water level in the aquifer that is:
 - Prescribed by regulation
 - For a consolidated aquifer—5 m
 - For an unconsolidated aquifer—2 m.
- Spring trigger thresholds, where there is a decline in the water level of the aquifer that is:
 - Prescribed by regulation
 - 0.2 m or greater.

An Immediately Affected Area (IAA) is defined under the Water Act as the area of an aquifer where the water level is predicted to decline, due to water extraction by petroleum tenure holders, by more than the bore trigger threshold within three years of the UWIR. An IAA bore is a bore located within this area.

A Long-term Affected Area (LAA) is defined under the Water Act as the area of an aquifer where the water level is predicted to decline, due to water extraction by petroleum tenure holders, by more than the bore trigger threshold at some time in the future.

A potentially affected spring is defined under the Water Act as a spring overlying an aquifer where the water level is predicted to decline by more than the spring trigger threshold at the location of the spring at some time in the future. The potentially affected aquifer is not necessarily the spring source aquifer. The UWIR includes springs within 10 km of the spring trigger threshold as potentially affected, to allow for the limitations of modelling small changes in water level/pressure (QWC, 2012a).

Where impacts to a bore occur and make good obligations apply, a petroleum tenure holder is required to:

- Undertake a bore assessment
- Enter into a make good agreement with the owner of the bore
- Comply with the make good agreement
- If asked to vary the make good agreement, negotiate a variation of the make good agreement.

The Water Act also defines the roles and responsibilities of the Office of Groundwater Impact Assessment (OGIA) for assessment and management of cumulative impacts on groundwater resources such as third-party bores and springs resulting from multiple resource projects in the Surat Basin. With the Surat and southern Bowen basins undergoing a major expansion in natural gas production in 2011, this led to declaration of the Surat Cumulative Management Area (Surat CMA). QWC has prepared an UWIR (QWC, 2012a) for the Surat CMA, which includes the GFD Project area.

Underground Water Impact Report for the Surat Cumulative Management Area

The UWIR for the Surat CMA was released in 2012 and is a statutory instrument under the Water Act. The report assesses the cumulative impacts of water extraction by conventional petroleum and gas production as well as non-conventional (including coal seam) gas production on groundwater in the Surat CMA, and establishes integrated management arrangements.

In preparing the UWIR, QWC undertook groundwater flow modelling to predict impacts on water levels and found that 85 registered water bores would experience water level declines by more than the trigger threshold within three years (by 2015), and a total of 528 bores would be affected at some time

in the future (i.e. an additional 443 bores). Under the Water Act, petroleum tenure holders are required to 'make good' the impairment of private bore supplies that may result from petroleum and gas activities. The UWIR identifies which petroleum tenure holder is responsible as more than one tenure holder could be contributing to the impact.

The UWIR includes a Water Monitoring Strategy, an integrated regional water monitoring network to collect data on groundwater levels and basic groundwater quality in the Surat CMA. The network includes 498 water level monitoring points at 142 locations and 120 water quality monitoring points. There are already networks of monitoring bores in place, and the remaining monitoring points are being constructed by petroleum tenure holders.

There are five spring complexes in the Surat CMA where the predicted decline in groundwater level in the source aquifer is more than 0.2 metres at the location of the spring (QWC, 2012a). The Spring Impact Management Strategy in the UWIR requires petroleum tenure holders to evaluate and submit a report to OGIA on potential mitigation options at these locations. Petroleum tenure holders are also required to monitor conditions in springs and submit the results to OGIA. Santos GLNG is fulfilling the requirements of the Spring Impact Management Strategy as detailed in Section 9.1.

An Annual Report 2013 for the Surat Underground Water Impact Report was released in December 2013 which identifies a number of changes to the industry development profile and available information about private water bores since the UWIR was prepared. The changes have resulted in reduction in the number of private bores predicted to be impacted in the short term (by 2015) to 65 (OGIA, 2013b).

Water resource plans and resource operations plans

Water resource plans are subordinate legislation to the Water Act and define the availability and allocation of water to provide for the sustainable management of surface water (including overland flow) and groundwater resources in a catchment area. The objective of water resource plans is to achieve a sustainable balance between meeting human needs and those of the environment. Resource operations plans are developed to implement water resource plans and provide day-to-day rules for the sharing and management of water.

The GFD Project area lies within the water resource plan (WRP) areas for the following:

- The Water Resource (Fitzroy Basin) Plan 2011 and the Fitzroy Basin Resource Operations Plan 2004, which regulate the allocation and management of surface water (including overland flow) and groundwater in the Fitzroy Basin.
- The Water Resource (Great Artesian Basin) Plan 2006 and Great Artesian Basin Resource Operations Plan 2007, which regulate the allocation and management of groundwater in the Great Artesian Basin.

A water licence is required for water supply not authorised under the Petroleum Act or the P&G Act in accordance with the rules in the applicable water resource plan and resource operations plan.

2.2.3 Environmental Protection Act 1994

The *Environmental Protection Act 1994* (Qld) (EP Act) is the key legislation for environmental management and protection in Queensland. It aims to protect Queensland's environment while allowing for development that improves quality of life and maintains ecological processes.

The EP Act addresses the management and disposal of coal seam water. Once coal seam water is extracted, (depending on its quality) it can be classified as a waste under the EP Act and through

either an environmental authority or a beneficial use approval (under the *Waste Reduction and Recycling Act 2011* (Qld)) water can managed or used for beneficial uses.

Environmental Protection (Water) Policy 2009

The *Environmental Protection (Water) Policy 2009* (Qld) (EPP Water) has been established to protect Queensland waters while allowing for ecologically sustainable development. It sets the broad environmental protection measures for the protection of Queensland waters and provides a framework for identifying environmental values for aquatic ecosystems and for human uses, and determining water quality guidelines and objectives to enhance or protect the environmental values.

The EPP Water states the relevant environmental values and water quality objectives for water, and the relevant water quality guidelines and indicators for protecting these values. Environmental values of specific waters to be protected or enhanced are defined in Schedule 1 of the EPP Water. Where waters are not specifically identified in Schedule 1, the environmental values are defined under Section 6(2) of the EPP Water.

Environmental Protection Regulation 2008

Regulated waste is defined in Schedule 7 of the *Environmental Protection Regulation 2008* (Qld) (EP Regulation). An amendment to the regulation in September 2013 provides for better quality coal seam water to be exempt from the definition of regulated waste.

Coal Seam Gas Water Management Policy 2012

The aim of the *Coal Seam Gas Water Management Policy 2012* (Qld) (EHP, 2012a) (CSWMP) is to encourage the beneficial use of coal seam water where practicable in a way that protects the environment and maximises its productive use as a valuable resource.

The policy requires that coal seam water be used for a purpose that is beneficial to the environment, existing or new water users, and/or existing or new water-dependent industries where practicable. If beneficial use options have been considered and are not feasible, treating and disposing of coal seam water must be undertaken in a way that firstly avoids, and then minimises and mitigates negative impacts on environmental values.

2.2.4 Waste Reduction and Recycling Act 2011

The *Waste Reduction and Recycling Act 2011* (Qld) (WRR Act) aims to reduce the consumption of natural resources and minimise the disposal of waste by encouraging waste avoidance and the recovery, re-use and recycling of waste.

The WRR Act authorises particular and general beneficial uses of coal seam water. The granting of a beneficial use approval can change the status of coal seam water from a waste under the EP Act to a resource that is to be used for a beneficial purpose.

2.2.5 Nature Conservation Act 1992

Native flora and fauna species are protected in Queensland under the *Nature Conservation Act 1992* (Qld) (NC Act). The subordinate *Nature Conservation (Wildlife) Regulation 2006* (NC Regulation) contains the following categories reflecting both abundance and levels of legislative protection: Extinct in the Wild, Endangered, Vulnerable, Near Threatened and Least Concern. Protected areas on State land such as National Parks and Conservation Parks are listed in the *Nature Conservation (Protected Areas) Regulation 1994*. The NC Act lists and protects individual species and an ecological community associated with groundwater-dependent springs found within and surrounding the GFD Project area.

2.2.6 Sustainable Planning Act 2009

The purpose of the *Sustainable Planning Act 2009* (Qld) (SP Act) is to achieve sustainable planning outcomes through managing the process by which development takes place and managing the effects of development on the environment.

The SP Act seeks to achieve ecological sustainability through managing development processes and associated environmental effects, and to streamline the coordination of planning and local, regional and State planning instruments.

Works for taking or interfering with groundwater in the GAB are assessable development under the SP Act and require a development permit.

2.3 Santos GLNG policy framework

2.3.1 Environment, Health and Safety Management System

The Santos GLNG Environment, Health and Safety Management System is a company-wide framework that describes the requirements for effective environmental and safety practice across Santos GLNG's activities and operations.

The system, based on the International Organisation for Standardisation (ISO) 14001 and Australian Standard (AS) 4801 standards, has been designed to ensure consistent standards for employees and contractors. It incorporates industry best practice and includes 17 management standards and more than 30 hazard standards.

The Environment, Health and Safety Management System has been in place since the beginning of the GLNG Project in 2010 and is continually being improved to ensure it is current and effective in managing and mitigating environmental impacts.

The application of the Environment, Health and Safety Management System enables Santos GLNG to achieve the objectives detailed in Santos GLNG's Environment and Health and Safety (EHS) policies, which provide the overall direction for the Environment, Health and Safety Management System.

2.3.2 Environmental Policy

Santos GLNG has a corporate Environmental Policy which details the company's Environmental Vision to "continuously seek to find new ways to minimise our environmental impact across the lifecycle of our [Santos GLNG] activities"; it includes specific commitments for maintenance and improvement of the Environment, Health and Safety Management System; and provides general principles of environmental stewardship responsibilities for Santos GLNG employees and contractors. The Environmental Policy also outlines a commitment to operational compliance, including monitoring, auditing, and review and reporting processes.

2.3.3 Standards

Santos GLNG's Environment, Health and Safety Management System includes two types of standards:

- Management standards, which define the requirements necessary to ensure that environmental, health, safety and process safety risk is systematically managed.

- Hazard standards, which detail the controls required to manage the risks of specific hazards to acceptable levels.

Under the Environment, Health and Safety Management System, groundwater is specifically addressed through Environment hazard standard (EHS) 10: Water resources.

The purpose of EHS 10 is to ensure protection from degradation and sustainable use of watercourses, lakes, springs, overland flows, underground water and other natural ecosystems associated with these water resources. The key requirements of the standard include:

- Surface water and groundwater resources and the associated natural environment shall be included in planning of new or amended disturbances to enable the protection and sustainable use of the resource.
- Legislation, and local and regional water resource planning, shall be considered prior to undertaking development, new or modified operational activities, or harvesting surface water or groundwater.
- Necessary approvals, licences, permits and certificates required by regulatory authorities shall be obtained prior to extracting or interfering with surface water or groundwater.
- The quantity of water extracted shall be minimised where practical, and the quality and quantity monitored.
- Disposal of wastewater should consider the waste management hierarchy and shall be conducted in a manner which prevents the degradation of waters and land.

2.3.4 GFD Project Environmental Protocol for Constraints Planning and Field Development

The constraints approach is based upon the GFD Project environmental protocol for constraints planning and field development (Santos GLNG, 2014d) (Constraints protocol). The Constraints protocol applies to all gas field related activities. The scope of the Constraints protocol is to:

- Enable Santos GLNG to comply with all relevant State and Federal statutory approvals and legislation
- Support Santos' environmental policies and the General Environmental Duty (GED) as outlined in the EP Act
- Promote the avoidance, minimisation, mitigation and management of direct and indirect adverse environmental impacts associated with land disturbances
- Minimise cumulative impacts on environmental values.

The Constraints protocol details the process that Santos GLNG will use to identify, assess and manage potential impacts to the environment during field planning and development. This process has been successfully used for the approved GLNG Project, which increases the certainty of GFD Project environmental outcomes.

The general principles of the Constraints protocol, in order of preference, are to:

- Avoid — avoid direct and indirect impacts to environmentally sensitive areas
- Minimise— minimise potential impacts on environmentally sensitive areas
- Mitigate — implement mitigation and management measures to minimise adverse impacts
- Remediate and rehabilitate — actively remediate and rehabilitate impacted areas

- Offset — offset residual risk in accordance with regulatory requirements.

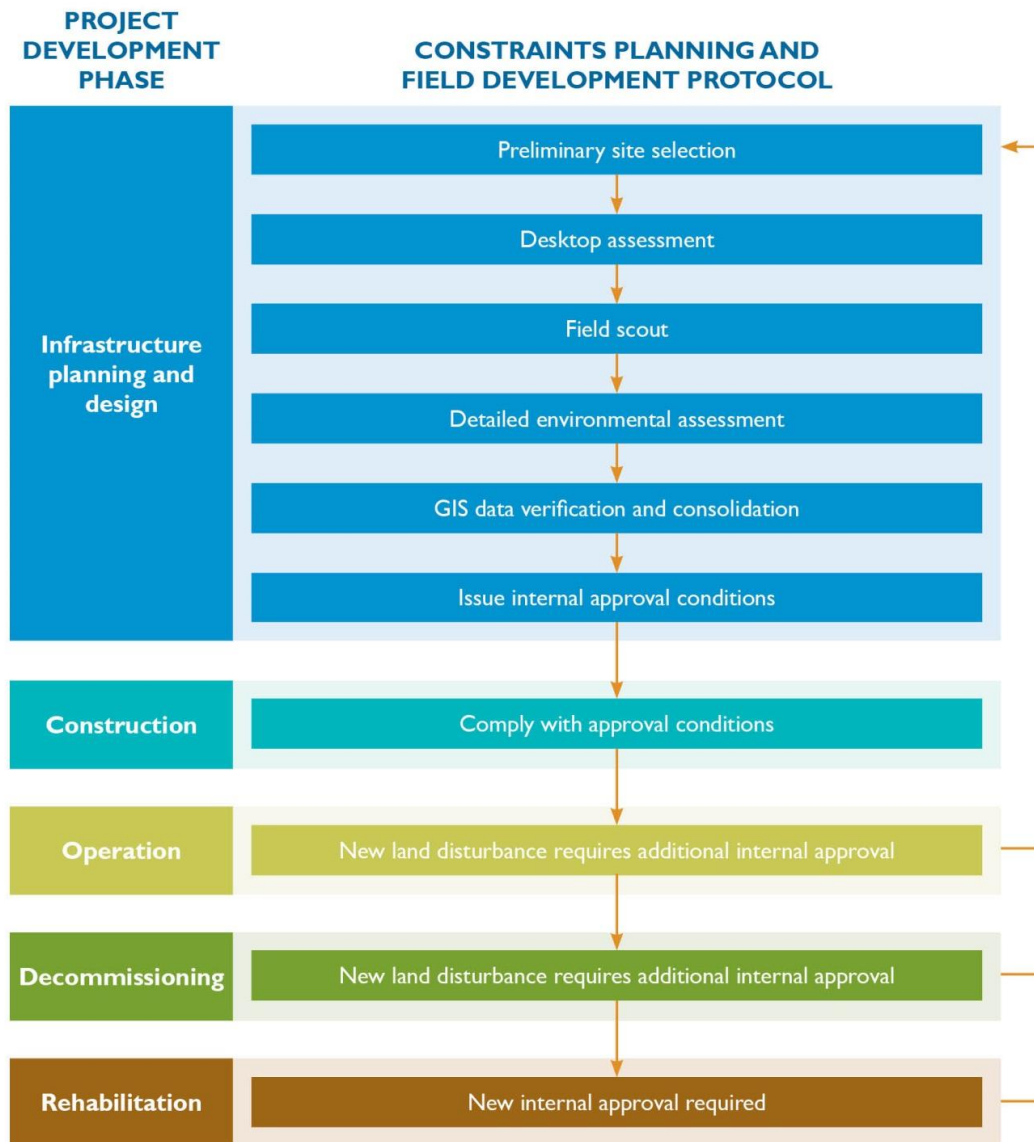
Consistent with Santos GLNG's environmental management hierarchy, the Constraints protocol prioritises avoidance of environmental impact during field planning by identifying those areas that are not amenable to development. This includes areas of high environmental value as identified in regulatory frameworks and Santos GLNG's baseline surveys. For areas that are considered appropriate to develop, Santos GLNG will identify impacts to environmental values that could potentially occur due to the construction, operations and decommissioning activities of the GFD Project, and determine pre-mitigated impacts (i.e. those that would occur without mitigation).

Relevant mitigation and management measures based on the approved environmental management framework already implemented for the GLNG Project are then applied to the pre-mitigated impacts to identify the mitigated (residual) impacts. This process increases certainty about potential impacts by identifying those areas that are not amenable to development, and for those areas where development could occur, how development should proceed.

The post-EIS field development process is a continuation of the field planning process and will be ongoing throughout the life of the GFD Project. The field development process will inform the GFD Project's design, together with a range of other factors including technical feasibility, cost and risk as required by standards applicable to the design, construction, operations, decommissioning and rehabilitation of gas developments. This information will be used to support the subsequent approvals process such as environmental approval application and the plan of operations.

The tasks involved in the field development process are summarised in Figure 2.1.

Figure 2.1 Field development process



3. Methodology

The GFD Project area for the groundwater assessment includes the hydrogeological units underlying GFD Project tenures and within the Surat CMA (Figure 1.1).

3.1 Existing environment and environmental values

A desktop study was undertaken to establish an understanding of the existing groundwater environment, environmental values and sensitive receptors within the GFD Project area. The study results provided the basis from which to identify and assess potential impacts associated with the GFD Project activities.

The desktop study involved acquiring available data from Santos GLNG, government agencies and reports in the public domain and then analysing the data using tools including hydrogeological maps and cross-sections. Primary information sources included:

- Geology maps (1:250,000) for Surat (sheet 55-16) (BMRGG, 1971a), Roma (sheet 55-12) (BMRGG 1971b), Taroom (sheet 55-8) (BMRGG, 1967) and Baralaba (sheet 55-4) (BMRGG 1966).
- Private bore and spring data provided by the OGIA (2013a).
- Groundwater registered bore database and Water Management System data supplied by DNRM (2013a).
- Published studies on GAB springs including:
 - Ecological and Botanical survey of springs in the Surat Cumulative Management Area (Fensham et al., 2012).
 - Hydrogeological attributes associated with springs in the Surat Cumulative Management Area, (Klohn Crippen Berger (KCB) 2012a).
 - Desktop assessment of the source aquifer for springs in the Surat Cumulative Management Area (KCB, 2012b).
- Data from the Santos GLNG Baseline Assessment Manager (BAM) and Envirosys databases, including baseline assessment data for landholder bores and data from the Santos GLNG groundwater monitoring network (2013).
- Government reports including:
 - The Surat and Bowen Basins South-West Queensland (DME, 1997).
 - Hydrogeological Framework Report for the Great Artesian Basin Water Resource Plan Area (DNRM, 2005).
 - Hydrogeology of the Surat Cumulative Management Area (QWC, 2012b).
 - Underground Water Impact Report for the Surat Cumulative Management Area (QWC, 2012a).
- Santos GLNG reports including:
 - CSG Water Monitoring and Management Plan – Stage 2 Revision 2, Santos GLNG Project Report (Santos GLNG, 2013d)

- Groundwater (Deep Aquifer Modelling) for Santos GLNG Environmental Impact Statement (Matrixplus, 2009).
- EPP (Water), which provides the environmental values (EVs) and water quality objectives (WQOs) for the Fitzroy Basin.
- The draft EVs developed by the Queensland Murray-Darling Committee (2012) for the Maranoa-Balonne River Basin.

3.2 Impact assessment and management measures

A quantitative assessment of cumulative depressurisation impacts due to the production of gas has been undertaken using the OGIA (formerly QWC) numerical groundwater model for the Surat CMA. A qualitative assessment of other potential groundwater-related impacts has been undertaken using a significance assessment method. The groundwater impact assessment has been conducted within the context of the constraints planning process applied to the GFD Project.

3.2.1 Constraints planning

The planning and development of gas field infrastructure is an incremental process. The GFD Project will be progressively developed as the gas resource is realised. The GFD Project Environmental Protocol for Constraints Planning and Field Development (Santos GLNG, 2014d) (the Constraints Protocol) enables Santos GLNG to systematically identify and assess EVs and then avoid and manage potential environmental impacts as gas field development progresses.

Santos GLNG utilises the Santos Geographic Information System (GIS) for constraints planning and field development. The Santos GIS contains a number of mapping layers including environmental and social constraints as well as multiple infrastructure types. The GIS is used to identify constraints and locate infrastructure to avoid particular EVs. As new data becomes available, it is updated in the Santos GIS through a process of data acquisition, cleansing and verification.

A full list of current constraints that have been considered for the GFD Project and the relevant development restrictions that apply are detailed in Table 3.1. Potential (pre-mitigated) impacts have been determined following application of the avoidance measures in the constraints table. For example, the no-go areas in Table 3.1 were modelled as non-production zones in the groundwater numerical model with no simulated extraction of groundwater.

Table 3.1 GFD Project constraints relevant to the groundwater impact assessment

Level of constraint	Constraint layer	Permitted activities
No-go area	Category A Environmentally Sensitive Areas (ESA's) (as listed in section 25 on the <i>Environmental Protection Regulation 2008</i> (EP Reg.)) (that are located within Santos GLNG tenures)	No petroleum activities are permitted.
	- National parks 1 (Nature Conservation Act 1992 (NC Act)) - Conservation parks (NC Act) - Forest reserves (NC Act)	
	Spring vents and/or spring complexes that are protected under the EPBC Act (i.e. spring where the listed Threatened Ecological Community (TEC) <i>The community of native species dependent on natural discharge of groundwater from the Great Artisan Basin</i> has been identified and/ or springs that support other EPBC listed threatened species) plus 200 m buffer zone	
	Wetlands of national importance (+ 200 m buffer)	
	Wetlands of High Ecological significance' also known as 'High conservation value wetlands' as detailed in the Map of Referrable Wetlands dataset (QLD)	
Surface development exclusion area	200m Primary Protection Zone buffers around Category A ESA's (that are located within Santos GLNG tenures)	Low impact petroleum activities ⁴ permitted.
	- National parks (NC Act) - Conservation parks (NC Act) - Forest reserves (NC Act)	
	The following Category C ESAs ² (that are located within GLNG tenures):	
	- Nature Refuges (defined under NC Act) - Koala Habitat Areas (as per the Nature Conservation (Koala) Conservation Plan 2006. (NC Koala Conservation Plan)) - Declared Catchment Areas (defined under Water Act 2000)	
High constraint area	The following Category B ESAs (as listed in section 25 on the EP Reg.) (that are located within Santos GLNG tenures):	Linear infrastructure ⁵ permitted with site-specific mitigation measures including pre-clearance survey,
	- Coordinated conservation areas (as defined under the NC Act) - Ramsar Sites (International Convention) - State Forest Park / Special Forestry Areas (as defined under Forestry Act 1959)	
	Watercourses (Stream orders) + 100 m buffer	
	'General ecologically significant wetlands' or 'Wetlands of other environmental value' as detailed in the Map of Referrable Wetlands dataset	
	All other Spring vents / spring complexes (not protected under the EPBC Act) located within Santos GLNG tenures and a	

Level of constraint	Constraint layer	Permitted activities
	200 m primary protection buffer	stakeholder consultation, restrictive conditions, and potential offsets). Low impact petroleum activities ⁴ permitted.
Moderate constraint area	100m Secondary buffer zone around Spring vents and/or spring complexes protected under the EPBC Act (including their 200 m primary buffer zone)	Linear infrastructure ⁵ and all limited petroleum activities (both linear and Non-linear infrastructure ⁶), with specific mitigation measures applied, which may include pre clearance surveys, stakeholder consultation, site-specific controls, and potential offsets. Low impact petroleum activities permitted ³ .
	The following Category C ESAs ² (that are located within Santos GLNG tenures): State forests / Timber reserves (<i>Forestry Act 1959</i>)	
	• Matters of National Environmental Significance (MNES) identified under the EPBC Act, including: • MNES Habitat – threatened species habitat and migratory species habitat • MNES Threatened Ecological Communities (TEC's) derived from State Regional Ecosystem (RE) mapping • MNES Flora species • MNES Threatened TEC's verified during field surveys	
	100m Secondary Protection Zone buffer area around Category A ESA's + the 200m buffer (located within Santos GLNG tenures) • National parks (NC Act) • Conservation parks (NC Act) • Forest reserves (NC Act)	
	The following Category B ESAs (as listed in section 25 on the EP Reg.) + 200m Primary Protection buffer (that are located within Santos GLNG tenures): • 'Endangered' Regional Ecosystems (ERE's)	
	The following Category C ESAs ² + 200m Primary Protection buffer (that are located within Santos GLNG tenures): • Essential habitat (NC Act) • Essential regrowth habitat (NC Act) • 'Of Concern' Regional Ecosystems • Resource reserves (NC Act)	
	EVNT Species (NC Act)	
Low constraint areas	High value regrowth (Endangered RE)	Wider range of project

Level of constraint	Constraint layer	Permitted activities
	High value regrowth (Of Concern RE)	activities, including all Petroleum activities ⁷ are permitted in these areas with standard mitigation and management conditions. Offsets are unlikely.
	No concern at present regional ecosystems	
	Non-remnant vegetation	
	Existing Santos infrastructure	
	Existing roads, rail, pipeline and other infrastructure that would have to be considered during field development	

¹ Specific and mutually beneficial activities in a (Limited Depth) National Park may be allowed with express written permission from DNPRSR. Santos will only seek permission to enter a (Limited Depth) National Park on limited occasions where no other feasible option exists.

² Category C ESA as defined in the Environmental Authority PEN103814911

³ Low impact petroleum activities means petroleum activities which do not result in the clearing of native vegetation, earthworks or excavation work that cause either, a significant disruption to the soil profile or permanent damage to vegetation that cannot be easily rehabilitated immediately after the activity is completed. Examples of such activities include (but are not necessarily limited to) chipholes, coreholes, geophysical surveys, seismic surveys, soil surveys, topographic surveys, cadastral surveys, ecological surveys, construction of environmental monitoring equipment (including surface water).

⁴ Limited petroleum activities means any low impact petroleum activity and single well sites (includes observation, pilot, injection and production wells) and associated infrastructure (water pumps and generators, sumps, flare pits or dams) located on the well site, multi-well sites and associated infrastructure (water pumps and generators, sumps, flare pits, dams or tanks) located on the well sites, construction of new access tracks that are required as part of the construction or servicing a petroleum activity, upgrading or maintenance of existing roads or tracks, power and communication lines, gas gathering lines from a well site to the initial compression facility, water gathering lines from a well site to the initial water storage or dam, and camps within well site that may involve sewage treatment works that are a no release works.

⁵ Linear infrastructure means linear infrastructure including (but not limited to) gas and water gathering lines, low and high pressure gas and water pipelines, powerlines, communication, roads and access tracks (associated with limited petroleum activities and petroleum activities)

⁶ Non-linear infrastructure means infrastructure including (but not limited to) exploration and production wells, compressor stations, regulated dams, reverse osmosis plants, brine encapsulation facilities, workers camps, and maintenance facilities

⁷ Petroleum activities include low impact petroleum activities or limited petroleum activities and all other GFD Project activities including major facilities such as permanent accommodation camps, gas treatment facilities, air strips, water facilities including dams, water storage infrastructure, water treatment and amendment facilities, gas hubs, and nodal compressors.

3.2.2 Numerical groundwater modelling

The State of Queensland has developed a number of quantified criteria for depressurisation impacts related to development of gas to protect EVs.

A cumulative assessment of aquifer depressurisation related to petroleum and gas development (including conventional and non-conventional gas) in the Surat CMA, which includes development for the GFD Project, has been undertaken using the OGIA (formerly QWC) numerical groundwater model. The results of the modelling have been compared to the criteria as a measure of the level of impact.

The numerical groundwater modelling approach is detailed in Section 7.2 of this report. The criteria used to assess aquifer depressurisation impacts are in the Water Act, which defines the following groundwater drawdown trigger thresholds:

- Bore trigger thresholds, where there is a decline in the water level in an aquifer that is:
 - Prescribed by regulation
 - For a consolidated aquifer—5 m
 - For an unconsolidated aquifer—2 m.
- Spring trigger thresholds, where there is a decline in the water level of the aquifer that is:
 - Prescribed by regulation
 - 0.2 m.

Further detail on the approach to assessing depressurisation impacts on aquifers, bores and springs is provided in Section 7.

3.2.3 Significance assessment

For potential impacts to groundwater other than aquifer depressurisation due to groundwater extraction for production of gas, there are no relevant quantified guidelines available for assessment - it is the sensitivity or vulnerability of the EV and the potential magnitude of the impact that are important. For these activities and related impacts, a significance assessment methodology was applied.

The criteria used to rank the sensitivity of EVs are set out in Table 3.2.

Table 3.2 Sensitivity criteria

Sensitivity	Description
High	The environmental value is listed on a recognised or statutory state, national or international register as being of conservation significance. The environmental value is intact and retains its intrinsic value. The environmental value is unique to the environment in which it occurs. It is isolated to the affected system/area, which is poorly represented in the region, territory, country or the world. It has not been exposed to threatening processes, or they have not had a noticeable impact on the integrity of the environmental value. GFD Project activities would have an adverse effect on the value.
Moderate	The environmental value is recorded as being important at a regional level, and may have been nominated for listing on recognised or statutory registers. The environmental value is in a moderate to good condition despite it being exposed to threatening processes. It retains many of its intrinsic characteristics and structural elements.

Sensitivity	Description
	It is relatively well represented in the systems/areas in which it occurs but its abundance and distribution are limited by threatening processes. Threatening processes have reduced its resilience to change. Consequently, changes resulting from GFD Project activities may lead to degradation of the prescribed value. Replacement of unavoidable losses is possible due to its abundance and distribution.
Low	The environmental value is not listed on a recognised or statutory register. It might be recognised locally by relevant suitably qualified experts or organisations. The environmental value is in a poor to moderate condition as a result of threatening processes, which have impacted its intrinsic value. It is not unique or rare and numerous representative examples exist throughout the system / area. It is abundant and widely distributed throughout the host systems / areas. There is no detectable response to change or change does not result in further degradation of the environmental value. The abundance and wide distribution of the environmental value ensures replacement of unavoidable losses is achievable.

The criteria used to rank the magnitude of potential impacts on EVs are set out in Table 3.3.

Table 3.3 Magnitude criteria

Magnitude	Description
High	An impact that is widespread, long lasting and results in substantial and possibly irreversible change to the environmental value. Avoidance through appropriate design responses or the implementation of area-specific environmental management controls are required to address the impact.
Moderate	An impact that extends beyond the area of disturbance to the surrounding area but is contained within the region where the GFD Project is being developed. The impacts are short term and result in changes that can be ameliorated with specific environmental management controls.
Low	A localised impact that is temporary or short term and either unlikely to be detectable or could be effectively mitigated through standard environmental management controls.

The significance of each potential impact was determined by combining the sensitivity and magnitude criteria in a risk assessment process as shown in Table 3.4.

Table 3.4 Significance matrix

Magnitude	Sensitivity		
	High	Moderate	Low
High	Major	High	Moderate
Moderate	High	Moderate	Low
Low	Moderate	Low	Negligible

The significance classifications used in Table 3.4 (major, high, moderate, low and negligible) are defined in Table 3.5.

Table 3.5 Significance classifications

Significance	Description
Major	Arises when an impact will potentially cause irreversible or widespread harm to an environmental value that is irreplaceable because of its uniqueness or rarity. Avoidance through appropriate design responses is the only effective mitigation.
High	Occurs when the proposed activities are likely to exacerbate threatening processes affecting the intrinsic characteristics and structural elements of the environmental value. While replacement of unavoidable losses is possible, avoidance through appropriate design responses is preferred to preserve its intactness or conservation status.
Moderate	Results in degradation of the environmental value due to the scale of the impact or its susceptibility to further change even though it may be reasonably resilient to change. The abundance of the environmental value ensures it is adequately represented in the region, and that replacement, if required, is achievable.
Low	Occurs where an environmental value is of local importance and temporary or transient changes will not adversely affect its viability provided standard environmental management controls are implemented.
Negligible	Does not result in a noticeable change and hence the proposed activities will have negligible effect on environmental values. This typically occurs where the activities are located in already disturbed areas.

3.2.4 Mitigation and management measures

To manage the risk of adverse impact to the EVs of groundwater, measures such as avoidance, mitigation, and management were identified to reduce the level of impact identified through the assessment process. Mitigation and management measures will be applied, as appropriate, during the planning and design, construction, operation, decommissioning and rehabilitation phases of the GFD Project.

The mitigation and management measures identified are based on the existing measures contained within the approved environmental management framework that Santos GLNG has already developed and implemented for the GLNG Project. This approach is supported by the Santos GLNG Environment, Health and Safety Management System described in Section 2.3. Applying the same mitigation and measurement measures from the GLNG Project to the GFD Project will ensure a consistent approach by construction and operational personnel and a common understanding for both regulators and the community of the measures to be applied and that the required management outcomes are achieved.

3.2.5 Significance of residual impacts and environmental management planning

Impacts were assessed on the basis of the characterisation of the existing groundwater EVs detailed in this report. Both environmental sensitivity and potential magnitude of impacts were considered in the assessment. The significance of residual impacts was determined after consideration of the applicable existing Santos GLNG management and impact mitigation strategies. The assessment provided an indication of the effectiveness of such measures and strategies in managing the identified risk of adverse impact to groundwater EVs.

4. Physical setting and geology

4.1 Topography

The topographic relief in the GFD Project tenures is dominated by a north-south topographical high of the Expedition and Shotover ranges and the east-west topographical high of the Great Dividing Range. Topographically low areas are associated with major river catchments, specifically the Comet River, the Dawson River and the Balonne River as described further below. Surface elevations within the GFD Project area range between approximately 60 m and 1,230 m Australian Height Datum (AHD).

4.2 Hydrology

The GFD Project tenures are drained by three river systems; the Comet River in the northwest, the Dawson River in the central and eastern part and the Balonne River in the south and southwest.

The Condamine-Balonne Catchment is located in the Murray Darling Basin which eventually discharges to the Great Australian Bight in South Australia. The Dawson River and Comet River catchments are located in the Fitzroy River Basin which discharges into the Coral Sea near Rockhampton. The Fitzroy River Basin in Central Queensland is the largest catchment in eastern Australia, covering an area of approximately 142,000 km², consisting of six sub-catchments: Nogoa, Comet, Mackenzie, Isaac-Connors, Dawson and Lower Fitzroy. The Fairview and Scotia gas fields are located in the southern section of the Fitzroy River Basin in the upper reaches of the Dawson River catchment. The Arcadia gas field is located in the central-eastern portion of the Comet River catchment and the Roma gas field is located in the upper reaches of the Condamine-Balonne catchment (see Figure 4.1).

The majority of the rivers and streams in the GFD Project tenures are ephemeral and characterised by high variations in duration and volume of flows due to highly variable rainfall and runoff and high evaporation rates. Prolonged baseflow occurs only in wetter years in most streams. Some sections of streams in the GFD Project tenure are spring-fed (Figure 4.1). More information about watercourse springs in the Surat CMA is provided in Section 6.1.2.

4.2.1 Fitzroy River Basin

Dawson River Catchment

The Fairview and Scotia gas fields are within the upper reaches of the Dawson River catchment that extends upstream and westwards from Guluguba, encompassing the townships of Injune and Wandoan (Figure 4.1), up to the Dawson River north the Banana Shire within the larger Fitzroy Basin.

Major streams within the GFD Project tenures associated with the Upper Dawson River Catchment include the Dawson River, Hutton Creek, Baffle Creek, Juandah Creek and Eurombah Creek (URS, 2014).

Portions of the Arcadia gas field (along the surface water divide) are located within the Lower Dawson River catchment. Major streams within the GFD Project area of the lower Dawson catchment include Conciliation and Zamia creeks. Conciliation Creek flows east from Expedition State Forest with Zamia Creek flowing in a north easterly direction from Palmgrove National Park (URS, 2014). The Dawson River downstream of Dawson's Bend is perennial, maintained by spring flows arising from the river bed and adjacent to the stream. This spring fed reach of the Dawson River extends from the outflow of Hutton Creek to Yebna Crossing (Golder, 2011; Coffey Environments, 2012 and QWC, 2012a).

Comet River Catchment

The Arcadia gas field is partially situated predominantly within the Comet River Catchment (Figure 4.1). The Comet River Catchment extends west of the Lower Dawson River catchment, encompassing the townships of Springsure, Rolleston and Fernlees in the west and the township of Comet in the northern extent within the larger Fitzroy Basin.

The main tributaries of the Comet River in the GFD Project tenures are Humbolt Creek, Planet Creek, Clematis Creek and Arcadia Creek (URS, 2014).

4.2.2 Condamine-Balonne River Basin

The Condamine-Balonne River Basin in southern Queensland extends about 100 km southwest into NSW and covers 14 % of the total area of the Murray-Darling Basin. The Roma gas field tenures are predominantly located within the Condamine-Balonne catchment.

The Condamine River flows in a westerly direction from the Great Dividing Range near Warwick until the confluence with Dogwood Creek from where it becomes the Balonne River approximately 50 km northeast of Surat. Major tributaries of the Condamine River that are located in the Roma gas field tenures include Dogwood Creek, a tributary of the Condamine River, and Balonne River Upland Tributaries (URS, 2014).

4.3 Climate

The climate of the GFD Project tenures is classified as inland sub-tropical. The GFD Project tenures typically experience a dry winter season (April to September) with a relatively hot and wet December and January where temperatures can exceed 40°C (BOM, 2013).

The Bureau of Meteorology (BOM) also measures meteorological data at a number of weather stations within and in the vicinity of GFD Project tenures, providing information on temperature, wind speed, wind direction, relative humidity, and rainfall that can be used to characterise the existing

environment. A summary of the BOM weather stations is provided in Table 4.1. The locations of the BOM weather stations are also shown in Figure 4.1.

Table 4.1 BOM weather stations (BOM, 2013)

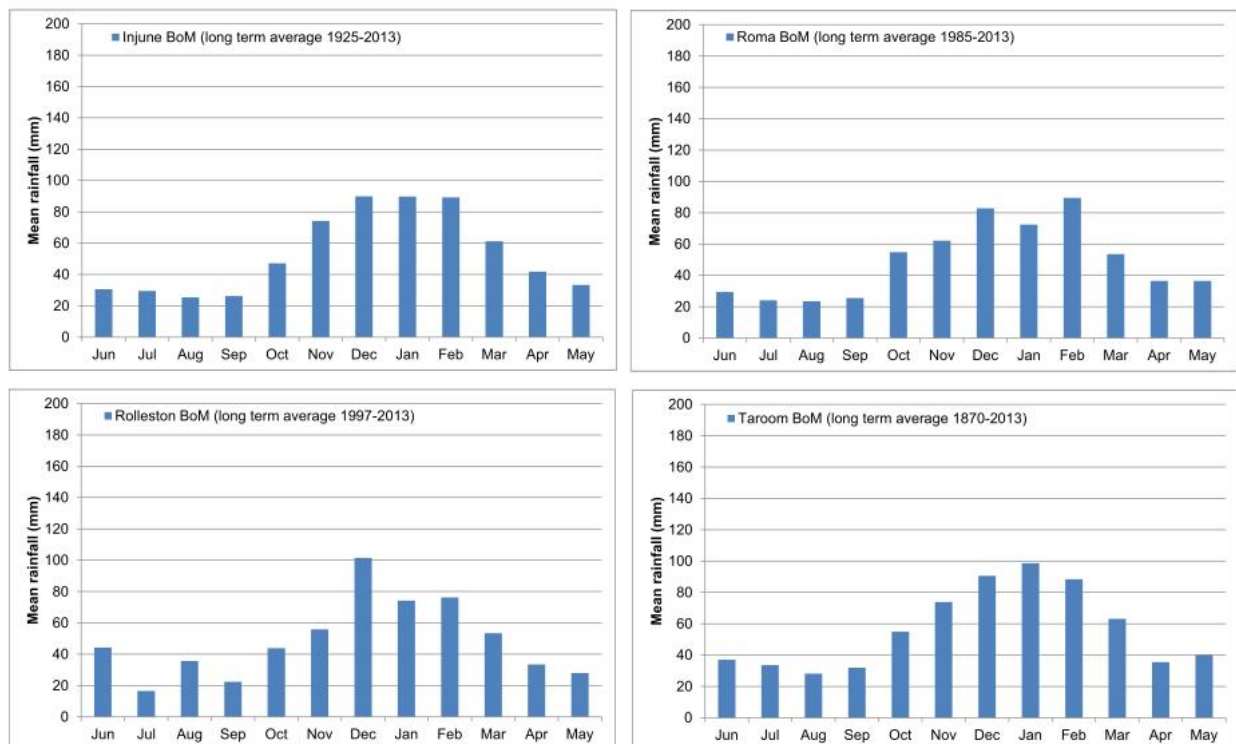
BOM Station	Station number	Latitude	Longitude	Elevation (mAHD)	Mean rainfall (mm/yr) *	Evaporation (mm/yr)*
Roma Airport	043091	26°32'39" S	148°46'40" E	307	585	2,516
Injune	043015	25°50'34" S	148°34'01" E	390	635	na
Taroom	035070	25°38'27" S	149°47'45" E	199	674	na
Rolleston	042112/ 035129	24°27'36" S	148°37'48" E	214	639	na

(1) * long-term average (until 2013).

(2) na = not available.

The GFD Project tenures near Roma experience the lowest average annual rainfall and those near Taroom, experience the highest average annual rainfall (Figure 4.2). While rainfall is similar in winter months for the gas fields, the northern and central areas generally experience higher rainfall than the southern area during summer. Average annual evaporation rates are higher than rainfall in the GFD Project tenures based on observations at Roma.

Figure 4.2 Monthly average rainfall



4.4 Geology

4.4.1 Geological setting

The GFD Project tenures and target coal measures are located within Permian to Cretaceous Bowen and Surat geological basins (Figure 4.3). The Bowen Basin and Surat Basin have structurally separate sedimentary depositional centres, but they are stratigraphically and hydraulically connected (DME, 1997). Most of the basins' sedimentary units dip at shallow angles (generally less than 10°) to the southwest (URS, 2013a).

The Early Permian to Mid-Triassic Bowen Basin geological units outcrop in the northern half of the GFD Project tenures, to about 100 km north of Taroom and about 50 km northeast of Injune. South of this area, sedimentary rocks of the Early Jurassic to Early Cretaceous Surat Basin sequence outcrop and unconformably overlie the older Bowen Basin units. Tertiary and Quaternary age volcanic and sedimentary rocks and unconsolidated sediments overlie these older formations in some areas. The geological setting of the GFD Project tenures is described in Table 4.2 and the regional geology is presented on Figure 4.4.

Conceptual geological cross-sections for the GFD Project area are shown in Appendix A: Geological cross-sections for the GFD Project area. The locations of these cross-sections are shown on Figure 4.5. The sections were generated using stratigraphic data from Santos GLNG and the Queensland Digital Exploration Reports System (QDEX) well logs, and the DNRM groundwater database. Cross-sections C-C' to F-F', O-O' and N-N' are adapted from the Stage 1 CSG Water Monitoring and Management Plan (CWMMP) (Golder, 2011) and cross-sections H-H' to L-L' are adapted from the Scotia factual report (Golder, 2012).

Table 4.2 Summary of geological stratigraphy

Period	Basin	Group	Formation	Description
Quaternary			Alluvium/colluvium	Clay, silt, sand and gravel deposits; includes areas of colluvium and residual soils.
Tertiary			Main Range Volcanics	Alkali-olivine basalt, minor tuff, sandstone, mudstone.
			Sediments	Undifferentiated poorly consolidated sedimentary rocks; sub-labile to quartzose sandstone, siltstone, mudstone, minor conglomerate, coal, and limestone.
Cretaceous	Surat	Rolling Downs	Wallumbilla Formation – Coreena Member	Glauconitic siltstone, mudstone, very fine-grained sandstone, shelly fossils.
			Wallumbilla Formation – Doncaster Member	Mudstone, siltstone; minor quartz sandstone in part glauconitic, silty limestone, gypsum.
		Blythesdale Group	Bungil Formation	Glauconitic, labile to quartzose, siltstone, mudstone.
			Mooga Sandstone	Sandstone, siltstone, mudstone.
Jurassic		Orallo Formation	Orallo Formation	Sandstone, siltstone, mudstone, conglomerate, coal.
			Gubberamunda Sandstone	Sandstone, minor conglomerate, siltstone.
		Injune Creek Group	Westbourne Formation	Fluvial-lacustrine sediments: fine-grained sandstone interbedded with siltstone, claystone, minor coal.
			Springbok Sandstone	Clayey lithic sub labile to very lithic

Period	Basin	Group	Formation	Description
				sandstone; calcareous in part; interbedded with carbonaceous mudstone and siltstone.
			Birkhead Formation/Walloon Coal Measures / Juandah Coal Measures / Tangalooma Formation /Taroom Coal Measures	Carbonaceous siltstone and mudstone, minor labile sandstone, coal. The Walloon Coal Measures transgressively grade into the siltstone and sandstone units of the Birkhead Formation.
			Eurombah Formation	Shale, siltstone, sandstone.
		Bundamba	Hutton Sandstone	Poorly sorted, coarse to medium-grained, feldspathic sub labile sandstone (at base) and fine-grained, well-sorted quartzose sandstone (at top); minor carbonaceous siltstone, mudstone, coal and rare pebble conglomerate.
			Evergreen Formation	Labile and sub labile, sandstone, carbonaceous mudstone, siltstone and minor coal; local oolitic ironstone.
			Precipice Sandstone	Thick-bedded, cross-bedded, pebbly quartzose sandstone, minor lithic sub labile sandstone, siltstone, mudstone.
Triassic	Bowen	Mimosa	Moolayember Formation	Micaceous lithic sandstone, micaceous siltstone.
			Clematis Sandstone	Medium to course grained quartzose to sublabile, micaceous sandstone, siltstone, mudstone.
			Rewan Group	Lithic sandstone, green to reddish brown mudstone and minor volcanilithic pebble conglomerate.
Permian		Blackwater	Bandanna Formation	Sandstone, siltstone, shale, mudstone, coal, tuff, conglomerate.
			Black Alley Shale	Shale, siltstone, tuff bentonite, labile sandstone.
		Back Creek	Peawaddy Formation	Carbonaceous mudstone and siltstone, lithic sublabile sandstone, coquinitic siltstone.
			Catherine Sandstone	Quartzose to sublabile sandstone, siltstone, mudstone.
			Ingelara Formation	Conglomeratic sandy siltstone, mudstone, sandstone.
			Freitag Formation	Sublabile sandstone, pebbly sandstone, siltstone, mudstone.
			Aldebaran Sandstone	Quartzose to lithic sandstone, siltstone, carbonaceous shale and minor coal.
		Cattle Creek Formation	Quartzose to sublabile sandstone and mudstone and coal.	
		Reids Dome Beds	Siltstone, shale, labile sandstone, lithic conglomerate and coal (including the Staircase Coal seams).	
Devonian			Timbury Hills Formation	Fine-grained, quartz rich metasedimentary rocks.

(1) mbgl - metres below ground level, unconformities indicated with bold line.

The Roma gas field is underlain by sedimentary formations associated with the Surat Basin. Some of these formations are regionally significant aquifers. Jurassic to Cretaceous sedimentary formations outcrop across the GFD Project tenures, but are predominantly overlain by Quaternary alluvium. There is a Tertiary basalt intrusion at the Grafton Range in the north of the Roma area. The natural gas bearing formations of interest within the Roma field are the Jurassic age Walloon Coal Measures.

The Scotia gas field is directly underlain by the Jurassic formations of the lower Surat Basin (Hutton Sandstone, Evergreen Formation and Precipice Sandstone) and the Triassic formations of the upper Bowen Basin (Rewan Group). The natural gas bearing formations of interest within this field are the late Permian Bandanna Formation of the Blackwater Group and the Jurassic age Walloon Coal Measures (part of the Injune Creek Group).

The Fairview gas field is directly underlain by the Jurassic formations of the lower Surat Basin (Hutton Sandstone, Evergreen Formation and Precipice Sandstone) and the Triassic formations of the upper Bowen Basin (Moolayember Formation and Clematis Sandstone). The natural gas bearing formations of primary interest are the late Permian Bandanna Formation of the Blackwater Group and the early Permian Staircase Coals (Bowen Basin).

The Arcadia gas field area is located within the outcropping extent of the Bowen Basin. The target formation for natural gas production is the late Permian Bandanna Formation of the Blackwater Group.

Bowen Basin

The Early Permian to Middle Triassic aged Bowen Basin is a north-south trending belt extending through the GFD Project tenures. Geological units of the Bowen Basin outcrop in the northern half of the GFD Project tenures. The GFD Project tenures in the Arcadia gas field are located within the outcropping extent of the Bowen Basin (see Figure 4.3).

The Bowen Basin began as an extensive north-south trending back-arc basin developed on the landward (west) side of a continental arc associated with continent-ocean plate convergence. During the Early Permian period (~ 299 million years ago (ma)), the back-arc extended on the western margin of the basin producing a series of half-grabens, such as the Denison Trough, where initial deposition commenced. At the same time, andesite and volcanoclastics were deposited on the basin's eastern margin. Following the incursion of the sea over the arc, deltaic facies developed, with the subsequent accumulation of extensive coal deposits. Compressive deformation during the Late Permian period resulted in the deposition of volcanolithic sediments. Subsequent infilling of the sea by prograding deltas translated into the formation of wetlands and associated fluvial systems. Compressive tectonics in Middle to Late Triassic (251 to 141 ma) terminated sediment accumulation and caused uplifting of the entire area (URS, 2013a).

Deposition in the Bowen Basin was concentrated in two depositional centres, the Taroom Trough on the eastern edge of the basin, within the GFD Project tenures, and the Denison Trough, which is west of the GFD Project tenures. The main structural feature through the GFD Project tenures is the Comet Ridge, located along the western margin of the Taroom Trough in the southern extent of the Bowen Basin. The Comet Ridge comprises mainly Devonian rocks and is covered by a relatively thin sequence of gently folded Permian and Triassic rocks which make up the Bowen Basin.

The oldest formation of the Bowen Basin is the Reids Dome Beds, a unit of highly variable thickness. The Reids Dome Beds unconformably underlie the Early Permian aged formations of the Back Creek Group, which include the Aldebaran Sandstone and a number of other formations. The Aldebaran Sandstone is the deepest aquifer to the northwest of the GFD Project tenures, near the town of Emerald. The other formations within the Back Creek Group are generally of low permeability. The Black Alley Shale consists of shale, siltstone, tuff, bentonite and labile sandstone. The Black Alley

Shale and the Bandanna Formation are part of the Late Permian Blackwater Group. The thickness of the Bandanna Formation is variable in the GFD Project tenures, ranging between 60 to 100 m.

The Bandanna Formation is unconformably overlain by the oldest formation of the Triassic Mimosa Group, the Rewan Group. This formation is the oldest formation to outcrop within the Arcadia Valley. The Clematis Sandstone is a prominent formation forming the steep cliffs of the Expedition Range, and is overlain by mudstone and sandstone units of the Moolayember Formation. Arcadia Valley has been in-filled with Cainozoic sandy sediments, which are overlain by Quaternary alluvium deposits along natural drainage features. The unconformable contact between the Moolayember Formation and the overlying Precipice Sandstone forms the boundary between the Bowen Basin and the Surat Basin.

The late Permian Bandanna Formation of the Blackwater Group contains the main gas bearing units in the Bowen Basin and is the target formation for natural gas production in the Arcadia and Fairview gas fields.

Surat Basin

The Surat Basin overlies the central portion of the Bowen Basin, and extends from the southern part of the Expedition Range southward to the Gunnedah Basin in New South Wales (Figure 4.3). The Surat Basin sequence formed during a widespread subsidence phase subsequent to an extensive period of uplift and erosion during the Middle-Late Triassic (251 to 141 ma.) (Schlumberger, 2010). Sedimentation started in the Triassic and ceased in the Middle Cretaceous period (141 to 65 ma). The geologic succession cycle consists of braided stream deposits, followed by meandering stream and paludal coal-bearing sediments in the Jurassic period, shifting to coastal plain and shallow marine sediment accumulation as a result of the increase in sea level deposits in the Cretaceous period. Thick, semi-impervious units separate the complex multilayered system of aquifers. The lower part of each depositional cycle is therefore predominantly sandstone with mostly siltstone, mudstone and coal in the upper parts (URS, 2013a).

Within the GFD Project tenures, the Surat Basin rocks generally comprise Cretaceous age fine grained sedimentary rocks (predominantly mudstone, siltstone and labile sandstone units of the Mooga Sandstone, Bungil Formation, Wallumbilla Formation) underlain by Jurassic age sandstone and mudstone units (typified by quartzose sandstone of the Precipice Sandstone, carbonaceous mudstone of the Evergreen Formation and predominantly quartzose Hutton Sandstone). The Jurassic age strata generally outcrop in the northern and north eastern portion of the GFD Project tenures. The regional dip of the Mesozoic age rocks is to the southwest with older units outcropping in the northeast and younger rocks towards the southwest. Locally, in the south eastern portion of the GFD Project tenures, the near surface layers of these Mesozoic age rocks are deeply weathered, lateritised or more commonly silicified, forming erosion resistant silcrete that developed during the Early Tertiary period.

The Walloon Coal Measures are the main gas bearing units within the Surat Basin and are the target formation for natural gas operations within the Roma and Scotia gas fields.

Tertiary and Quaternary sedimentation

Most of the surface geology is dominated by geological units belonging to the two Permian-Cretaceous basins. Tertiary (65 to 2.6 ma) and Quaternary (2.5 to 0 ma) age volcanic and sedimentary rocks, as well as unconsolidated sediments dominate the surface geology in some areas. The surface and near surface strata can be deeply weathered and lateritised or, more commonly, silicified profiles that form erosion-resistant surficial silcrete.

Sedimentary deposition in the Tertiary consisted mostly of quartzose sandstone and conglomerate in small and isolated basins. Poorly consolidated siliciclastic sediments occur in the northern-most portion of the GFD Project tenures, as well as in a roughly east-west belt along the Condamine-Balonne River system, south of the Warrego Highway. A second group of Tertiary rocks in the GFD Project tenures comprises alkali basaltic to trachytic intrusive and extrusive rocks. The basalts and trachytes are typically small plugs and flows which generally form topographic highs.

Quaternary alluvium occurs in the lower-lying areas throughout the Surat Basin and the Bowen Basin overlying Permian, Mesozoic and Tertiary sediments and volcanics. Quaternary alluvium generally occurs along existing streams, forming very gently sloping alluvial plains or slightly elevated terraces. These young alluvial sediments generally reflect the characteristics of the parent rock material in the immediate source areas. The alluvium sourced from Permian age sedimentary rocks, Mesozoic age fine grained rocks (i.e. siltstone and mudstone), and Tertiary age volcanics are generally clay dominated with high shrink-swell and dispersive clays common. Alluvium sourced from sandstone-dominant Mesozoic age rocks and silicified or lateritised Tertiary age sedimentary rocks generally comprises sand or clayey sand.

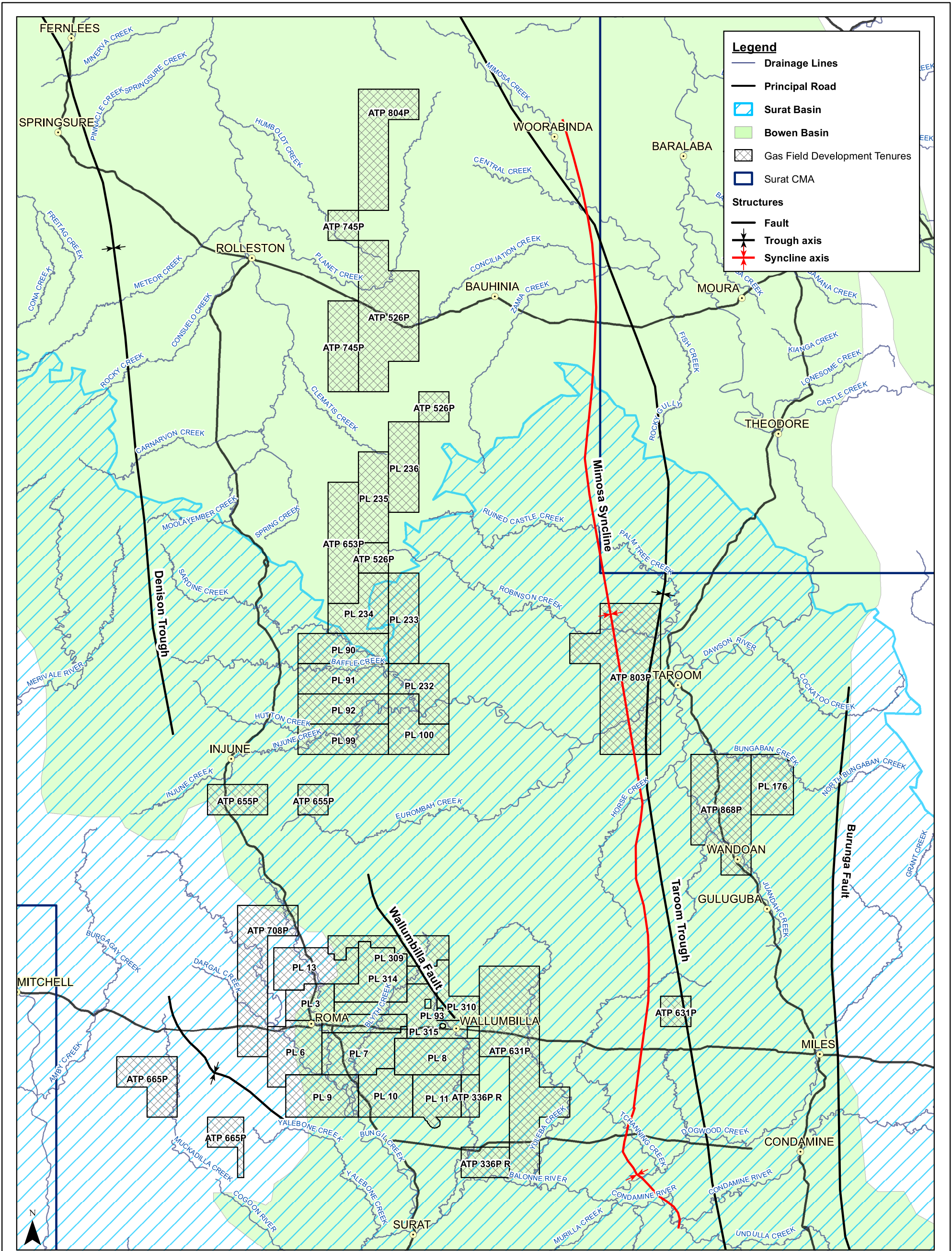
4.4.2 Geological structures

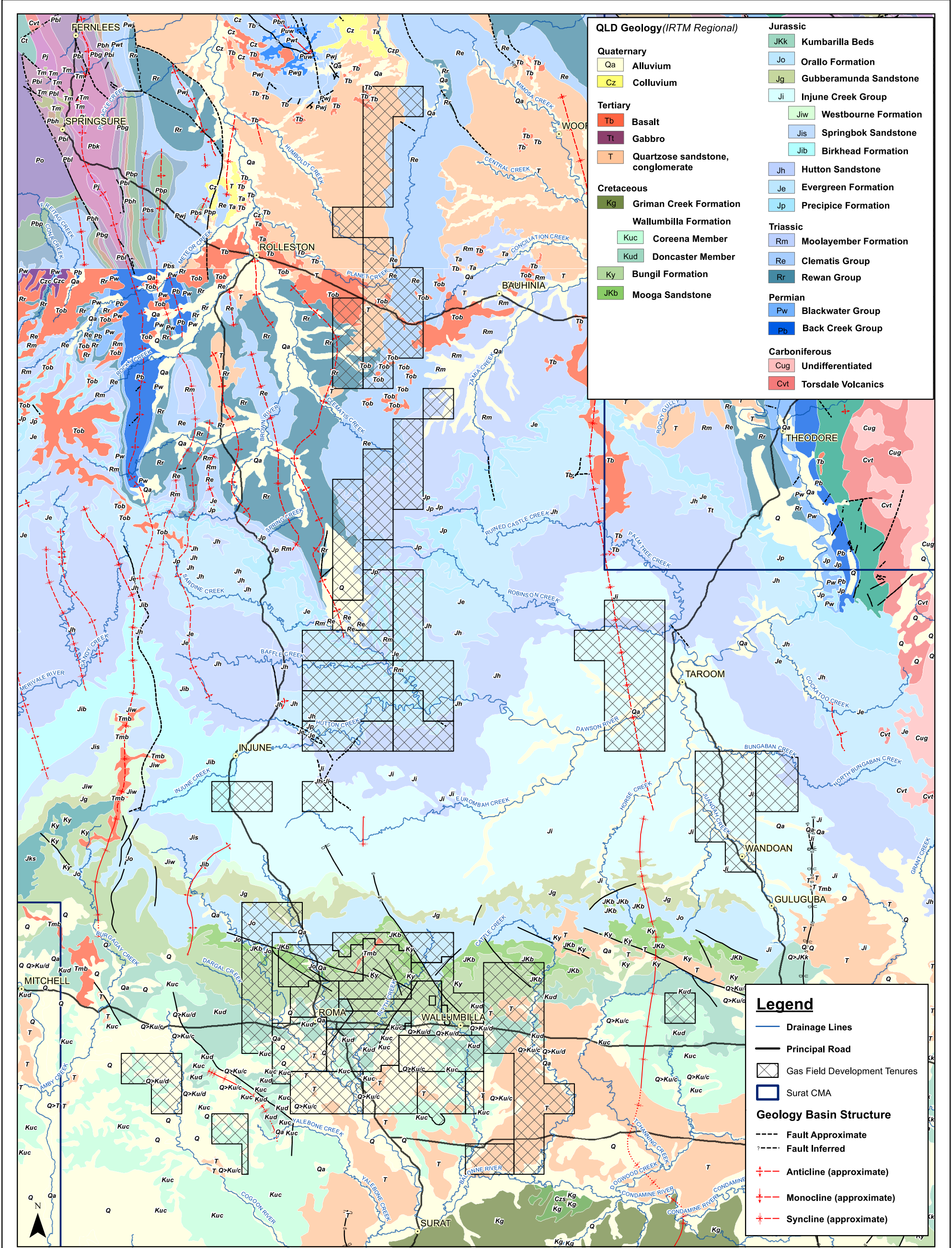
Near the northern margin of the Surat Basin, the main geological units, including the targeted Walloon Coal Measures are not strongly deformed. The faulting and folding that is recognised in the older subsurface strata is either absent or attenuated in the outcropping Jurassic-Cretaceous sediments. Some features are, however, visible in the outcrop including the Alicker and Eurombah Anticlines, the Hutton-Wallumbilla Fault and a number of west northwest trending faults (Figure 4.3 and Figure 4.4). The northwest trending Hutton-Wallumbilla Fault is located west of Roma (Figure 4.3) and is downthrown to the west with a displacement of up to 450 m in the basement sediments and is highly variable over the Roma gas field. Displacement in the overlying Surat Basin sediments is less than 30 m. Minor faulting observed in the Surat Basin sequence is likely due to sediment compaction, differential sedimentation, and some fault reactivation, (URS, 2009).

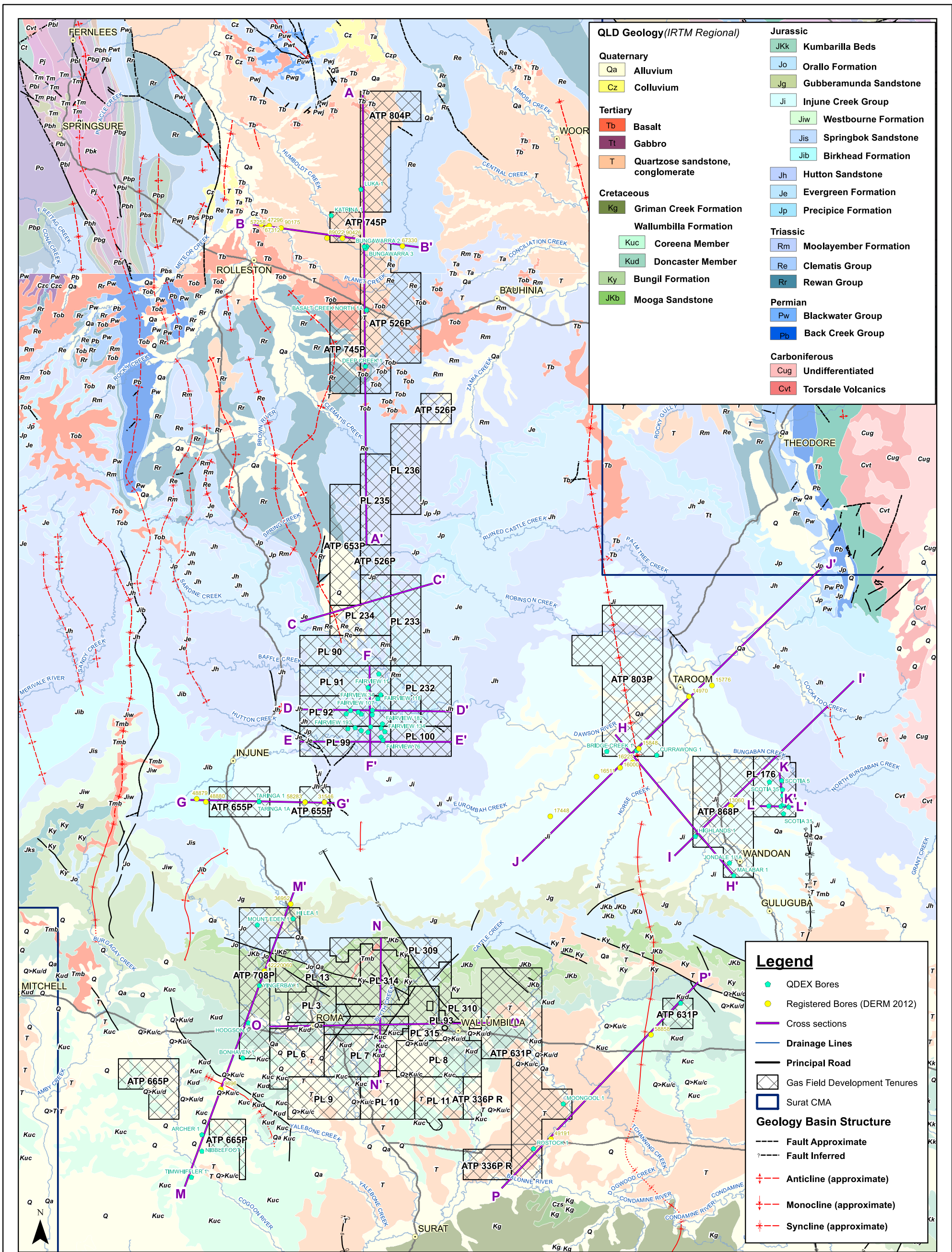
West-northwest trending faults also occur in the Roma area. These faults are likely a result of gradual uplift or subsidence related to the Surat Basin through the Tertiary period (URS, 2009). These faults have limited or no vertical displacement but they leave a clearer topographic imprint than the larger faults in the same region due to their younger age.

The central part of the GFD Project tenures, near Injune, is situated between two large reverse fault systems that are oriented approximately north-south (Santos GLNG, 2013d). Immediately to the east of Injune is an anticline which plunges to the south-southeast and corresponds to a southerly extension of the Comet Ridge in the geological basement. The anticline is complementary to the Mimosa Syncline and runs through the eastern area of the GFD Project tenures near Taroom.

The major structural feature in the north of the GFD Project tenures is the Comet Ridge, which comprises mainly Devonian age basement rocks, and is covered by a relatively thin sequence of Permian and Triassic rocks. The Permian and Triassic sequence of sediments was folded principally during the late Triassic Period, although some of the deformation within the Permian sediments possibly occurred during the period of uplift and emergence in the Lower Permian. Fold axes are generally parallel trending northwest to the Comet Ridge axis. The Permian-Triassic folds are truncated by the erosional unconformity surface on which the Precipice Sandstone was deposited. The overlying Jurassic and Cainozoic rocks are not folded (Golder, 2011).







5. Hydrogeology

This section describes the hydrogeological setting of the GFD Project tenures, including the groundwater quality and yield in major aquifers, groundwater use and springs.

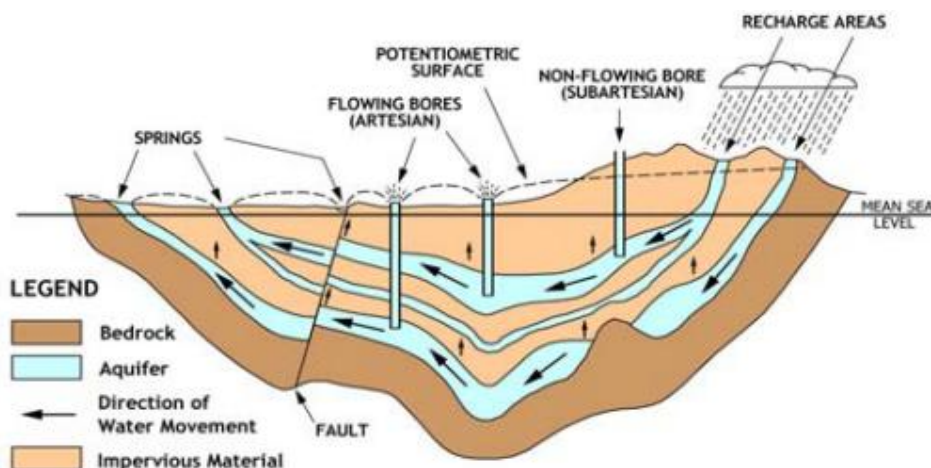
The GFD Project tenures are underlain by a number of aquifers that provide water supply for agriculture, industry and sustain numerous springs and groundwater dependent ecosystems. Major aquifers are associated with the GAB, which comprises groundwater bearing units of the Surat Basin and the upper Bowen Basin, as well as water bearing zones within Tertiary rocks and alluvial deposits.

5.1 Regional hydrogeological setting

The GFD Project tenures are located within the GAB, which consists of Surat Basin sediments and the uppermost aquifer (the Clematis Sandstone) of the underlying Bowen Basin (QWC, 2012a). The Rewan Group forms the basal unit of the GAB on a regional scale.

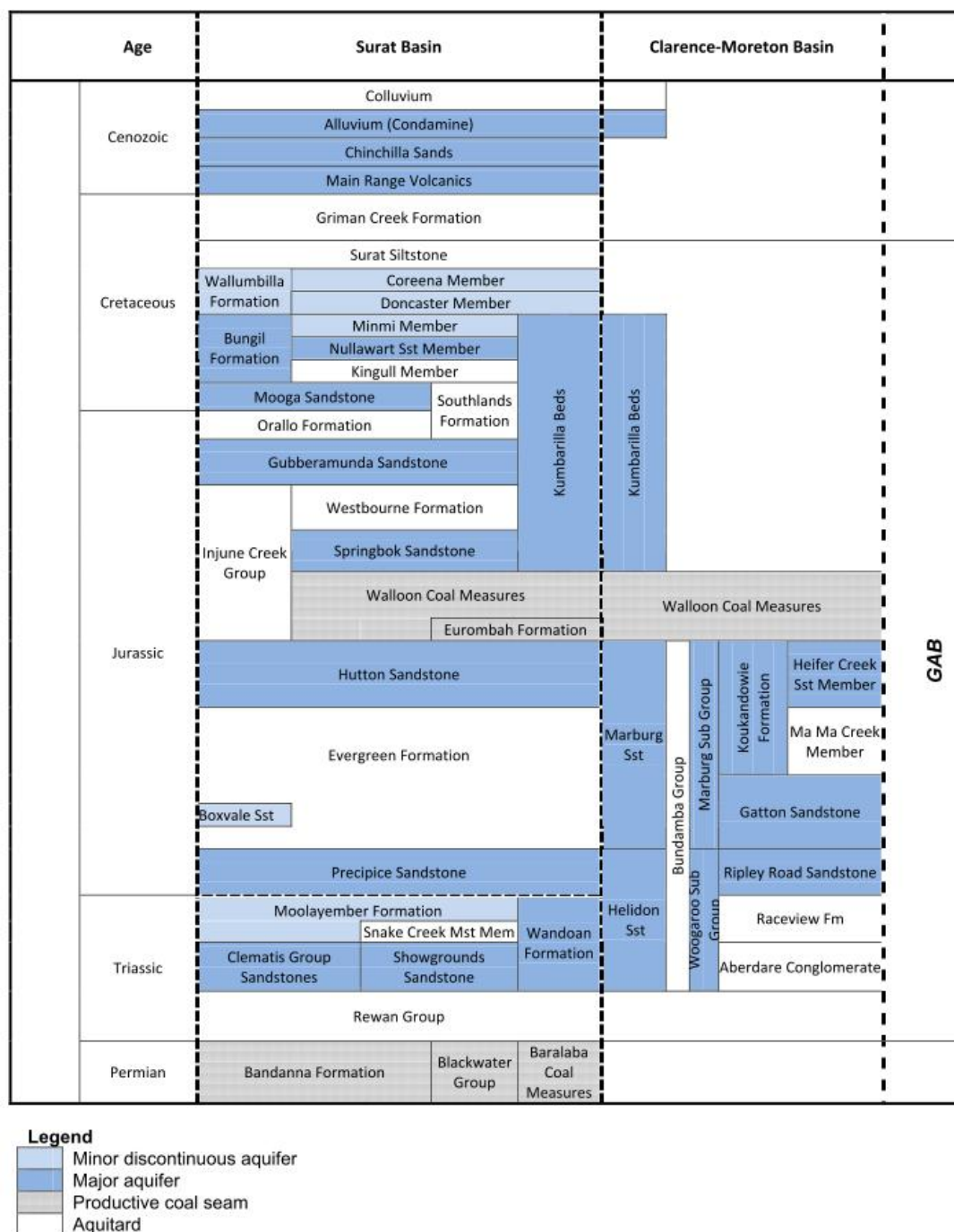
Figure 5.1 shows a generalised west-east cross-section of the GAB. The GAB comprises a sequence of alternating layers of permeable sandstone aquifers and lower permeability siltstone and mudstone aquitards, which generally dip in a south westerly direction. The thickness of the sedimentary sequence reaches nearly 2,500 m in the centre of the Mimosa syncline. The individual sandstone, siltstone and mudstone formations range in thickness from less than 100 m to more than 600 m (QWC, 2012a).

Figure 5.1 Generalised cross-section of the Great Artesian Basin (DERM, 2011a)



Regionally, the main aquifers and aquitards in the GAB are controlled by the lithology and extent of stratigraphic units or geologic formations. Figure 5.2 shows the sequence of the aquifers and aquitards within the basin. The sandstone units, defined as aquifers, store and transmit groundwater and are sufficiently permeable to yield economically significant quantities of groundwater. The siltstone and mudstone units within these systems are of low permeability. They restrict groundwater flow or leakage between aquifers, and are defined as aquitards. At a local level most of the aquifers contain minor inter-bedded siltstone and mudstone that are reflected in lower bore yields. Similarly, several aquitards contain minor aquifers of permeable sandstone and siltstone units that can yield reasonable quantities of water in these otherwise unproductive formations (QWC, 2012a).

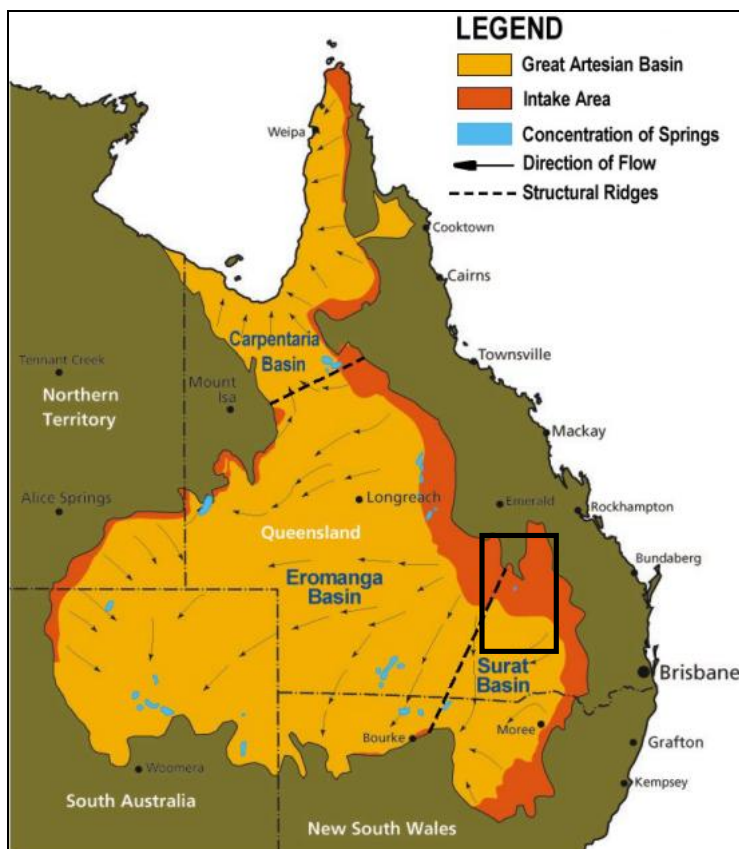
Figure 5.2 Regional hydrostratigraphy (QWC, 2012a)



5.1.1 Recharge

Figure 5.3 shows the main recharge areas and the dominant (regional) flow directions within the GAB. The GFD Project area is located in the recharge area of the GAB. Most recharge occurs along the outcrop areas in the north, northwest, northeast and east along the Great Dividing Range. Recharge occurs predominantly by rainfall, either by direct infiltration into the outcrop areas, or indirectly via leakage from streams or overlying aquifers. Calibrated recharge rates estimated from QWC's regional groundwater model give recharge rates into the GAB aquifers ranging geographically from 1 to 30 mm per year with a median of 2.8 mm per year (QWC, 2012a).

Figure 5.3 Great Artesian Basin (DERM, 2011a)



Recharge water flows primarily along the bedding planes and fractures of aquifers and aquitards from the recharge areas to the south, southwest and west, though there is a minor northward flow component in some aquifers (Hodgkinson et al., 2009), e.g. near Taroom. Groundwater moves very slowly and flow velocities in the GAB have been estimated to range from 1 to 5 m per year (Habermehl, 1980). Groundwater movement within the GAB is dominated by sub-horizontal flow in the aquifers, with vertical leakage from the aquifers through the low permeability aquitards occurring throughout the basin at a much slower rate.

The GAB aquifers are recharged mainly on the eastern margins of the GAB along the western slopes of the Great Dividing Range. Regional groundwater flow is from the topographically higher recharge areas around the basin margins towards the lowest parts of the basin in the southwest.

5.1.2 Discharge

Natural discharge from aquifers in GFD Project tenures occurs through vent springs, baseflow to rivers (watercourse springs), vertical leakage between aquifers and subsurface flow into adjoining areas. Further detail on discharge through springs is provided in Section 6.1.2.

Extraction of groundwater in GFD Project tenures occurs via bores used for stock and domestic supply or agriculture, uncontrolled artesian bores and petroleum and gas production. Further detail on discharge via bores is provided in Section 6.1.1.

5.2 Hydrogeological units

The main productive water bearing formations in the GFD Project area include:

- Quaternary alluvial aquifer systems associated with the unconsolidated sediments of the Condamine-Balonne River, the Dawson River and the Comet River systems.
- Tertiary fractured basalt and sediments caps.
- Water bearing formations of the GAB. These include the Clematis Sandstone, Precipice Sandstone, Hutton Sandstone, Springbok Sandstone, Gubberamunda Sandstone, Mooga Sandstone and Bungil Formation.

An overview of the main hydrogeological units for water supply in the GFD Project area is presented in Table 5.1. The Bungil and Orallo formations are generally not considered to be aquifers, but are used for water supply in the GFD Project area and have therefore been included in Table 5.1. The alluvial systems and Tertiary fractured basalts are not connected across the GFD Project areas; however, these formations are still targeted for water supply.

Table 5.1 Main hydrogeological units for water supply in the GFD Project tenures

Aquifer	Outcrop area (Gas field)	Aquifer type	Thickness* (m)	Depth	Development
Alluvium	All	Unconfined		At surface	Limited, stock, seasonal
Tertiary fractured basalts and sediments	Arcadia, Roma	Unconfined	10 to 30	At surface	Limited, stock/domestic
Bungil Formation	Roma	Minor aquifer/ water bearing formation	200	At surface north of Roma, dips south	Limited Stock/domestic
Mooga Sandstone	Roma	Important aquifer	25 to 200	At surface north of Roma, dips south	Stock/domestic, town water supplies, baseflow
Orallo Formation	Roma	Aquitard	140 to 270	At surface north of Roma, dips south	Limited, Stock/domestic
Gubberamunda Sandstone	Roma	Important aquifer	45 to 300	At surface north of Roma, dips south	Important GAB aquifer, town water supply, stock
Springbok Sandstone	Scotia, Fairview	Important aquifer	70	At surface south of Injune, dips south	Limited, discontinuous, stock
Hutton Sandstone	Scotia, Fairview	Important aquifer	700	At surface north of Injune and Taroom, dips south	Important GAB aquifer, Drinking water, town water supplies, stock, baseflow
Precipice Sandstone	Fairview	Important aquifer	80	At surface north of Injune and Taroom, dips south	Important GAB aquifer, Drinking water, town water supplies, stock, baseflow
Clematis Sandstone	Fairview, Arcadia	Important aquifer	130 [^]	At surface south and west of Rolleston	Important GAB aquifer, town water supplies, stock, baseflow

(1) * Santos GLNG (2013d), ^ Geoscience Australia website.

5.2.1 Alluvial aquifer systems

Alluvial systems exist in the vicinity of GFD Project tenures associated with the main drainage systems: the Condamine-Balonne River system in the southern Roma area, the Dawson River system in the central-eastern Taroom area and the Comet River system in the northern area near Rolleston.

The Condamine Alluvium, located near Dalby, is the most significant and highly developed alluvial system in the Surat CMA. It consists of gravels and fine to coarse-grained channel sands inter-bedded with clays (QWC, 2012a). The Condamine Alluvium is remote from the GFD Project tenures (Figure 1.3).

Alluvial aquifers in the GFD Project tenures have been variably developed for irrigation, stock and domestic and town water supplies. Data from registered landholder bores in the alluvium indicates yields range between 1-23 L/s and water quality is typically fresh and slightly acidic to neutral. There are 29 registered landholder bores screened in the various alluvial aquifer systems in the GFD Project tenures mostly located near Scotia of which all are reported to support stock and domestic purposes with an estimated take of 87 ML/year (OGIA, 2013a).

5.2.2 Tertiary fractured basalts and sediments

The Tertiary Main Range Volcanics host aquifers used for irrigation, stock and domestic and town supplies. The aquifers occur at depths ranging from 2 to 155 m below ground surface with thicknesses generally varying from 10 to 30 m. Bore yields are highly variable due to variable aquifer properties. They range from less than 5 L/s to 50 L/s, with an average of approximately 20 L/s. Water quality is generally of good quality with a salinity range from less than 100 mg/L to approximately 1,100 mg/L. This is interpreted to indicate that the aquifers respond quickly to recharge from direct infiltration of rainfall, particularly in the elevated areas, and contribute recharge to connected aquifers. Tertiary basalts occur in the Arcadia gas field.

Tertiary basalts occur in the north of the GFD Project area overlying the Bowen Basin sediments. In general, the aquifers in these basalts are not as high yielding as that of the Main Range Volcanics (QWC, 2012a). Registered landholder bores installed in the northern Tertiary Basalts in the Arcadia gas field are used for stock and domestic purposes, have alkaline and brackish water quality and have low yields (0.5-2.5 L/s).

There are eight registered landholder bores screened in the Tertiary basalts in the GFD Project tenures of which all are reported to support stock and domestic purposes with an estimated take of 24 ML/year (OGIA, 2013a).

Tertiary aged sediments, comprising sub-labile to quartzose sandstone, siltstone, mudstone, minor conglomerate, coal, and limestone, underlie the northern GFD Project tenures in the Arcadia gas field. There are six registered landholder bores screened in the Tertiary aged sediments in the GFD Project tenures of which all are reported to support stock and domestic purposes with an estimated take of 18 ML/year (OGIA, 2013a). Water quality associated with Tertiary sediments is slightly alkaline and brackish and yields are low (0.5-1.3 L/s).

5.2.3 GAB hydrogeological units

5.2.3.1 Water bearing units

The main aquifers within the GAB, from the youngest to oldest, are the Bungil Formation, Mooga Sandstone, Gubberamunda Sandstone, Springbok Sandstone, Hutton Sandstone, Precipice Sandstone, and the Clematis Sandstone. The stratigraphy of these major GAB aquifers is laterally

continuous although this does not necessarily translate in a hydraulic continuity due to the variability of the sediments and depositional environments. These formations have equivalents in different sub-basins of the GAB (divided by structures) and a number of them have significant water in storage and zones of enhanced permeability. These units, depending on depth, can be extensively developed for groundwater use. Groundwater level contour maps that depict groundwater flow directions and aquifer extents are based on output from the calibrated UWIR model (QWC, 2012c) (Appendix B: Groundwater level data).

Water quality in most GAB aquifers is generally fresh to brackish and suitable for stock watering. Water quality is spatially variable due to the lateral and vertical variability in the lithology of the formation and variations in groundwater recharge and residence time.

Bungil Formation

The Bungil Formation was deposited in a shallow marine and deltaic environment and is up to 200 m thick in some areas of the Surat Basin (Santos GLNG, 2013d). It comprises sandstone, mudstone and siltstone. Recharge of the Bungil Formation occurs within outcropping areas of the formation north of Roma. The Bungil Formation outcrops in GFD Project tenure ATP 708P, where it is unconfined and potentially connected to surface water features. Groundwater flow is in a south to southwest direction (Appendix B.2, groundwater level contours for the Bungil Formation and Mooga Sandstone). The Bungil Formation has a relatively good groundwater supply and is mainly used for stock and domestic purposes. Groundwater quality is slightly alkaline and typically fresh. There are 107 registered landholder bores screened in the Bungil Formation in the GFD Project tenures around Roma of which all are reported to support stock and domestic purposes with an estimated take of 649 ML/year (OGIA, 2013a). Yield information is available for one registered landholder bore (4.55 L/s).

Mooga Sandstone

The Mooga Sandstone comprises fluvial quartzose to sublamine sandstone with thinly inter-bedded dark grey mudstone and siltstone, of swamp origin (Santos GLNG, 2013d). The Mooga Sandstone underlies the Bungil Formation, and outcrops in the GFD Project tenures near Roma. Groundwater from the Mooga Sandstone is used in the southern GFD Project tenures around Roma and flows in a south to southwest direction (Appendix B.2, groundwater level contours for the Bungil Formation and Mooga Sandstone).

Groundwater is mainly used for stock and domestic purposes and town water supply for Roma, Wallumbilla and Yuleba (Santos GLNG, 2013d). The Mooga Sandstone is an important aquifer in the Surat Basin and provides supplies of good quality water (typically fresh). There are 262 registered landholder bores within the Mooga Sandstone in the GFD Project tenures around Roma, of which 257 are reported to support stock and domestic purposes with an estimated take of 1,459 ML/year (OGIA, 2013a). Bore yield varies from 1.2 to 8.2 L/s.

Gubberamunda Sandstone

The Gubberamunda Sandstone comprises fluvial sandstone, minor conglomerate, siltstone and mudstone and has a measured thickness ranging between 45 to 300 m (Santos GLNG, 2013d). Groundwater within the Gubberamunda Sandstone aquifer is sub-artesian in places. It is the most highly developed aquifer (due to its shallow depth allowing for easy access) in the Surat Basin (Santos GLNG, 2013d). Groundwater flows in a south to southwest direction in the Gubberamunda Sandstone in the GFD Project tenures (Appendix B.3).

Groundwater from the Gubberamunda Sandstone is mainly used for stock watering in the southern GFD Project tenures around Roma. The Gubberamunda Sandstone is mapped to outcrop along the

northern and eastern margins of the Surat Basin, where it is intensely leached and ferruginised. Springs vents occur in these outcrop areas (Santos GLNG, 2013d). Details on these springs are provided in Section 6.1.2.

The Gubberamunda Sandstone provides good quality water and is typically slightly alkaline and brackish, but locally fresh. There are 153 registered landholder bores in the Gubberamunda Sandstone in the GFD Project tenures of which 139 are reported to support stock and domestic purposes (OGIA, 2013a). Estimated take from the Gubberamunda Sandstone within GFD Project tenures is 1,869 ML/year (OGIA, 2013a). Bore yield varies from 1 to 11 L/s.

Springbok Sandstone

The Springbok Sandstone unconformably overlies the Walloon Coal Measures and underlies the Westbourne Formation, a regional aquitard. Comprised of clayey lithic sandstone with localised calcareous deposits, the Springbok Sandstone is also inter-bedded with carbonaceous mudstone and siltstone units. The Weald Sandstone located in the upper part of the Springbok Sandstone is the main water-bearing unit in the Injune Creek Group (Santos GLNG, 2013d).

The Springbok Sandstone was deposited by fluvial systems which, in some areas, eroded into the upper siltstone and mudstone units of the Walloon Coal Measures and occasionally into its coal seams, resulting in direct contact of the Springbok Sandstone with the natural gas producing coal layers in some areas. In other areas, the Springbok Sandstone is separated from producing coal layers by low permeability sediments of the upper Walloon Coal Measures (Santos GLNG, 2013d). The Springbok Sandstone can be subdivided into a number of units with a very low hydraulic conductivity unit in the middle which would act as an aquitard. Groundwater flow in the Springbok Sandstone is in a south to southwest direction in the GFD Project tenures (Appendix B.4).

Sections of the Springbok Sandstone are good water bearing zones in some locations; in other locations the Springbok Sandstone is highly compacted with very low vertical permeability (QWC, 2012a). There are areas where a localised unconformable contact between the lower Springbok Sandstone and the upper coal beds of the Walloon Coal Measures results in hydraulic connection (Santos GLNG, 2013d). The Springbok Sandstone aquifer extends primarily underneath GFD Project tenures in the Roma area.

There is only one registered groundwater bore in the GFD Project tenures that is registered for use in the Springbok Sandstone (also screened across the Mooga Sandstone). This bore is used for urban water supply in PL 6 of the Roma Gas Field.

Walloon Coal Measures

The Walloon Coal Measures and its equivalents in Scotia are part of the Injune Creek Group and consist of siltstone, mudstone, fine-to-medium grained lithic sandstone, and coal deposited over time from rivers and into lakes and swamps across the Surat Basin and Clarence-Moreton Basin (Scott et al., 2004). In the Surat Basin, the Walloon Coal Measures have been subdivided into four formations; the Durabilla Formation, Taroom Coal Measures, Tangalooma Sandstone and Juandah Coal Measures.

The Walloon Coal Measures are considered to be an aquitard although in places it functions as an aquifer. In those cases, the volumes of water extracted are limited. The coal seams are generally the more permeable units within a sequence of dominantly low permeability mudstone, siltstone or fine-grained sandstone units. Permeability decreases with depth in the Walloon Coal Measures, especially vertical permeability which is very low at depths greater than 800 m (target depth for natural gas)(Queensland Carbon Geostorage Initiative (QCGI), 2009).

Groundwater flow is generally from higher elevations in the north and east toward the west and southwest. A groundwater level contour map has been created using calibrated UWIR model output (QWC, 2012b) for the Walloon Coal Measures and is presented in Figure B.5 (Appendix B: Groundwater level data).

Coal seams within the Walloon Coal Measures do not continue to the western margin of the basin. The Walloon Coal Measures grade into the siltstone and sandstone units of the Birkhead Formation (USQ, 2011). The Birkhead Formation acts primarily as a confining bed in the Surat Basin, providing only small supplies of poor quality water dominantly associated with fine grained sandstone units (QWC, 2012a).

The water quality is generally poor and bore yields are low. However, the Walloon Coal Measures are developed for stock, domestic, industrial and urban purposes where aquifers can be accessed at shallow depths near the outcrop areas (DNRM, 2005). In the GFD Project tenures, these outcrop areas occur near Injune (ATP 655P) and Taroom (ATP 803P, ATP 868P and PL176).

There are 61 registered landholder bores in the Walloon Coal Measures in the GFD Project tenures of which all are reported to be for stock and domestic purposes (OGIA, 2013a). Estimated take from the Walloon Coal Measures within GFD Project tenures is 337 ML/year (OGIA, 2013a). Bore yields are typically low (0.6-1.8 L/s).

Hutton Sandstone

The Hutton Sandstone underlies the Eurombah Formation (aquitard) of the Injune Creek Group. It consists of very fine to medium-grained sandstone with inter-bedded siltstone units. The Hutton Sandstone typically has the greatest aquifer thickness in the Surat Basin and is an important GAB aquifer, although it has many low permeability zones. The base of the Hutton Sandstone is generally more sand-rich and the most productive for groundwater. Highly permeable zones tend to be thin while the rest of the sequence provides a large storage capacity and contributes to the overall formation transmissivity (Santos GLNG, 2013d).

The groundwater flow direction in the Hutton Sandstone is south to southeast near Roma and north near Scotia, which differs from the general southwest groundwater flow direction observed for the other hydrogeological units of the GAB (Figure B.6, Appendix B: Groundwater level data). This is thought to demonstrate a low level of connectivity between the Injune Creek Group and the Hutton Sandstone (Santos GLNG, 2013d).

The Hutton Sandstone outcrops in the GFD Project tenures near Taroom (ATP 803P, PL176 and ATP 868P in the Scotia gas field); and also outcrops north of Injune near GFD Project tenure ATP 655P in the Fairview gas field. Groundwater in the Hutton is typically slightly alkaline and brackish. The Hutton Sandstone is not a reliable groundwater source due to its non-continuous distribution and poor water quality within the western tenures of the GFD Project tenures (Santos GLNG, 2013d).

A total of 94 registered landholder bores are licenced to take groundwater from the Hutton Sandstone within the GFD Project tenures of which 90 are reported to be for stock and domestic purposes (OGIA, 2013a). Estimated take from the Hutton Sandstone within GFD Project tenures is 1,198 ML/year (OGIA, 2013a). Bore yields vary from 0.1 to 12 L/s.

A number of springs hydraulically connected to the Hutton Sandstone are present in the vicinity of GFD Project tenures. Details on these springs are provided in Section 6.1.2.

Precipice Sandstone

The Precipice Sandstone is mainly comprised of sandstone and conglomerate. The Precipice Sandstone sediments were deposited in a fluvial environment in braided river systems. The Precipice Sandstone is approximately 80 m thick on average and hydraulically isolated from the Hutton Sandstone by the Evergreen Formation aquitard. The Precipice Sandstone is thin or absent in some areas near Roma (Santos GLNG, 2013d). Groundwater generally flows in an easterly direction within the Precipice Sandstone in the GFD Project tenures (Appendix B.7). The Precipice Sandstone outcrops in a narrow zone across the central part of the GFD Project tenures, and represents the basal (oldest and deepest) formation of the Surat Basin.

Water quality is typically fresh and of near neutral pH. The Precipice Sandstone sometimes exhibits very good aquifer potential and generally produces plentiful supplies of potable sub-artesian water in the Fairview and Scotia gas fields (Santos GLNG, 2013d), which is primarily used for stock.

Twenty-eight registered landholder bores are licenced to take groundwater from the Precipice Sandstone in the GFD Project tenures of which 25 are reported to be for stock and domestic purposes (OGIA, 2013a). Estimated take from the Precipice Sandstone within GFD Project tenures is 389 ML/year (OGIA, 2013a). Bore yields range from 0.4 to 9.2 L/s.

A number of springs, hydraulically connected to the Precipice Sandstone, are present in the GFD Project area. Details on these springs are provided in Section 6.1.2.

Clematis Sandstone

The Clematis Sandstone comprises medium to coarse grained quartzose to micaceous sandstone, siltstone and mudstone and granule to pebble conglomerate. The Clematis Sandstone is overlain by the Moolayember Formation (Santos GLNG, 2013d). The Clematis Sandstone outcrops in and around the northern GFD Project tenures (ATP 804P and ATP 745P). The Clematis Sandstone is thin or absent in some areas in near Roma and areas southwest of Fairview (Santos GLNG, 2013d). Groundwater flow directions in the Clematis Sandstone are east in the north of the GFD Project tenures and to the southeast in the south of the GFD Project tenures (Appendix B.8). The Clematis Sandstone can produce good supplies of potable groundwater.

Forty-five DNRM registered landholder bores within the GFD Project tenures are licenced for use in this unit, all of which are reported to support stock and domestic purposes (OGIA, 2013a). Bore yields range from 0.5 to 10 L/s.

There are many springs located along the Clematis Sandstone-Moolayember Formation boundary west of GFD Project tenures ATP 804P and ATP 745P, along the sandstone cliff walls of the Expedition Range. Details on these springs are provided in Section 6.1.2.

5.2.3.2 Aquitards

The main aquitards in the GFD Project tenures are the Rewan Group, Moolayember Formation, Evergreen Formation, Birkhead Formation, Westbourne Formation, Wallumbilla Formations and to a lesser extent the Orallo Formation. Minor aquifers occur within the Moolayember Formation and the Doncaster and Coreena Members of the Wallumbilla Formation and the Evergreen Formation. These minor aquifers are not high yielding or laterally continuous, and water quality is often poor; these units are therefore considered to behave regionally as aquitards.

The Westbourne Formation, ranging in thickness from 100 m to 200 m, separates the Gubberamunda Sandstone from the underlying Springbok Sandstone. The Evergreen Formation is a thick aquitard (averaging 300 m) lying between the Hutton Sandstone and underlying Precipice Sandstone aquifers.

Wallumbilla Formation

The Coreena Member comprises siltstone and fine sandstone inter-bedded with mudstone and the Doncaster Member comprises mainly mudstone, siltstone and minor quartz sandstone.

In the GFD Project tenures, two units of the Wallumbilla Formation outcrop in the area around Roma and Wallumbilla, the Coreena Member and the Doncaster Member. There are 18 registered landholder bores in GFD Project tenures around Roma that are licenced to take water from the Wallumbilla Formation and all are licensed for stock/domestic use (OGIA, 2013a). Groundwater quality is predominantly fresh and alkaline (URS, 2009).

Orallo Formation

The Orallo Formation is comprised of lithic sandstone, siltstone and mudstone deposited dominantly in swamps and as overbank deposits (Santos GLNG, 2013d). The formation thickness varies from 140 to 270 m, averaging 200 m. The Orallo Formation outcrops north of Roma in GFD Project tenure ATP 708P and acts as a confining bed for the Gubberamunda Sandstone. It is not present on the Nebine Ridge where the Mooga Sandstone rests directly on the Gubberamunda Sandstone. Recharge to the minor aquifers in Orallo Formation occurs in the northern and eastern margins of the Surat Basin.

Groundwater quality within the Orallo Formation is fresh to brackish and slightly alkaline (URS, 2009). Thirteen registered landholder bores are licenced to take water from the Orallo Formation for stock/domestic purposes in the GFD Project tenures (OGIA, 2013a). Bore yields vary from 1.8 to 14.3 L/s.

Westbourne Formation of the Injune Creek Group

The Westbourne Formation is part of the Injune Creek Group and underlies the Gubberamunda Sandstone. It comprises alternating sequences of mudstone and lithic sandstone with minor siltstone and coal in the upper portions and thinly-bedded siltstone and low permeability sandstone in the lower portions. The Westbourne Formation was deposited in a low energy fluvial and marginal-marine environment and reaches a thickness of greater than 60 m in the Roma gas field. The Westbourne Formation outcrops just north of GFD Project tenure ATP 708P. There are no landholder registered bores licenced to take water from this unit GFD Project tenures (OGIA, 2013a).

Eurombah Formation of the Injune Creek Group

The Eurombah Formation forms the base of the Injune Creek Group and is comprised of siltstone and mudstone deposited by swamps and low-energy streams. The Eurombah Formation forms the aquitard between the Walloon Coal Measures and the Hutton Sandstone aquifer and has an average thickness of 45 m. In some areas the Eurombah Formation is absent and there may be hydraulic connection between the Walloon Coal Measures and the Hutton Sandstone.

There are four registered landholder bores licenced to take water from the Eurombah Formation in GFD Project tenures ATP 803P west of Taroom and ATP 868P near Wandoan and all are licensed to take water for stock and domestic purposes (OGIA, 2013a). Bore yields are expected to be low with only one registered landholder bore (0.4 L/s).

Evergreen Formation

The Evergreen Formation comprises very fine, quartzose sandstone and acts as a thick (~ 500 m) confining bed that separates the Precipice Sandstone and Hutton Sandstone.

The Boxvale Sandstone, a member of the Evergreen Formation, is present as a discontinuous layer within the Evergreen Formation. Groundwater quality within the Evergreen Formation is slightly brackish and slightly alkaline. Eight registered landholder bores are licensed to take water from the Evergreen Formation for stock/domestic purposes in the GFD Project tenures. Bore yields range between 1.5 and 2.5 L/s.

Moolayember Formation

The Moolayember Formation is defined as a minor discontinuous aquifer, but regionally acts as an aquitard. The aquifer is not high yielding and water quality is often poor (QWC, 2012a). The Moolayember Formation consists of micaceous lithic sandstone and siltstone.

The Moolayember Formation is considered as the base aquitard in the Roma area, based on its low permeability and considerable thickness (Santos GLNG, 2013d).

There are two registered landholder bores licenced to take water from this unit and both are licensed to take water for stock and domestic purposes (OGIA, 2013a).

Rewan Group

The GAB aquifers are separated from the Bandanna Formation (from which gas is produced in the Bowen Basin) by a very thick sequence (~ 1,000 m) of fine-grained, low permeability siltstone and mudstone units of the Rewan Group (QWC, 2012a).

Groundwater quality is of neutral pH and saline. Nine registered landholder bores are completed within this unit in GFD Project tenure ATP 745P and all are licensed to take water for stock and domestic purposes (OGIA, 2013a). Bore yields are low, ranging from 0.6 to 1.2 L/s.

5.2.4 Hydrogeological units underlying the GAB

Bandanna Formation

The Bandanna Formation is the productive gas formation within the Bowen Basin and comprises inter-bedded coal, mudstone, siltstone and minor clayey sandstone. The thickness of the Bandanna Formation varies from 70 m to 250 m. The Bandanna Formation is the target coal seam in the northern and eastern GFD Project tenures (Arcadia, Fairview and Scotia gas fields). The outcrop area to the north of GFD Project tenure ATP 804P constitutes the primary recharge zone for the formation.

Groundwater flow within the Bandanna Formation is dependent on the permeability of individual coal seams, and their vertical and lateral interconnection. The coal seams of the Bandanna Formation have a slightly higher permeability than the predominantly low permeability sandstone and siltstone units. The coal seams therefore tend to be relative water bearing zones within the coal measures but due to their low permeability do not transmit significant groundwater, nor constitute useful aquifers. Groundwater flow direction in the GFD Project tenures for the Bandanna Formation is primarily in an easterly direction. A groundwater level contour map has been created using the calibrated UWIR model output (QWC, 2012c) for the Bandanna Formation and is presented in Figure B.9, Appendix B: Groundwater level data.

Water quality within the Bandanna Formation is typically alkaline and brackish. There is limited groundwater extraction for agricultural purposes from this formation and there are no registered landholder bores within the GFD Project tenures.

Early Permian Sediments

Limited data is available on the groundwater conditions within the deeper Permian sedimentary rocks underlying the Bandanna Formation. However, in general these formations are fine-grained, cemented, and have low permeability (QWC, 2012a). As sedimentation was not continuous across the Bowen Basin, the formations are not as laterally extensive as in the GAB. The formations have complex geology and display laterally variable hydraulic properties. Water quality is poor with very high salinities in some places (QWC, 2012a).

5.3 Interconnectivity of the coal sequences

5.3.1 Interconnectivity studies

Santos GLNG has assessed the hydraulic connectivity between formations to characterise the level of hydraulic connectivity between the gas producing coal beds and the overlying and underlying aquifers. Santos GLNG is also further assessing potential horizontal pathways for impact propagation, i.e. assessing the horizontal variability of formation characteristics. This includes characterisation of the formations considered as aquitards. The studies carried out to date include (Santos GLNG, 2013d):

- Monitoring of water pressures at a number of multi-level pressure monitoring bores and vibrating wire piezometers to determine horizontal and vertical groundwater gradients.
- Monitoring water quality including isotopes ($^{12}/^{13}\text{C}$) at private bores, monitoring bores and gas wells to define the chemical signature of formations.
- A deep aquifer monitoring program involving conversion of eight conventional wells into monitoring wells.
- Fitting of existing landholder bores with pressure gauges and automatic recording loggers to observe response to pumping from nearby pumping activities.
- A field coring program involving in situ and laboratory testing of hydraulic conductivity.
- The Managed Aquifer Recharge (MAR) trials at Hermitage within the Roma gas field, which comprised injection and pumping trials and the assessment of the hydraulic responses.
- Ongoing testing of hydraulic conductivity in the major coal measures of the Walloon Coal Measures.

The results of the hydraulic connectivity program demonstrate that under natural conditions, there is limited hydraulic connectivity between the formations. Ongoing studies will provide further characterisation on the level of connectivity between the formations when coal seam water extractions start (Santos GLNG, 2013d). These studies comprise groundwater monitoring activities, hydrogeological investigations, and assessment of field data to inform refinement and calibration of the OGIA groundwater model.

Current conceptual understanding of the connectivity of the target coal seams to overlying and underlying formations is presented in the UWIR for the Surat CMA (QWC, 2012a) and summarised below.

5.3.2 Walloon Coal Measures

The coal seams within the Walloon Coal Measures are separated by lower permeability mudstone, siltstone and fine-grained sandstone. For the most part, low permeability units are found at the top of the formation, in between the productive coal seams and at the bottom of the formation, below the lowermost productive coal seams. These relatively low permeability units are aquitards that generally

separate the productive coal seams from the Springbok Sandstone aquifer above and the Hutton Sandstone aquifer below, except in areas where the upper aquitard has been eroded away (QWC, 2012a), i.e. the upper target coal seam is in direct contact with the Springbok Sandstone in those areas.

The thickness of the aquitard layer between the productive coal seams of the Walloon Coal Measures and the Springbok Sandstone is typically about 15 m, although in some places the aquitard can be absent. In the GFD Project tenures, the thickness of the upper aquitard ranges between < 5 m near PL10 and PL11 to > 40 m near ATP 708P in the southern area near Roma. Near Injune (ATP 655P) it ranges between 5 and 20 m and near Taroom it ranges between 0 and 40 m, decreasing in thickness towards the northeast (QWC, 2012a). In addition to this aquitard layer, the hydraulic properties of the lower part of the Springbok Sandstone vary greatly. The lower part of the Springbok Sandstone behaves in places as an aquitard.

The Eurombah Formation, an aquitard layer separating the lowermost productive coal seams (the Taroom Coal Measures) from the underlying Hutton Sandstone is about 45 m thick. In the GFD Project tenures, the lower aquitard is mostly greater than 40 m, except near Injune (ATP 655P) and to the northeast of Wandoan (PL176) where it can be thinner or absent.

The lithology of the aquitards is variable. Data presented in the UWIR estimates the horizontal permeability to range from 1.5 m/day to 2.5×10^{-6} m/day, averaging 9×10^{-3} m/day, and the vertical permeability to be one to three orders of magnitude lower (QWC, 2012a).

Prior to gas development in the Walloon Coal Measures, a difference in water levels existed between the coal measures and the overlying and underlying aquifers, implying limited hydraulic connection between the formations. However, steeper hydraulic gradients are generated due to depressurisation of the coal measures resulting in increased potential for induced flow between the units (QWC, 2012a).

In areas outside the GFD Project tenures to the southeast, the Walloon Coal Measures are considered to be hydraulically connected to the Condamine Alluvium (Figure 1.1). Groundwater modelling has predicted that there is likely to be negligible additional depressurisation of the underlying Walloon Coal Measures in the vicinity of the Condamine Alluvium due to GFD operations and therefore no increase in drawdown in the Condamine Alluvium. The OGIA has started the Condamine Interconnectivity Research Project which aims to improve understanding of the interconnectivity between the Condamine Alluvium and the underlying Walloon Coal Measures and the potential impacts of gas production on water pressure in underlying and overlying aquifers.

5.3.3 Bandanna Formation

The Bandanna Formation is laterally isolated from equivalent coal measures by erosion or faulting and therefore, depressurisation of the Bandanna Formation is unlikely to affect aquifers north and east of the GFD Project area.

The deeper Permian formations underlying the Bandanna Formation have low permeability and it is therefore considered unlikely that depressurisation of the Bandanna Formation will markedly affect the underlying formations.

The Bandanna Formation is generally isolated from the overlying main aquifers by the thick and low permeability mudstone units of the Rewan Group. Therefore, the depressurisation of the Bandanna Formation will generally be attenuated by those aquitard units. However, there is a narrow, north-south trending zone lying to the east of Injune, where the overlying Rewan Group and Clematis Sandstone have been eroded away prior to deposition of the Precipice Sandstone, bringing the Precipice Sandstone into direct contact with Bandanna Formation and underlying Permian formations.

Due to this unconformity, there is potentially a degree of hydraulic connection between the Bandanna Formation and the Precipice Sandstone in this area (QWC, 2012a). The area is now known to be smaller than the one published in the Surat UWIR (QWC, 2012a), which the current model assumes. This area of potential connection is to the south west of the Fairview gas field.

The Precipice Sandstone is separated from the overlying Hutton Sandstone by the Evergreen Formation, which is a thick aquitard. The Evergreen Formation is an effective seal recognised as a trap for conventional petroleum and gas resources. It is likely that depressurisation of the Bandanna Formation will be largely attenuated in the Precipice Sandstone and intervening Evergreen Formation, mitigating impacts on the overlying Hutton Sandstone (QWC, 2012a).

5.4 Groundwater-surface water interaction

An assessment of the environmental values of ecological systems that are dependent upon groundwater-surface interaction is presented in Section 6.1.2 which presents the occurrence of groundwater dependent ecosystems (GDEs) within the GFD Project area. In identifying the location, nature and environmental values of the GDEs, Section 6.1.2 describes the hydrogeological nature of groundwater-surface water interactions across the project in so far as they are relevant to approval of the proposed GFD Project.

In summary, however, groundwater – surface water interactions occur in the GFD Project area in three main forms:

- Discharge of groundwater to streams (watercourse or baseflow springs)
- Recharge of groundwater systems via leakage from streams
- Interaction between streams and associated alluvial groundwater resources.

Stream discharges in the GFD Project area typically show distinct seasonal variations with the majority of flow occurring during the summer wet months of December through March. Stream flows in the GFD Project area are predominately ephemeral, highly episodic and with discharges typically generated only as a result of significant runoff events.

Flow regimes for the largest catchments in the Project area, while semi-permanent, are still subject to prolonged periods of zero flow during the dry winter months or during periods of drought (URS, 2014). Prolonged periods of baseflow-dominated discharge are uncommon in the Project area except where watercourse springs occur such as near the Dawson River at Taroom and Utopia Downs. The watercourse springs in the GFD Project area that provide baseflow to streams are detailed in Section 6.1.2 and shown on Figure 6.3.

5.5 Groundwater levels and flow direction

Southern Central Queensland has a long history of economic development which has resulted in a steady expansion in the volume and rate of groundwater extracted, particularly for the agricultural sector in the region (DNRM, 2012). This long period of groundwater development has seen a marked decrease in groundwater pressure or levels within the sandstone aquifers and resulted in a large number of once artesian bores ceasing to flow within the GAB. During preparation of the Water Resource (Great Artesian Basin) Plan 2006, it was recognised that there was considerable uncertainty about trends in water resource conditions, and monitoring networks have since been installed to improve understanding (DNRM, 2012). Government initiatives to cap free flowing artesian bores have resulted in some restoration of pressure decreases in certain areas (DNRM, 2005).

Santos GLNG has installed a groundwater monitoring network for their current GLNG development in the GFD Project tenures. Groundwater level information is also available for DNRM monitoring bores installed within and adjacent to the GFD Project tenures. Figure 5.4 shows the groundwater monitoring network in and adjacent to the GFD Project tenures, including DNRM and Santos GLNG monitoring bores.

Table 5.2 presents the available groundwater level information in the GFD Project tenures by hydrogeological unit. Groundwater levels are shallowest in the alluvium, while the Gubberamunda Sandstone, Injune Creek Group and the Hutton Sandstone experience artesian conditions at some locations.

Table 5.2 Groundwater levels for hydrogeological units in and around GFD Project tenures (DNRM, 2013a and Santos GLNG, 2013a)

Formation	Groundwater or piezometric level (mbgs)
Alluvium	-19.2 to -2.0
Tertiary volcanics	-61.4 to -18.0
Bungil Formation	-144.0 to +16.5
Mooga Sandstone	-100.6 to +44.3
Orallo Formation	-54.5 to -10.0
Gubberamunda Sandstone	-133.2 to +54.5
Injune Creek Group [#]	-54.9 to +0.60
Hutton Sandstone	-118.6 to +21.30
Evergreen Formation	-110.5 to -7.0
Precipice Sandstone	-158.2 to 4.5
Moolayember Formation	-45.7
Clematis Sandstone	-21.1 to +46.8
Rewan Group	-54.9 to -18.3
Bandanna Formation	na

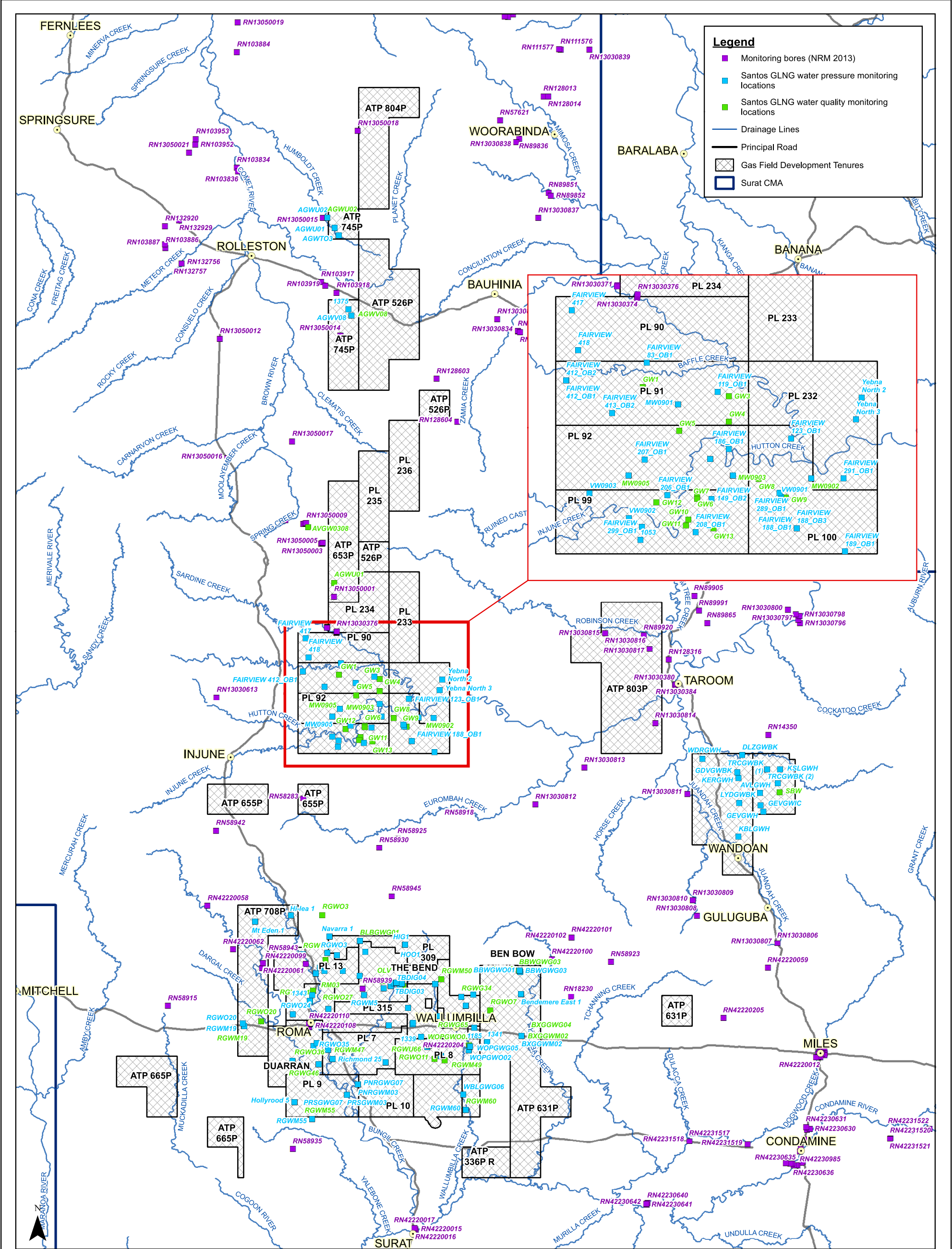
(1) na - not available.

(2) mbgs - metres below ground surface (positive groundwater levels indicate artesian heads).

(3) [#] includes Birkhead and Eurombah Formations.

Hydrographs presenting seasonal trends in groundwater levels for Santos GLNG monitoring bores installed in the Mooga Sandstone, Orallo Formation, Gubberamunda Sandstone, Springbok Sandstone and Westbourne Formation and the Precipice Sandstone are presented in Appendix B: Groundwater level data. Santos GLNG will install monitoring wells in GFD Project tenures in accordance with regulatory requirements.

Groundwater levels are influenced by seasonal variations as well as levels of groundwater extraction for water supply (irrigation, stock, domestic, industrial), conventional gas and non-conventional gas. Non-conventional gas development in the Bowen Basin commenced in 1995 and non-conventional gas development commenced in the Surat Basin commenced in 2002. Conventional oil and gas development has been occurring in parts of the Surat Basin such as near Roma since the late 1890's (Converge, 2014).



Groundwater level contour maps, created using calibrated model heads (QWC, 2012c), for aquifers in the GFD Project tenures are presented in Appendix B: Groundwater level data . In general, groundwater flow direction for the Surat Basin sediments follows the hydraulic gradient towards the south. Groundwater flow in the alluvium generally follows topography and the flow direction of the associated creek. Groundwater flow directions in the Bowen Basin are typically in an easterly direction. Detail on groundwater flow direction for each hydrogeological unit is provided in Section 5.2.

5.6 Hydrogeological parameters

A number of flow and pressure tests have been carried out on bores in the GFD Project tenures to determine the transmissivity for producing aquifers. Hydraulic parameters were estimated from static recovery tests (over 240 tests) and exploration tests. The hydraulic parameters characterising the formations are presented by QWC in the UWIR (2012a) report. A summary of results is presented in Table 5.3.

Table 5.3 Hydraulic properties of water bearing formations in the GFD Project tenures (QWC, 2012a)

Formation	Horizontal conductivity – range (m/day)	Horizontal conductivity – median (m/day)	Yield (L/s)*
Alluvium	$1.4 \times 10^{-1} - 1.5 \times 10^3$	8.6	1.30 – 17.70
Tertiary volcanics	$2.0 \times 10^{-2} - 6.8$	5.4×10^{-1}	0.50 – 2.52
Bungil Formation/ Mooga Sandstone	$2.8 \times 10^{-5} - 5.4$	4.1×10^{-2}	na
Orallo Formation	$9.3 \times 10^{-5} - 5.9$	3.0×10^{-1}	na
Gubberamunda Sandstone	$3.7 \times 10^{-3} - 3.3 \times 10^1$	8.5×10^{-1}	na
Westbourne Formation	$1.9 \times 10^{-5} - 4.6$	1.0×10^{-2}	na
Springbok Sandstone	$1.7 \times 10^{-6} - 4.1$	4.1×10^{-3}	na
Walloon Coal Measures – aquitards	$2.6 \times 10^{-6} - 1.5$	1.0×10^{-2}	0.4 – 15.75 [#]
Walloon Coal Measures – coal seams	$8.3 \times 10^{-5} - 2.2$	7.8×10^{-2}	
Hutton Sandstone	$8.3 \times 10^{-6} - 1.3 \times 10^1$	5.0×10^{-2}	0.01 – 9.00
Evergreen Formation	$4.3 \times 10^{-6} - 6.9$	3.4×10^{-3}	na
Precipice Sandstone	$2.6 \times 10^{-6} - 2.3 \times 10^1$	2.0×10^{-2}	9.19 – 9.90
Moolayember Formation	$8.3 \times 10^{-6} - 1.0 \times 10^1$	1.6×10^{-3}	na
Clematis Sandstone	$8.3 \times 10^{-6} - 5.5 \times 10^1$	2.7×10^{-2}	na
Rewan Group	$8.3 \times 10^{-6} - 1.9$	3.6×10^{-4}	0.01 – 1.20
Bandanna Formation	$8.3 \times 10^{-6} - 7.8$	1.0×10^{-3}	na

(1) na - not available, * sourced from DNR database for bores located in GFD Project tenures.

(2) # Birkhead and Eurombah Formations.

Santos GLNG also conducted packer testing in the field and constant head testing in the laboratory to assess hydraulic properties of the Mooga Sandstone, Orallo Formation, Gubberamunda Sandstone and Westbourne Formation in the GFD Project tenures. Packer testing has been performed at three locations: The Bend, Ben Bow and Duarran (shown on Figure 5.4). A summary of the results is presented in Table 5.4. The Gubberamunda Sandstone has the highest horizontal hydraulic conductivity of the four formations. Horizontal hydraulic conductivities are generally one to four orders of magnitude greater than vertical hydraulic conductivities.

Table 5.4 Hydraulic properties of water bearing formations in GFD Project tenures (Santos GLNG, 2013d)

Location	Formation	Depth (mbgl)	Estimated horizontal hydraulic conductivity (m/day) from Packer testing	Horizontal hydraulic conductivity (m/day)	Vertical hydraulic conductivity (m/day) from constant head testing
The Bend	Mooga Sandstone	55.00-55.06	na	9×10^{-3}	8×10^{-4}
		158.50-158.56	na	8×10^{-2}	3×10^{-3}
	Orallo Formation	198.00-200.15	$<9 \times 10^{-4}$	na	na
		219.06-219.06	na	2×10^{-1}	9×10^{-7}
		228.00-230.15	2×10^{-2}	na	na
	Gubberamunda Sandstone	238.00-240.15	2×10^{-1}	na	3×10^{-1}
		258.00-260.15	2×10^{-1}	na	na
		264.50-264.57	na	7×10^{-6}	9×10^{-5}
		283.70-283.78	na	na	2×10^{-5}
	Westbourne Formation	268.40-270.70	$<9 \times 10^{-4}$	na	5×10^{-6}
Ben Bow	Orallo Formation	233.70-233.90	na	na	2×10^{-5}
		246.80-247.00	na	na	6×10^{-5}
	Gubberamunda Sandstone	254.00-254.20	na	5×10^{-2}	5×10^{-4}
		267.10-267.40	na	4×10^{-3}	3×10^{-4}
		271.30-271.50	na	3×10^{-3}	4×10^{-1}
	Westbourne Formation	316.00-318.15	$<9 \times 10^{-4}$	na	na
		321.20-321.30	na	na	4×10^{-6}
		330.30-330.50	na	na	4×10^{-5}
		331.00-333.50	$<9 \times 10^{-4}$	na	na
Duarran	Gubberamunda Sandstone	487.50-487.56	na	na	6×10^{-6}
		531.00-231.03	na	3×10^{-2}	3×10^{-1}
		535.00-535.04	na	7×10^{-4}	2×10^{-5}
		538.00-538.04	na	3×10^{-6}	2×10^{-5}
	Westbourne Formation	586.00-586.06	na	na	2×10^{-5}
		599.00-599.06	na	na	1×10^{-6}

(1) na – not available.

Santos GLNG also conducted two constant rate pumping tests for the Roma Managed Aquifer Recharge (MAR) trial at two wells ('2i' and '4i') at The Bend to estimate aquifer transmissivity and storativity of the Gubberamunda Sandstone aquifer (URS, 2013b). The results confirmed the heterogeneity of the Gubberamunda Sandstone and are presented in Table 5.5.

Table 5.5 Summary of Gubberamunda Sandstone aquifer hydraulic characteristics (URS, 2013b)

Location	Transmissivity (m ² /day)	Storativity
Representative of Gubberamunda Sandstone proximal to well '2i' (early time data)	20 to 40	$\sim 10 \times 10^{-3}$
Representative of Gubberamunda Sandstone regional to well '2i' (late time data)	65 to 75	$\sim 1 \times 10^{-4}$
Representative of Gubberamunda Sandstone regional to well '4i' (early and late time data)	75 to 85	$\sim 1 \times 10^{-4}$

5.7 Groundwater quality

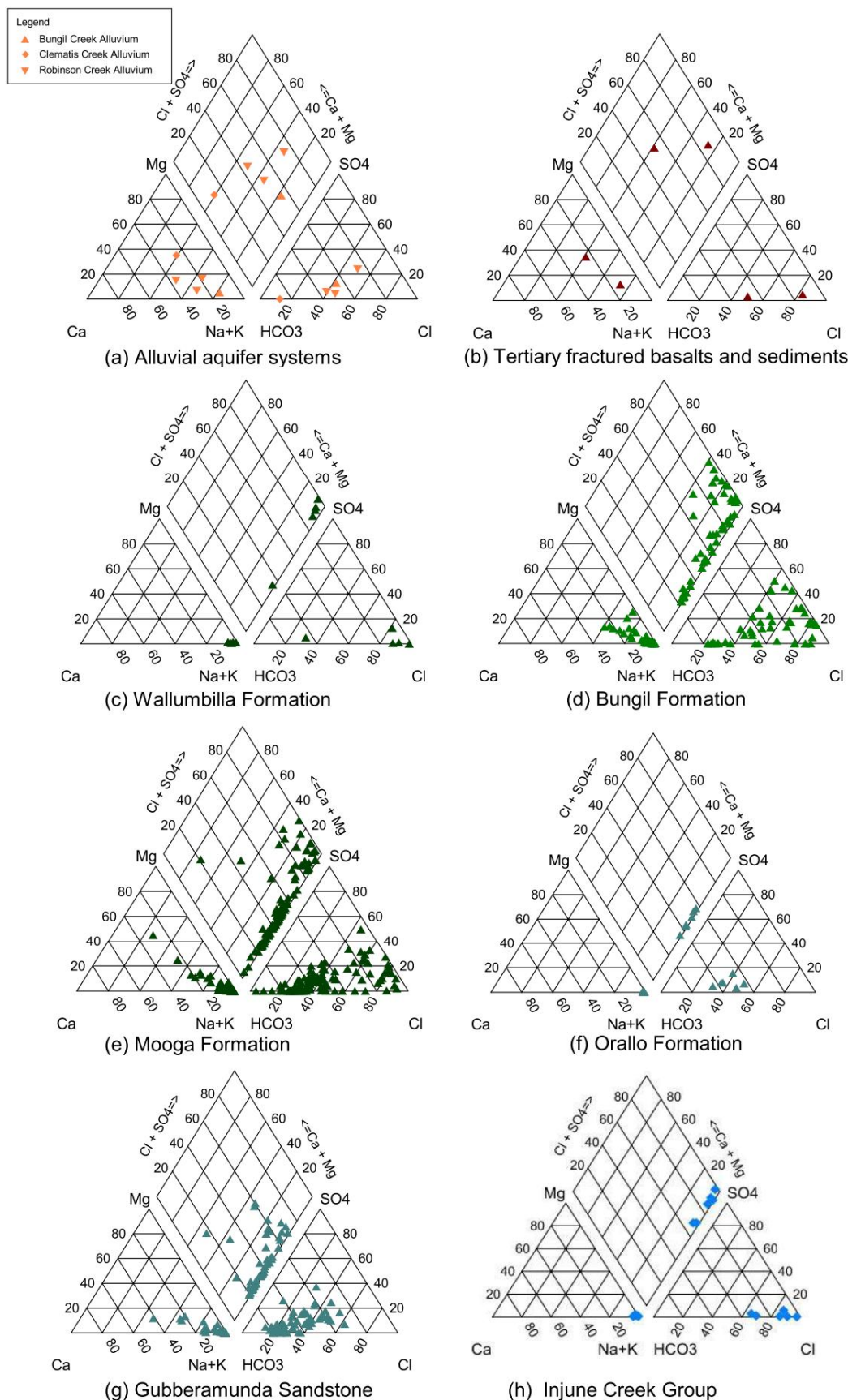
Groundwater quality for hydrogeological formations relevant to GFD Project activities was assessed using the following data:

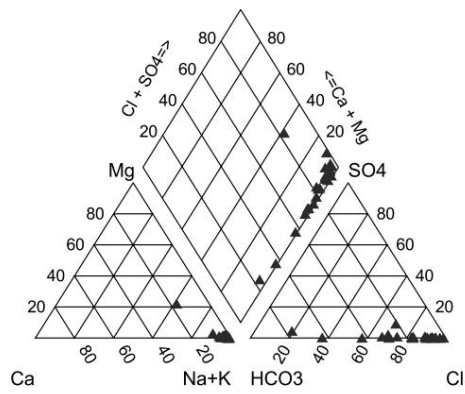
- groundwater baseline assessment data, provided by Santos GLNG in June 2013 (Baseline Assessment Manager) (Santos GLNG, 2013a)
- groundwater monitoring network data, provided by Santos GLNG in June 2013 (Envirosys) (Santos GLNG, 2013a)
- available groundwater quality data in the DNRM database, provided by DNRM in May 2013 (DNRM, 2013a).

The use of these three datasets provides representative groundwater quality data for the relevant hydrogeological units in the GFD Project tenures. Groundwater monitoring data provided by Santos GLNG covers the GLNG upstream Project areas, including the GFD Project tenures. Ionic charge balance was used to calculate bicarbonate concentrations in cases where bicarbonate was not reported. Major ion chemistry for groundwater samples for each of the relevant hydrogeological units in the GFD Project tenures is presented in piper diagrams (Figure 5.5). A piper diagram is a graphical representation of the major ion chemistry of a water sample and can be used to graphically show the general water characteristics in terms of major ion concentrations (Ca^{2+} , Mg^{2+} , Na^{2+} , K^{+} , Cl^{-} , HCO_3^{-} , and SO_4^{2-}).

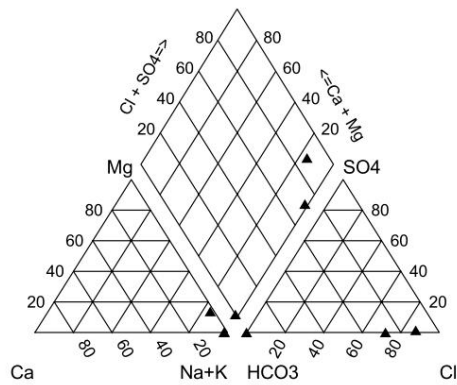
EC and pH for groundwater samples for each of the relevant hydrogeological units in the GFD Project tenures is presented in Figure 5.6 in stratigraphic order. Water bearing units are shown in blue, aquitards in light grey and coal measures in dark grey. Groundwater quality results are also summarised in Table 5.6.

Figure 5.5 Piper plots for each of the relevant hydrogeological units in the GFD Project tenures

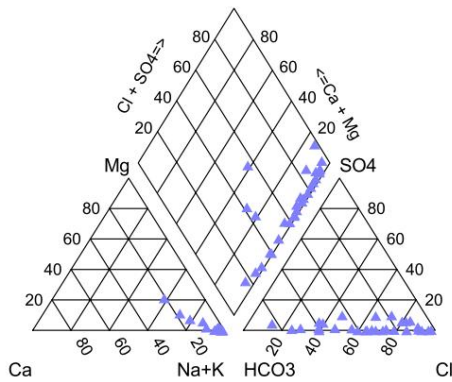




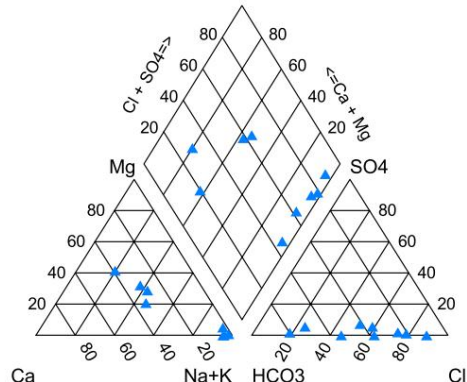
(i) Walloon Coal Measures



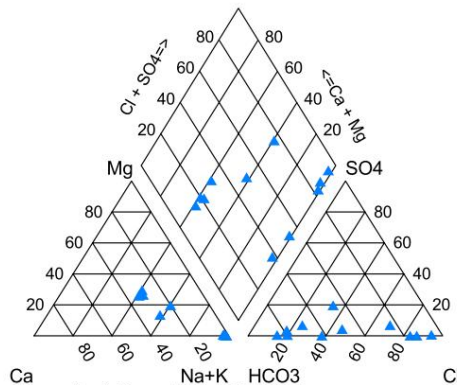
(j) Eurombah Formation



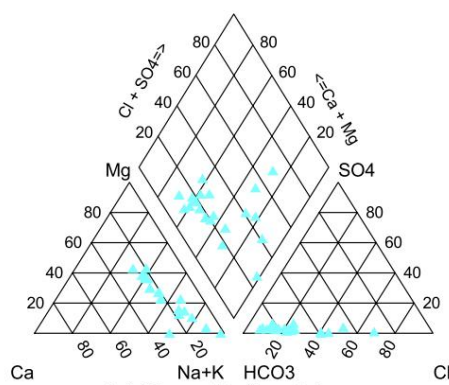
(k) Hutton Sandstone



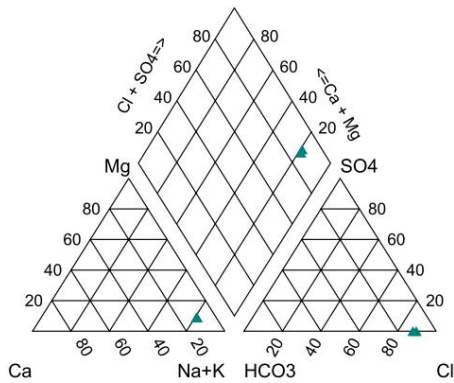
(l) Evergreen Formation



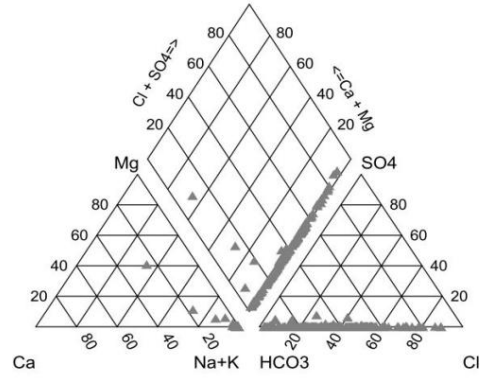
(m) Precipice Sandstone



(n) Clematis Sandstone



(o) Rewan Group



(p) Bandanna Formation

Figure 5.6 Water quality for hydrogeological units in the GFD Project tenures (in stratigraphic order)

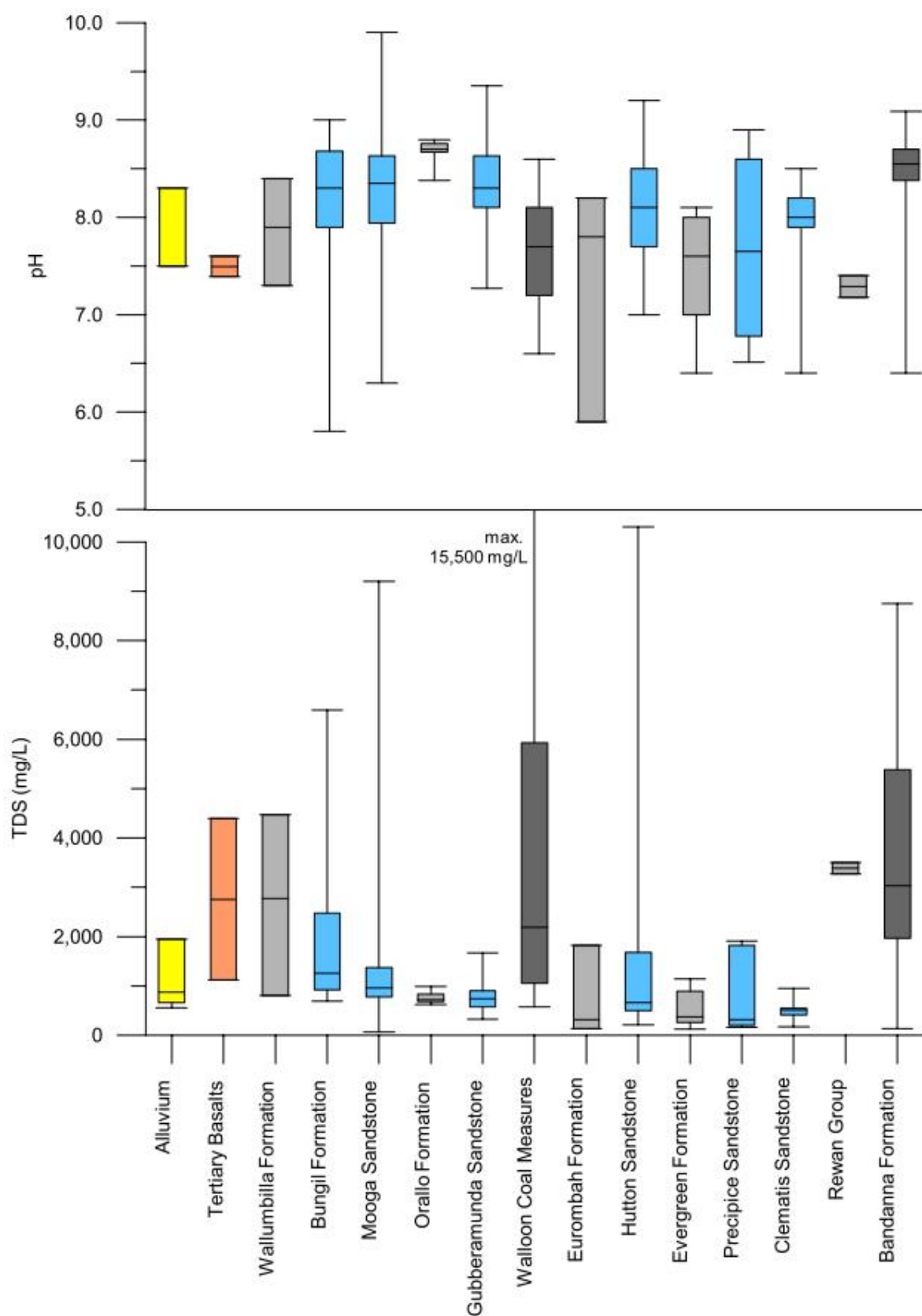


Table 5.6 Groundwater quality summary for each of the relevant hydrogeological units (median (range))

Parameter	Unit	Alluvium	Tertiary Basalts	Bungil Formation	Mooga Sandstone	Gubberamunda Sandstone	Injune Creek Group	Walloon Coal Measures	Hutton Sandstone
pH	pH units	7.5 (7.5-8.3)	7.4-7.6*	8.3 (5.8-9.0)	8.4 (6.3-9.9)	8.3 (7.3-9.4)	8.1 (7.4-9.1)	7.7 (6.6-8.6)	8.1 (7.0-9.2)
Conductivity	µS/cm	1,530 (955-2,500)	2,100-7,510*	1,650 (1,161-8,000)	1,550 (121-10,000)	1,195 (542-2,700)	6,460 (2,700-9,000)	3,700 (935-23,400)	1,090 (367-16,000)
Fe	mg/L	na	<0.05^	0.08 (0.01-4.00)	0.04 (0.01-1.15)	0.06 (0.01-6.09)	0.35^	0.04 (0.02-0.05)	0.04 (0.02-5.06)
Mn	mg/L	na	0.002^	0.010 (0.002-0.14)	0.010 (0.002-0.053)	0.010 (0.002-0.172)	0.043^	0.065 (0.02-0.11)	0.022 (0.01-0.758)
Parameter	Unit	Precipice Sandstone	Clematis Sandstone	Wallumbilla Formation	Orallo Formation	Eurombah Formation	Evergreen Formation	Rewan Group*	Bandanna Formation
pH	pH units	7.7 (6.5-8.9)	8.0 (6.4-8.5)	7.9 (7.3-8.4)	8.7 (8.4-8.8)	7.8 (5.9-8.2)	7.6 (6.4-8.1)	7.2-7.4	8.6 (6.4-9.1)
Conductivity	µS/cm	557 (305-3,360)	870 (350-1,250)	4,535 (1,450-8,633)	1,220 (944-1,640)	1,100 (230-3,350)	730 (240-2,130)	5,760-6,260	4,057 (143-14,200)
Fe	mg/L	0.33 (0.04-1.93)	0.01 (0.01-0.60)	0.10 (0.03-0.16)	0.18 (0.12-0.30)	0.09^	0.6 (0.1-10.0)	na	0.16 (<0.05-27.00)
Mn	mg/L	0.083 (0.01-0.148)	0.01 (0.01-0.04)	0.030 (0.01-0.69)	0.009 (0.002-0.026)	0.03-0.08^	na	0.046-0.49	0.005 (0.001-0.350)

(1) Data sourced from DNRM (2013a) and Santos GLNG (2013a) databases.

(2) na = no data available.

(3) * Median not calculated as only 2 samples.

(4) ^ Only 1 sample available.

5.7.1 Alluvial aquifer systems

Groundwater quality data for the alluvial system is derived from 5 bores located in the Roma and Scotia gas fields. Hydrochemical results indicate alluvial groundwater quality is typically fresh, with a median electrical conductivity (EC) of 1,530 microsiemens per centimetre ($\mu\text{S}/\text{cm}$) (Table 5.6). The dominant ions are Na^+ , Ca^{2+} , HCO_3^- and Cl^- (Figure 5.5).

5.7.2 Tertiary fractured basalts and sediments

Groundwater quality data for the Tertiary basalts is available near Rolleston (GFD Project tenure ATP 745P). Hydrochemical results indicate groundwater associated with Tertiary basalts in this area is typically brackish (Table 5.6). The dominant ions are Na^+ , Mg^{2+} , Ca^{2+} , Cl^- and HCO_3^- (Figure 5.5). Groundwater quality associated with Tertiary sediments is brackish, with an EC of 12,360 $\mu\text{S}/\text{cm}$. The dominant ions are Na^+ and Cl^- .

5.7.3 GAB water bearing units

Bungil Formation

Groundwater quality data for the Bungil Formation is only available in the Roma area near outcrop. Hydrochemical results indicate that groundwater from the Bungil Formation is typically brackish, with a median EC value of 1,650 $\mu\text{S}/\text{cm}$ (Table 5.6). The dominant ions are Na^+ , Cl^- and HCO_3^- (Figure 5.5). Dissolved metal concentrations in the Bungil Formation are typically low, with the exception of elevated iron concentrations.

Mooga Sandstone

Groundwater quality data for the Mooga Sandstone is only available in the Roma area. Hydrochemical results indicate the Mooga Sandstone groundwater is fresh to brackish, with a median electrical conductivity value of 1,550 $\mu\text{S}/\text{cm}$ (Table 5.6). The dominant ions are Na^+ , Cl^- and HCO_3^- (Figure 5.5).

Gubberamunda Sandstone

Groundwater quality data for the Gubberamunda Sandstone is only available in the Roma area. Hydrochemical results indicate the Gubberamunda Sandstone groundwater quality is typically fresh, with a median EC value of 1,195 $\mu\text{S}/\text{cm}$ (Table 5.6). The dominant ions are Na^+ and HCO_3^- (Figure 5.5). Dissolved metal concentrations are typically low, although some locations have elevated dissolved iron and manganese concentrations.

Springbok Sandstone (Injune Creek Group)

Groundwater quality data was not available for the Springbok Sandstone in the GFD Project tenures to provide an assessment, however groundwater quality data was available for the Injune Creek Group, including the Westbourne Formation and Springbok Sandstone, from the DNRM database. Groundwater quality specifically for the Walloon Coal Measures was not included in the Injune Creek Group summary statistics.

Hydrochemical results indicate the Injune Creek Group groundwater quality is typically brackish, with a median conductivity of 6,460 $\mu\text{S}/\text{cm}$ (Table 5.6). The piper diagram (Figure 5.5) shows that the dominant ions are Na^+ , Cl^- and HCO_3^- .

Walloon Coal Measures

Groundwater quality data for Walloon Coal Measures is available in the Scotia and Roma areas. Hydrochemical results indicate the groundwater is typically brackish, with a median EC value of

3,700 $\mu\text{S}/\text{cm}$ (Table 5.6). The dominant ions are Na^+ , Cl^- and HCO_3^- (Figure 5.5). Dissolved metal concentrations are typically low. .

Hutton Sandstone

Groundwater quality data for the Hutton Sandstone is available in the Scotia, Fairview and Roma areas. Hydrochemical results indicate the groundwater quality is typically fresh to brackish, with a median EC value of 1,090 $\mu\text{S}/\text{cm}$ (Table 5.6). The dominant ions are Na^+ , Cl^- and HCO_3^- (Figure 5.5). Dissolved metal concentrations are typically low, although some locations have elevated dissolved metal concentrations, including iron and manganese.

Precipice Sandstone

Groundwater quality data for the Precipice Sandstone is available in the Scotia, Fairview and Roma areas. Hydrochemical results indicate groundwater quality is slightly alkaline, with a median EC value of 557 $\mu\text{S}/\text{cm}$ (Table 5.6). The dominant ions are Na^+ , HCO_3^- and Cl^- (Figure 5.5). Dissolved metal concentrations are typically low, with the exception of elevated iron concentrations.

Clematis Sandstone

Groundwater quality data for the Clematis Sandstone is available in the Arcadia and Roma areas. Groundwater is typically fresh, with a median EC of 870 $\mu\text{S}/\text{cm}$ (Table 5.6). The dominant ions are Na^+ , HCO_3^- , Cl^- and Ca^{2+} at some locations (Figure 5.5). Dissolved metal concentrations are typically low, with the exception of elevated iron concentrations at some locations.

5.7.4 GAB aquitards

Wallumbilla Formation

Groundwater quality data for the Wallumbilla Formation is available in the Roma area. Groundwater quality ranges from fresh to saline, with a median EC of 4,535 $\mu\text{S}/\text{cm}$ (Table 5.6). The dominant ions are Na^+ and Cl^- (Figure 5.5). Dissolved metal concentrations are typically low, with the exception of elevated manganese concentrations at some locations.

Orallo Formation

Groundwater quality data for the Orallo Formation is available in the Roma area. Hydrochemical results indicate groundwater is fresh to brackish, with a median EC of 1,220 $\mu\text{S}/\text{cm}$ (Table 5.6). The dominant ions are Na^+ , HCO_3^- and Cl^- (Figure 5.5). Dissolved metal concentrations are typically low.

Westbourne Formation of the Injune Creek Group

Groundwater quality data was not available for the Westbourne Formation in the GFD Project tenures to provide an assessment, however groundwater quality data was available for the Injune Creek Group (which comprises the Westbourne Formation and Springbok Sandstone) from the DNRM database. Data for the Injune Creek Group are provided in the Springbok Sandstone section of Section 5.7.3.

Eurombah Formation of the Injune Creek group

Groundwater quality data for the Eurombah Formation is available for the Scotia area. Groundwater is typically fresh to brackish, with a median EC of 1,100 $\mu\text{S}/\text{cm}$ (Table 5.6). The dominant ions are Na^+ and Cl^- (Figure 5.5).

Evergreen Formation

Groundwater quality data for the Evergreen Formation is available in the Scotia and Fairview areas. Hydrochemical results indicate the groundwater is typically fresh, with a median EC of 730 $\mu\text{S}/\text{cm}$ (Table 5.6). The dominant ions are Na^+ , Cl^- and HCO_3^- and at some locations Ca^{2+} and Mg^{2+} (Figure 5.5).

Moolayember Formation

Insufficient groundwater quality data was available for the Moolayember Formation in the GFD Project tenures to provide an assessment. However, the Moolayember Formation groundwater quality is recognised as typically fresh, although can be brackish to saline in parts; dominated by Na^+ , HCO_3^- and Cl^- (URS, 2009).

Rewan Group

Groundwater quality data for the Rewan Group is available in the Arcadia area. Hydrochemical results indicate groundwater is saline (Table 5.6). The dominant ions are Na^+ , and Cl^- (Figure 5.5).

5.7.5 Hydrogeological units underlying the GAB

Bandanna Formation

Groundwater quality data for Walloon Coal Measures are available in the Fairview gas field. Hydrochemical results indicate the groundwater is typically brackish, with a median EC of 4,057 $\mu\text{S}/\text{cm}$ (Table 5.6). The dominant ions are Na^+ , Cl^- and HCO_3^- (Figure 5.5). Dissolved metal concentrations are typically low.

6. Receptors and environmental values

This section identifies sensitive groundwater receptors and the groundwater EVs in the Surat CMA and GFD Project tenures.

6.1 Sensitive groundwater receptors

The sensitive groundwater receptors in the Surat CMA and GFD Project tenures are:

- users that access groundwater from hydrogeological units for domestic water supplies and stock watering, and to a lesser extent, agriculture, aquaculture, urban and industrial purposes
- ecosystems dependent on groundwater from springs, including spring vents and watercourse springs which provide baseflow to streams.

OGIA (2013a) provided the data on landholder bores and springs that was used in this study, including interpretation of screened formation/source aquifer.

6.1.1 Hydrogeological units used for water supply

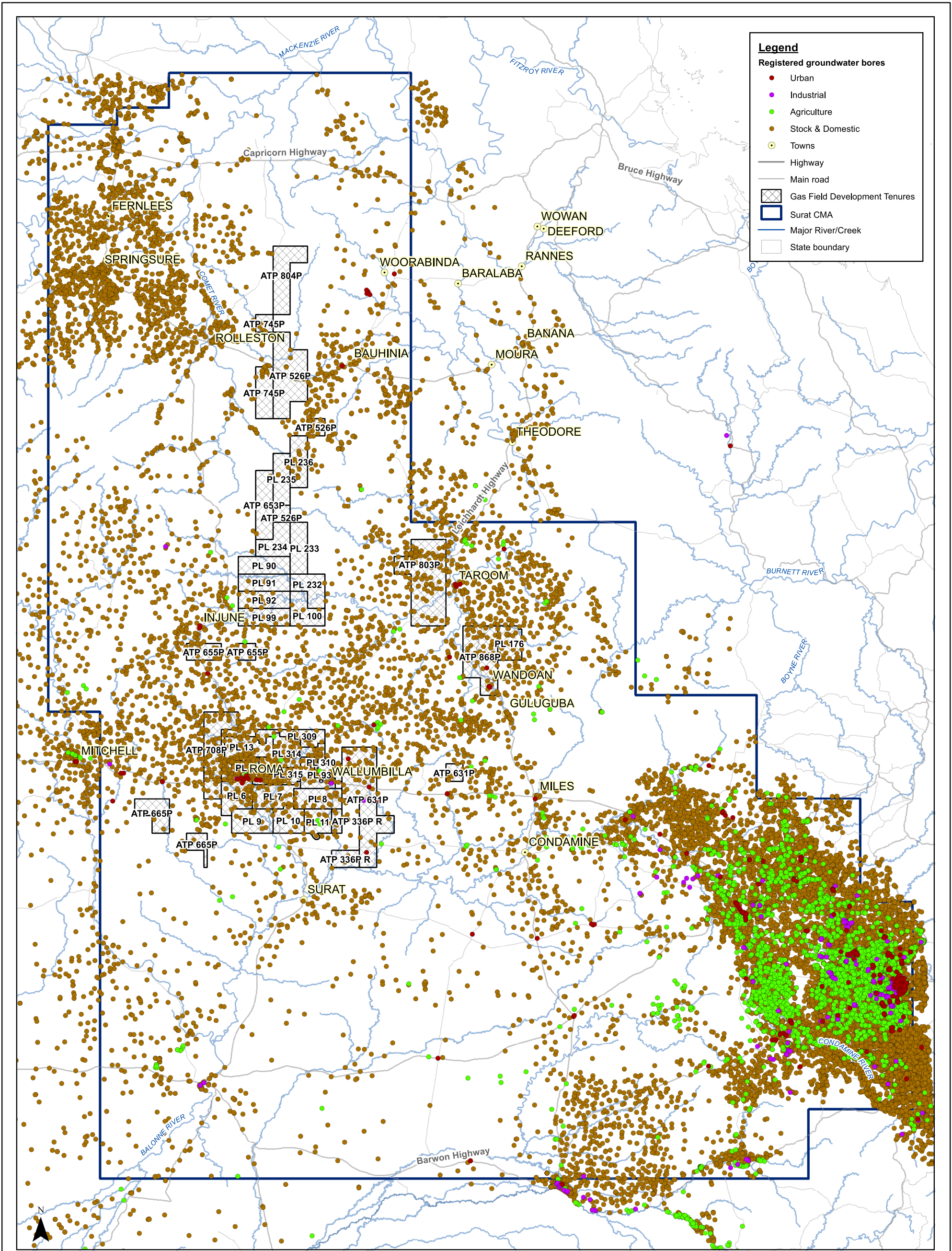
Groundwater bores in Queensland are registered in the DNRM groundwater database, and water licence information is recorded in the Water Management System (WMS). The bore data provided by the OGIA (2013a) for this assessment was originally sourced from the DNRM groundwater database and WMS.

Groundwater used for petroleum and gas production is exempt from requiring a water licence and is not considered in this section.

Groundwater users in the Surat CMA

The UWIR indicates there are approximately 21,000 water bores in the Surat CMA, which are used for stock, domestic, agriculture, urban and industrial purposes and extract around 215,000 ML/year (including 85,000 ML/year from GAB formations) (QWC, 2012a). Of that about 80,000 ML/year is used for stock and domestic purposes, and about 105,000 ML/year is used for agricultural use, with the remainder for urban and industrial use (QWC, 2012a).

The spatial distribution of registered landholder bores in the Surat CMA and their use is shown on Figure 6.1. There could also be unregistered bores located within the Surat CMA.



Groundwater users in GFD Project tenures

The OGIA (2013a) bore data indicates that of the 21,000 registered landholder bores in the Surat CMA, 872 are located within GFD Project tenures. The number of registered bores in each hydrogeological unit in GFD Project tenures, and the volume of take estimated by the OGIA, are provided in Table 6.1. Most registered bores in GFD Project tenures take groundwater from the Mooga Sandstone. There are no registered bores screened in the Bandanna Formation in GFD Project tenures.

Table 6.1 Number of registered bores per hydrogeological unit in GFD Project tenures (OGIA, 2013a)

Hydrogeological unit	Number of registered bores	Volume of estimated take (ML/year)	Gas fields	GFD Project tenures
Alluvium	29	87	Arcadia, Scotia, Roma	ATP 803P, ATP 868P, PL 3, PL 13, PL 236
Cainozoic Sediments	6	18	Arcadia, Roma	ATP 526P, ATP 745P, PL 3
Tertiary Volcanics	8	24	Arcadia	ATP 745P
Wallumbilla Formation	18	88	Roma	PL 3, ATP 631P, ATP 708P, PL 10, PL 6, PL 7, PL 9
Bungil Formation	107	649	Roma	ATP 336P R, ATP 631P, ATP 665P, ATP 708P, PL 10, PL 11, PL 13, PL 176, PL 3, PL 310, PL 314, PL 315, PL 6, PL 7, PL 8, PL 9
Mooga Sandstone	262	1,459	Roma	ATP 336P R, ATP 631P, ATP 665P, ATP 708P, PL 10, PL 11, PL 13, PL 3, PL 309, PL 310, PL 314, PL 315, PL 6, PL 7, PL 8, PL 9
Mooga Sandstone and Springbok Sandstone	1	13	Roma	PL 6
Orallo Formation	13	65	Roma	ATP 708P, PL 13, PL 3, PL 309, PL 314, PL 6, PL 7
Gubberamunda Sandstone	153	1,869	Roma	ATP 336P R, ATP 631P, ATP 708P, PL 13, PL 3, PL 309, PL 310, PL 314, PL 315, PL 6, PL 7, PL 8, PL 9, PL 93
Gubberamunda Sandstone and Precipice Sandstone	1	13	Roma	PL 6
Birkhead Formation	1	5	Scotia	PL 176
Walloon Coal Measures	61	337	Fairview, Scotia, Roma	ATP 655P, ATP 708P, ATP 803P, ATP 868P, PL 176, PL 3, PL 309, PL 314, PL 6
Eurombah Formation	4	46	Scotia	ATP 803P, ATP 868P
Hutton Sandstone	94	1,198	Fairview, Scotia, Roma	ATP 655P, ATP 803P, ATP 868P, PL 10, PL 100, PL 13, PL 176, PL 309, PL 314, PL 315,

Hydrogeological unit	Number of registered bores	Volume of estimated take (ML/year)	Gas fields	GFD Project tenures
				PL 6, PL 9, PL 99
Evergreen Formation	30	150	Fairview, Scotia, Roma	ATP 655P, ATP 803P, PL 100, PL 176, PL 314, PL 91, PL 92, PL 99
Precipice Sandstone	28	389	Fairview, Scotia, Roma	ATP 655P, ATP 708P, ATP 803P, ATP 868P, PL 13, PL 176, PL 3, PL 6, PL 91, PL 92, PL 99
Moolayember Formation	2	14	Arcadia, Roma	PL 3, PL 236
Clematis Sandstone	45	378	Arcadia, Scotia, Roma	ATP 526P, ATP 653P, ATP 803P, PL 11, PL 235, PL 236, PL 3
Rewan Group	9	45	Arcadia	ATP 653P, ATP 745P
Total	872	6,856		

Registered bore data (OGIA, 2013a) indicates that groundwater in GFD Project tenures is mainly used for stock and domestic supply and to a lesser extent for agriculture (including irrigation and intensive stock watering), urban supply and industrial purposes. The number of bores used for stock and domestic, agriculture, urban and industrial purposes is provided in Table 6.2.

The total volume of groundwater taken from registered bores in GFD Project tenures is estimated to be 6,856 ML/year (OGIA, 2013a). Estimated annual volumes of groundwater take by purpose are provided in Table 6.2 and Figure 6.2.

Table 6.2 Volume of groundwater extracted across the GFD Project tenures (OGIA, 2013a*)

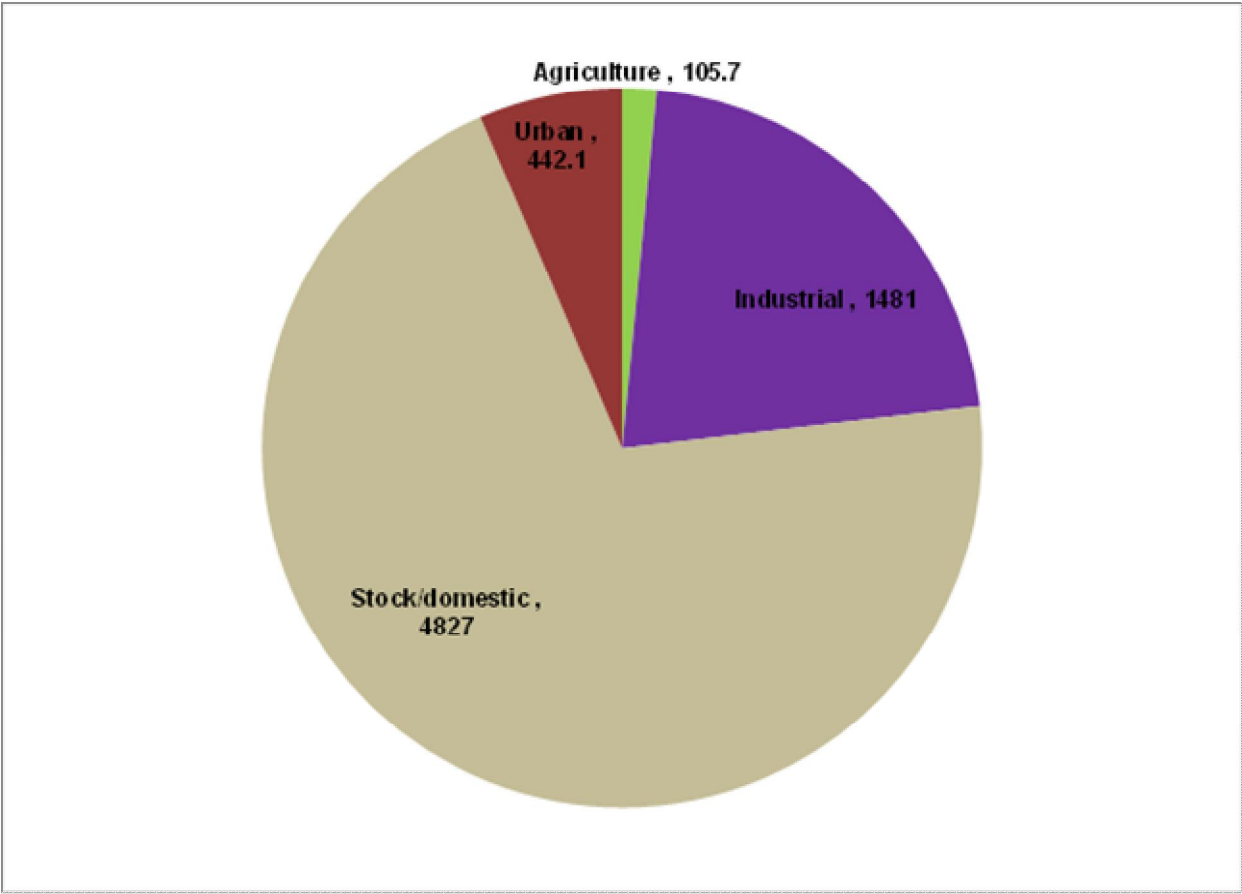
Registered use	Stock/Domestic	Agriculture	Urban	Industrial
Number of bores	842	6	18	6
Total annual volume (megalitres per year (ML/year))	4,827^	105.7	442.1	1,481
Average annual volume per bore (ML/year)	5.7	17.6	24.6	246.8

(1) Groundwater taken for petroleum and gas production not presented.

(2) * Bore data provided by the OGIA (2013a) was originally sourced from the DNRM groundwater database and WMS.

(3) ^ Stock/domestic volumes estimated by the OGIA where not licensed.

Figure 6.2 Estimated volume of take for registered bores in GFD Project tenures (ML/year)



6.1.2 Springs

Groundwater dependent ecosystems (GDEs) are communities of plants, animals and other organisms that depend on groundwater for survival (Department of Land and Water Conservation, 2002). A GDE may be either entirely dependent on groundwater for survival, or may use groundwater opportunistically or for a supplementary source of water (Hatton and Evans, 1998). Within the Surat CMA and GFD Project tenures, the main types of GDEs are spring vents (grouped into complexes) and watercourse springs fed by natural discharge from aquifers of the GAB.

A spring vent is a single point in the landscape where groundwater is discharged at the surface. A spring vent can be mounded or flat and may be represented by wetland vegetation with no visible water at the location of the spring. Spring vents can form in locations including where there is a change in geology or permeability, a geologic structure provides a path to the surface or there is thinning of a confining layer (QWC, 2012a).

A group of spring vents located in close proximity to each other is called a spring complex. Spring vents in a spring complex are located in similar geology, are connected to the same source aquifer, and individual vents are never more than 6 km apart (QWC, 2012a).

A watercourse spring is a section of a watercourse where groundwater enters the stream from a GAB aquifer through the streambed. This type of spring is also referred to as a baseflow fed watercourse (QWC, 2012a). Watercourse springs provide baseflow to streams and support in-stream aquatic ecosystems, and may be of particular ecological importance during periods of low rainfall.

The regulatory framework in Queensland through the UWIR considers all potentially affected springs as a result of water extraction by petroleum tenure holders in the Surat CMA and implements a Spring Impact Management Strategy for those springs at risk of impact.

Spring vents in the Surat CMA

There are 72 spring complexes comprising 329 spring vents in the Surat CMA (OGIA, 2013a) (listed in Appendix C1 and shown on Figure 6.3). The UWIR identified 71 spring complexes comprising 330 spring vents, however this has since been revised by the OGIA because four of the spring vents in the original data set could not be found during field investigations (x346, x380, x381 and x431) and new spring vents within identified spring complexes have been recorded.

Some spring vents in the Surat CMA are of conservation significance as they provide unique ecological habitats and may be associated with a range of cultural heritage values. The need to protect the unique species associated with these springs has been recognised under:

- The *Environment Protection Biodiversity Conservation Act 1999* (Cth) (EPBC Act).
- The *Nature Conservation Act 1992* (Qld) (NC Act).

This legislation recognises and lists both individual species associated with springs and ecological communities of native species dependent on springs (QWC, 2012a).

Table 6.3 provides a summary of the listings under these statutes for springs in the Surat CMA (Fensham et al., 2012).

Table 6.3 Summary of springs vents in the Surat CMA with EPBC Act and NC Act listings (QWC, 2012a)

Listed species/ community	Conservation status		Number of springs complexes associated with the listing in the Surat CMA (spring vents)*
	EPBC Act	NC Act	
The community of native species dependent on natural discharge of groundwater from the GAB	Endangered		10 (92)
<i>Eriocaulon carsonii</i>	Endangered	Endangered	5 (17)
<i>Myriophyllum artesium</i>	-	Endangered	1 (5)
<i>Arthraxon hispidus</i>	Vulnerable	Vulnerable	2 (17)
<i>Phaius australis</i>	Endangered	Endangered	1 (1)
<i>Thelypteris confluent</i>	-	Vulnerable	1 (2)
<i>Livistona nitida</i>	-	Near threatened	3 (7)

(1) * The number in the bracket represents the total number of spring vents within the complexes.

Within the Surat CMA, there are 94 spring vents contained in 12 spring complexes that are associated with an EPBC Act listing (OGIA, 2013a) (Appendix C1). Of these, 92 spring vents (in 10 spring complexes) are described as RE 11.3.22, which corresponds to the EPBC Act listed 'community of native species dependant on natural discharge of groundwater from the GAB' (Fensham et al., 2012).

The Queensland Herbarium provides conservation rankings for spring vents in the Surat CMA. The conservation rankings are described in Table 6.4 and are provided for each spring vent in Appendix C1.

Table 6.4 Conservation ranking for GAB springs (adopted from Fensham et al., 2012)

Conservation ranking	Description
Category 1a	Contains at least one GAB endemic species not known from another location beyond this spring complex.
Category 1b	Contains endemic species known from more than one spring complex; or has populations of threatened species listed under State or Commonwealth legislation that do not conform to Category 1a.
Category 2	Provides habitat for populations of plant and/or animal species not known from habitat other than spring wetlands within 250km.
Category 3	Spring wetland vegetation without isolated populations (Category 2) with at least one native plant species that is not a widespread coloniser of disturbed areas (Appendix D: Potential impact maps).
Category 4a	Spring wetland vegetation comprised of exotic and/or only native species that are wide spread colonisers of disturbed areas (Appendix D: Potential impact maps).
Category 4b	The original spring wetland is destroyed by impoundment or excavation. The probability of important biological values being identified in the future is very low.
Category 5	All springs inactive.

Spring vents in the GFD Project tenures

There are 11 spring complexes within GFD Project tenures. The complexes, their vents and conservation ranking are listed in Table 6.5.

Table 6.5 Spring vents located in GFD Project tenures

Complex number	Complex name	Vent number	Source aquifer(s)	Gas field	EPBC Act	Conservation Ranking
78	78	551, 552	Clematis Sandstone	Arcadia	X	3
229*	Ponies	284	Hutton Sandstone	Fairview	X	2
230	Lucky Last	287, 340, 686, 687, 687.1, 687.2, 687.3, 687.4, 687.5, 687.6, 688, 689	Evergreen Formation (Boxvale Sandstone), Precipice Sandstone	Fairview	✓	1b
308	308	nv383	Clematis Sandstone	Arcadia	X	-
311	311	499, 500, 500.1, 535, 536, 536.1, 536.2, 537, 692, 693, 694, 695, 696, 697, 698, 699, 704	Precipice Sandstone	Fairview	X	2
327	327	nv385	Precipice Sandstone	Fairview	X	-
507^	VI_mile	188, 679, 680, 680.1	Gubberamunda Sandstone	Roma	X	4b
561	Spring Rock Creek	285	Evergreen Formation (Boxvale Sandstone), Precipice Sandstone	Fairview	X	3
583@	Lenore Hills	nv621	Tertiary Volcanics, Clematis Sandstone	Arcadia	X	3
591	Yebna 2	534	Evergreen Formation, Precipice Sandstone	Fairview	✓	3
592#	Abyss	286, 286.1, 286.2, 286.3	Hutton Sandstone	Fairview	286 ⁺	1b

(1) * These springs are most likely associated with perched groundwater systems and therefore unlikely to be affected by water level changes in the aquifer.

(2) ^ Vent 187 not located within GFD Project tenure.

(3) # Vents 682 and 716 not located within GFD Project tenure.

(4) @ Vents 710 and nv622 not located within GFD Project tenure

(5) + Vent 286 is listed under the EPBC Act.

Watercourse springs in the Surat CMA

There are 43 identified watercourse springs in the Surat CMA (OGIA, 2013a) (listed in Appendix C2 and shown on Figure 6.3). It is important to note that many of the watercourse springs in the Surat CMA have not been ground-truthed and may not actually be present.

Watercourse springs in GFD Project tenures

Eleven watercourse springs are located within GFD Project tenures. These are listed in Table 6.6.

Table 6.6 Watercourse springs located in GFD Project tenures

Site number	Source aquifer (OGIA, 2013a)	Watercourse receiving baseflow	Gas field
W10	Mooga Sandstone, Gubberamunda Sandstone	Blyth Creek	Roma
W14	Hutton Sandstone	Bungaban Creek	Scotia
W17	Mooga Sandstone	Bungeworgorai Creek	Roma
W18	Gubberamunda Sandstone	Bungil Creek	Roma
W19	Mooga Sandstone	Bungil Creek	Roma
W26	Clematis Sandstone	Clematis Creek	Arcadia
W35	Clematis Sandstone	Conciliation Creek	Arcadia
W40	Precipice Sandstone	Dawson River	Fairview
W81	Hutton Sandstone	Hutton Creek	Fairview
W82	Hutton Sandstone	Injune Creek	Fairview
W164	Mooga Sandstone	Yuleba Creek	Roma

6.2 Environmental values

6.2.1 Environmental Protection (Water) Policy 2009

The EPP Water provides a framework for identifying EVs for Queensland waters and the water quality guidelines (WQGs) and water quality objectives (WQOs) to enhance or protect those EVs. The EPP Water defines environmental values of water as:

“particular values or uses of the water that are conducive to a healthy ecosystem or for public amenity, safety or health and that require protection from the effects of habitat alteration, waste releases, contaminated runoff and changed flows”.

The Arcadia, Fairview and Scotia gas fields are located within the Comet and Dawson river sub-basins of the Fitzroy River Basin. Final EVs and WQOs have been adopted by the Queensland Government for these sub-basins and are included in the following Arcadia, Fairview and Scotia gas fields documents listed under Schedule 1 of the EPP Water:

- Comet River Sub-basin Environmental Values and Water Quality Objectives (DERM, 2011a)
- Dawson River Sub-basin Environmental Values and Water Quality Objectives (DERM, 2011b).

The Roma gas field is located in the Condamine-Balonne River Basin. Draft EVs have been developed by the Condamine Alliance (2012a and 2012b) for this river basin.

The EVs identified for the Comet, Dawson and Condamine-Balonne river basins are summarised in Table 6.7. The EVs of groundwater and surface water have been considered. Surface water EVs are relevant to this assessment because watercourse springs occur in each of the gas fields.

Table 6.7 Environmental values of groundwater in the Comet, Dawson and Condamine-Balonne river basins

Environmental values	Comet River Sub-Basin	Dawson River Sub-Basin	Condamine-Balonne River Basin
Protection of aquatic ecosystem	✓	✓	✓
Primary contact recreation (e.g. swimming)*	✓	✓	✓
Secondary recreation (e.g. boating)*	✓	✓	✓
Visual (no contact) recreation*	✓	✓	✓
Drinking water supplies	✓	✓	✓
Crop irrigation	✓	✓	✓
Stock watering	✓	✓	✓
Farm supply/use	✓	✓	✓
Aquaculture (e.g. red claw, barramundi)*	X	✓	✓
Human consumers of aquatic food*	✓	✓	X
Industrial use (including manufacturing plants, power generation)	✓	✓	X
Protection of cultural and spiritual activities	✓	✓	✓

(1) * Primary and secondary recreational contact, visual recreation and aquaculture and human consumers of aquatic food have been included as EV's for groundwater due to groundwater contributions to surface water baseflow in some tenures.

6.2.2 Beneficial use of groundwater by hydrogeological unit

The beneficial use of groundwater in GFD Project tenures has been assessed by hydrogeological unit considering:

- The use of registered bores in each hydrogeological unit
- The source aquifer of spring vents and watercourse springs
- The suitability of the groundwater in each hydrogeological unit for different uses based on an assessment of water quality.

The use of registered bores and source aquifer of springs has been assessed using the data provided by OGIA (2013a). The suitability of groundwater for different uses has been assessed by comparing available water quality data (Section 5.7) with the relevant guidelines for different beneficial uses. The relevant guidelines include the Australian and New Zealand Environment Conservation Council (ANZECC) (2000) Guidelines for Fresh and Marine Water Quality, the ANZECC (2000) Guidelines for Primary Industry, the National Health and Medical Research Council (NHMRC) (2011) Australian Drinking Water Guidelines (ADWG) and the Queensland Water Quality Guidelines (DERM, 2009). The Water Quality Objectives (WQOs) adopted by the Queensland government to protect groundwater quality and maintain Environmental Values have also been considered. WQOs are available for the Fitzroy River Basin (DERM, 2011a; DERM, 2011b) where the Arcadia, Fairview and Scotia gas fields are located, but are currently unavailable for the Condamine-Balonne River Basin where the Roma gas field is located.

The guideline values used to assess the beneficial use of groundwater (where groundwater quality data are available) are shown in Table 6.8. Beneficial use of groundwater for stock watering, drinking water and aquatic ecosystems (where groundwater discharges as a watercourse spring) have been considered. Other uses may also exist including industrial and agriculture.

Table 6.8 Groundwater quality guidelines

Parameter	Unit	ANZECC 2000 ¹ Freshwater	ANZECC 2000 ² Livestock	Drinking Water ³
pH	pH units	6.5-7.5	Na	6.5-8.5
Conductivity	µS/cm	30-350 ⁴	5,970 [#]	900*
Na	mg/L	na	Na	180*
Ca	mg/L	na	1000	Na
Cl	mg/L	na	Na	250*
SO ₄	mg/L	na	1000	500
Fe	mg/L	na	Na	0.3*
Mn	mg/L	1.9	Na	0.5

(1) ANZECC 2000 Guidelines for Fresh and Marine Water Quality: trigger values for 95% protection; southeast Australia (upland rivers).

(2) ANZECC 2000 Guidelines for Primary Industry: trigger values for livestock water quality – Table 4.3.1: # value for beef cattle (Note this value has been converted from mg/L to µS/cm for comparison to sample results (EC (µS/cm) = TDS (mg/L)/0.67)).

(3) NHMRC 2011 Australian Drinking Water Guidelines for health (*in the absence of a guideline for health, the aesthetic guideline value is used, where available).

(4) The Queensland Water Quality Guidelines (DERM, 2009) have derived preliminary freshwater guideline values for EC for the Fitzroy central zone (340 µS/cm) and Maranoa-Balonne-Border Rivers zone (325 µS/cm).

Table 6.9 presents the beneficial use of groundwater in each hydrogeological unit in GFD Project tenures. Beneficial use is presented based on the use of bores in each hydrogeological unit and source aquifer of springs (OGIA, 2013a) and available groundwater quality data.

Table 6.9 Beneficial use of groundwater in GFD Project tenures

Hydrogeological unit	Sensitive groundwater receptors in GFD Project tenures	Beneficial use based on bore and spring data (OGIA, 2013a)	Beneficial use according to groundwater quality data
Alluvium	29 bores	Stock and domestic	Stock watering
Cainozoic Sediments	6 bores	Stock and domestic	Unsuitable for use
Tertiary Volcanics	8 bores 1 spring vent	Stock and domestic Aquatic ecosystems	Stock watering
Wallumbilla Formation	18 bores	Stock and domestic	Stock watering
Bungil Formation	107 bores	Stock and domestic	Stock watering
Mooga Sandstone	263 bores^ 4 watercourse springs	Stock and domestic Agriculture Urban Industrial Aquatic ecosystems	Stock watering Drinking water in some areas
Orallo Formation	13 bores	Stock and domestic	Stock watering in some areas
Gubberamunda Sandstone	154 bores* 1 spring vent 2 watercourse springs	Stock and domestic Agriculture Urban Industrial Aquatic ecosystems	Drinking water in some areas Stock watering
Springbok Sandstone	1 bore^	n/a – bore screened across Mooga Sandstone	Stock watering in some areas
Birkhead Formation	1 bore	Stock and domestic	No data
Walloon Coal Measures	62 bores	Stock and domestic	Stock watering
Eurombah Formation	4 bores	Stock and domestic	Drinking water in some areas Stock watering
Hutton Sandstone	94 bores 2 spring vents 3 watercourse springs	Stock and domestic Agriculture Urban Industrial Aquatic ecosystems	Drinking water in some areas Stock watering
Evergreen Formation	30 bores 3 spring vents	Stock and domestic Aquatic ecosystems	Drinking water in some areas Stock watering
Precipice Sandstone	29 bores* 5 spring vents 1 watercourse spring	Stock and domestic Urban Aquatic ecosystems	Drinking water in some areas Stock watering
Moolayember Formation	2 bores	Stock and domestic	Stock watering in some areas

Hydrogeological unit	Sensitive groundwater receptors in GFD Project tenures	Beneficial use based on bore and spring data (OGIA, 2013a)	Beneficial use according to groundwater quality data
Clematis Sandstone	45 bores 3 spring vents 2 watercourse springs	Stock and domestic Aquatic ecosystems	Drinking water in some areas Stock watering
Rewan Group	9 bores	Stock and domestic	Stock watering in some areas

(1) ^ One bore screened across Mooga Sandstone and Springbok Sandstone

(2) * One bore screened across Gubberamunda Sandstone and Precipice Sandstone

6.2.3 Sensitivity of environmental values

The sensitivities of the EVs and associated sensitive groundwater receptors, ranked in accordance with the criteria in Table 3.2, are presented in Table 6.10.

Table 6.10 Sensitivity of environmental values

Environment values	Sensitive groundwater receptors	Sensitivity [^]	Justification for sensitivity
Protection of aquatic ecosystems.	Spring complexes associated with an EPBC or NC Act listing.	High	Protected by legislation (EPBC or NC Act).
	Spring complexes not associated with an EPBC or NC Act listing.	Moderate	Spring complexes are regionally important. Spring complexes vary in condition from poor to good.
	Watercourse springs.	Moderate	Not EPBC or NC Act listed. Watercourse springs provide baseflow to streams and support in-stream ecosystems.
Groundwater supplies for drinking water.	GAB aquifers including the Mooga Sandstone, Gubberamunda Sandstone, Hutton Sandstone, Precipice Sandstone and Clematis Sandstone.	Moderate	Groundwater from these aquifers is used as a source of drinking water in the area
	Water bearing formations including the Eurombah Formation and Evergreen Formation.	Moderate	Provide minor drinking water supplies.
Groundwater supplies for stock watering, agriculture, farm supply/use and industrial use (including manufacturing plants, power generation).	Alluvium, tertiary volcanics and GAB aquifers including the Bungil Formation, Mooga Sandstone, Gubberamunda Sandstone, Springbok Sandstone, Hutton Sandstone, Precipice Sandstone and Clematis Sandstone.	Moderate	Groundwater from these aquifers is a source of water for stock watering, agriculture, farm supply/use and industrial use in the area.
	Water bearing formations including the Wallumbilla Formation, Orallo Formation,	Low	Provide minor stock watering, agriculture, farm and industrial

Environment values	Sensitive groundwater receptors	Sensitivity [^]	Justification for sensitivity
	Eurombah Formation, Evergreen Formation, Moolayember Formation and Rewan Group.		supplies.
Surface water supplies for drinking water, stock watering, agriculture, farm supply/use and industrial use (including manufacturing plants, power generation).	Watercourse springs.	Moderate	Consistent baseflow associated with springs are observed in the Dawson River downstream of the confluence with Hutton Creek.
Surface water recreation, including primary contact recreation (e.g. swimming), secondary recreation (e.g. boating) and visual (no contact) recreation.	Watercourse springs.	Low	Consistent baseflow associated with springs are observed in the Dawson River downstream of the confluence with Hutton Creek and may support surface water recreation.
Aquaculture (e.g. red claw, barramundi) and human consumers of aquatic food.	Watercourse springs.	Moderate	Consistent baseflow associated with springs are observed in the Dawson River downstream of the confluence with Hutton Creek and may support aquaculture.
Protection of cultural and spiritual activities.	Spring complexes.	Moderate	There are no registered indigenous cultural heritage places registered on the World Heritage List, National Heritage List and Commonwealth Heritage List within the GFD Project area. For the State register there are 1,845 registered indigenous cultural heritage places registered on the cultural heritage databases and register maintained by the department of Aboriginal and Torres Strait Islander and Multicultural Affairs. A number of these sites are in close proximity to springs and may be linked to the presence of a permanent source of water. Cultural heritage values associated with springs may include mythological associations, ritual and ceremonial associations, economic and subsistence associations and major or personal historical events.
	Watercourse springs.	Moderate	

(1) [^] Only the highest sensitivity is recorded.

7. Numerical groundwater flow modelling results and cumulative impacts

An integral part of the production of natural gas from coal seams is the extraction of groundwater to depressurise the coal seam and enable gas to flow. The Queensland Government's numerical groundwater model for the Surat CMA has been used to assess potential cumulative aquifer depressurisation and drawdown associated with the GFD Project and development proposed by other proponents. Depressurisation is a reduction in groundwater pore pressure (pressure head) in a confined groundwater system due to extraction of groundwater. Drawdown is a decline in groundwater level in a bore, or a decline in water table elevation in an unconfined groundwater system, due to the extraction of groundwater.

7.1 Queensland framework for assessment and management of groundwater impacts

The Queensland Government has implemented a legislative regime to ensure the petroleum and gas industry develops in a responsible way. The regime applies to conventional petroleum and gas production as well as non-conventional (coal seam) gas production.

Under the regime, petroleum tenure holders have the right to extract groundwater in the process of petroleum and gas production (P&G Act), but are required to monitor and manage the impacts on springs and water supplies (Water Act). This includes a requirement to 'make good' impairment (due to changes in pressure or water quality) of private bore supplies caused by the exercise of these rights.

In areas where gas fields are being developed by multiple companies, the impacts of water extraction on groundwater levels may overlap. In these situations a cumulative approach is required to assess and manage impacts and a CMA may be declared. The OGIA is responsible for assessing cumulative impacts in these areas and establishing integrated management arrangements through the preparation of a UWIR.

7.1.1 The Surat Cumulative Management Area

The Surat CMA (Figure 7.1) was established in 2011 for the Surat Basin and the southern Bowen Basin, where development of gas by multiple different companies is occurring in adjacent areas. Gas is produced from the Walloon Coal Measures (and equivalents) of the Surat Basin and the Bandanna Formation of the Bowen Basin.

The Walloon Coal Measures is a geologic formation of the GAB. The GAB is the source of springs of high ecological and cultural significance and is also of economic importance. There are approximately 21,000 water bores in the Surat CMA, which are used for stock, irrigation, industry and urban consumption and extract around 215,000 ML/year (including 85,000 ML/year from GAB) (QWC, 2012a).

7.1.2 The Underground Water Impact Report for the Surat Cumulative Management Area

The UWIR for the Surat CMA was released in 2012 and is a statutory instrument under the Water Act. The report assesses the cumulative impacts of water extraction by petroleum tenure holders on groundwater

in the Surat CMA, and establishes integrated management arrangements. In preparing the UWIR, QWC undertook numerical groundwater modelling to predict potential impacts on water pressure.

The UWIR found that 85 registered water bores would experience water level declines of more than 5 m within three years, and 528 bores would be affected at some time in the future. Under the Water Act, petroleum tenure holders are required to 'make good' impairment of private bore supplies that result from petroleum and gas activities. The UWIR identifies which petroleum tenure holder is responsible for potential impacts to each bore as more than one tenure holder could be contributing to the impact.

The UWIR includes a Water Monitoring Strategy, which requires proponents to monitor groundwater levels and quality as part of an integrated regional water monitoring network for the Surat CMA. The network includes 498 water level monitoring points at 142 sites and 120 water quality monitoring points. There are already networks of monitoring bores in place, and the remaining works are being constructed by petroleum tenure holders. Santos GLNG's program for monitoring bore construction to meet UWIR requirements is detailed in Section 9.1.1.

There are five spring complexes in the Surat CMA where the predicted decline in water levels in the source aquifer is more than 0.2 metres at the location of the springs. The Spring Impact Management Strategy in the UWIR requires petroleum tenure holders to evaluate and submit a report to OGIA on potential mitigation options at these sites. Petroleum tenure holders are also required to monitor conditions in springs, including flow, physical condition, water chemistry, and submit the results to OGIA.

7.1.3 Annual Report 2013 for the Surat Underground Water Impact Report

The Annual Report 2013 for the Surat Underground Water Impact Report (OGIA, 2013b) outlines a number of changes to the industry development profile and available information about private water bores since the UWIR was prepared. Gas development in the Surat CMA has not commenced as early as planned, bore assessments conducted by tenure holders have found that the source aquifer for some bores is a shallower aquifer than the aquifer identified in the DNRM groundwater database and some unregistered bores have been identified. This has resulted in changes to the short term impacts described in the UWIR.

The UWIR found that 85 registered water bores would experience water level declines of more than 5 m within three years (by 2015). Based on the new development profile and updated bore data, the Annual Report assessed that 65 registered water bores would experience water level declines of more than 5 m within three years (by 2015) (OGIA, 2013b).

7.1.4 Replacement of the Underground Water Impact Report for the Surat Cumulative Management Area

Queensland's regulatory framework requires that the OGIA reviews and replaces the UWIR at least every three years. The new UWIR for the Surat CMA is due to be prepared in 2015.

In developing a new UWIR, the OGIA may build a new model, re-calibrate with new monitoring data and/or incorporate changes to planned petroleum and gas development in model simulations.

If required, the OGIA will revise the assignment of responsible tenure holder obligations in the UWIR to reflect changes in tenure ownership and the new assessment of potential impacts to bores and springs. The OGIA will also assess if the Water Monitoring Strategy or Spring Impact Management Strategy should be revised.

The new UWIR will specify Santos GLNG's responsibilities for making good on impacts to landholder bores, water monitoring, and requirements for monitoring of springs and or any mitigation responses. If approved, the GFD Project will be incorporated into the development scenarios that Santos GLNG will submit to OGIA for inclusion in subsequent UWIR reports.

7.2 Numerical groundwater modelling methodology

The numerical groundwater predictive model for the Surat CMA has been used to assess potential cumulative impacts associated with depressurisation of the Walloon Coal Measures and Bandanna Formation, associated with gas production.

The numerical groundwater flow model for the Surat CMA was developed to assess potential cumulative depressurisation impacts associated with water extraction for petroleum and gas production by Santos, QGC, Origin, and Arrow. The initial model simulation informed the UWIR (QWC, 2012a) and included Santos GLNG's approved production activity.

Since the UWIR was released in 2012, and for the purpose of determining potential groundwater impact from the GFD Project, the numerical groundwater flow model has been refined and run twice. The first simulation provided a baseline scenario, referred to as 'the UWIR Scenario'. This regional groundwater flow model for the Surat CMA included Santos GLNG's production activities, as well as other production developments including all petroleum tenure holders.

In mid-2013 the OGIA modelled the regional groundwater flow for the Surat CMA to simulate development changes associated with the GFD Project and more development proposed by another proponent. This second simulation is referred to as 'the EIS Scenario'

The production areas for Santos GLNG and other proponents under the UWIR and EIS scenarios are shown on Figure 7.1.

7.2.1 Overview of the Surat CMA model

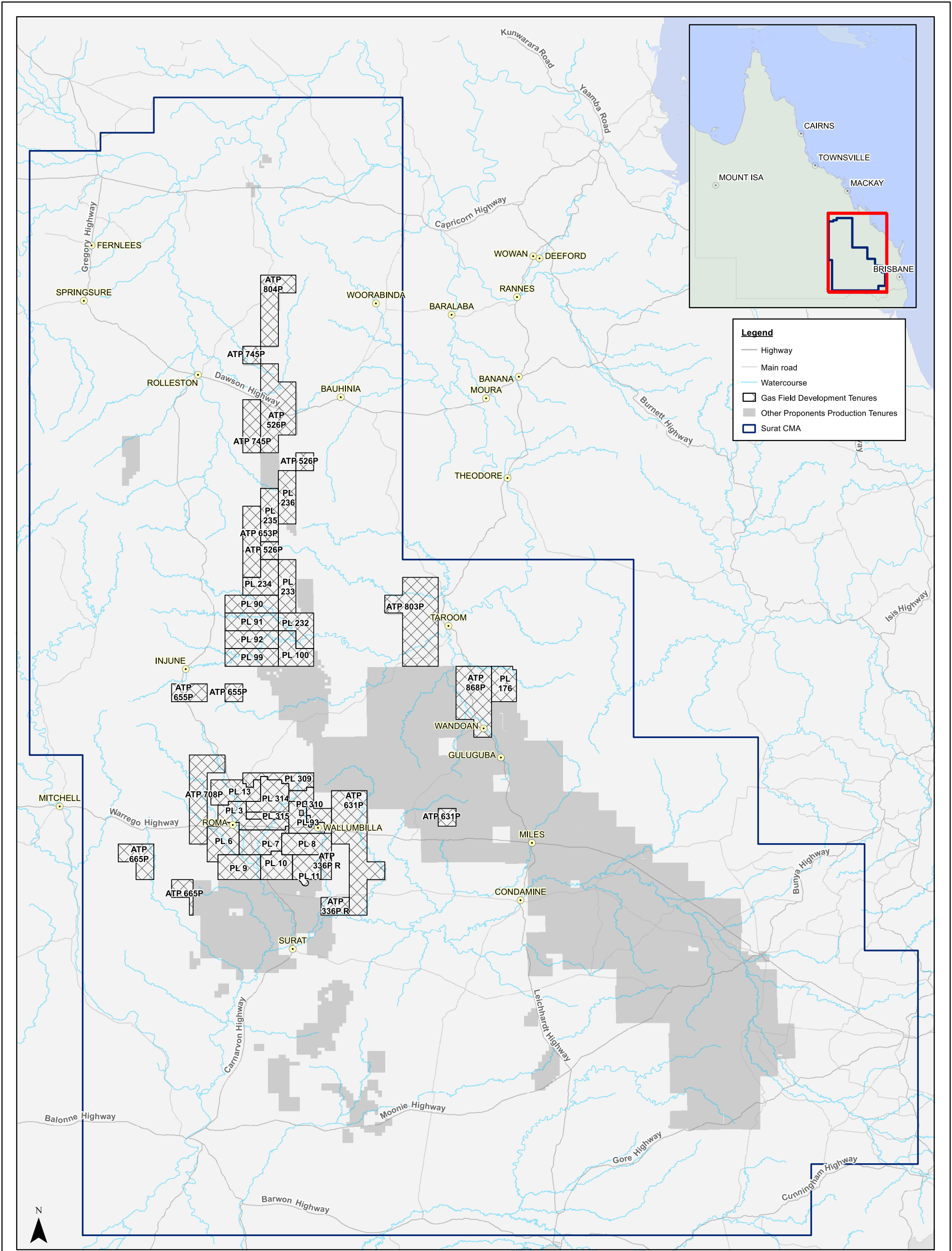
The numerical groundwater flow model for the Surat CMA was developed using the MODFLOW 2005 code (Harbaugh, 2005), which has been comprehensively tested and utilised within the groundwater industry.

Each of the major proponents developing gas from coal seams in the Surat CMA (Santos, QGC, Origin and Arrow) initially provided QWC with hydrogeological information from field investigations, together with estimated coal seam depressurisation targets for their production areas.

The model has 19 layers to represent all of the major aquifers and aquitards within the Surat CMA (Table 7.1), distributed across more than 3 million 1.5 km x 1.5 km model cells (QWC, 2012a). A comprehensive description of the model is given in the UWIR (QWC, 2012a) and accompanying groundwater model report (QWC, 2012c) and predictive uncertainty report (QWC, 2012d).

The model was developed in line with the national groundwater modelling guidelines that were current at the time the model was prepared (Barnett et al., 2012).

Due to high levels of groundwater extraction from the Condamine Alluvium, the Condamine Alluvium was simulated using a separate sub-model (the Condamine model), which has a finer grid resolution, thus enabling a high resolution representation of drawdown in groundwater levels. The input to the Condamine Alluvium model was derived from distributed inter-aquifer leakage output from the regional Surat CMA groundwater model.



Santos
GLNG Project

Data Source: All tenements data supplied by Santos.
Roads from © State of Queensland (DNRM), 2013
Drainages from © Commonwealth of Australia (Geoscience Australia), 2006

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Scale 1:1,700,000
0 10 20 30
Kilometers
Coordinate System: GCS GDA 1994
Scale correct when printed at A3 Portrait
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Gas Field Development Project
Figure 7.1
Coal seam gas production areas in the Surat CMA

**PARSONS
BRINCKERHOFF**

Table 7.1 UWIR model layers and corresponding formations (QWC, 2012a)

Model layer	Formation
1	Alluvium (Condamine) and Main Range Volcanics
2	Griman Creek/Wallumbilla Formation and Surat Siltstone
3	Bungil Formation and Mooga Sandstone
4	Orallo Formation
5	Gubberamunda Sandstone
6	Westbourne Formation
7	Upper Springbok Sandstone
8	Lower Springbok Sandstone
9	Walloon Coal Measures (upper aquitard)
10	Walloon Coal Measures (coal, mudstone, siltstone and sandstone)
11	Walloon Coal Measures (lower aquitard)
12	Hutton/Marburg Sandstone
13	Evergreen Formation
14	Precipice Sandstone
15	Moolayember Formation
16	Clematis/Showground Sandstones
17	Rewan Group
18	Bandanna Formation
19	Permian Sediments

7.2.2 Model assumptions and limitations

The model for the Surat CMA simulates a simplified version of a complex geological and hydrogeological system (QWC, 2012c). This simplification is required to allow the model to be run, calibrated and utilised within a reasonable timeframe. Further, the model assumptions that were incorporated were deemed appropriate and acceptable given the purpose of the model, i.e. to investigate the regional scale effect of coal seam depressurisation on aquifers. In this context, the assumptions made are considered to be conservative in respect of the scale of the underground water impact that is predicted (i.e. the assumptions, when compounded, would tend to overestimate the scale of the impact).

A summary of the assumptions incorporated into the Surat CMA groundwater model, and their resulting limitations, include:

- The inability of the model to simulate features with an extent of less than 1.5 km across, as this is the grid spacing within the model. However, given the area of assessment and the scale of the impact being assessed, the model cell size and spacing are deemed appropriate and reasonable.
- The number of layers within the model has been limited to 19, preventing smaller-scale variations in permeability from being represented within the units listed in Table 7.1. However, again given the area of assessment, the scale of impact being assessed, vertical discretisation of the model layers is deemed appropriate and reasonable for the purpose of determining the likely impact to groundwater from coal seam depressurisation.

- The potential effects of faults and other structural features on groundwater flow within the Surat CMA have not been simulated in the model. However at the scale of investigation, the calibration of the model and its subsequent parameterisation are considered to result in a fair and reasonable reflection of the regional effect of geological structures on groundwater flow.
- The transmissivity of model layers has been assumed to be constant over time. Although this limits the ability of the model to simulate water level changes in unconfined aquifers, the predominance of confined aquifers within the Surat CMA minimises the errors arising from this assumption.
- Calibrated parameters are subject to a relatively high degree of uncertainty, due to the limited availability of accurate monitoring data. The lack of data is particularly apparent at depth in the southwest of the Surat CMA, as well as in the Clematis Sandstone and Bandanna Formation.
- Although the calibrated model closely matches the available data, similar levels of fit may be achieved using a range of different parameter values. The reporting of the 95th percentile of results from multiple model runs has been used to address the uncertainty resulting from this non-uniqueness and capture the maximum likely impact from gas production.
- The groundwater model does not simulate the effects of dual phase flow (i.e. water and gas flow) and represents only the flow of groundwater. This is expected to lead to inaccuracy in the short-term simulation of depressurisation within the coal seams, but is not expected to affect predictions of long-term water pressure changes in other formations. Further, the calibration of the model and its subsequent parameterisation is considered to result in a more conservative assessment in respect of the effect of dual phase flow on predicted impacts to groundwater.

7.2.3 Representing the extraction of gas

Future extractions of gas have been represented in the model for the Surat CMA using the MODFLOW evapotranspiration (EVT) package, which allows the user to control groundwater levels, as opposed to the MODFLOW Well Package, which requires extraction rates to be specified. This is because plans for future extraction of gas are based on the groundwater level required to extract gas from the coal seams and do not explicitly specify extraction rates. By utilising the EVT package, extraction proceeds at a specified maximum rate until groundwater pressure drops below the level of the nominated EVT surface (40 m above the top of the target coal seam). Extraction rates gradually decrease between the level of the EVT surface and the EVT extinction depth (20 m above the top of the coal seam).

7.2.4 Model calibration and predictions

The model was used to represent current and historic trends in groundwater levels from approximately 1,500 bores in the Surat CMA, prior to predicting the future impacts of the extraction of gas. This process, known as model calibration, was achieved by varying the model input parameters until a satisfactory fit to observed groundwater levels was achieved. Available data on the hydraulic properties of each layer, from more than 3,000 hydraulic tests, were used to constrain the values of the input parameters which were applied to the model.

To account for the inherent uncertainties relating to key model parameter estimates, predictive model runs were undertaken using the null-space Monte Carlo approach (Watermark, 2012; Tonkin and Doherty, 2007). In this approach, the model is run multiple (200) times to derive a suite of parameter values, all of which result in acceptable calibration of the model. Model predictions from all calibrated runs are then aggregated to provide a probabilistic estimate of impacts. For instance, estimates of groundwater depressurisation at each model cell can be expressed in terms of the 50th percentile (median) and 95th percentile of all 200 calibrated model predictions.

As a precautionary approach, the 95th percentile of values were selected in each case (i.e. 95% of predictions show a reduction in groundwater level which is less than or equal to the chosen value). These values were used to produce contours of maximum predicted groundwater impacts in the Surat CMA.

7.2.5 The UWIR Scenario

This regional groundwater flow model for the Surat CMA included Santos GLNG's production activities, as well as other production developments including all petroleum tenure holders such as QGC, Origin Energy, AGL and Arrow Energy

Since the regional groundwater flow model was constructed to support preparation of the UWIR, minor amendments have been made to the model arising from local issues and to improve the operational efficiency of the model. The alterations do not affect predictions of short-term impacts and only slightly affect predictions of long-term impacts. In the long-term the alterations result in a slightly smaller number of affected bores than predicted in the UWIR. The alterations also result in slight changes to predicted impacts in aquifers beneath springs in the northern most part of the development area. In consideration of these changes and their consequences, the spring impact management arrangements specified in the UWIR remain precautionary and appropriate. The amended model is now used for assessment purposes and is referred to in this report as 'the UWIR Scenario'.

7.2.6 The EIS Scenario

In mid-2013 the OGIA modelled the regional groundwater flow for the Surat CMA to simulate development changes associated with the GFD Project and more development proposed by another proponent. This second simulation is referred to as 'the EIS Scenario'

Model input files to simulate the proposed Santos GLNG GFD Project production were provided to the OGIA to combine with the files provided by another proponent so that the EIS Scenario could be modelled. The files provide information on the time-varying extraction rates in each model cell, based on the following approach:

- Production wells were assigned at evenly spaced intervals within the production zones of each GFD Project gas field tenure (shown on Figure 7.1) in every time step, based on data supplied by Santos GLNG based on the number of planned wells in each tenure.
- For each tenure, extraction rates from nearby operational production wells were used to estimate a typical water production curve over the life of each planned GFD Project production well. As a conservative measure, the highest producing well from the surrounding area was chosen to represent the production rates of each GFD Project production well. Water production rates for the Fairview Early Permian field were based on data provided by Santos GLNG.
- The estimated water production rates were used to provide an initial water extraction rate at each EVT boundary cell (simulated gas wells) and therefore simulate a realistic time to full depressurisation within the field. Within the model, the water production rate decreases below this initial rate as the simulated pressure head in the target coal seam approaches 40 m (head of water above the target coal seam).
- The target coal seam (and corresponding model layer) was identified for each tenure as the Walloon Coal Measures (Layer 10), the Bandanna Formation (Layer 18) or the Permian Sediments (Layer 19, although conservatively modelled as Layer 18).
- The development scenario modelled for the UWIR (QWC, 2012c) was assumed for the period prior to 1 January 2012. Model input files were prepared for the period from 1 January 2012, with existing wells in each gas field assumed to commence production on 1 January 2012.
- The life of each gas field was assumed to be 30 years from peak production for that tenure, i.e. 30 years from when the maximum number of wells for that tenure was installed.

7.3 Impact assessment results

Results for the EIS Scenario have been compared to the results for the UWIR Scenario to enable assessment of the change in cumulative impacts due to the additional production proposed by Santos GLNG and another proponent.

The model scenarios assess cumulative aquifer depressurisation due to groundwater extraction, including for conventional oil and gas production as well as non-conventional (coal seam) gas production in the Surat CMA. This includes the natural gas from coal seam development proposed by Santos, QGC, Origin and Arrow in 2011 (included in the UWIR Scenario and EIS Scenario), as well as the additional development proposed by the Santos GLNG GFD Project and another proponent (included in the EIS Scenario).

The cumulative impact assessment methodology follows a similar approach to the methodology in the UWIR. Impacts have been assessed using the 95th percentile results of the numerical groundwater flow modelling. The 95th percentile values have been used as a precautionary approach so the maximum likely impacts can be assessed (QWC, 2012c).

It should be noted that actual impacts are likely to be less than what is presented in this chapter of the report for the following reasons:

- The EIS Scenario is a maximum development scenario for this EIS.
- The impacts presented are the 95th percentile of 200 model runs. This means that 95% of predictions result in impacts that are less than or equal to the impacts presented in this report.
- The groundwater model does not simulate the effects of dual phase flow (i.e. water and gas flow) and represents only the flow of groundwater. This is expected to lead to an overestimation of impacts to groundwater, particularly within the project tenures.

7.3.1 Depressurisation impacts

Depressurisation impacts in the Surat CMA

The figures in Appendix D: Potential impact maps, show the long-term cumulative depressurisation pattern for each aquifer in the Surat CMA under the EIS Scenario. The depressurisation patterns are cumulative and include the impacts of the development proposed by Santos, QGC, Origin and Arrow in 2011 (reported in the UWIR), as well as the additional development recently proposed by the GFD Project and another proponent. For the purpose of this report, long-term relates to the period of the model scenario (3,000 years).

The change in maximum depressurisation for each aquifer due to the EIS Scenario, compared to the UWIR Scenario, is presented in Table 7.2. Model results indicate there will be no increase in the maximum depressurisation for each aquifer in the Surat CMA due to the additional development simulated in the EIS Scenario.

The change in area of impact due to the EIS Scenario, compared to the UWIR Scenario, is shown on Figure 7.2 and presented in Table 7.2. The area of impact has been assessed in a similar way to the Long Term Affected Area (LAA) described in the UWIR. The LAA is the area that will experience groundwater pressure reductions greater than 5 m for consolidated aquifers, or 2 m for unconsolidated aquifers, at some time in the future due to cumulative water extraction by petroleum tenure holders.

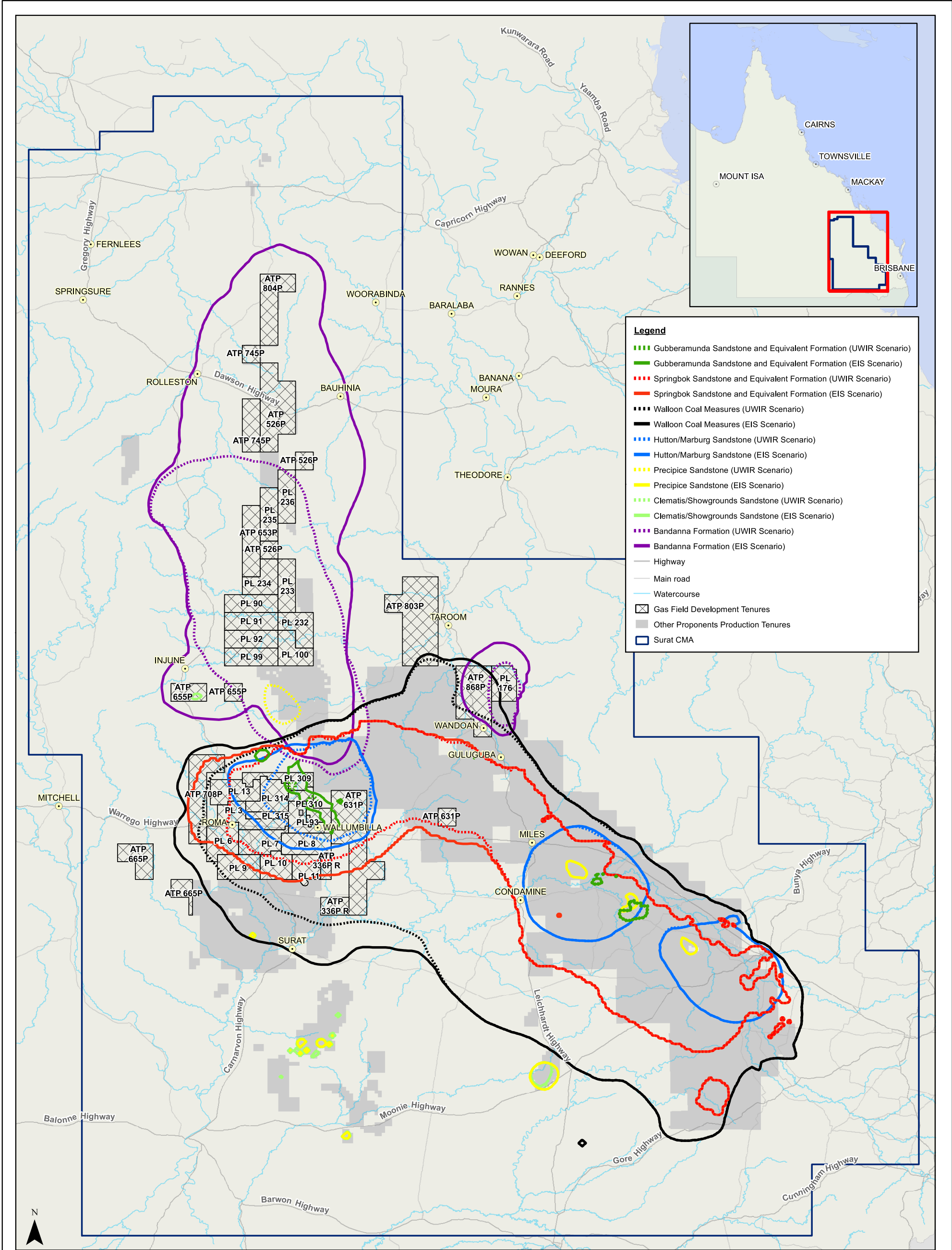
The results indicate the area of impact will increase due to the expansion of areas being developed. The largest increases in depressurisation impacted areas occur within the two target coal formations (the Walloon Coal Measures and the Bandanna Formation). There are also increases in the extent of the depressurisation impacted areas within the overlying Springbok Sandstone, the Hutton/Marburg Sandstone and the Gubberamunda Sandstone.

Table 7.2 Change in maximum depressurisation and area of impact under the EIS Scenario compared to the UWIR Scenario

Aquifer	Change in maximum depressurisation (m)	Change in area of impact (km ²) [#]	Location of change in area of impact
Condamine Alluvium and Main Range Volcanics	No change in maximum depressurisation*	N/A*	N/A*
Bungil Formation/Mooga Sandstone	0.3 m reduction in maximum depressurisation	No change	There is no area of impact under the UWIR Scenario or EIS Scenario.
Gubberamunda Sandstone	No change in maximum depressurisation	294 km ² increase in area of impact	Expansion of the area of impact up to 15 km near Wallumbilla.
Springbok Sandstone	1 m reduction in maximum depressurisation	1,940 km ² increase in area of impact	Expansion of the area of impact up to 15 km west near Hodgson and up to 10 km south near Wallumbilla.
Walloon Coal Measures	No change in maximum depressurisation	3,412 km ² increase in area of impact	Expansion of the area of impact up to 20 km south near Surat, up to 15 km west near Hodgson and up to 25 km near Wandoan.
Hutton/Marburg Sandstone	No change in maximum depressurisation	1,027 km ² increase in area of impact	No change in the contours in the east. Increase in area of impact near Wallumbilla by up to 15 km towards the west.
Precipice Sandstone	No change in maximum depressurisation	233 km ² reduction in area of impact	No change in the contours in the east and south. No area of impact south-west of Injune under the EIS Scenario.
Clematis/Showground Sandstone	No change in maximum depressurisation	13 km ² reduction in area of impact	Small reduction in area of impact.
Bandanna Formation	1 m reduction in maximum depressurisation	9,514 km ² increase in area of impact	Large expansion of the area of impact 80 km north towards Rolleston and 35 km west near Injune.

(1) * Condamine model not run; no change in drawdown observed between the EIS Scenario and UWIR Scenario for the Walloon Coal Measures underlying the Condamine Alluvium, implying no additional drawdown in the Condamine Alluvium.

(2) # The area that will experience groundwater pressure reductions greater than 5 m for consolidated aquifers, or 2 m for unconsolidated aquifers, at some time in the future due to cumulative water extraction by petroleum tenure holders.



Depressurisation in GFD Project tenures

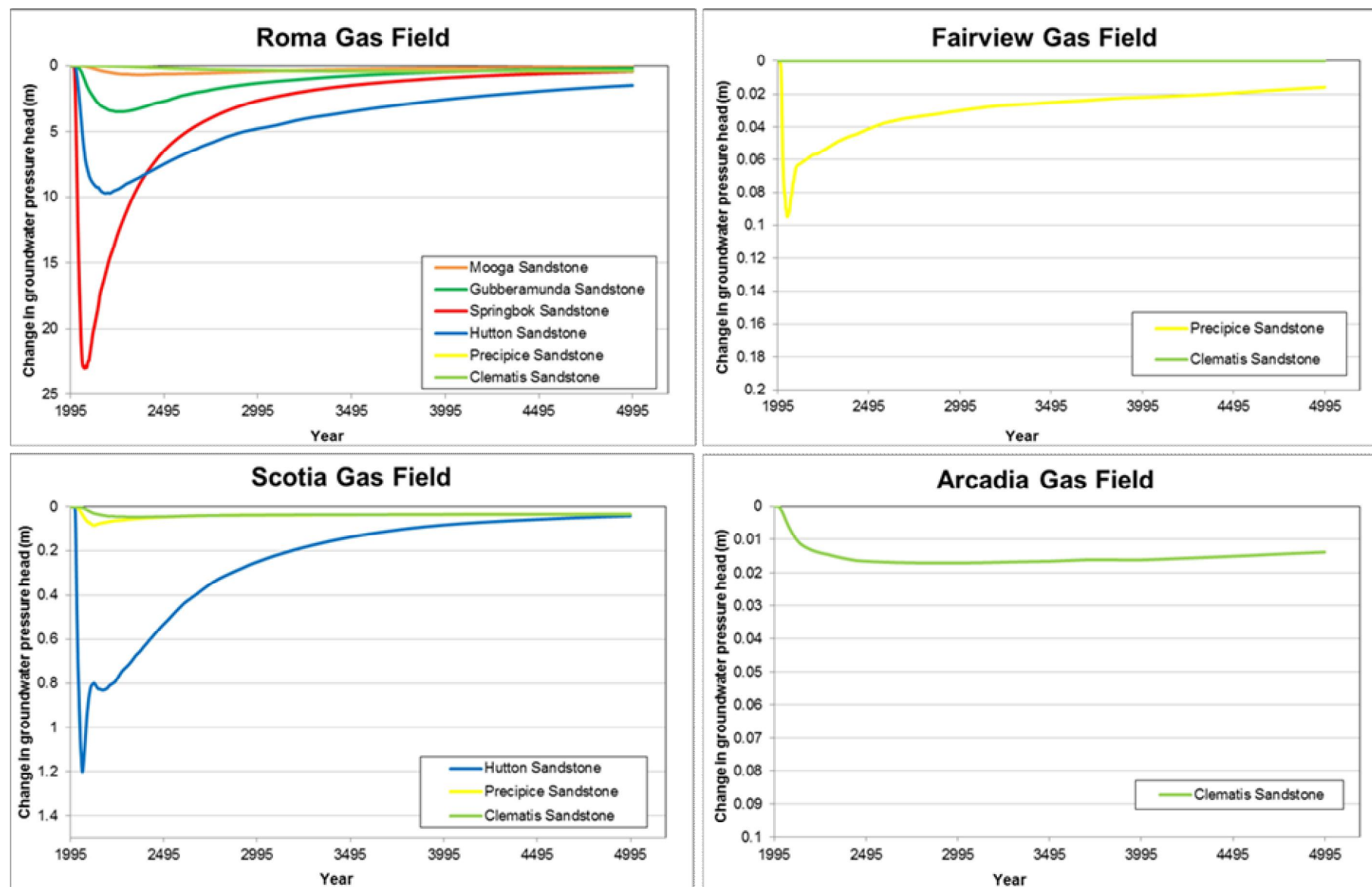
Based on the maximum development scenario for this EIS model results indicate that maximum depressurisation in GFD Project tenures will occur within the target coal formations where water extraction for production of gas is undertaken. Maximum depressurisation in the coal formations will occur between 2020 and 2030. There will be a lag in the time to maximum depressurisation (area of extent) in overlying and underlying formations, with the timeframes dependent on how directly connected the formation is to the target coal formations (i.e. dependent on vertical hydraulic conductivity). Predicted depressurisation and recovery trends in GFD Project tenures are as follows:

- Roma - Maximum depressurisation of the target Walloon Coal Measures will occur in approximately 2025. Maximum depressurisation in the Springbok Sandstone (75.4 m), Gubberamunda Sandstone (23.2 m) and Hutton Sandstone (20.7 m) will subsequently occur in 2058, 2069 and 2155, respectively. In aquifers that are effectively separated from gas bearing formations by aquitards, including the Bungil Formation/Mooga Sandstone, the predicted drawdown is comparatively small and there will be a significant time lag (decades) before maximum impacts occur.
- Fairview – Maximum depressurisation of the target Bandanna Formation coal seams will occur in approximately 2020. Maximum depressurisation of 5.4 m will occur in the Clematis/Showground Sandstone in 2053 and maximum depressurisation of 3.4 m will occur in the Precipice Sandstone in 2023. Predicted cumulative impacts in the Hutton/Marburg Sandstone and Walloon Coal Measures are less than 0.5 m and there will be a significant time lag before maximum impacts occur.
- Arcadia - Maximum depressurisation of the target Bandanna Formation will occur in approximately 2030. There will be a significant time lag before a maximum depressurisation of 0.2 m occurs in the Clematis/Showground Sandstone.
- Scotia - Maximum depressurisation of the Bandanna Formation will occur in approximately 2022 and maximum depressurisation of the Walloon Coal Measures will occur in 2058. There is likely to be less than 2 m of depressurisation to overlying and underlying formations, including the Springbok Sandstone, Hutton Sandstone, Precipice Sandstone and Clematis Sandstone. Maximum depressurisation of overlying and underlying formations will occur between 2058 and 2205.

Depressurisation effects on aquifers are expected to persist for prolonged periods after extraction of gas has ceased. The rate of recovery will be greatest in the years after water extraction ceases, but will reduce exponentially with time. It is estimated that for the coal measures and the significantly affected aquifers there will be a 50% recovery from maximum impact 30 to 80 years after maximum depressurisation. Poorly connected aquifers may take several hundred years to reach 50% recovery.

Figure 7.3 presents long-term cumulative depressurisation hydrographs for a central location (model cell) in each GFD Project gas field under the EIS Scenario (excluding the target coal measures).

Figure 7.3 Predicted aquifer depressurisation for a central location in GFD Project gas fields



7.3.2 Impacts to landholder bores

In accordance with the methodology applied for the UWIR, landholder bores have been identified as potentially impacted where a decline in groundwater pressure of 5 m or more for consolidated aquifers, or 2 m or more for unconsolidated aquifers, is predicted at some time in the future at the location of the bore.

The OGIA provided the bore data set used to identify source aquifers of bores within the Surat CMA. Bores that access the Westbourne Formation, Evergreen Formation, Rewan Group and Bowen Permian have not been assessed due to their classification as aquitards. This follows the methodology applied for the UWIR.

Impacted landholder bores in the Surat CMA

The UWIR identified 85 landholder bores where aquifer pressure is predicted to decline within three years by more than 5 m for consolidated aquifers and 2 m for unconsolidated aquifers. This was revised to 65 bores in the Annual Report for the UWIR (OGIA, 2013b). The predicted changes in depressurisation due to the proposed GFD Project will not result in additional impacts to landholder bores before 2015, as the additional production wells are not proposed to start production until after that date.

The UWIR identified 528 landholder bores where aquifer pressure is predicted to decline at some time in the future by more than 5 m for consolidated aquifers and 2 m for unconsolidated aquifers. Due to cumulative petroleum and gas development in the Surat CMA under the EIS Scenario, an additional 73 private water bores are predicted to be impacted by a decline in groundwater pressure of more than 5 m for consolidated aquifers and 2 m for unconsolidated aquifers at some time in the future. A summary of these additional water bores, including their use, is provided in Table 7.3.

Table 7.3 Additional water bores cumulatively impacted under the EIS Scenario compared to the UWIR Scenario in the Surat CMA

Model layer used for assessment	Screened formation	Change in number of impacted bores	Bore use (OGIA, 2013a)
3	Mooga Sandstone and Bungil Formation	0	N/A
5	Orallo Formation	0	N/A
5	Gubberamunda Sandstone	+ 17	Stock and domestic
8	Springbok Sandstone*	0	N/A
10	Walloon Coal Measures**	+ 46	Stock and domestic
12	Eurombah Formation	0	N/A
12	Hutton/Marburg Sandstone	+ 7	Stock and domestic (4) Agriculture (3)
14	Precipice Sandstone	0	N/A
16	Moolayember Formation	0	N/A
16	Clematis Sandstone	0	N/A
18	Bandanna Formation	+ 3	Stock and domestic
TOTAL		+ 73	

1) * One bore screened in both Mooga Sandstone and Springbok Sandstone.

2) ** One bore screened in both Springbok Sandstone and Walloon Coal Measures.

Impacted landholder bores in GFD Project tenures

The cumulatively impacted landholder bores in GFD Project tenures under the UWIR Scenario and EIS Scenario are presented in Table 7.4.

Within GFD Project tenures, 48 additional landholder bores may be impacted in the Roma and Scotia gas fields under the EIS Scenario compared to the UWIR Scenario.

Table 7.4 Impacted landholder bores in GFD Project tenures

Model layer used for assessment	Screened formation	UWIR Scenario	EIS Scenario	Change in number of impacted bores	Gas field
5	Gubberamunda Sandstone	1	16	+ 15	Roma
8	Springbok Sandstone*	1	1	0	Roma
10	Walloon Coal Measures**	7	39	+ 32	Scotia, Roma
12	Hutton/Marburg Sandstones	4	5	+ 1	Roma
TOTAL		13	61	+ 48	

1) * One bore screened in both Mooga Sandstone and Springbok Sandstone.

2) ** One bore screened in both Springbok Sandstone and Walloon Coal Measures.

7.3.3 Impacts to springs

The UWIR identified a total of 330 spring vents and 43 watercourse springs within the Surat CMA. However, the most up to date springs data set provided by the OGIA in August 2013 identified 329 spring vents. This is because four of the spring vents in the original data set could not be found during field investigations (x346, x380, x381 and x431) and three new spring vents have been identified by a proponent (complex 605 including spring vents nv717, nv718 and nv719). This assessment has considered the latest springs data set provided by OGIA.

Springs of interest

Groundwater model results for the EIS Scenario were used to conduct an initial screening to identify springs of interest; defined as springs underlain by a formation (including the coal seams) where the long-term maximum predicted impact on water pressures at the location of the spring (but not necessarily in the source aquifer of the spring) exceeds 0.2 m, or is within 10 km of 0.2 m of depressurisation. As a precautionary approach, EPBC springs located just outside the 10 km buffer were also included, which translated to including EPBC springs a further 5 km beyond the 10 km buffer. The buffers are precautionary as they allow for the limitations associated with modelling very small changes in water pressure.

There are 45 spring complexes (Table 7.5) and 33 watercourse springs (Table 7.6) located within the Surat CMA that have been recognised as springs of interest.

Springs at risk of impacts in the Surat CMA

A risk-based methodology was employed to assess the likelihood of the springs of interest experiencing depressurisation impacts due to the cumulative development of gas in the Surat CMA under the EIS scenario. The approach recognises that there is some uncertainty associated with the source aquifers

nominated in the OGIA dataset. The methodology was developed in consultation with the OGIA and follows a similar approach to that used in the UWIR for the Surat CMA.

Springs where impacts to a source aquifer nominated in the OGIA (2013a) dataset were predicted under the EIS Scenario have been identified as being at risk of impacts. For the remaining springs of interest, the numerical groundwater modelling predicted impacts to an underlying aquifer that is not the source aquifer nominated in the OGIA dataset. These springs have only been identified as being at risk of impacts where:

- The spring is identified in the UWIR as requiring monitoring. It is understood that the risk assessment undertaken by the QWC for the UWIR applied a precautionary approach for these springs due to their high ecological value and/or hydrogeological uncertainty, such as source aquifer proximity to target production formations or the presence of structures.
- Hydrogeological assessment has indicated that the impacted aquifer could potentially be the source aquifer for the spring. Springs for which available information indicates a high level of confidence in the source aquifer nominated in the OGIA dataset were excluded.

Hydrogeological assessment involved:

- Interrogation of groundwater model results for the EIS Scenario to identify the impacted formations underlying each spring complex and watercourse spring, and the magnitude of the predicted impact.
- Mapping of the location of each spring complex and watercourse spring with surface geology, watercourses and geological basin structure data (i.e. mapped major faults, anticlines and synclines) from the Geological Survey of Queensland Digital Geoscience Vector Data (December 2011).
- Grouping of springs based on common underlying geology and their proximity to watercourses and geological structures.
- Review of the stratigraphy and structural information for each group of springs to assess whether an impacted formation underlying the spring could potentially be a source aquifer, for example based on the occurrence of faults or thick aquitards at the location of the springs. Geological data were sourced from the nearest QDEX exploration bore or geological cross section line.
- Surface geology and proximity to watercourses was also reviewed to identify springs that are most likely water table discharge.

A total of 13 spring complexes and 19 watercourse springs have been identified as being at risk of impacts due to the cumulative development of gas in the Surat CMA under the EIS scenario. The results are presented in Tables 7.5 and 7.6 and summarised as follows:

- Nine spring complexes and sixteen watercourse springs are predicted to have groundwater pressure reductions in an underlying source aquifer nominated in the OGIA dataset and are assessed to be at risk of impacts. Two spring complexes predicted to have groundwater pressure reductions in an underlying source aquifer are not considered to be at risk of impacts; spring complex 507 has been destroyed by cattle and local practices (QLD Herbarium, 2012) and spring complex 506 is most likely associated with a perched groundwater system and is therefore unlikely to be associated with water level changes in the aquifer (QWC, 2012a).
- Three spring complexes (229, 584 and 592) and three watercourse springs (W80, W81 and W82) are predicted to have groundwater pressure reductions in an underlying aquifer that is not the source aquifer nominated in the OGIA dataset and were identified in the UWIR as requiring monitoring. It is understood that the risk assessment undertaken by the QWC for the UWIR applied a precautionary approach for these springs due to their high ecological value and/or hydrogeological uncertainty and these springs are therefore assessed to be at risk of impacts.
- For the majority of the springs of interest, there is a large stratigraphic separation (over 1 km in most cases) and no major faults between the impacted formation underlying the spring (the Bandanna Formation in most cases) and the spring and there is negligible risk of impacts. One spring complex (302) was assessed to be potentially sourced from an impacted formation underlying the spring that is not the source aquifer nominated in the OGIA dataset.

Table 7.5 Spring complexes at risk of depressurisation impacts in the Surat CMA under the EIS scenario

Spring complex number	Spring complex name	Vent number(s)	Most likely source aquifer (OGIA, 2013a)	Impacted in source aquifer or other underlying formation?	Risk assessment notes	At risk of cumulative impacts
1	Rainbow spring	nv4, nv337, nv339, nv340, nv343, nv365, nv366, nv368, nv369, 549, 550	Precipice Sandstone, Clematis Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
8	Dawson River 8	26, 28, 38	Hutton sandstone	Source aquifer	Source aquifer nominated in OGIA dataset impacted under the EIS scenario Monitored by another proponent in accordance with UWIR or JIP requirements	Yes
9	Cockatoo Creek	64, 64.1, 65, 65.1, 65.2, 66, 319, 320, 320.1, 321, 321.1, 321.2, 321.3, 321.4, 321.5, 321.6, 321.7, 327.8, 684	Precipice Sandstone	Bandanna Formation	KCB (2012b) indicates Bandanna Formation is unlikely to be the source aquifer, so the risk of impacts due to the EIS Scenario is negligible	No
16	16	548	Clematis Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
35	35	nv367, nv386	Clematis Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
68	SF2120	547, nv341	Clematis Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
74	Yebna	nv329	Evergreen Formation, Precipice Sandstone, Clematis Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
76	Eden Vale	701, nv605	Evergreen Formation (Boxvale	Bandanna Formation	KCB (2012b) indicates Bandanna Formation is unlikely to be the source aquifer, so the risk of	No

Spring complex number	Spring complex name	Vent number(s)	Most likely source aquifer (OGIA, 2013a)	Impacted in source aquifer or other underlying formation?	Risk assessment notes	At risk of cumulative impacts
			Sandstone)		impacts due to the EIS Scenario is negligible	
78	78	551, 552	Clematis Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
84	Conom	nv356, nv357, nv358	Clematis Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
85	Newton	538, nv328, nv331, nv332	Hutton Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
229	Ponies	284	Hutton Sandstone	Precipice Sandstone, Clematis Sandstone, Bandanna Formation	Identified in the UWIR as requiring monitoring due to the high ecological value and/or hydrogeological uncertainty associated with the spring Monitored by Santos GLNG in accordance with UWIR or JIP requirements	Yes
230	Lucky Last	287, 340, 686, 687, 687.1, 687.2, 687.3, 687.4, 687.5, 687.6, 688, 689	Evergreen Formation (Boxvale Sandstone), Precipice Sandstone	Source aquifer	Source aquifer nominated in OGIA dataset impacted under the EIS scenario Monitored by Santos GLNG in accordance with UWIR or JIP requirements A spring impact mitigation strategy has been developed by Santos GLNG in accordance with the requirements of the UWIR	Yes
233	Moolayember	408, 675, 676	Clematis Sandstone	Bandanna Formation	KCB (2012b) indicates Bandanna Formation is unlikely to be the source aquifer, so the risk of impacts due to the EIS Scenario is negligible	No
254	254	nv5	Clematis Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
260	Scott's Creek	189, 190, 191, 192,	Hutton Sandstone	Source aquifer	Source aquifer nominated in OGIA dataset impacted	Yes

Spring complex number	Spring complex name	Vent number(s)	Most likely source aquifer (OGIA, 2013a)	Impacted in source aquifer or other underlying formation?	Risk assessment notes	At risk of cumulative impacts
		192.1			under the EIS scenario Monitored by another proponent in accordance with UWIR or JIP requirements A spring impact mitigation strategy has been developed by another proponent in accordance with the requirements of the UWIR	
267	267	nv6, nv7	Hutton Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
283	Barton	702, 703	Gubberamunda sandstone	Source aquifer	Source aquifer nominated in OGIA dataset impacted under the EIS scenario Monitored by another proponent in accordance with UWIR or JIP requirements A spring impact mitigation strategy has been developed by another proponent in accordance with the requirements of the UWIR	Yes
296	Carnarvon Gorge	553, 554, 554.3, 555, 556, 677, 678, 712 , 713, 714, 715, nv392, nv394, nv396, nv435	Evergreen Formation (Boxvale Sandstone), Precipice Sandstone, Hutton Sandstone	Bandanna Formation	KCB (2012b) indicates Bandanna Formation is unlikely to be the source aquifer, so the risk of impacts due to the EIS Scenario is negligible	No
302	302	539, 539.1	Precipice Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation could potentially be the source aquifer for the spring Not currently monitored under the UWIR or JIP	Yes
304	ExpedRange	541, 542, 543, 544, 544.1, 544.2, 544.3, 545, 546, nv2, nv3, nv348, nv349, nv350, nv351, nv352, nv353, nv354, nv355	Clematis Sandstone, Cainozoic Sediments	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No

Spring complex number	Spring complex name	Vent number(s)	Most likely source aquifer (OGIA, 2013a)	Impacted in source aquifer or other underlying formation?	Risk assessment notes	At risk of cumulative impacts
306	306	nv371	Clematis Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
307	Elgin	nv359, nv372, nv373, nv375, nv376, nv377, nv378, nv379	Clematis Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
308	308	nv383	Clematis Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
309	309	nv384	Clematis Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
310	310	nv370	Precipice Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
311	311	499, 500, 500.1, 535, 536, 536.1, 536.2, 537, 692, 693, 694, 695, 696, 697, 698, 699, 704	Precipice Sandstone	Source aquifer	Source aquifer nominated in OGIA dataset impacted under the EIS scenario Monitored by Santos GLNG in accordance with UWIR or JIP requirements A spring impact mitigation strategy has been developed by Santos GLNG in accordance with the requirements of the UWIR	Yes
326	326	705	Clematis Sandstone	Bandanna Formation	KCB (2012b) indicates Bandanna Formation is unlikely to be the source aquifer, so the risk of impacts due to the EIS Scenario is negligible	No
327	327	nv385	Precipice Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
328	328	nv374	Precipice Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the	No

Spring complex number	Spring complex name	Vent number(s)	Most likely source aquifer (OGIA, 2013a)	Impacted in source aquifer or other underlying formation?	Risk assessment notes	At risk of cumulative impacts
					spring	
335	335	nv406	Hutton Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
339	Lonely Eddie	706, 707, 708, 709	Precipice Sandstone	Source aquifer	Source aquifer nominated in OGIA dataset impacted under the EIS scenario Not currently monitored under the UWIR or JIP	Yes
506	SprRidge	184, 185, 186	Gubberamunda Sandstone	Source aquifer	The UWIR indicates these springs are most likely associated with a perched groundwater system and therefore unlikely to be affected by water level changes in the aquifer.	No
507	VI_mile	187, 188, 679, 680, 680.1	Gubberamunda Sandstone	Source aquifer	Destroyed by cattle and local practices (QLD Herbarium, 2012) and is not included in the UWIR monitoring or mitigation requirements	No
510	Cleanskins	nv417	Clematis Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
561	Spring Rock Creek	285	Evergreen Formation (Boxvale Sandstone), Precipice Sandstone	Source aquifer	Source aquifer nominated in OGIA dataset impacted under the EIS scenario Monitored by Santos GLNG in accordance with UWIR or JIP requirements A spring impact mitigation strategy has been developed by Santos GLNG in accordance with the requirements of the UWIR	Yes
583	Lenore Hills	710, nv621, nv622	Tertiary Volcanics, Clematis Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
584	Wambo	711, 711.1	Cainozoic Sediments	Mooga Sandstone, Gubberamunda Sandstone, Springbok	Identified in the UWIR as requiring monitoring due to the high ecological value and/or hydrogeological uncertainty associated with the spring	Yes

Spring complex number	Spring complex name	Vent number(s)	Most likely source aquifer (OGIA, 2013a)	Impacted in source aquifer or other underlying formation?	Risk assessment notes	At risk of cumulative impacts
				Sandstone, Walloon Coal Measures, Hutton Sandstone, Precipice Sandstone	Monitored by another proponent in accordance with UWIR or JIP requirements	
586	Boxvale	nv437	Evergreen Formation (Boxvale Sandstone)	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
587	Timor	x436	Hutton Sandstone	Precipice Sandstone, Clematis Sandstone, Bandanna Formation	Hydrogeological assessment indicates the underlying impacted formations are unlikely to be the source aquifer for the spring	No
591	Yebna 2	534	Evergreen Formation, Precipice Sandstone	Source aquifer	Source aquifer nominated in OGIA dataset impacted under the EIS scenario Monitored by Santos GLNG in accordance with UWIR or JIP requirements A spring impact mitigation strategy has been developed by Santos GLNG in accordance with the requirements of the UWIR	Yes
592	Abyss	286 , 286.1, 286.2, 286.3, 682, 716	Hutton Sandstone	Precipice Sandstone, Clematis Sandstone, Bandanna Formation	Identified in the UWIR as requiring monitoring due to the high ecological value and/or hydrogeological uncertainty associated with the spring Monitored by Santos GLNG in accordance with UWIR or JIP requirements	Yes
593	Cockatoo3	685	Precipice Sandstone	Bandanna Formation	KCB (2012b) indicates Bandanna Formation is unlikely to be the source aquifer, so the risk of impacts due to the EIS Scenario is negligible	No
594	Elgin2	540	Tertiary Basalt, Clematis Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
605	Kangaroo Creek	nv717, nv718, nv719	Cainozoic Sediments, Springbok	Source aquifer	Source aquifer nominated in OGIA dataset impacted under the EIS scenario	Yes

Spring complex number	Spring complex name	Vent number(s)	Most likely source aquifer (OGIA, 2013a)	Impacted in source aquifer or other underlying formation?	Risk assessment notes	At risk of cumulative impacts
			Sandstone		Located on another proponent's tenure	

(1) **Bold** Environment Protection and Biodiversity Conservation (EPBC) Act 1999 listed springs, including communities of native species dependant on natural discharge of groundwater from the Great Artesian Basin and springs containing individual EPBC listed species.

Table 7.6 Watercourse springs at risk of depressurisation impacts in the Surat CMA under the EIS scenario

Site number	River/Reach	Most likely source aquifer (OGIA, 2013a)	Impacted in source aquifer or other underlying formation?	Risk assessment notes	At risk of cumulative impacts
W6	Bethecurriba Creek	Kumbarilla Beds	Walloon Coal Measures, Hutton Sandstone	Hydrogeological assessment indicates the underlying impacted formations are unlikely to be the source aquifer for the spring	No
W7	Bethecurriba Creek	Kumbarilla Beds	Walloon Coal Measures, Hutton Sandstone	Hydrogeological assessment indicates the underlying impacted formations are unlikely to be the source aquifer for the spring	No
W10	Blyth Creek	Mooga Sandstone, Gubberamunda Sandstone	Source aquifers	Source aquifer nominated in OGIA dataset impacted under the EIS scenario	Yes
W14	Bungaban Creek	Hutton Sandstone	Source aquifer	Source aquifer nominated in OGIA dataset impacted under the EIS scenario	Yes
W15	Bungaban Creek (North)	Hutton Sandstone	Source aquifer	Source aquifer nominated in OGIA dataset impacted under the EIS scenario	Yes
W16	Bungeworgorai Creek	Gubberamunda Sandstone	Source aquifer	Source aquifer nominated in OGIA dataset impacted under the EIS scenario	Yes
W17	Bungeworgorai Creek	Mooga Sandstone	Gubberamunda Sandstone, Springbok Sandstone, Walloon Coal Measures, Hutton Sandstone, Precipice	Hydrogeological assessment indicates the underlying impacted formations are unlikely to be the source aquifer for the spring	No

Site number	River/Reach	Most likely source aquifer (OGIA, 2013a)	Impacted in source aquifer or other underlying formation?	Risk assessment notes	At risk of cumulative impacts
			Sandstone		
W18	Bungil Creek	Gubberamunda Sandstone	Source aquifer	Source aquifer nominated in OGIA dataset impacted under the EIS scenario	Yes
W19	Bungil Creek	Mooga Sandstone	Source aquifer	Source aquifer nominated in OGIA dataset impacted under the EIS scenario	Yes
W22	Carnarvon Creek	Precipice Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
W26	Clematis Creek	Clematis Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
W28	Cockatoo Creek	Precipice Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
W29	Cockatoo Creek	Precipice Sandstone	Hutton Sandstone, Bandanna Formation	Hydrogeological assessment indicates the underlying impacted formations are unlikely to be the source aquifer for the spring	No
W35	Conciliation Creek	Clematis Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
W39	Dawson River	Hutton Sandstone	Source aquifer	Source aquifer nominated in OGIA dataset impacted under the EIS scenario The UWIR inaccurately lists Santos GLNG as the responsible tenure holder for this spring, which actually falls on another proponent's tenure	Yes
W40	Dawson River (Central)	Precipice Sandstone	Source aquifer	Source aquifer nominated in OGIA dataset impacted under the EIS scenario Monitored by Santos GLNG in accordance with UWIR or JIP requirements	Yes

Site number	River/Reach	Most likely source aquifer (OGIA, 2013a)	Impacted in source aquifer or other underlying formation?	Risk assessment notes	At risk of cumulative impacts
W42	Dawson River (NW)	Precipice Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
W59	Eurombah Creek	Hutton Sandstone	Source aquifer	Source aquifer nominated in OGIA dataset impacted under the EIS scenario Located on another proponent's tenure	Yes
W76	Horse Creek (East Branch)	Gubberamunda Sandstone	Source aquifer	Source aquifer nominated in OGIA dataset impacted under the EIS scenario Located on another proponent's tenure	Yes
W77	Horse Creek (East Branch)	Mooga Sandstone, Gubberamunda Sandstone	Source aquifers	Source aquifer nominated in OGIA dataset impacted under the EIS scenario Located on another proponent's tenure	Yes
W78	Horse Creek (East Branch) Tributary	Mooga Sandstone, Gubberamunda Sandstone	Source aquifers	Source aquifer nominated in OGIA dataset impacted under the EIS scenario Located on another proponent's tenure	Yes
W79	Horse Creek (East Branch) Tributary	Mooga Sandstone, Gubberamunda Sandstone	Source aquifers	Source aquifer nominated in OGIA dataset impacted under the EIS scenario Located on another proponent's tenure	Yes
W80	Hutton Creek	Hutton Sandstone	Precipice Formation, Clematis Sandstone, Bandanna Formation	Identified in the UWIR as requiring monitoring due to the high ecological value and/or hydrogeological uncertainty associated with the spring Monitored by Santos GLNG in accordance with UWIR or JIP requirements	Yes
W81	Hutton Creek	Hutton Sandstone	Precipice Formation, Clematis Sandstone, Bandanna Formation	Identified in the UWIR as requiring monitoring due to the high ecological value and/or hydrogeological uncertainty associated with the spring Monitored by Santos GLNG in accordance with UWIR or JIP requirements	Yes

Site number	River/Reach	Most likely source aquifer (OGIA, 2013a)	Impacted in source aquifer or other underlying formation?	Risk assessment notes	At risk of cumulative impacts
W82	Injune Creek	Hutton Sandstone	Precipice Formation, Clematis Sandstone, Bandanna Formation	Identified in the UWIR as requiring monitoring due to the high ecological value and/or hydrogeological uncertainty associated with the spring Monitored by Santos GLNG in accordance with UWIR or JIP requirements	Yes
W105	Maranoa River	Gubberamunda Sandstone	Springbok Sandstone, Walloon Coal Measures, Hutton Sandstone	Hydrogeological assessment indicates the underlying impacted formations are unlikely to be the source aquifer for the spring	No
W106	Maranoa River	Mooga Sandstone, Gubberamunda Sandstone	Springbok Sandstone, Walloon Coal Measures, Hutton Sandstone	Hydrogeological assessment indicates the underlying impacted formations are unlikely to be the source aquifer for the spring	No
W113	Mimosa Creek	Clematis Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
W114	Mimosa Creek Tributary	Clematis Sandstone	Bandanna Formation	Hydrogeological assessment indicates the Bandanna Formation is unlikely to be the source aquifer for the spring	No
W122	Murri Murri Creek	Kumbarilla Beds	Springbok Sandstone, Walloon Coal Measures, Hutton Sandstone, Precipice Sandstone	Hydrogeological assessment indicates the underlying impacted formations are unlikely to be the source aquifer for the spring	No
W141	Robinson Creek	Hutton Sandstone	Source aquifer	Source aquifer nominated in OGIA dataset impacted under the EIS scenario	Yes
W160	Western Creek	Kumbarilla Beds	Source aquifer	Source aquifer nominated in OGIA dataset impacted under the EIS scenario Located closer to another proponent's tenure	Yes
W164	Yuleba Creek	Mooga Sandstone	Source aquifer	Source aquifer nominated in OGIA dataset impacted under the EIS scenario	Yes

Springs at risk of impacts within or near to GFD Project tenures

Of the 13 spring complexes and 19 watercourse springs in the Surat CMA identified as being at risk of impacts due to cumulative development of gas under the EIS scenario, 8 spring complexes and 12 watercourse springs are located within or near GFD Project tenures (Figure 7.4). Tables 7.7 and 7.8 present predicted maximum depressurisation, year of maximum depressurisation, and year the 0.2 m trigger is exceeded for these springs under the EIS scenario.

The UWIR identified 6 spring complexes and 12 watercourse springs located within or near Santos GLNG tenure to be at risk of impacts. Two additional spring complexes (302 and 339) and one additional watercourse spring (W141) located within or near GFD Project tenures have been assessed to be at risk of impacts under the EIS scenario.

Table 7.7 Spring complexes at risk of depressurisation impacts within or near GFD Project tenure

Spring complex name	Spring complex number	Vent number(s)	Most likely source aquifer (OGIA, 2013a)	Impacted underlying formations where the source aquifer is not impacted*	Gas field	Summary of model predictions for the EIS Scenario			
						Maximum impact to source aquifer (m) <i>(UWIR scenario maximum impact)</i>	Year 0.2 m trigger is exceeded	Maximum impact^ (m)	Year of maximum impact
Ponies	229	284	Hutton Sandstone	Precipice Sandstone, Clematis Sandstone, <i>Bandanna Formation</i>	Fairview	<0.2	1999	508	2018
Lucky Last	230	287, 340, 686, 687, 687.1, 687.2, 687.3, 687.4, 687.5, 687.6, 688, 689	Evergreen Formation (Boxvale Sandstone), <i>Precipice Sandstone</i>	NA	Fairview	1.68 <i>(1–1.5)</i>	2016	1.68	2052
302	302	539, 539.1	Precipice Sandstone	<i>Bandanna Formation</i>	East of Arcadia	<0.2	2093	26.3	2585
311	311	499, 500, 500.1, 535, 536, 536.1, 536.2, 537, 692, 693, 694, 695, 696, 697, 698, 699	<i>Precipice Sandstone</i>	NA	Fairview	<0.2 <i>(0.2–0.5)</i>	NA	<0.2	2054
Lonely Eddie	339	706, 707, 708, 709	<i>Precipice Sandstone</i>	NA	NW of Fairview	<0.2	NA	<0.2	2125
Spring Rock Creek	561	285	Evergreen Formation (Boxvale Sandstone), <i>Precipice</i>	NA	Fairview	1.89 <i>(1–1.5)</i>	2016	1.89	2054

Spring complex name	Spring complex number	Vent number(s)	Most likely source aquifer (OGIA, 2013a)	Impacted underlying formations where the source aquifer is not impacted*	Gas field	Summary of model predictions for the EIS Scenario			
						Maximum impact to source aquifer (m) <i>(UWIR scenario maximum impact)</i>	Year 0.2 m trigger is exceeded	Maximum impact^ (m)	Year of maximum impact
			<i>Sandstone</i>						
Yebna 2	591	534	Evergreen Formation, <i>Precipice Sandstone</i>	NA	Fairview	<0.2 <i>(0.2–0.5)</i>	NA	<0.2	2069
Abyss	592	286, 286.1, 286.2, 286.3, 682, 716	Hutton Sandstone	Precipice Sandstone, Clematis Sandstone, <i>Bandanna Formation</i>	Fairview	<0.2	2000	391	2017

(1) NA – Not applicable

(2) **Bold** Impacted under the EIS Scenario but not the UWIR Scenario

(3) * Impacted underlying formations shown where the source aquifer is not impacted

(4) ^ Impact assessment results are presented for the formation shown in *italics*

Table 7.8 Watercourse springs at risk of depressurisation impacts within or near GFD Project tenures

Watercourse spring site number	Watercourse name	Most likely source aquifer (OGIA, 2013a)	Impacted underlying formations where the source aquifer is not impacted*	Gas field	Summary of model predictions for the EIS Scenario			
					Maximum impact to source aquifer (m)	Year 0.2 m trigger is exceeded	Maximum impact^ (m)	Year of maximum impact
W10	Blyth Creek	Mooga Sandstone, Gubberamunda Sandstone	NA	Roma	5.1	2027	5.1	2235
W14	Bungaban Creek	Hutton Sandstone	NA	Scotia	0.7	2056	0.7	2205
W15	Bungaban Creek (North)	Hutton Sandstone	NA	East of Scotia	0.7	2056	0.7	2205
W16	Bungeworgorai Creek	Gubberamunda Sandstone	NA	North West of Roma	<0.2	NA	<0.2	2535
W18	Bungil Creek	Gubberamunda Sandstone	NA	Roma	<0.2	NA	<0.2	2125
W19	Bungil Creek	Mooga Sandstone	NA	Roma	0.21	2425	0.21	2535
W40	Dawson River (Central)	Precipice Sandstone	NA	Fairview	<0.2	NA	<0.2	2076
W80	Hutton Creek	Hutton Sandstone	Precipice Formation, Clematis Sandstone, Bandanna Formation	West of Fairview	<0.2	2000	70.1	2020
W81	Hutton Creek	Hutton Sandstone	Precipice Formation, Clematis	Fairview	<0.2	1996	714	2017

Watercourse spring site number	Watercourse name	Most likely source aquifer (OGIA, 2013a)	Impacted underlying formations where the source aquifer is not impacted*	Gas field	Summary of model predictions for the EIS Scenario			
					Maximum impact to source aquifer (m)	Year 0.2 m trigger is exceeded	Maximum impact^ (m)	Year of maximum impact
			Sandstone, <i>Bandanna Formation</i>					
W82	Injune Creek	Hutton Sandstone	Precipice Formation, Clematis Sandstone, <i>Bandanna Formation</i>	Fairview	<0.2	1998	417	2017
W141	Robinson Creek	<i>Hutton Sandstone</i>	NA	West of Scotia	<0.2	NA	<0.2	2062
W164	Yuleba Creek	<i>Mooga Sandstone</i>	NA	Roma	0.54	2145	0.54	2475

(1) NA – Not applicable

(2) **Bold** Impacted under the EIS Scenario but not the UWIR Scenario.

(3) * Impacted underlying formations shown where the source aquifer is not impacted

(4) ^ Impact assessment results are presented for the formation shown in *italics*

8. Potential GFD Project impacts and management measures

A number of GFD Project activities, if undertaken without adequate management controls in place, have the potential to impact on the identified groundwater EVs. Section 7 of this report describes the modelled magnitude and extent of aquifer depressurisation and drawdown associated with the GFD Project, and also discusses the quantification of the potential impact on landholder bores and springs in the GFD Project area and the wider Surat CMA. This section (Section 8) describes qualitatively the other potential impacts to groundwater EVs due to depressurisation of coal seams and other GFD project activities. Mitigation and management measures are then identified and described, including those addressing the quantified impacts discussed in Section 7. Section 8 concludes with the significance assessment of the potential impacts and the residual impacts remaining after application of the mitigation and management measures.

8.1 Project activities and potential impacts

The key potential impacts to groundwater EVs associated with GFD Project activities are summarised in Table 8.1 and described in detail in the following sub-sections (Sub-sections 8.1.1 to 8.1.3). Sub-section 8.1.1 complements Section 7 and addresses other potential impacts related to coal seam depressurisation. Sub-section 8.1.2 deals with potential mechanisms to impact groundwater levels/pressures other than by coal seam depressurisation. Sub-section 8.1.3 assesses potential impacts to groundwater quality.

8.1.1 Potential impacts related to coal seam depressurisation

The extraction of coal seam water is an integral part of the production of natural gas and has the potential for long-term, regional scale aquifer depressurisation and other impacts. Coal seam depressurisation can result in:

- Decline in groundwater levels/pressure in bores and reduced supply to groundwater users.
- Reduced spring flow and loss or degradation of groundwater dependent ecosystems.
- Reduced stream base flow (watercourse spring flow) and loss or degradation of dependent aquatic ecosystems or loss or reduction of supply to downstream surface water users.
- Subsidence, altering groundwater flow and aquifer storage.
- Subsidence, causing ground surface displacement and altering surface water flow paths.

The impacts of depressurisation of the coal seams on bores and springs (including due to induced flow between aquifers) have been assessed quantitatively using numerical groundwater modelling. The modelling approach and impact assessment results are detailed in Section 7.

Subsidence

The risk of subsidence impacts to groundwater EVs due to coal seam depressurisation is very low. As groundwater is extracted and the coal seams are depressurised, an increase in vertical effective stress will occur, which can result in:

- Settlement of the overlying formations, altering groundwater flow paths and aquifer storage.
- Ground surface subsidence, altering surface water flow paths.

Although pressure reductions in the coal seams are expected to occur as a result of GFD Project operations (Section 7.3.1), the risk of significant subsidence of the land surface is very low because:

- The pressure reductions are predicted to occur in formations comprising consolidated rock.
- The greatest pressure reductions are predicted to occur at depths of several hundred metres or more below the surface.

Subsidence modelling undertaken for the current approved Santos GLNG activities indicate that for an average reduction in pressure of 700 m of head in the Walloon Coal Measures, the calculated subsidence in the Walloon Coal Measures is 0.28 m. For an average reduction in pressure of 1,000 m of head in the Bandanna Formation, the calculated subsidence in the Bandanna Formation is 0.15 m. At the surface, the calculated subsidence is considerably lower again. The modelling predicted maximum differential settlements at the surface of 0.06 m over a distance of 1.5 km for the Roma gas field, and 0.045 m over a distance of 3 km for the Arcadia and Fairview gas fields. Settlements of this scale are too small to cause changes to surface water or groundwater flow paths and as a result, no impact to groundwater EVs is expected (Santos GLNG, 2013d).

8.1.2 Potential impacts on groundwater levels related to other project activities

Without adequate controls in place construction, operation, decommissioning and rehabilitation of other project components of the gas field development may involve work with the potential to impact on groundwater levels/pressures in ways other than by depressurisation of coal seams. These components include:

- Production wells
- Fluid injection wells, monitoring bores and potentially underground gas storage wells
- Gas and water gathering lines
- Gas and water transmission pipelines (within or between tenures and gas fields)
- Gas compression and treatment facilities
- Water storage and management facilities
- Access roads and tracks
- Accommodation facilities and associated services (e.g. sewage treatment)
- Maintenance facilities, workshops, construction support, warehousing and administration buildings
- Utilities such as water and power generation and supply (overhead and/or underground)
- Laydown, stockpile and storage areas
- Borrow pits and quarries
- Communications.

Drilling and construction of wells

The drilling, construction, operation, maintenance and decommissioning of production wells, as well as the construction of re-injection wells, water supply bores and monitoring bores, is required for production of natural gas from coal seams. The wells to be constructed for the GFD Project will intersect multiple hydrogeological units and although the likelihood is considered remote with adequate management controls

in place, there is the potential for long-term, localised depressurisation of aquifers to occur through the following:

- Without adequate controls in place constructed wells can create a connection between previously isolated aquifers, inducing vertical leakage of groundwater within the borehole. This can affect water levels in nearby bores and spring flow, in turn affecting groundwater users and ecosystems dependent on springs.
- Without adequate controls management of artesian flow (where encountered) can lead to uncontrolled flow of groundwater at the surface. Groundwater level data from DNRM monitoring bores indicate that the Gubberamunda Sandstone, Injune Creek Group and Hutton Sandstone aquifers may be artesian in parts of the study area. Uncontrolled artesian flow can reduce pressure in aquifers and adversely affect water levels in nearby bores.

Hydraulic fracturing

Hydraulic fracturing, or coal seam stimulation, is a process used to improve the efficiency of natural gas extraction from coal seams. Hydraulic fracturing is not used for all wells and most wells drilled to date in Queensland have not been fracture stimulated. Hydraulic fracturing is generally, although not exclusively, used in areas where the coal seams have lower permeability. By improving the production efficiency, it potentially reduces the number of required wells to deliver the required rate of gas production.

In the hydraulic fracturing process, fluid is pumped down a well and then into the coal seams through small holes or perforations in the steel casing. The fluid is pumped at sufficient pressure to open small passageways into the coal seam and interconnect the naturally occurring fractures or cleats. Once the coal seam has been fractured, sand size particles (known as a propanant) are placed by the fluid to hold open (prop open) the fracture connections. The fluid used in the stimulation process is then allowed to flow back into the well and is pumped to the surface.

The hydraulic fracturing process has the potential to impact groundwater levels or pressures by creating or enhancing a pathway between the coal seam and an aquifer. The likelihood of this occurring is considered to be low. The hydraulic fracturing process is engineered and designed to ensure that fracturing remains within the target coal seam, thus preventing the formation of new pathways to aquifers. Fractures created during the hydraulic stimulation process generally are of the order of several millimetres wide and may propagate many metres horizontally away from the well.

Shallow subsurface activities

Other GFD Project components with potential to impact on groundwater levels and pressures are the ancillary infrastructure activities such as installation of borrow pits, buried pipelines and storage dams. The disturbance created by these activities is generally the product of excavation and is restricted to within several metres of the surface. At these depths, aquifers are limited in extent, almost always unconfined and any depressurisation due to excavation activities is likely to be negligible.

8.1.3 Changes to water quality

A number of GFD Project activities have the potential to lead to changes in groundwater quality, including:

- Drilling and construction of production wells, re-injection wells, water supply bores and monitoring bores
- Groundwater extraction for gas production
- Hydraulic fracturing
- Storage of coal seam water
- Brine management and injection

- Managed Aquifer Recharge
- Beneficial use for irrigation or stock watering
- Surface activities.

Degradation of groundwater quality can lead to:

- Loss or degradation of springs or other GDEs dependent on affected aquifers
- Degradation of the beneficial use of groundwater supplies
- Degradation of the beneficial use of surface water supplies (where watercourse springs are affected).

Drilling and construction of wells

The drilling, construction, operation, maintenance and decommissioning of production wells, as well as the construction of re-injection wells, water supply bores and monitoring bores, are required for production of gas. The wells to be constructed for the GFD Project will intersect multiple hydrogeological units and there is the potential for localised changes to the quality of groundwater to occur through the following:

- Without adequate controls constructed wells can create an artificial connection between previously isolated aquifers, inducing vertical leakage of groundwater within the borehole. This can change water quality.
- Without adequate controls management of artesian flow (where encountered) can lead to uncontrolled flow of groundwater at the surface. Uncontrolled artesian flows can adversely affect the quality of underlying shallow aquifers.

Groundwater extraction for gas production

Depressurisation of the coal seams for production of gas has the potential to induce flow between aquifers above and below the Walloon Coal Measures or Bandanna Formation. Although this can lead to changes in groundwater quality if aquifers of differing water quality become hydraulically connected, the results of numerical groundwater modelling indicate that depressurisation impacts are significantly reduced away from the coal seams, and the potential for increased vertical flux between aquifers is limited.

Hydraulic fracturing

As described in Section 8.1.2, the hydraulic fracturing process creates or enhances small fractures in the coal seam by pumping fluid and sand size particles into the coal seams through small holes or perforations in the well's steel casing. Once the coal seam has been fractured, the fluid used in the stimulation process is then allowed to flow back into the well and is pumped to the surface.

Hydraulic fracturing fluid typically includes up to 99% water and sand, with about 1% of a range of additives in diluted quantities (EHP, 2014; USEPA, 2010). The additives assist in carrying and dispersing the sand into the coal seam. The materials used by Santos GLNG in the hydraulic fracturing process have been subjected to a risk assessment (Santos GLNG, 2014b) and are publicly disclosed on the Queensland Department of Environment and Heritage Protection (EHP) website. In accordance with Queensland regulations the materials used do not include benzene, toluene, ethylbenzene, xylene (BTEX) or polycyclic aromatic hydrocarbons (PAHs) compounds as additives.

The hydraulic fracturing process has the potential to impact groundwater through the subsurface transport of:

- Gas
- Remnant hydraulic fracturing fluids which have not been removed during the flowback process or by subsequent coal seam water extraction by production wells.

Transport of gas and remnant hydraulic fracturing fluids have the potential to impact water quality within the target coal seams and hydrogeological units connected to them. This may subsequently affect the water quality of landholder water supplies and springs (if present). The transport of gas and fluids from the coal seams may occur along faults or fractures/unconformities within the rock, or as a result of failures in the casing or seals of production wells.

The results of groundwater modelling indicate that the coal seams have limited connectivity with the adjacent aquifers. The majority of gas and fracturing fluid transport is therefore likely to occur within the target coal seams themselves. The hydraulic fracturing process is designed to ensure that fracturing remains within the target seam, thus preventing the formation of new pathways to other aquifers.

Impacts on groundwater quality, restricted to the Bandanna Formation in the northern area and the Walloon Coal Measures in the central and southern areas, may occur. The effects are expected to be localised within the target coal formations and within the GFD Project tenures. There may be impacts to springs where the coal seam is the source aquifer, or to groundwater users taking groundwater from the coal seams, however most of the fluids are removed during flowback and subsequent gas production.

Storage of coal seam water

The water extracted from coal seams in the study area is likely to be of variable quality and there is potential for the salinity of this water to be higher than shallow aquifers and surface water bodies in the area.

Coal seam water has the potential to impact on water quality in shallow aquifers through seepage from storage dams. The potential for this to occur is limited as storage dams will be constructed and operated in accordance with the EHP guidelines for the management of regulated dams (EHP, 2012b).

Brine management and injection

The quality of water extracted from coal seams will determine the management options for its beneficial use or disposal in accordance with the Coal Seam Gas Water Management Policy (EHP, 2012a). If the management of the water extracted from coal seams requires treatment such as desalination (e.g. using reverse osmosis technology), this will result in the generation of a concentrated effluent or brine from the process.

The management and injection of brine and disposal of solid salt has the potential to impact groundwater quality through:

- Seepage of brine from storage dams to shallow aquifers
- Leakage from licenced waste disposal facilities where salts are disposed
- Cross-flow of GAB aquifers due to poorly constructed injection wells or failure of injection wells due to corrosion.

The management of brine and/or solid salt will be in accordance with the Coal Seam Gas Water Management Policy (EHP, 2012a) and approval conditions. Considered management options include:

- Commercial salt production where practicable including collaboration with other proponents

- Brine injection into selected deep saline aquifers. Santos GLNG currently has approval to inject brine into the Timbury Hills Formation in the Fairview Gas Field and is currently undertaking feasibility studies for injection into the Timbury Hills Formation in the Roma Gas field.
- Crystallisation to form solid salt for disposal into a licensed waste disposal facility.

Managed aquifer recharge

Managed aquifer recharge (MAR) is currently being considered for the Gubberamunda Sandstone aquifer near Roma and across other project areas. MAR involves the injection of treated coal seam water into aquifers.

The injection water proposed for the MAR scheme near Roma has a TDS of approximately 325 mg/L, which equates to an electrical conductivity of approximately 500 $\mu\text{S}/\text{cm}$. This is substantially lower (i.e. better quality) than the average electrical conductivity in the receiving Gubberamunda Sandstone aquifer, which is approximately 1,284 $\mu\text{S}/\text{cm}$ (see Section 5.7.3). The MAR scheme proposed for the Gubberamunda Sandstone will therefore have a positive impact on groundwater pressure and quality.

Beneficial reuse for irrigation and stock watering

Options for the beneficial use of coal seam water include irrigation and stock watering. Over-irrigation using coal seam water has the potential to cause localised impact to shallow groundwater resources and impacts to nearby groundwater users and springs or other GDEs if not managed in accordance with regulatory water quality limits.

Surface activities

The construction and decommissioning of ancillary infrastructure where there is some component of excavation (such as borrow pits, buried pipelines and storage dams) without adequate controls in place has the potential to impact shallow aquifers through fuel leaks and spills. Potential impacts will be restricted to areas where groundwater is shallow or the water table is intersected, and will be short-term and localised.

Fuel spills, during construction and decommissioning activities, can leak into the underlying hydrogeological unit and impact the water quality of shallow aquifers. Without adequate controls in place and the presence of a flow pathway this has the potential to cause localised impacts to nearby shallow aquifers.

8.1.4 Summary

The potential impacts to groundwater EVs associated with GFD Project activities are summarised in Table 8.1.

Table 8.1 Potential impacts associated with GFD Project activities

Potential impacts		Construction phase activities	Operations phase activities	Decommissioning and rehabilitation phase activities	Applicable management plans
Aquifer depressurisation	Decline in groundwater levels/pressure in bores and reduced supply to groundwater users.	Drilling and construction of production wells, re-injection wells, water supply bores and monitoring bores.	Operation of production wells, i.e. extraction of groundwater for natural gas production (addressed in Section 7).	Decommissioning of production wells.	Draft Environmental Management Plan. Constraints Protocol.
	Reduced stream baseflow (watercourse spring flow) and loss or reduction of supply to downstream surface water users.	Shallow sub-surface activities, including the installation of borrow pits, quarries, laydown areas, buried pipelines and storage dams.	Operation and maintenance of water supply bores.		Water Resource Management Plan.
	Reduced spring flow and loss or degradation of dependent ecosystems (including EPBC listed springs).				Underground Water Impact Report for the Surat Cumulative Management Area.
	Reduced stream baseflow (watercourse spring flow) and loss or degradation of dependent aquatic ecosystems.				Joint-Industry Early Warning System for EPBC Springs Quality Plan (Early Warning System (EWS) Plan)
	Subsidence, altering groundwater flow paths and aquifer storage.	None.	Operation of production wells, i.e. extraction of groundwater for natural gas production.	None	Water Resource Management Plan.
	Subsidence, causing ground surface displacement and altering surface water flow paths.				Ground Deformation Monitoring and Management Plan. Underground Water Impact Report for the Surat Cumulative Management Area.

Potential impacts		Construction phase activities	Operations phase activities	Decommissioning and rehabilitation phase activities	Applicable management plans
Changes to water quality.	Degradation of the beneficial use of groundwater supplies.	Drilling and construction of production wells, re-injection wells, water supply bores and monitoring bores. Shallow sub-surface activities, including the installation of borrow pits, quarries, laydown areas, buried pipelines and storage dams. Construction of surface infrastructure.	Hydraulic fracturing. Storage of brine generated during treatment of coal seam water. Brine disposal through injection into deep formations. Storage of coal seam water. Disposal of coal seam water through reinjection into aquifers (Managed Aquifer Recharge). Disposal of coal seam water through beneficial reuse for irrigation and stock watering. Hydro-testing of gas or treated water pipelines. Sewage treatment facilities.	Decommissioning of production wells. Rehabilitation of surface infrastructure.	Constraints Protocol. Water Resource Management Plan. Coal Seam Water Management Strategy. Draft Environmental Management Plan. Hydraulic Fracturing Risk Assessment. Contingency Plan for Emergency Environmental Incidents. Land Release Management Plan. Underground Water Impact Report for the Surat Cumulative Management Area. Stimulation Impact Monitoring Program.
	Loss or degradation of ecosystems dependent on springs sourced from affected aquifers.				

8.2 Mitigation and management measures

The mitigation and management measures identified for reducing the significance of potential impacts on groundwater EVs are based on the existing measures contained within the approved environmental management framework that Santos GLNG has previously developed and implemented for the GLNG Project. Applying the same mitigation and management measures from the GLNG Project to the GFD Project will ensure a consistent approach by construction and operational personnel and a common understanding for both regulators and the community of the measures to be applied and that the required outcomes are achieved. A summary of the Santos GLNG management plans currently in place is provided in Table 8.2. An overview of the key management measures to be applied for project activities to effectively manage potential impacts on groundwater EVs is provided in Sections 8.2.1 to 8.2.9.

Table 8.2 Santos GLNG management plans

Management plan	Key provisions
<i>GFD Project Environmental Protocol for Constraints Planning and Field Development (Constraints Protocol)</i>	The Constraints protocol applies to all gas field related activities. The scope of the Constraints protocol is to: • Enable Santos GLNG to comply with all relevant State and Federal statutory approvals and legislation • Support Santos GLNG's environmental policies and the General Environmental Duty (GED) as outlined in the Environmental Protection Act 1994 (Qld) (EP Act) • Promote the avoidance, minimisation, mitigation and management of direct and indirect adverse environmental impacts associated with land disturbances • Minimise cumulative impacts on environmental values. The Constraints Protocol provides a framework to guide placement of infrastructure and adopts the following management principles: • Avoidance — avoiding direct and indirect impacts • Minimisation — minimise potential impacts • Mitigation — implement mitigation and management measures • Remediation and rehabilitation — actively remediate and rehabilitate impacted areas • Offset — offset residual adverse impacts in accordance with regulatory requirements. The Constraints Protocol enables the systematic identification and assessment of environmental values and the application of development constraints to effectively avoid and/or manage environmental impacts.
<i>Water Resource Management Plan (WRMP)</i>	The WRMP has been developed to proactively detail how Santos GLNG manages and monitors potential adverse impacts to water resources, recently defined as a matter of national environmental significance. The WRMP includes the following management plans: • Hydraulic connectivity characterisation • Joint Industry Plan for EPBC Act listed springs • Evaluation of Prevention or Mitigation Options for Fairview Springs • Stimulation Impact Monitoring Program • Ground Deformation Monitoring and Management Plan • Hydraulic Fracturing Risk Assessment: Compendium of Assessed Fluid Systems • Dawson River Discharge Scheme Receiving Environment Monitoring Program.
<i>Coal Seam Water Management Strategy(CWMS)</i>	The CWMS outlines the overarching approach to managing coal seam water. The strategy prioritises the beneficial use of coal seam water where practicable, while avoiding, minimising and mitigating environmental impacts in accordance with the relevant regulatory framework.

Management plan	Key provisions
<i>Draft Environmental Management Plan (Draft EM Plan)</i>	The Draft EM Plan identifies the environmental values potentially affected by the GFD Project and proposes measures to manage the risk of potential adverse impact to these environmental values. The Draft EM Plan comprises: • Environmental values potentially affected by the GFD Project • Environmental management objectives and associated management measures • Environmental monitoring and reporting • Coal seam water management • Proposed conditions.
<i>Hydraulic Fracturing Risk Assessment: Compendium of Assessed Fluid Systems</i>	The Hydraulic Fracturing Risk Assessment report synthesises the hydraulic fracturing risk assessments completed on various hydraulic fracturing fluids and provides a framework for including new fluid systems within the risk assessment document. The body of the report provides generalised information, including the geology and hydrogeology of the area, risk assessment methodologies (qualitative and quantitative) and a high level understanding of current results. The appendices include risk assessments of individual hydraulic fracturing fluid systems.
<i>Contingency Plan for Emergency Environmental Incidents</i>	The Contingency Plan details the management practices in place within Santos GLNG to minimise environmental harm during an emergency environmental incident. The plan identifies potential incidents, and provides response actions, including escalation, communication, reporting and monitoring.
<i>Land Release Management Plan</i>	The LRMP addresses the management of releases of water to land in Santos GLNG's gas fields, including: • Coal seam water use for irrigation, construction and operations purposes • Treated sewage effluent releases to land • Use of treated sewage effluent for construction and operational purposes • Low point drain water releases to land • Hydrostatic test water releases to land. The document includes the principles, methods and controls to effectively manage and minimise the risk of environmental harm being caused by release of water to land.
<i>Underground Water Impact Report for the Surat Cumulative Management Area</i>	Santos GLNG will comply with the requirements of the Surat Cumulative Management Area (CMA) Underground Water Impact Report (UWIR) which include: • Groundwater monitoring in accordance with the Water Monitoring Strategy • Development of a Spring Impact Mitigation Strategy for specified springs • Spring monitoring in accordance with the Spring Monitoring Program

Management plan	Key provisions
	• Conducting bore assessments and entering into make good agreements with specified landholders • Developing and implementing a Baseline Assessment Plan.
<i>Joint-Industry Plan for an Early Warning System for EPBC Springs Quality Plan (EWS Plan)</i>	The Joint Industry Plan has been collaboratively developed by Santos GLNG, Origin Energy and Queensland Gas Company (the Proponents). The objectives of the Joint Industry Plan are to: • Summarise the monitoring requirements that have been requested of the proponents in the Surat Underground Water Impact Report for the Surat Cumulative Management Area (QWC, 2012a) and in the proponents' approval conditions by the Department of the Environment. • Propose an Early Warning System monitoring network and escalating levels of triggers to manage EPBC Act listed springs from adverse impacts associated with coal seam water extraction. • Demonstrate that the proponents will endeavour to identify potential adverse impact early and adequately respond to prevent adverse impact to EPBC Act listed springs. • Identify which proponent is responsible for management actions for each spring. • Demonstrate the proponents' commitments to meet the requirements of the EPBC Act approval.
<i>Ground Deformation Monitoring and Management Plan (GDMMP)</i>	The GDMMP details how Santos GLNG monitors and manages the risk from subsidence across its tenures. The plan includes monitoring methodology, exceedance management and response, and reporting requirements.
<i>Stimulation Impact Monitoring Program</i>	The plan was developed to provide a general description of the stimulation activities to be conducted by Santos GLNG, the regulatory requirements pertinent to stimulation monitoring, as well as the practices and procedures that comprise the monitoring program.

8.2.1 Groundwater extraction for gas production

Groundwater monitoring will provide a mechanism for early identification of potential depressurisation impacts due to groundwater extraction for gas production and will inform the measures required to be implemented to avoid or minimise adverse impacts on groundwater users and springs. Details of Santos GLNG's groundwater monitoring program for the GFD Project are provided in Section 9.

Bore impact management measures

The Water Act requires petroleum and gas companies to make good impairment to the adequacy of water supply from bores resulting from their water extraction. Petroleum tenure holders must carry out a bore assessment and enter into a make good agreement with the owner of bores in the immediately affected area (IAA), the area within which water levels are predicted by a UWIR to decline by more than 5 m within three years.

The UWIR assigns Santos GLNG as responsible for impacts to one bore located in the IAA. Santos GLNG has completed a bore assessment and entered into a make good agreement with the owner of this bore. The agreement specifies the measures to be implemented to minimise the impacts to the affected bore owner. Measures which may be considered for make good agreements include:

- Deepening of bores and/or pumps to increase available drawdown.
- Subsidising increased pumping costs.
- Replacing pumps.
- Replacing/relocating bores.
- Constructing additional bores.
- Increasing water storage capacity.
- Treating water to mitigate changes in water quality.
- Providing alternative water sources.

The predicted changes in depressurisation due to the proposed GFD Project will not result in additional impacts to landholder bores before 2015, as the proposed additional production wells are not scheduled to start production until after that date. This means the current IAA will not change under the GFD Project and there are no additional requirements for Santos GLNG to undertake bore assessments or enter into make good agreements with bore owners. Santos GLNG will comply with requirements for bore assessments and make good agreements identified in the subsequent UWIR.

Through Santos GLNG's groundwater monitoring program, potential impacts on private bores will be identified before the impacts become material. Where monitoring indicates that water extraction by Santos GLNG is affecting, or has the potential to affect supply from an existing bore, then Santos GLNG will undertake a bore assessment and enter into a make good agreement with the bore owner.

The Water Act also requires petroleum tenure holders to carry out baseline assessments of water bores on their tenures before production commences. A baseline assessment is an assessment of a private bore to obtain information about the bore condition and performance and baseline water levels and quality. The objective of the baseline assessments is to support the settling of make good agreements should they be required in the future. Details of Santos GLNG's baseline assessment program are provided in Section 9.1.2.

Spring Impact Mitigation Strategy

The UWIR assigns Santos GLNG as the tenure holder responsible for preparing Spring Impact Mitigation Strategies for three spring vent complexes in the Surat CMA: Lucky Last (230), Spring Rock Creek (561),

and 311/Yebna 2 (311/591). The UWIR requires that investigations be undertaken to assess potential options to prevent or mitigate predicted impacts to EVs at each site. At this stage, Spring Impact Mitigation Strategies are not required to include actions to directly prevent or mitigate predicted impacts on springs. This is because detailed investigations are required to understand the risks posed to EVs and the conceptual hydrogeology before potential mitigation options and their effectiveness can be adequately evaluated.

The springs identified in the UWIR as requiring development of a Spring Impact Mitigation Strategy are those where an impact of more than 0.2 m is predicted in the source aquifer of the spring. The results of the numerical groundwater modelling undertaken for the GFD Project indicate there are no new spring complexes where an impact of more than 0.2 m is predicted in the source aquifer under the EIS Scenario compared to the UWIR Scenario. However, Santos GLNG may be required to prepare a Spring Impact Mitigation Strategy where drawdown impacts have increased under the EIS Scenario, such as for Spring Ridge (complex 506).

The UWIR identifies a range of potential mitigation measures where EVs at springs are found to be at risk. The applicability of these measures to Lucky Last, Spring Rock Creek and 311/Yebna 2 have been investigated by Santos GLNG and an Evaluation of Prevention or Mitigation Options Report (EPMOR) (Golder, 2014) has been prepared and submitted to the OGIA for consideration.

The EPMOR identifies the following management measures for Lucky Last, Spring Rock Creek and 311/Yebna 2:

- Avoidance options to control and prevent changes in groundwater levels before they reach the springs by injecting coal seam water of appropriate quality into the source aquifer or underlying coal seams or by surface infiltration.
- Mitigation options to prevent adverse impacts at the springs by infiltrating or injecting coal seam water of appropriate quality into the source aquifer at or close to the spring.

The mitigation options identified in the EPMOR will be implemented when risks to the EVs of a spring are imminent. A program of monitoring the aquifer systems has commenced to ensure that potential impacts to groundwater pressure in the source aquifers of springs and impact propagation are detected in advance of reaching the spring areas (refer to Section 9.1.3).

Management measures for EPBC Act springs

As a condition of the GLNG Project EPBC approval Santos GLNG, together with three other proponents in the Surat CMA, have developed a Joint Industry Plan (JIP) for a groundwater monitoring and management system to have no adverse impact to EPBC springs protected by the EPBC Act from the production of gas (Santos GLNG, 2013b). The plan is a requirement of Santos GLNG's current approval under the EPBC Act and has been developed in consultation with Geoscience Australia, the Commonwealth Department of the Environment, and the Expert Panel for Major Coal Seam Gas Projects. The plan aligns with the spring monitoring and mitigation requirements in the UWIR. A summary of the key points of the plan are to establish:

- Consistent monitoring and management across the CMA to manage the risk of the impacts, combined with a defined network of monitoring bores for each proponent
- Use of the UWIR cumulative model to assess the risk to the springs
- To measure groundwater drawdown at locations and times prior to adverse impact to EPBC springs.
- Single proponent responsibility for EPBC springs aligning with the UWIR; and
- Alignment on exceedance response processes and timing.

The JIP establishes an Early Warning System (EWS) to provide adequate time for assessment and implementation of management measures prior to potential adverse impacts on the EVs of springs associated with an EPBC Act listing. The EWS involves the concept of impact propagation pathways and the use of groundwater level variations as an early warning proxy for impact to the ecosystem supported by the spring. A groundwater monitoring bore network that focuses on the primary source aquifers of springs associated with an EPBC Act listing (primarily the Hutton Sandstone and Precipice Sandstone) is currently being installed and includes:

- Early Warning Monitoring Installations (EWMI) close to the area of coal seam water extraction or between the extraction areas and the spring. These early warning bores are located to provide initial drawdown data, and secondary data in support of interpretation of observations made closer to springs.
- Trigger Monitoring Points (TMP) located within close proximity of the spring.

Under the JIP, Santos GLNG is responsible for the monitoring, management and mitigation of adverse impacts to Lucky Last (230), Yebna 2 (591) and Abyss (592) and must establish EWMIs and TMPs for these springs.

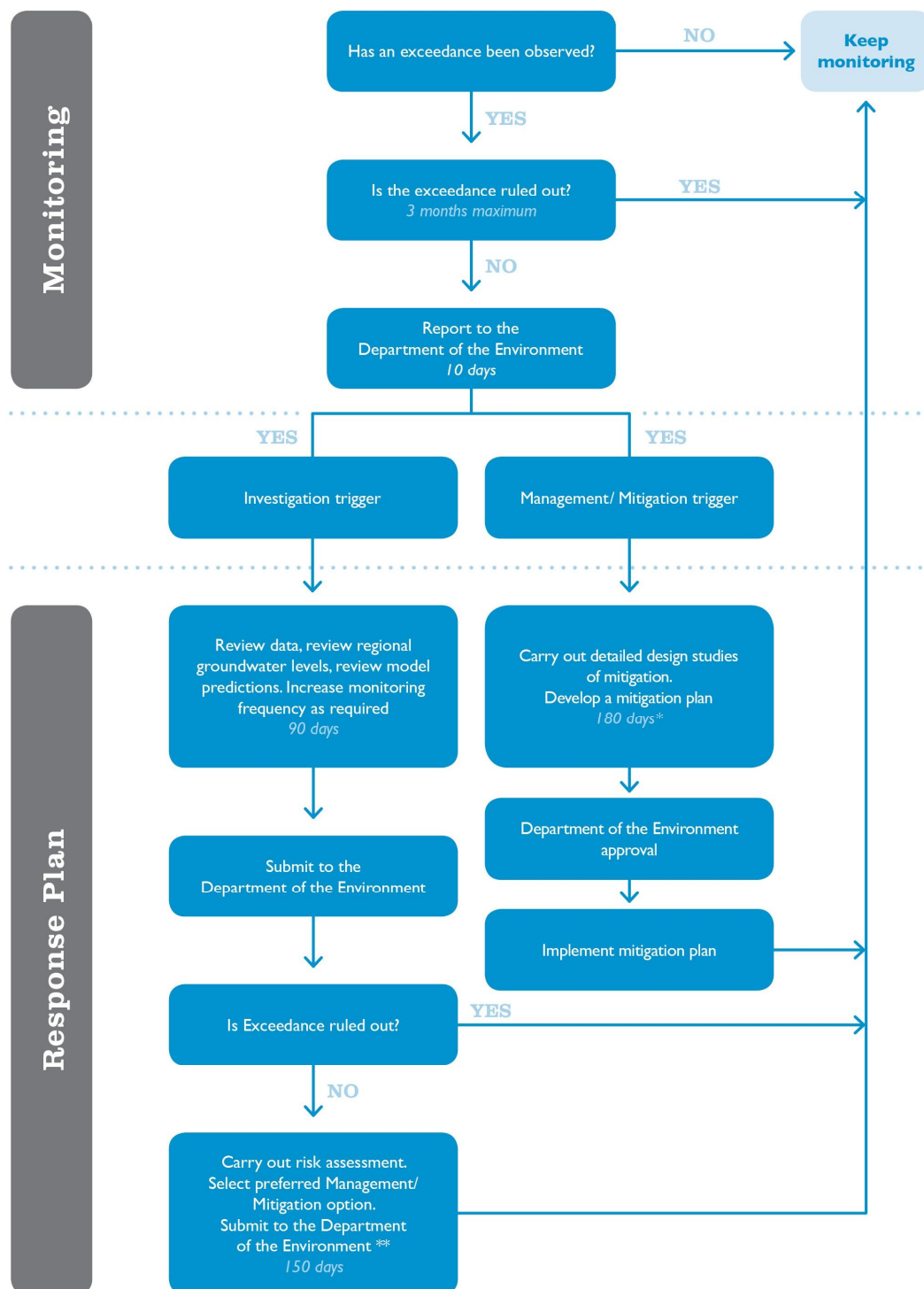
The JIP establishes drawdown triggers that instigate actions commensurate with increasing risk to springs associated with an EPBC Act listing:

- Investigation triggers – a nominated value that triggers an action such as data review, model review, increased monitoring frequency, increased monitoring parameters.
- Management/mitigation triggers – a nominated value at a TMP that triggers some action to be taken to prevent an impact occurring at a spring associated with an EPBC Act listing.

The monitoring and response plan associated with the investigation and management/mitigation triggers is presented in Figure 8.1. The JIP also establishes drawdown limits, a nominated value at a TMP that, if exceeded would result in a breach of the proponent's EPBC Act approval conditions.

Further detail on springs monitoring undertaken for the JIP is provided in Section 9.1.3.

Figure 8.1 Monitoring and response plan for springs associated with an EPBC Act listing (Santos GLNG, 2013b)



Subsidence management measures

Potential risks to the integrity of aquifers due to subsidence associated with the proposed GFD Project are considered to be very low as the major pressure reductions are predicted to occur in formations comprising consolidated rock at depths of several hundred metres below the surface. This is supported by the results of subsidence modelling undertaken for the current approved Santos GLNG activities (Santos GLNG, 2013c).

Notwithstanding the above conclusions, ground deformation and water level monitoring will be carried out to verify the above assumptions and the assessed risk, as described in Section 9.1.4.

8.2.2 Construction of wells and shallow subsurface infrastructure

Measures to minimise impacts to groundwater levels/pressure and quality from the drilling, construction and decommissioning of production wells, injection wells, water supply bores and monitoring bores, include the following:

- In addition to Santos GLNG's own design standards and robust safety procedures, the construction, operation and decommissioning of production wells will be in accordance with the *Code of practice for constructing and abandoning gas wells and associated bores in Queensland* (DNRM, 2013b) and the *Code of practice for gas well head emissions detection and reporting* (DEEDI, 2011). These standards require that production wells be lined with steel casing, which is cemented in place to isolate aquifers overlying the coal seam, and are pressure cemented to surface once they are no longer producing commercial quantities of gas.
- Well Integrity Plans will be developed for gas wells. These are risk management plans which evaluate and address potential risks to the environment for each well.
- DNRM is responsible for regulating gas production well construction, reviewing construction logs and periodically auditing drilling and construction procedures.
- Fuel or oil storage facilities will be contained within bunded (secondary containment) areas and accurate records kept of fuel, oil or chemical volumes stored on-site to allow regular quantity monitoring.
- The construction of water supply bores and monitoring bores will be in accordance with the *Minimum Construction Requirements for Water Bores in Australia* (National Water Commission, 2012).

Measures to minimise impacts to groundwater from shallow sub-surface activities, including the rehabilitation of borrow pits, laydown areas, buried pipelines and storage dams, are detailed in the Rehabilitation Management Plan (Santos GLNG, 2014e).

8.2.3 Operation of water supply bores

The impacts of water supply authorised under the Petroleum Act and the P&G Act are considered in Section 7 and will be managed in accordance with the requirements of the UWIR (outlined in Section 8.2.1).

Water supply not authorised under the Petroleum Act and the P&G Act will require a water licence under the Water Act. The water licence will be conditioned to protect nearby groundwater users and springs. The operation of water supply bores will be in accordance with the conditions on the relevant water licence.

8.2.4 Hydraulic fracturing

The risk of impacts to groundwater from hydraulic fracturing are expected to be minimal, however, the following controls will be implemented to ensure the risks remain minimal:

- Spill containment procedures will be implemented to prevent migration of chemicals into shallow groundwater systems.

- Pressure tests of well casing and cement will be conducted prior to hydraulic fracturing to confirm the integrity of the well.
- Chemicals will be subject to assessment through a Quantitative Risk Assessment prior to use.
- Process design will aim to retain fluids within the target seam.
- Flow back fluids will be appropriately contained, managed, recycled or disposed of in accordance with regulatory requirements.

Further detail is provided in the Hydraulic Fracturing Risk Assessment (Santos GLNG, 2014b).

8.2.5 Coal seam water management

Coal seam water management will be undertaken in accordance with Santos GLNG's Coal Seam Water Management Strategy (Santos GLNG, 2014f) and Draft Environmental Management Plan (Santos GLNG, 2014g) which have been developed to meet the requirements of the Queensland Government's Coal Seam Gas Water Management Policy (EHP, 2012a).

Coal seam water management dams will be designed in accordance with the requirements for regulated dams in the *Manual for Assessing Hazard Categories and Hydraulic Performance of Dams* (EHP, 2012b). Seepage into shallow groundwater is controlled using measures such as geosynthetic liners to limit the migration of fluids. Seepage monitoring will be undertaken to ensure effectiveness of the control measures (refer to Section 9.1.4).

8.2.6 Brine management and injection

To minimise the potential risk for seepage of brine into shallow groundwater, brine containment dams will be designed in accordance with the EHP guidelines for the management of regulated dams (EHP, 2012b). Seepage monitoring at brine dams is also undertaken in accordance with regulatory requirements.

Management of the risk of cross-contamination of GAB aquifers associated with brine injection and injection well failure will be undertaken in accordance with regulatory requirements. These requirements include management controls such as:

- Injection wells are designed, cased and cemented to manage the risk of movement of injection fluids into or between water resource aquifers. Injection wells are constructed according to the current standards applicable to water bore drilling activities under the Water Act. (i.e. *Minimum Construction Requirements for Water Bores in Australia* (National Water Commission, 2012)).
- Injection of brine is to occur in accordance with the regulatory quality criteria
- Injection monitoring is undertaken to:
 - record injection pressure, flow rate, and cumulative volume of the injection fluid
 - record annulus pressure
 - record standing volume of annulus fluid
 - incorporate pressure testing of packer, casing and cement
 - incorporate an annual packer isolation test.

An Injection Management Plan (IMP) is developed for each new injection well or scheme. The content of an IMP satisfies specific requirements stipulated in specific Environmental Authorities and must be approved by the regulatory authority before injection is authorised to proceed. Authority to inject requires injection to be undertaken in accordance with the IMP and encompasses operational and reporting requirements to further ensure the long-term management of the risk of cross contamination of aquifers from brine injection.

The coal seam water management section of the Draft Environmental Management Plan (Santos GLNG, 2014g) provides management options to ensure that the long-term management of brine occurs in a safe and environmentally and socially responsible manner and considers additional options for the management of brine which will be required as production of gas increases.

8.2.7 Managed Aquifer Recharge

MAR schemes will be developed in a safe and environmentally and socially responsible manner, in accordance with the EP Act and Water Supply (S&R) Act licence conditions.

As part of the MAR feasibility studies, Santos GLNG will undertake water quality testing and analysis to determine the quality of the groundwater in the receiving aquifer, as well as that of the source water. The quality of coal seam water will be managed and where required treated to match, or better, the quality of groundwater in the receiving aquifer. Treatment may include desalination of the water, de-oxygenation or chemical balancing to achieve the required regulatory water quality limits.

8.2.8 Beneficial reuse for irrigation and stock watering

To minimise impacts to groundwater quality in shallow aquifers due to beneficial reuse for irrigation and stock watering, the following measures will be implemented:

- Water quality will comply with regulatory limits relevant to the beneficial use.
- Irrigation operation procedures will be followed to ensure the quantity and quality of coal seam water is appropriate for the proposed receiving environment.
- Monitoring will be undertaken to ensure effectiveness of the measures and so that adaptive management approaches can be employed (refer to Section 9.1.4).

8.2.9 Surface activities

To minimise the potential risk of impacts of surface operations on shallow groundwater resources the storage and management of fuels and chemicals will occur in accordance with regulatory requirements. In the event of a spill or release the Contingency Plan for Emergency Environmental Incidents (Santos GLNG, 2013e) will be implemented.

The Contingency Plan for Emergency Environmental Incidents provides a framework for Santos GLNG to:

- Prepare for and respond to emergency environmental incidents
- Communicate with the appropriate parties in the event of emergency environmental incidents
- Investigate the cause of emergency environmental incidents that have occurred
- Implement remedial actions to reduce the likelihood of recurrence of similar emergency environmental incidents
- Develop procedures and plans for the management of emergency environmental incidents as required during the GFD Project lifetime.

In the event of a spill that could potentially impact shallow groundwater resources, the general response will be to:

- Evacuate non-essential personnel and eliminate sources of ignition
- Stop the source of the incident (e.g. spill) and coordinate shut down of relevant equipment, if possible
- Notify relevant parties including regulatory or emergency services as required and internally within Santos GLNG

- Identify the material (if unknown) and identify personal protective equipment, hazards and response procedures using safety data sheets
- Contain/isolate released material using emergency response equipment and/or set up perimeter to isolate area
- Stabilise and neutralise spilt material, e.g. using absorbents
- Clean up released materials, spill response materials and any affected media
- Evaluate and document the incident
- Investigate and remediate if necessary.

8.3 Significance assessment

An assessment of the magnitude and significance of the potential impacts to EVs associated with GFD Project activities was conducted in accordance with the methodology outlined in Section 3.2.3 and is presented in Table 8.3. Table 8.3 also presents an assessment of the magnitude and significance of the residual impacts remaining after application of the mitigation and management measures in Section 8.2.

The assessment in Table 8.3 does not consider depressurisation impacts associated with the operation of production wells for the GFD Project as these are quantitatively assessed in Section 7 using the numerical groundwater modelling.

Table 8.3 Significance assessment

Potential impacts		Phase	Pre-mitigated significance			Mitigation	Residual significance	
			Sensitivity of environmental value*	Magnitude of impact^	Significance		Magnitude of impact	Significance
Aquifer depressurisation	Decline in groundwater levels/pressure in bores and reduced supply to groundwater users	Construction	Moderate	Low^	Low	Water Resource Management Plan (WRMP)	Low^	Low
		Operations		Low^	Low	Coal Seam Water Management Strategy(CWMS)	Low^	Low
		Decommissioning		Low^	Low	Draft Environmental Management Plan (Draft EM Plan)	Low^	Low
	Reduced stream baseflow (watercourse spring flow) and loss or reduction of supply to downstream surface water users	Construction	Moderate	Low^	Low	Hydraulic Fracturing Risk Assessment: Compendium of Assessed Fluid Systems	Low^	Low
		Operations		Low^	Low	Contingency Plan for Emergency Environmental Incidents	Low^	Low
		Decommissioning		Low^	Low		Low^	Low
	Reduced spring flow and loss or degradation of dependent ecosystems (including EPBC listed springs)	Construction	High	Moderate^	High	Land Release Management Plan	Low^	Moderate
		Operations		Moderate^	High	Underground Water Impact Report for the Surat Cumulative Management Area	Low^	Moderate
		Decommissioning		Moderate^	High	Joint-Industry Plan for an Early Warning System for EPBC Springs Quality Plan (EWS Plan)	Low^	Moderate
	Reduced stream baseflow (watercourse spring flow) and loss or	Construction	Moderate	Low^	Low	Ground Deformation Monitoring and Management Plan	Low^	Low
		Operations		Low^	Low		Low^	Low

Potential impacts		Phase	Pre-mitigated significance			Mitigation	Residual significance	
			Sensitivity of environmental value*	Magnitude of impact^	Significance		Magnitude of impact	Significance
	degradation of dependent aquatic ecosystems	Decommissioning		Low^	Low	(GDMMP) Stimulation Impact Monitoring Program	Low^	Low
	Subsidence, altering groundwater flow paths and aquifer storage	Construction	Moderate	Low	Low		Low	Low
		Operations		Moderate	Moderate		Moderate	Moderate
		Decommissioning		Low	Low		Low	Low
	Subsidence, causing ground surface displacement and altering surface water flow paths	Construction	Moderate	Low	Low		Low	Low
		Operations		Low	Low		Low	Low
		Decommissioning		Low	Low		Low	Low
	Changes to water quality	Degradation of the beneficial use of groundwater supplies	Moderate	Moderate	Moderate		Low	Low
				Moderate	Moderate		Low	Low
				Low	Low		Low	Low
		Loss or degradation of ecosystems dependent on springs sourced from affected aquifers (including EPBC listed springs)	High	Moderate	High		Low	Moderate
				Moderate	High		Low	Moderate
				Low	Moderate		Low	Moderate

1) * Highest sensitivity of environmental value in Table 6.10.

2) ^ Does not include impacts due to operation of production wells, which are addressed in Section 7.

9. Monitoring and reporting

9.1 Groundwater monitoring programs

Santos GLNG's groundwater monitoring program to meet the requirements of environmental authorities granted under the EP Act is outlined in the Draft Environmental Management Plan (Draft EM Plan) (Santos GLNG, 2014g). Santos GLNG's groundwater monitoring program to meet the requirements of the Water Act through the UWIR and Commonwealth Government under the EPBC Act is outlined in the Water Resource Management Plan (Santos GLNG, 2014c).

If approved, the proposed GFD Project development will be included in the impact assessment for the subsequent UWIR and the resulting monitoring and reporting requirements will be incorporated into relevant Santos GLNG monitoring programs.

9.1.1 Groundwater pressure and quality

Regional groundwater monitoring program

Since 2008, Santos GLNG has implemented and operated a regional groundwater monitoring program to establish background groundwater conditions and monitor potential impact to GAB aquifers resulting from gas production (Santos GLNG, 2014g). The program involves monitoring three types of infrastructure:

- Dedicated groundwater monitoring bores targeting specific aquifers, monitoring water pressure and water quality.
- Private bores identified through the baseline assessment program undertaken by Santos GLNG as suitable for groundwater quality and/or groundwater level monitoring. These bores have been selected as they target a single known aquifer. Some have been included in the Santos GLNG Farm Wellhead Telemetry program, which provides for continuous monitoring of water levels in the bores.
- Multi-level vibrating wire piezometers (VWP), or quartz or sapphire pressure gauges, measuring the pressure of the surrounding formation at their installed depth. Multi-level installations allow for monitoring of water levels in various units within the same borehole. The piezometers, in the case of VWPs, are cement grouted during construction therefore no water sample can be collected from VWPs.

The current network extends across Santos GLNG's approved gas fields, as well as a number of the proposed GFD Project tenures. A summary of the current network, including target formation, is provided in Table 9.1. The locations of the groundwater monitoring installations are shown on Figure 9.1. The constructions of completed monitoring bores and vibrating wire piezometers are provided in Appendix E: Monitoring bore logs.

Table 9.1 Summary of regional groundwater monitoring locations

Formation	Private bores (including telemetered farm bores)	Santos GLNG vibrating wire piezometers	Santos GLNG groundwater monitoring bores	TOTAL
Bungil Formation	5	-	-	5
Mooga Sandstone	27	9	4	40
Orallo Formation	20	-	3	23
Gubberamunda Sandstone	14	15	14	43

Formation	Private bores (including telemetered farm bores)	Santos GLNG vibrating wire piezometers	Santos GLNG groundwater monitoring bores	TOTAL
Westbourne Formation	-	4	-	4
Springbok Sandstone	-	5	-	5
Walloon Coal Measures	10	38	-	48
Hutton Sandstone	8			8
Precipice Sandstone		8	5	13
Clematis Sandstone	1	-	-	1
Bandanna Formation	-	21	-	21
TOTAL	85	100	26	211

Santos GLNG also uses data from DNRM monitoring bores installed within and adjacent to the GFD Project tenures. The locations of DNRM monitoring bores in the vicinity of GFD Project tenures are shown on Figure 9.1.

Further development of the regional groundwater monitoring network is ongoing to meet the requirements of the Water Monitoring Strategy in the UWIR for the Surat CMA (detailed below). Existing and currently planned groundwater monitoring in the vicinity of GFD Project tenures will provide an initial baseline as well as early warning of unexpected impacts, and will allow appropriate groundwater management actions to be taken to manage and mitigate potential adverse impacts. If indicated to be required following future updates to the UWIR, Santos GLNG's regional groundwater monitoring network will be adapted to ensure appropriate monitoring for the GFD Project area.

Water Monitoring Strategy

The UWIR for the Surat CMA (QWC, 2012a) includes a Water Monitoring Strategy which requires petroleum tenure holders to:

- Install groundwater monitoring locations to form a regional groundwater monitoring network for the Surat CMA.
- Conduct ongoing monitoring and reporting of groundwater pressure and quality.
- Collect and report water production data from petroleum and gas wells and water quality and bottom hole pressure in selected wells.

Santos GLNG is currently installing the monitoring network required by the Water Monitoring Strategy, which includes 120 water pressure monitoring points and 24 water quality monitoring points in various formations of the Surat CMA (Table 9.2). Water quality parameters are required only at key locations, primarily to assist in understanding hydrogeological processes and establishing water quality trends in response to groundwater extraction. Santos GLNG's implementation plan for installation of the network, including details of the locations that are already in place, are provided in Appendix F: Implementation Plan for UWIR Water Monitoring Program. Santos GLNG regularly submits updates of the implementation plan to the OGIA.

Table 9.2 Monitoring locations to meet UWIR Water Monitoring Strategy requirements

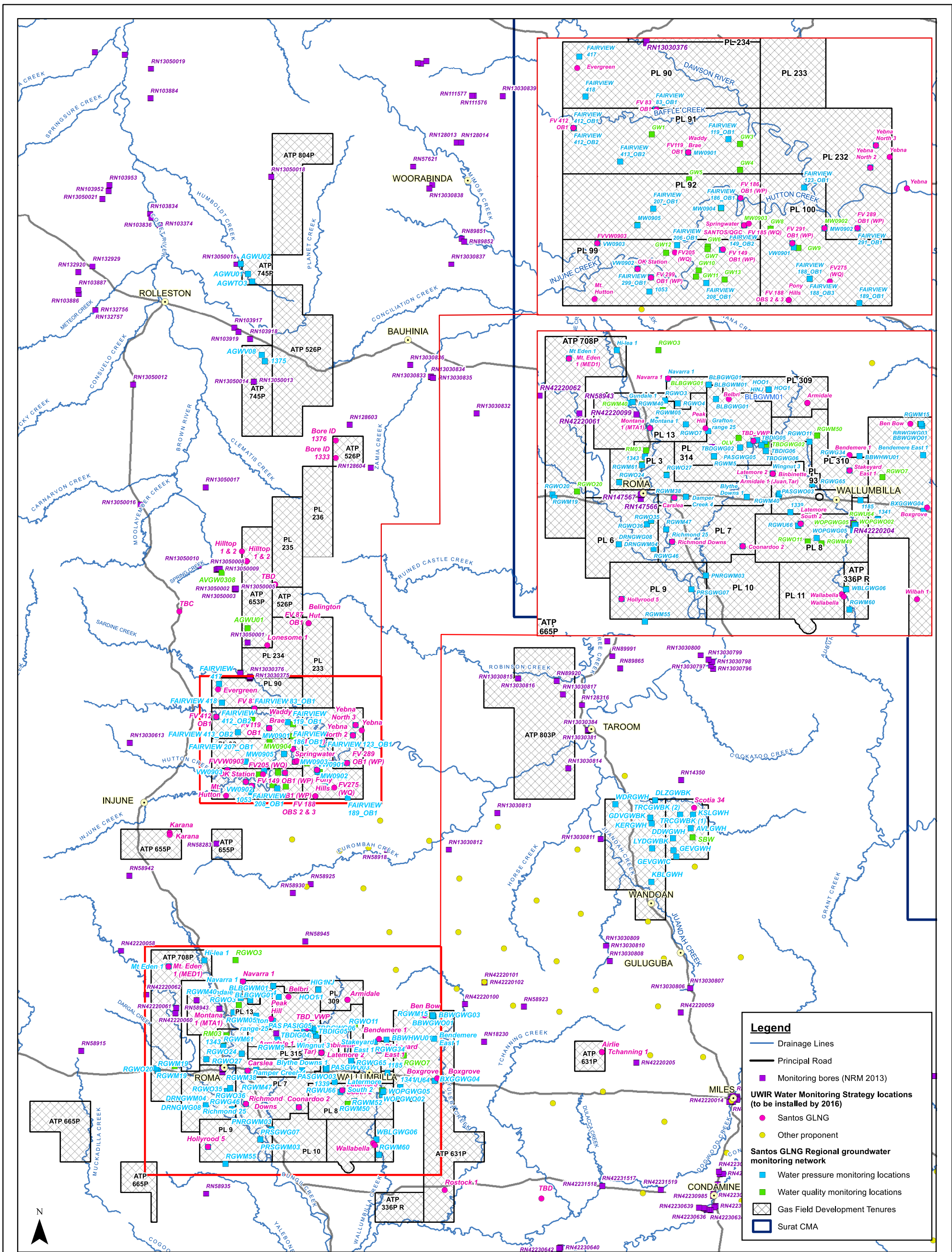
UWIR target unit	Water pressure monitoring points	Water quality monitoring points
Mooga Sandstone	6	3
Orallo Formation	2	1
Gubberamunda Sandstone	14	4
Westbourne Formation	2	0
Springbok Sandstone	10	3
Walloon Coal Measures	43	0
Hutton Sandstone	7	2
Evergreen Formation (=Boxvale SST)	2	0
Precipice Sandstone	12	4
Clematis Sandstone	7	2
Bandanna Formation	15	5
TOTAL	120	24

The Water Monitoring Strategy requires water level data to be collected at a minimum frequency of once a fortnight. For water quality monitoring points, field electrical conductivity and temperature are to be measured on a fortnightly basis and detailed laboratory analysis is to be undertaken annually for analytes including:

- Field parameters: pH, temperature, electrical conductivity, redox potential, free gas at wellhead (methane).
- Major ions: total alkalinity, carbonate, bicarbonate, calcium, magnesium, sodium, potassium, sulphate, chloride.
- Dissolved metals: As, Ba, B, Cd, Cr, Co, Cu, Fe, Hg, Mn, Ni, Pb, Se, Sr and Zn.
- Fluoride, total dissolved solids.
- Dissolved gas (methane).

More frequent water sampling for detailed laboratory analysis may be necessary if analysis of the trends in field parameters or water pressure suggests that a material shift in water quality could occur (QWC, 2012a).

Santos GLNG will comply with updates to the Water Monitoring Strategy that may be required by future updates to the UWIR.



9.1.2 Baseline assessments of landholder bores

A baseline assessment is an assessment of a private bore by a petroleum tenure holder to obtain information about the bore condition and performance and baseline water levels and quality. The information supports the settling of agreements between bore owners and petroleum tenure holders to make good impairment of bore supply caused by the extraction of groundwater during production of gas. The water level and quality information gathered by petroleum tenure holders also assists the OGIA with its ongoing assessment of the groundwater system (QWC, 2012a).

Section 397 of the Water Act requires petroleum tenure holders to carry out baseline assessments of water bores on their tenures before production commences. The baseline assessments must be carried out in accordance with a baseline assessment plan approved by EHP and the Guideline for Baseline Assessments.

Santos GLNG completed baseline assessments between 2009 and 2013, involving assessment of 793 bores associated with the Santos GLNG tenures (Golder, 2012b; URS, 2013c) (note: a higher number of bores has been reported in Golder (2012b) and URS (2013c) due to bores being visited on more than one occasion). Bores where baseline assessments have been completed are shown on Figure 9.2. Some of the landholder bores assessed have been included in the Santos GLNG Farm Wellhead Telemetry program, which provides ongoing monitoring of water levels in the bores. Santos GLNG will undertake additional baseline assessments if required in accordance with the Water Act.

The UWIR also requires that baseline assessments be undertaken for bores where an impact of 1 m or more is predicted within three years (the Baseline Assessment Area). The UWIR for the Surat CMA released in 2012 did not identify bores that are the responsibility of Santos GLNG within the Baseline Assessment Area. Santos GLNG will comply with requirements for baseline assessments in subsequent updates to the UWIR.

9.1.3 Springs monitoring

UWIR spring monitoring program

The UWIR for the Surat CMA (QWC, 2012a) requires petroleum tenure holders in the Surat CMA to monitor springs in accordance with the spring monitoring program. The spring monitoring program aims to collect information on springs above an aquifer that may at some future time be affected by water extraction for petroleum and gas activities. The objective of the spring monitoring program is to identify changes in the volume and chemistry of water flowing to a spring, and changes to the general character of springs, such that the potential for change to EVs at the spring can be assessed.

The locations and details of springs that are currently being monitored by Santos GLNG in accordance with the spring monitoring program are provided in Table 9.3 and Table 9.4. All of the UWIR springs monitoring sites are located within or nearby the Santos GLNG Fairview gas field (Figure 9.3). The UWIR inaccurately lists Santos GLNG as the responsible tenure holder for watercourse spring W39, which falls on another proponent's tenure.

Table 9.3 Spring vents currently monitored by Santos GLNG

Spring complex name	Spring complex number	Vent number(s)	Location of spring
Abyss	592	Selected: 286, 286.1, 286.2, 286.3, 682	On and off Santos GLNG tenure
Lucky Last	230	All: 287, 340, 686, 687, 687.1, 687.2, 687.3, 687.4, 687.5, 687.6, 688, 689	On Santos GLNG tenure
Ponies	229	All: 284	On Santos GLNG tenure
Spring Rock Creek	561	All: 285	On Santos GLNG tenure
Yebna 2	591	All: 534	On Santos GLNG tenure
311	311	Selected: 535, 536, 537, 704	On Santos GLNG tenure

Table 9.4 Watercourse springs currently monitored by Santos GLNG

Watercourse spring site number	Start Latitude	Start Longitude	Finish Latitude	Finish Longitude	Location of watercourse spring
W40	-25.6795	149.1373	-25.6848	149.0665	On Santos GLNG tenure
W80	-25.7434	148.6857	-25.6977	148.4273	Off-tenure
W81*	-25.7127	149.0837	-25.7151	149.0283	On Santos GLNG tenure
W82*	-25.8038	148.7799	-25.8119	148.7327	On Santos GLNG tenure

1) * Field studies indicate these locations are dry and do not receive baseflow - ongoing monitoring may not be required

Early warning monitoring for EPBC Act listed springs

As a condition of the GLNG Project EPBC approval Santos GLNG is also implementing the commitments of the Joint Industry Plan (JIP) for the Monitoring and Protection of EPBC Springs for the GLNG Project. The JIP (Santos GLNG, 2013b) establishes an EWS that involves the use of groundwater level variations as a proxy for early warning of impact to the ecosystem supported by the spring. Santos GLNG is responsible for a number of installations across the Surat CMA, including installations monitoring EPBC Act listed springs located on Santos tenures. The network includes an EWMI close to the area of coal seam water extraction or between the extraction areas and the spring, as well as a TMP located within close proximity of the spring.

The springs that are currently being monitored by Santos GLNG in accordance with the JIP are shown on Figure 9.3 and listed in Table 9.3, Table 9.4 and Table 9.5. The JIP includes the monitoring of the springs on a quarterly basis to match the frequency in the UWIR. Groundwater monitoring bores of the EWS are monitored daily for water level and six-monthly for water quality. The first year of quarterly spring monitoring was initiated by Santos GLNG in February 2013 for its on-tenures springs, and a joint industry spring baseline monitoring period of one year commenced in October 2013. The baseline monitoring includes assessment of fauna, flora and macro-invertebrates and collection of samples for isotope analysis in addition to water quality.

Table 9.5 Additional spring vents currently monitored by Santos GLNG (JIP)

Spring complex name	Spring complex number	Vent number(s)	Location of spring
Elgin 2	594	All: 540	Off-tenure

A Springs Quality Plan (Santos GLNG, 2013c) has been developed by the proponents for EWS monitoring which standardises:

- Field procedures for springs and groundwater sampling.
- Field quality assurance/quality control (QA/QC) procedures.
- Data management processes.
- Data control processes.

Additional springs for monitoring

Numerical groundwater modelling results, and a risk-based assessment of the potential impacts of aquifer depressurisation on springs (Section 7.3.3), indicate that under the EIS Scenario, there are two spring complexes and eight watercourse springs located within or near Santos GLNG tenures that are not currently monitored and may potentially be impacted due to cumulative petroleum and gas development in the Surat CMA (Table 9.6 and Table 9.7).

If identified and included within future publications of the UWIR, Santos GLNG or another petroleum tenure holder may be required to conduct site visits to ground truth the additional potentially impacted springs and develop plans for ongoing monitoring, including the selection of representative vents from each complex for monitoring. The locations of the additional springs for potential future monitoring are shown on Figure 9.3.

Table 9.6 Additional spring complexes for potential future monitoring

Spring complex name	Spring complex number	Vents to be considered for ongoing monitoring	Location of complex
302	302	539, 539.1	Off-tenure
Lonely Eddie	339	706, 707, 708, 709	Off-tenure

Table 9.7 Additional watercourse springs for potential future monitoring

Watercourse spring site number	Start Latitude	Start Longitude	Finish Latitude	Finish Longitude	Location of watercourse spring
W10	-26.4247	149.0838	-26.4733	149.0170	On Santos GLNG tenure
W14	-25.8366	150.0612	-25.9224	150.2350	On Santos GLNG tenure
W15	-25.9224	150.2350	-25.9036	150.2611	Off-tenure
W16	-26.2104	148.4429	-26.2284	148.4745	Off-tenure
W18	-26.2552	148.7095	-26.3097	148.7360	On Santos GLNG tenure
W19	-26.4219	148.7874	-26.4500	148.8050	On Santos GLNG tenure
W141	-25.4535	149.4793	-25.4337	149.3694	Off-tenure
W164	-26.3641	149.4379	-26.4723	149.4003	On Santos GLNG tenure

9.1.4 Other impact monitoring

Hydraulic fracturing

Santos GLNG undertakes monitoring prior to, and during, hydraulic fracturing activities in accordance with the Stimulation Impact Monitoring Plan (Santos GLNG, 2012). The Stimulation Impact Monitoring Plan requires that a baseline assessment of bores be completed prior to undertaking a stimulation activity to assess the quality of:

- Active landholders' groundwater bores (subject to access being permitted by the landholder) in an aquifer that is within 200 metres above or below the target gas producing formation and is spatially located with a two kilometre radius from the location of the stimulation initiation point.
- Other bores that could potentially be adversely impacted by the stimulation activities in accordance with the findings of the risk assessment required by conditions.

Ongoing monitoring of the well where hydraulic stimulation occurs is also undertaken in accordance with regulatory requirements.

Subsidence monitoring

Santos GLNG currently conducts baseline and ongoing geodetic monitoring programs to quantify deformation at the land surface.

The monitoring is undertaken in partnership with QGC, Arrow and APLNG, by consultant Altamira Information. The monitoring involves the use of interferometric synthetic aperture radar (InSAR), a radar technology used in geodesy and remote sensing, to assess ground surface motion across the gas fields (including the GFD Project tenures). The baseline monitoring, undertaken between Q4 2011 and Q2 2012 prior to the significant development of gas, did not detect large scale ground deformation, although several areas with local patterns of deformation related to various natural or anthropogenic factors were detected (Altamira Information, 2012).

Santos GLNG's plan for ongoing geodetic monitoring is detailed in the Ground Deformation Monitoring and Management Plan (Santos GLNG, 2013d). Santos GLNG, together with QGC, Arrow and APLNG, have engaged Altamira Information to collect satellite images every 24 to 48 days over a spatial coverage which includes the GFD Project tenures and the area of potential aquifer depressurisation identified in Section 7.3.1. The data is then processed using GIS software.

Dam seepage monitoring

Coal seam water dams are monitored in accordance with regulatory requirements to detect whether seepage is occurring from the dam.

Santos GLNG currently monitors 22 shallow groundwater monitoring wells in the vicinity of existing coal seam water dams (Santos GLNG, 2014g).

Irrigation program

Monitoring of irrigation programs for the GFD Project will be undertaken in accordance with regulatory requirements and EA conditions.

Groundwater monitoring undertaken for Santos GLNG's current irrigation programs includes monitoring of groundwater levels and quality within and surrounding the irrigation areas. Santos GLNG currently use a groundwater monitoring network which includes a combination of automated sensors and manual sampling.

9.2 Trigger levels and exceedance response

Groundwater monitoring data is managed in the Santos GLNG EQulS database, which facilitates data interpretation such as trend analysis and comparison of data against baseline information and trigger levels. Exceedance above trigger levels results in an automated alert. Continuous water pressure and water production data is managed in ENVAULT, and mirrored in the Santos GLNG in-house database, Historian. ENVAULT is an environmental data collection and presentation service provided by Greenspan.

Santos GLNG, in collaboration with APLNG and QGC, has developed a statistical methodology to enable removal of natural variability from the water pressure data sets. The methodology relies on statistical techniques to assist in the removal of non-gas effect. Santos GLNG is developing these techniques further by developing a method for estimation of, and subsequent removal of, localised and regional "non-gas" water pressure variations. The methodology also ensures compliance with the ANZECC (2000) and *Queensland Water Quality Guidelines* (2009).

9.2.1 Drawdown impacts to bores

The trigger levels defined in the Water Act with respect to water levels in landholder bores potentially affected by petroleum and gas activities are as follows:

- 5 metre drawdown for consolidated aquifers.
- 2 metre drawdown for unconsolidated aquifers.

In the event that a trigger level is exceeded and the bore owner has noticed a reduction in a bore's performance to the extent that it is causing some difficulty, Santos GLNG will undertake a bore assessment to establish whether the bore is, or is likely to be, impacted (i.e. have an impaired capacity) by the extraction of groundwater associated with petroleum and gas operations. A bore assessment may include the following response actions:

- Identify specific bores affected.
- Repeat measurement to confirm extent of drawdown and available water column.
- Establish whether the trigger level exceedance has resulted in impairment of the affected bore's function such that it is unfit for its intended purpose.
- Establish the primary and secondary contributing factors to the decrease in water levels (e.g. gas development, groundwater extraction from other developments, sustained below average rainfall, etc.).
- If gas production activities are determined to be the principal or a significant contributing factor to the impairment of bore function, Santos GLNG will negotiate a make good agreement with the bore owner to establish a suitable course of action. A make-good agreement is an agreement between a petroleum tenure holder and a bore owner that provides details on the make good measures to be undertaken by the petroleum tenure holder to make good the impact. Under the Water Act, potential make-good measures may include:
 - Deepening the bore
 - Constructing a new bore
 - Providing an alternative water supply
 - Undertaking periodic bore assessments and ongoing monitoring
 - Monetary compensation.

9.2.2 Drawdown impacts to springs

Santos GLNG's impact monitoring program for springs will ensure that both Commonwealth and Queensland State requirements for the monitoring and management of springs will be met.

State requirements

The trigger level defined in the Water Act with respect to water levels at springs potentially affected by extraction of gas is 0.2 metre drawdown. Exceedance of the trigger level prompts further investigation to assess the potential for impacts on EVs associated with the spring and consider the need for mitigation actions.

Commonwealth requirements

The JIP (Santos GLNG, 2013b) establishes the following triggers and drawdown levels for EPBC Act springs:

- Investigation triggers – a nominated value at an Early Warning Monitoring Installation and Trigger Monitoring Point that triggers an action such as data review, model review, increased monitoring frequency, increased monitoring parameters.
- Management/mitigation triggers – a nominated value at a Trigger Monitoring Point that triggers some action to be taken to prevent an impact occurring at an EPBC Act spring.
- Drawdown Limit – a nominated value at a Trigger Monitoring Point that, if exceeded, would be taken to represent a breach of the Commonwealth Approval Conditions. This value has been estimated to correspond to greater than 0 +/- 0.2 m impact in a source aquifer at an EPBC spring.

A groundwater level exceedance is defined as a value of the water level exceeding the defined drawdown levels for a continuous period of three months.

The monitoring and response plan associated with the investigation and management/mitigation triggers is presented in Figure 8.1. When an investigation trigger value is confirmed to be exceeded at an EWMI or TMP, Santos GLNG will verify the exceedance by:

- Assessing observation data with historical data for the bore. This may include the use of a statistical trend procedure to remove natural variations.
- Assessing water level data in neighbouring bores monitoring the same aquifer.
- Reviewing the model predictions and comparing with observed water levels.
- Identifying the potential causes that may have contributed to the exceedance.
- Increasing monitoring if necessary.
- Notifying the Department of the Environment within 10 days of confirmation of the exceedance.

Where an observed exceedance cannot be ruled out, Santos GLNG will undertake a risk assessment and other studies resulting in nomination of a concept mitigation approach. The mitigation concepts that may be considered could include:

- Blocking the impact propagation physically
- Blocking the impact propagation with some recharge
- Providing flow at the spring from an alternative supply
- Adding additional water to the shallow groundwater system (unconfined systems only)
- Using deeper artesian water for recharge of the source aquifer
- Increasing flow from the aquifer source to the surface
- Establishing spring impact offset through removal of impact from private usage.

Assessment of a suitable mitigation approach will involve field investigations to assess site specific features, assessment of the vulnerability of the spring to the level of predicted depressurisation and review of the hydrogeological conceptual model to understand the actual level of risk of impact to the spring.

When a management/mitigation trigger is exceeded, Santos GLNG will:

- Develop a mitigation design involving confirmation of the concept option nominated through additional field investigations, hydrogeological modelling and detailed engineering design studies.
- Develop a mitigation plan. The mitigation plan will identify the time before impact, the timing of mitigation and the value to be used as a “zero impact proxy”.
- Submit the mitigation plan to the Department of the Environment.
- Implement the mitigation plan.

9.2.3 Water quality impacts

Santos GLNG uses conservative water quality trigger levels, defined as a 10% change in physical or chemical parameter concentrations relative to baseline values, to provide an early warning of potential water quality impacts. The water quality trigger levels apply to bores and springs.

When a trigger level for water quality is reached, Santos GLNG undertakes the following response actions:

- Identify specific bores/springs affected.

- Resample and reanalyse to confirm extent of change to water quality – include revised analytical suite if warranted.
- Assess potential factors contributing to the change in water quality (e.g. gas development, groundwater extraction from other developments, etc.).
- Evaluate potential site-specific environmental values at risk from changes to water quality.
- Develop a second trigger level on the basis of the assessment, beyond which the water quality would be unfit for its intended purpose (likely to be a direct reference to published water quality guidelines, but may include derivation of site-specific guidelines for key parameters).
- Report to Santos GLNG management and to the regulator.

9.2.4 Subsidence impacts

Altamira Information has been engaged by Santos GLNG, QGC and APLNG to use interferometric synthetic aperture radar (InSAR) to establish a baseline of ground surface motion prior to significant development of gas and to conduct ongoing geodetic monitoring (Altamira Information, 2012).

Differentiation between gas production and non-gas production induced ground deformation will be possible through the analysis of the historic and ongoing InSAR measurements. The processed data provided by Altamira will be quantitatively processed in a GIS environment and a floating grid methodology will be used to evaluate areas of subsidence.

Ground motion is defined as stable where average annual deformation values are between – 8 mm/year and + 8 mm/year. Ground motions are defined as subsidence or uplift where average annual values are outside the range – 16 mm/year and + 16 mm/year respectively. The subsidence trigger (with non-gas production effects removed) is defined as an annual average ground motion of 16 mm/year for over 50% of data points of a 1.5 km x 1.5 km region. Sixteen millimetres represents an average annual rate of change equal to twice the magnitude considered ‘stable’ in the ground motion baseline.

Should the subsidence trigger be exceeded, Santos GLNG will carry out an analysis of the cause of the ground motion. Spatial and/or temporal analysis of the deformation data will provide a reasonable assessment of the possible cause. If deemed necessary, site walkovers, aerial photography, ground-based geodetic surveys and other environmental monitoring data may be commissioned as part of the ongoing monitoring plan.

9.3 Reporting

Santos GLNG publishes the following groundwater information online for public availability:

- Groundwater Impact Study (GWIS) updates.
- Other groundwater and surface water studies, e.g. supporting reports for regulatory authorities.

Santos GLNG will report to government in compliance with:

- The terms of environmental approvals issued by the DOTE and EHP.
- The terms of beneficial use approvals issued by EHP.
- UWIR requirements for the Water Monitoring Strategy, including a Water Monitoring Strategy network implementation report and required monitoring data every six months (QWC, 2012a).
- UWIR requirements for the Spring Impact Management Strategy (QWC, 2012a). JIP EWS commitments, which include simple reporting of data every year (data and plots of data against trigger as appropriate, trend analysis after collection of baseline) and a consolidated report every three years (Santos GLNG, 2013b).

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Appendix A

Geological cross-sections for the GFD Project area



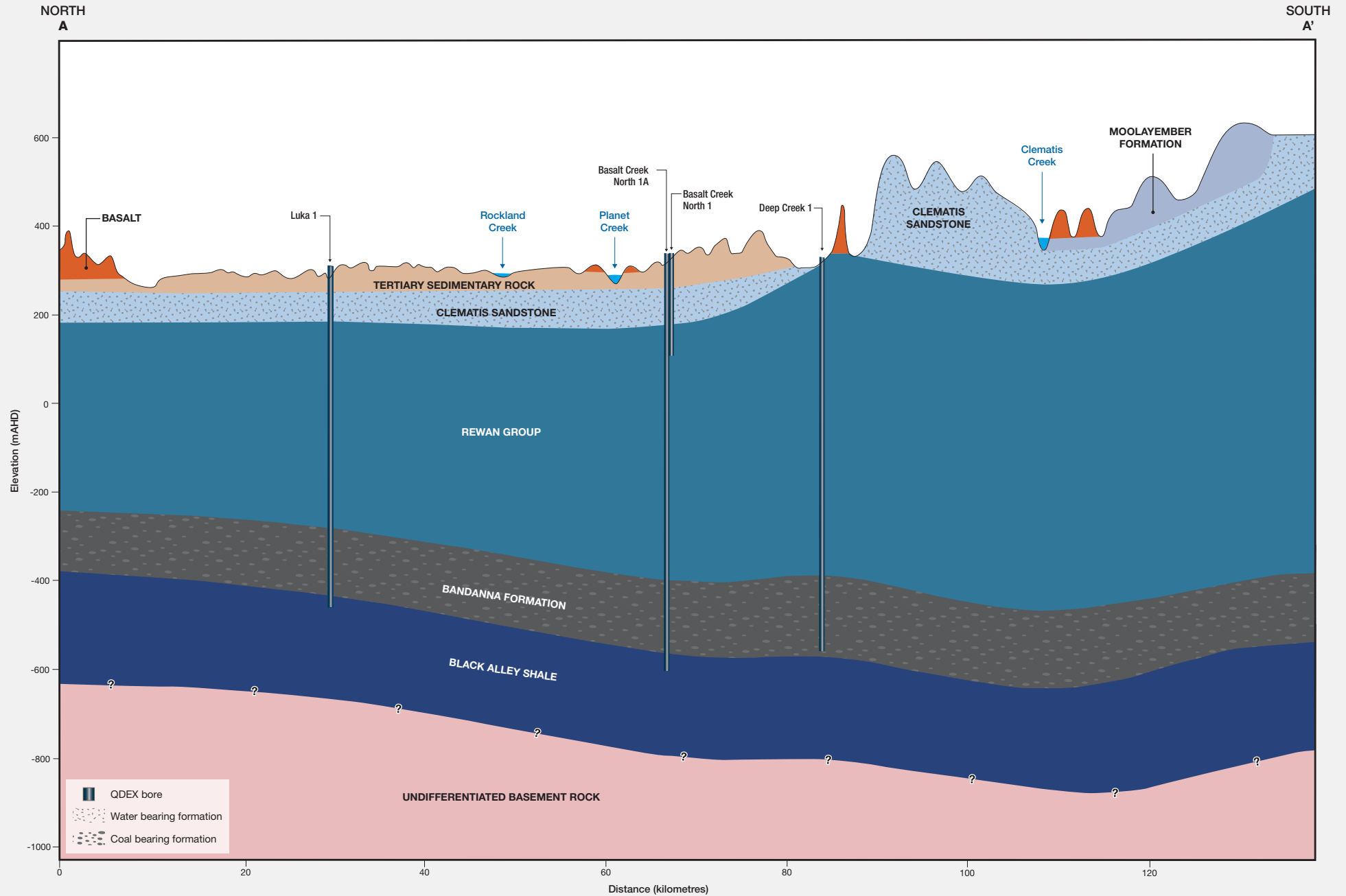


Figure A.1 CONCEPTUAL HYDROGEOLOGICAL CROSS-SECTION A - A'

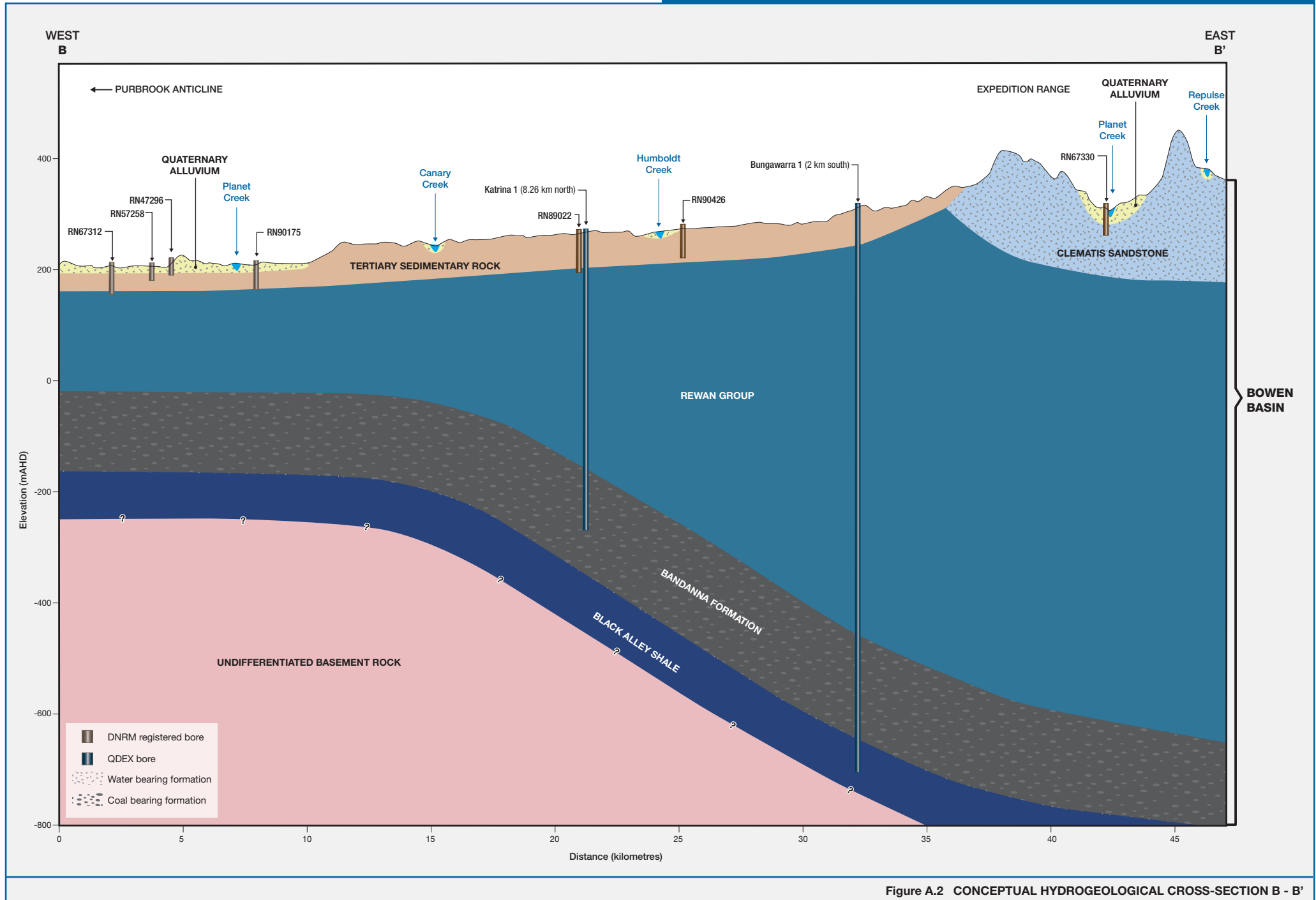
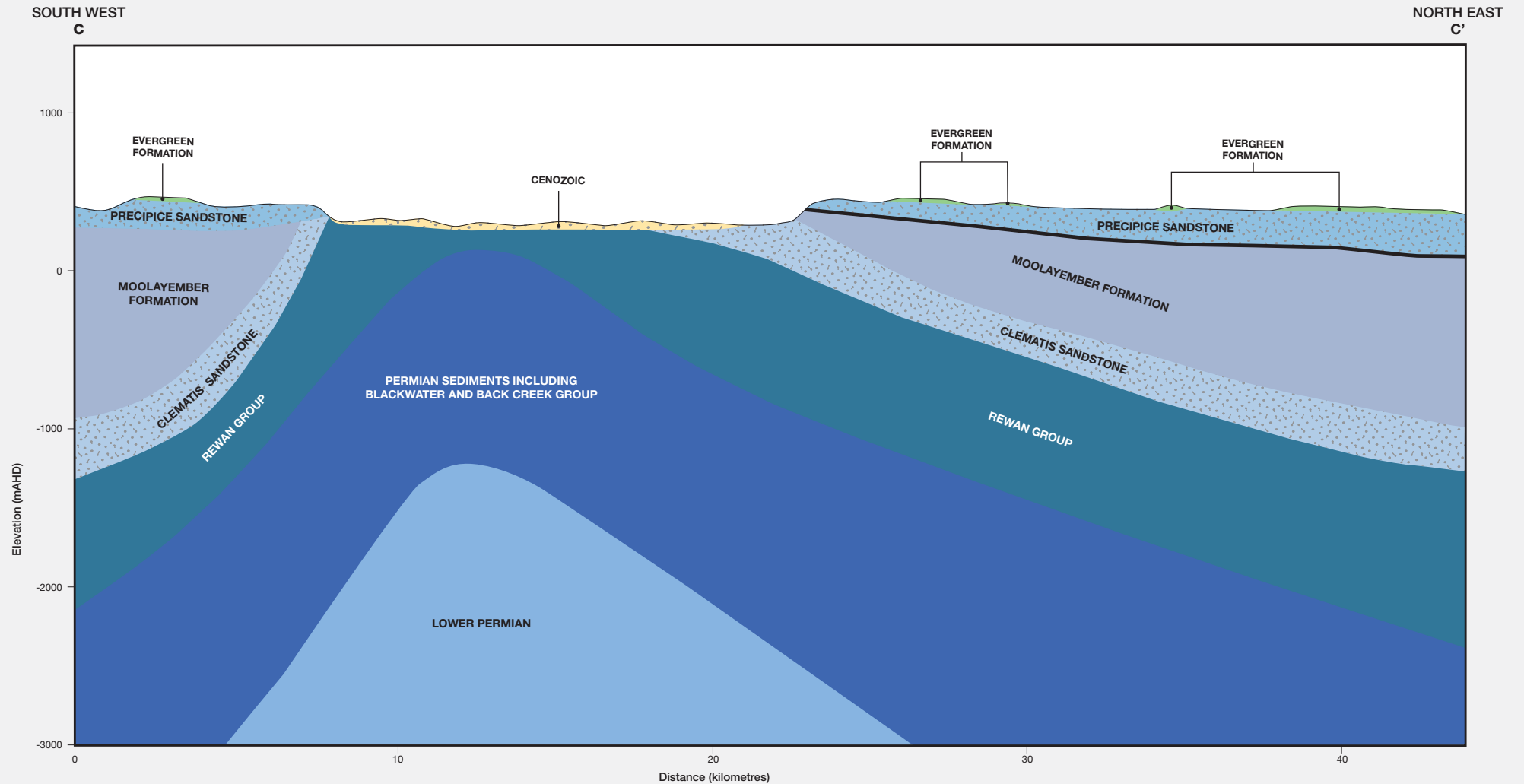
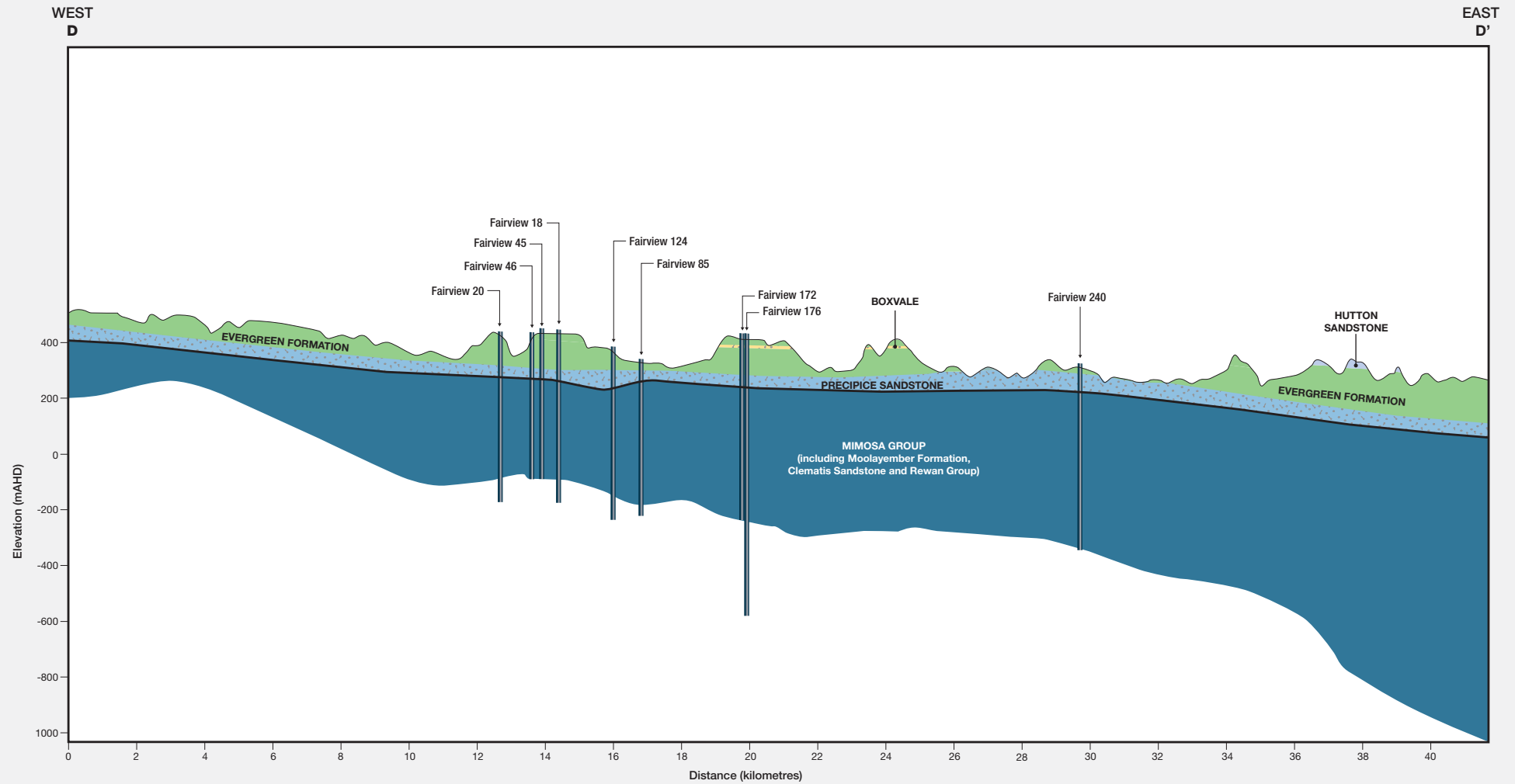
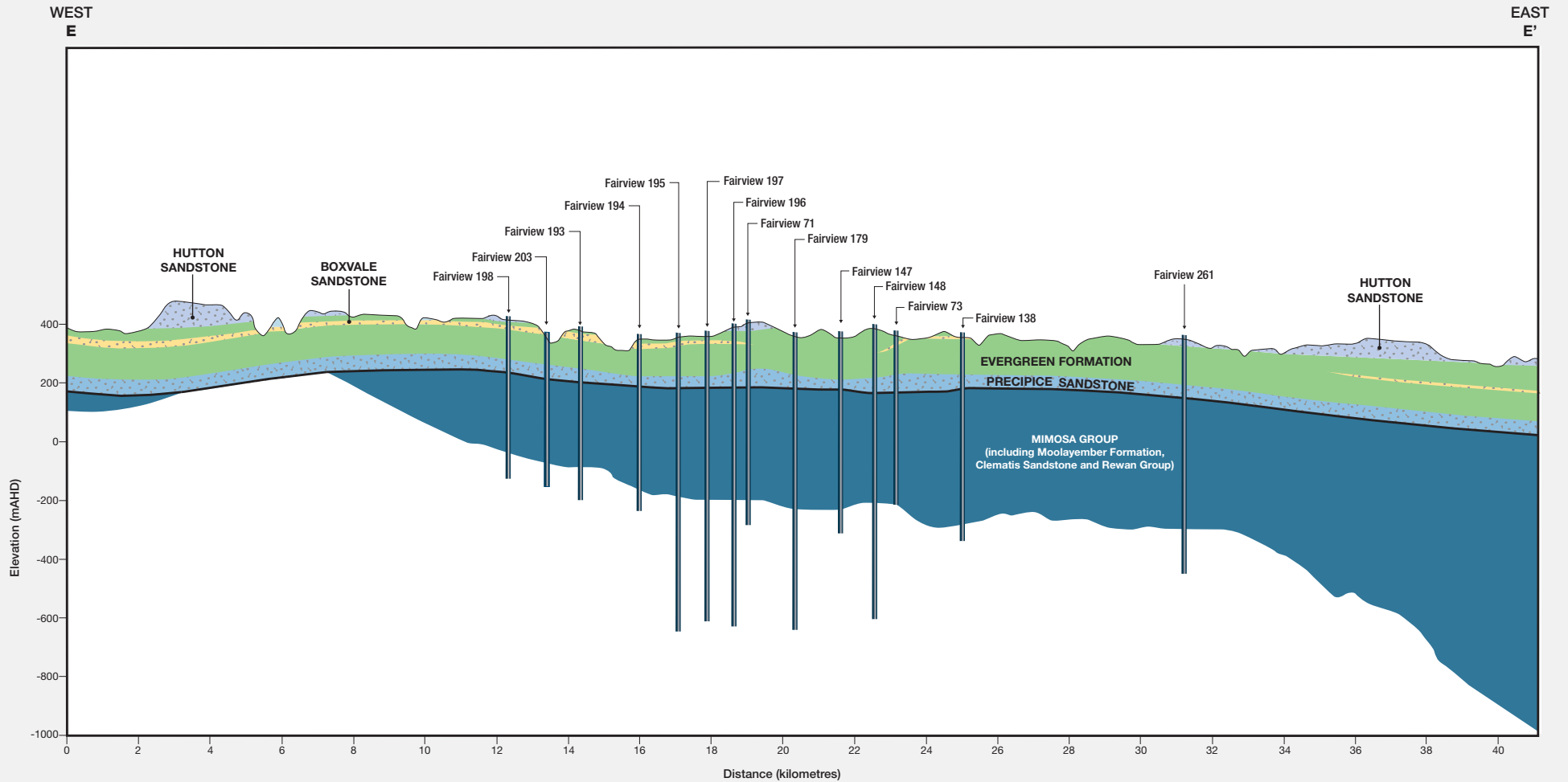


Figure A.2 CONCEPTUAL HYDROGEOLOGICAL CROSS-SECTION B - B'

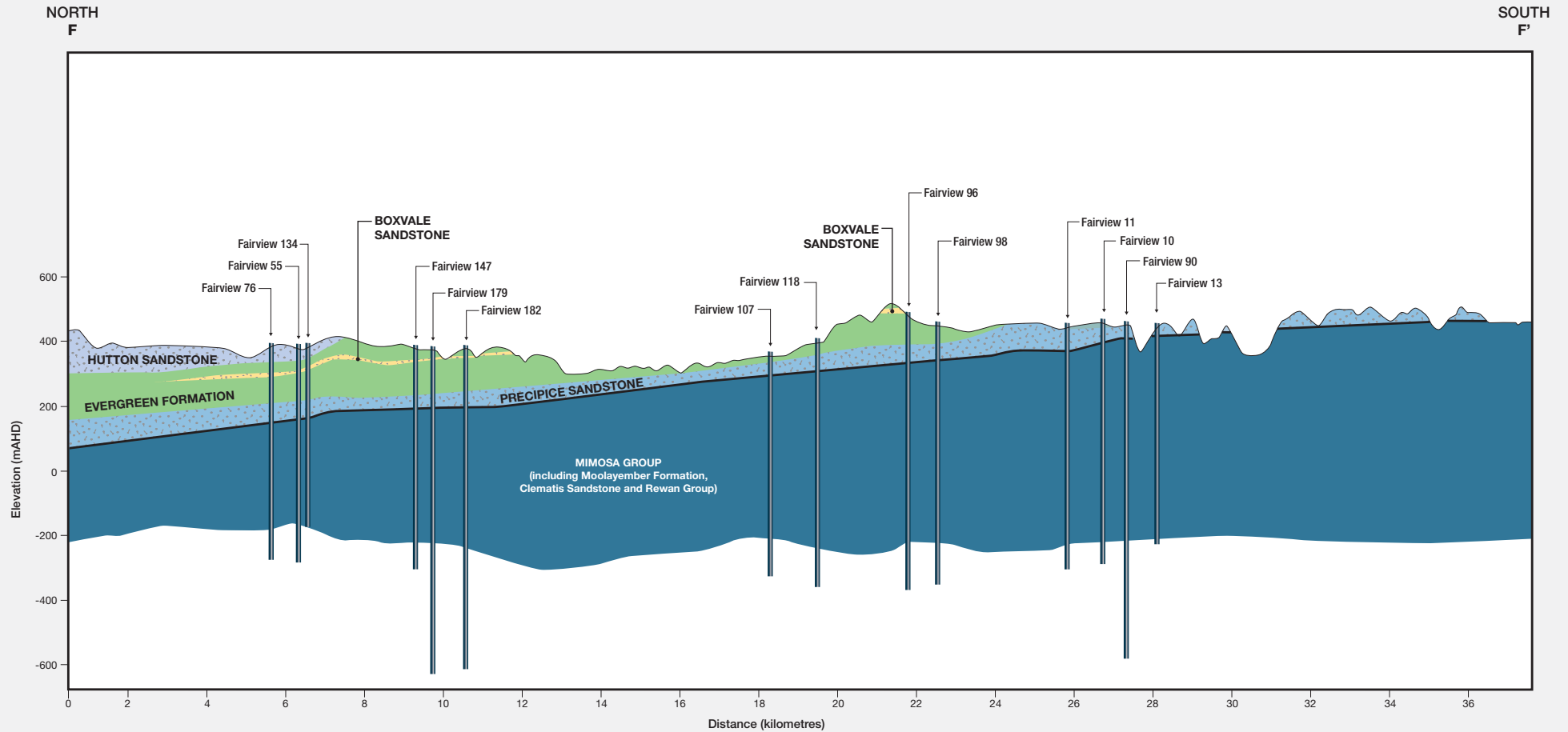




— Major unconformity
 . . . Water bearing formation
 ■ QDEX bore



— Major unconformity
 --- Water bearing formation
 ■ QDEX bore



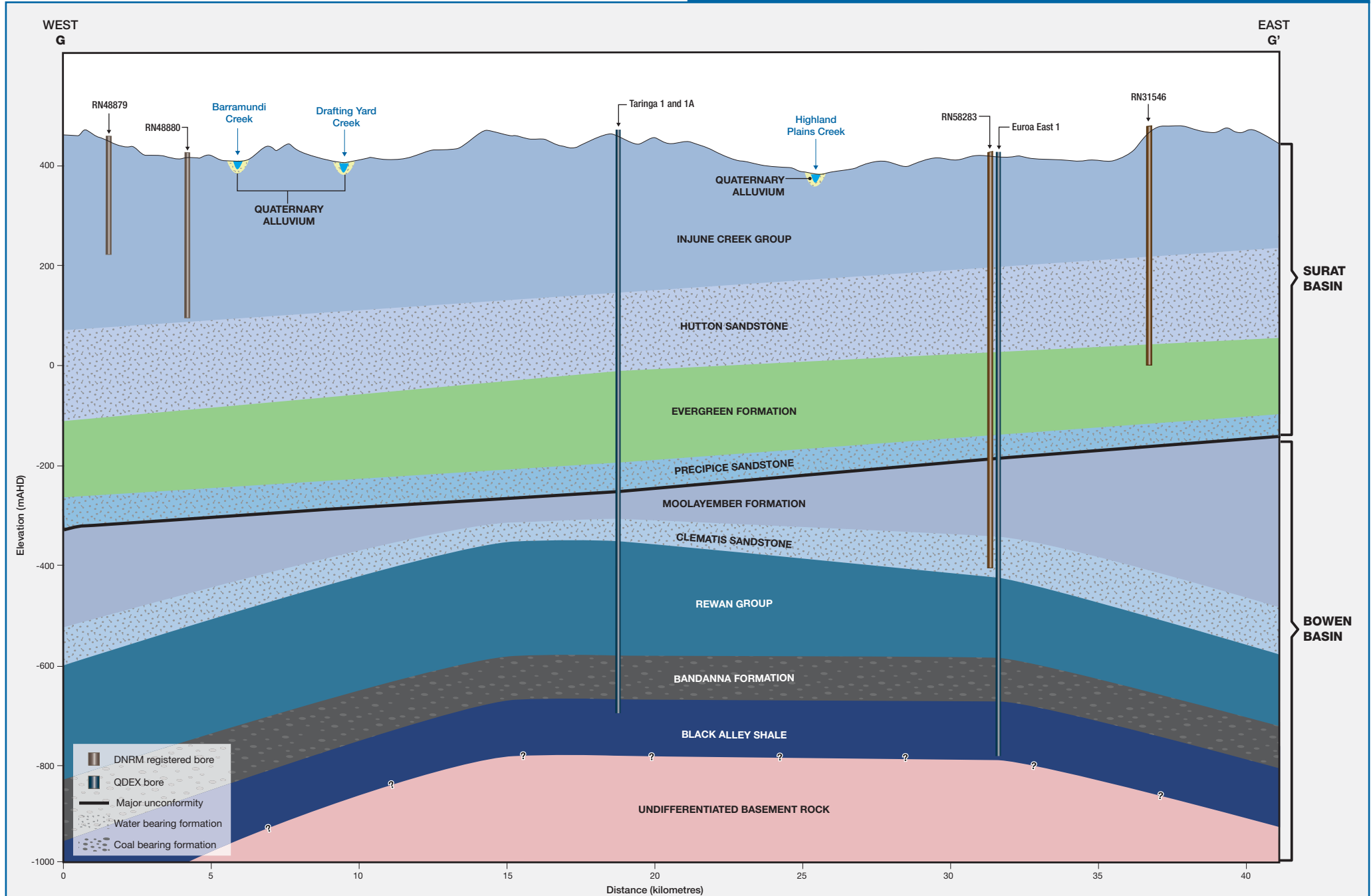
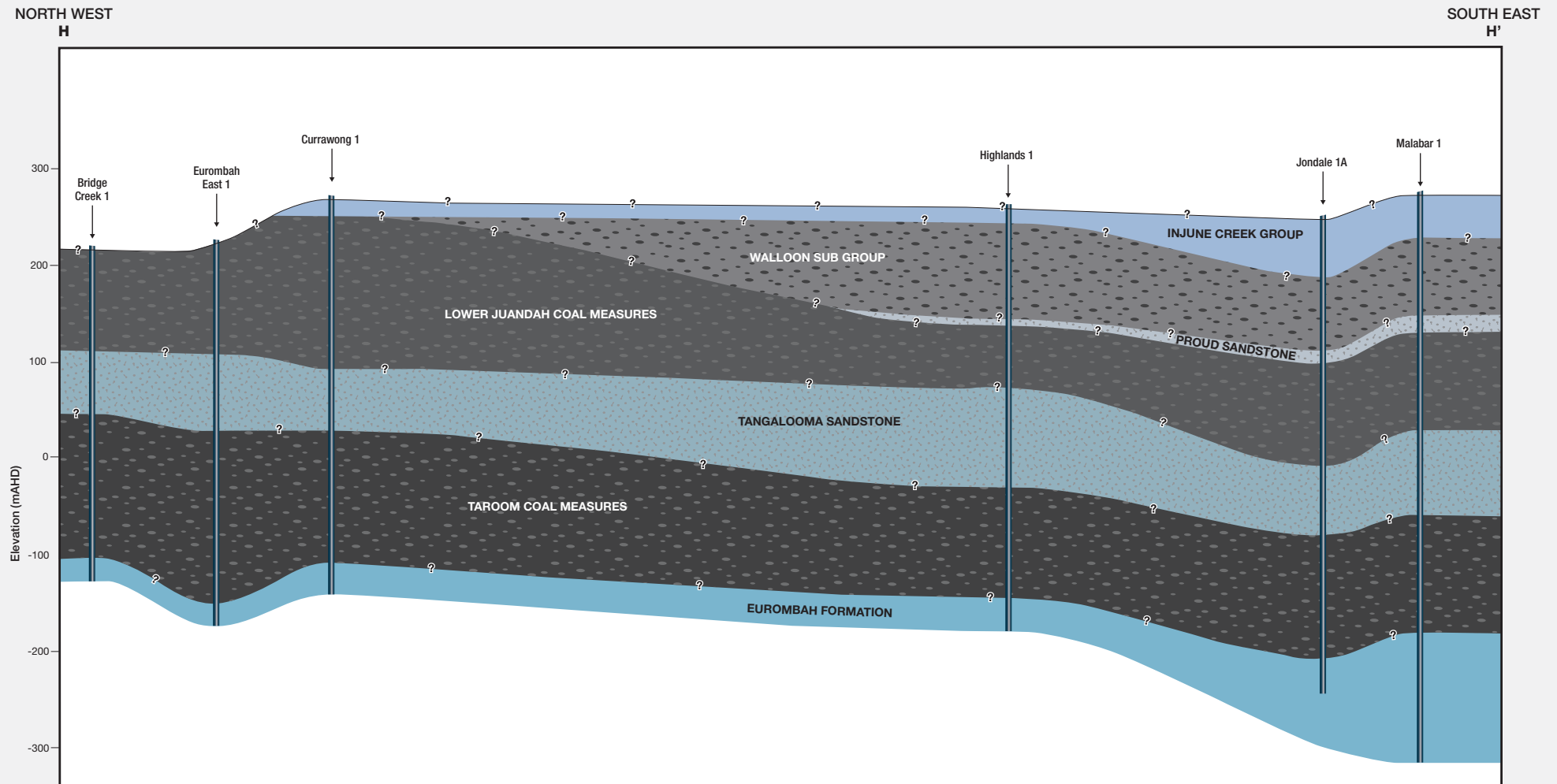
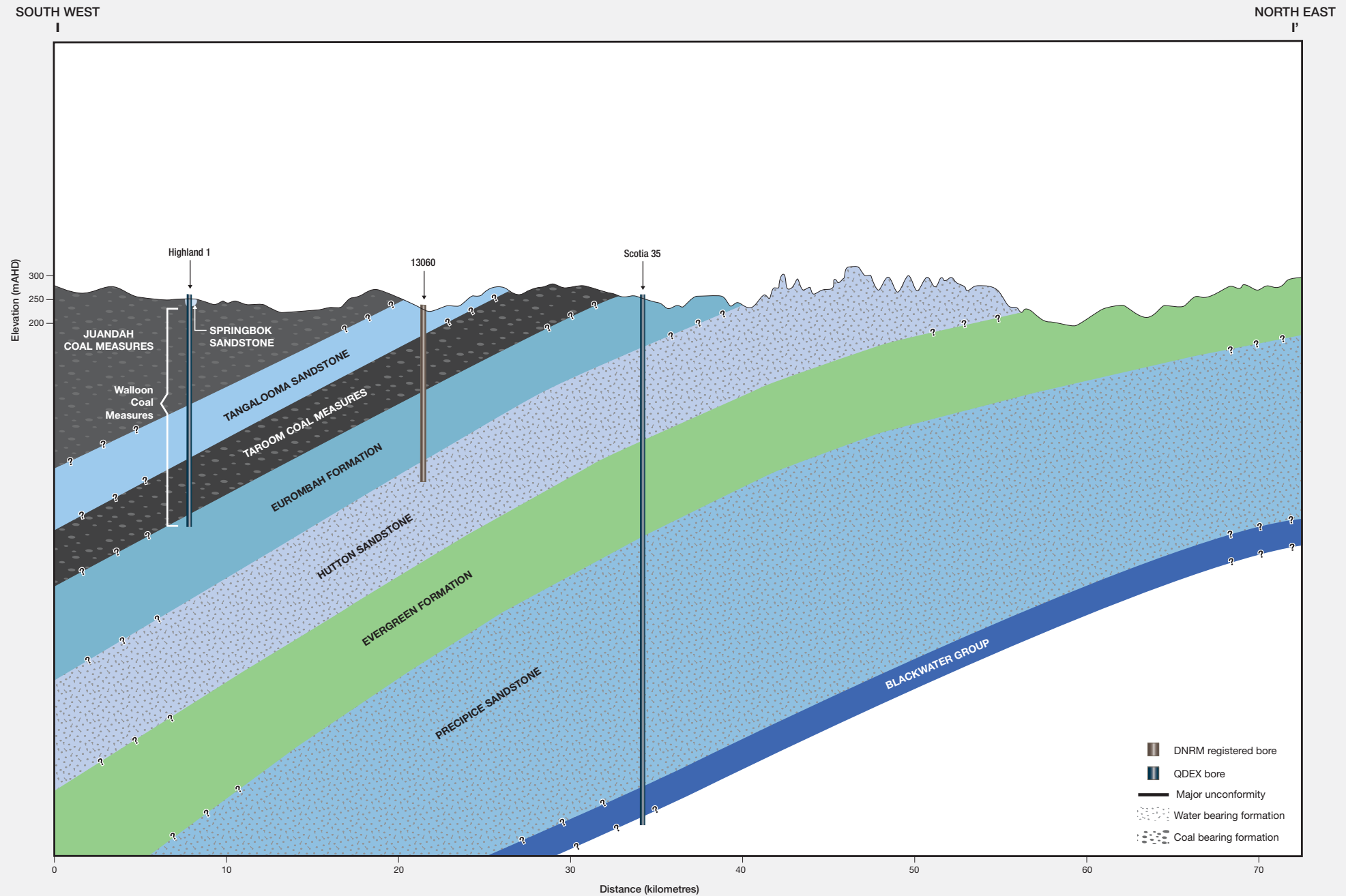
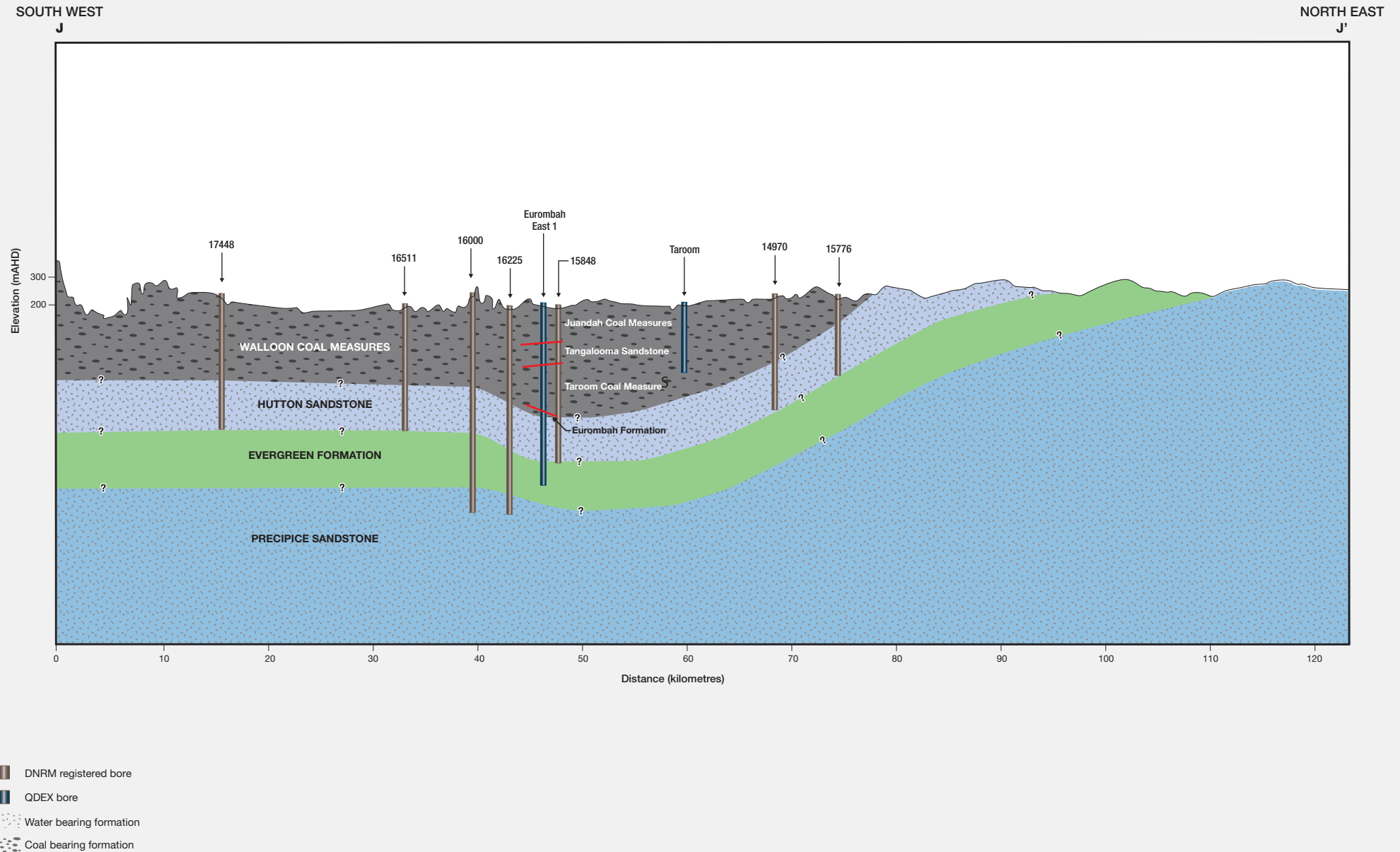


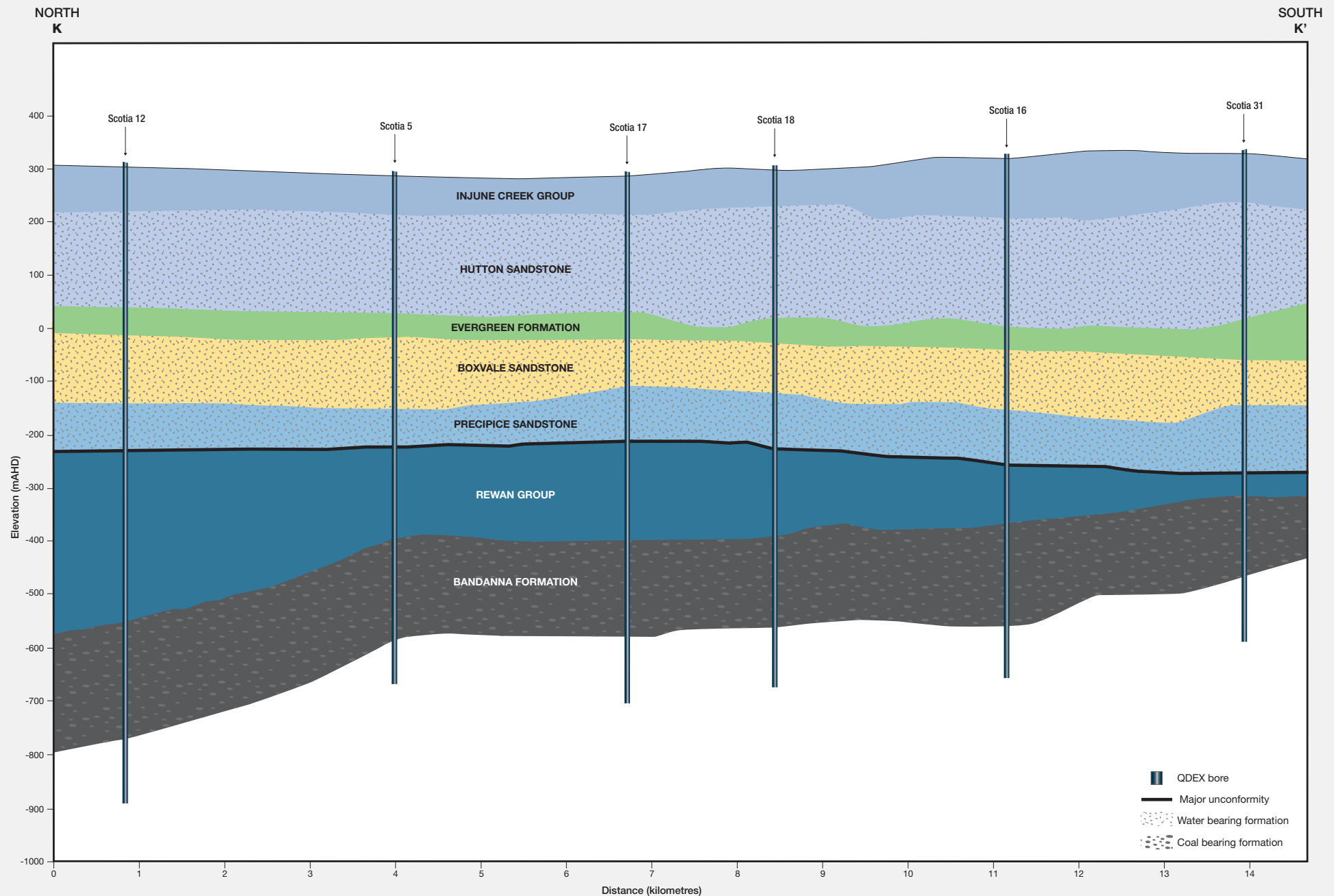
Figure A.7 CONCEPTUAL HYDROGEOLOGICAL CROSS-SECTION G - G'

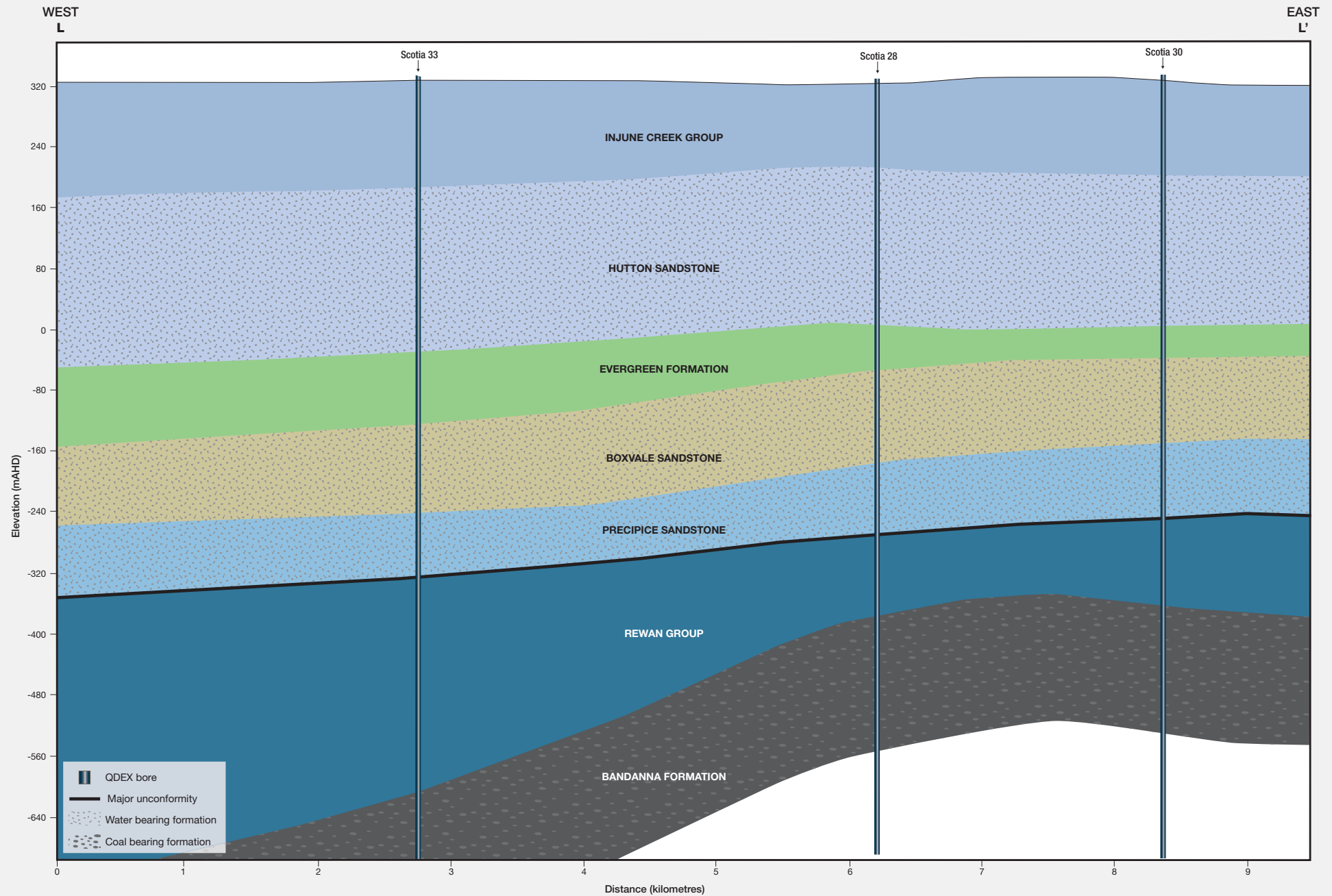


-  QDEX bore
-  Water bearing formation
-  Coal bearing formation









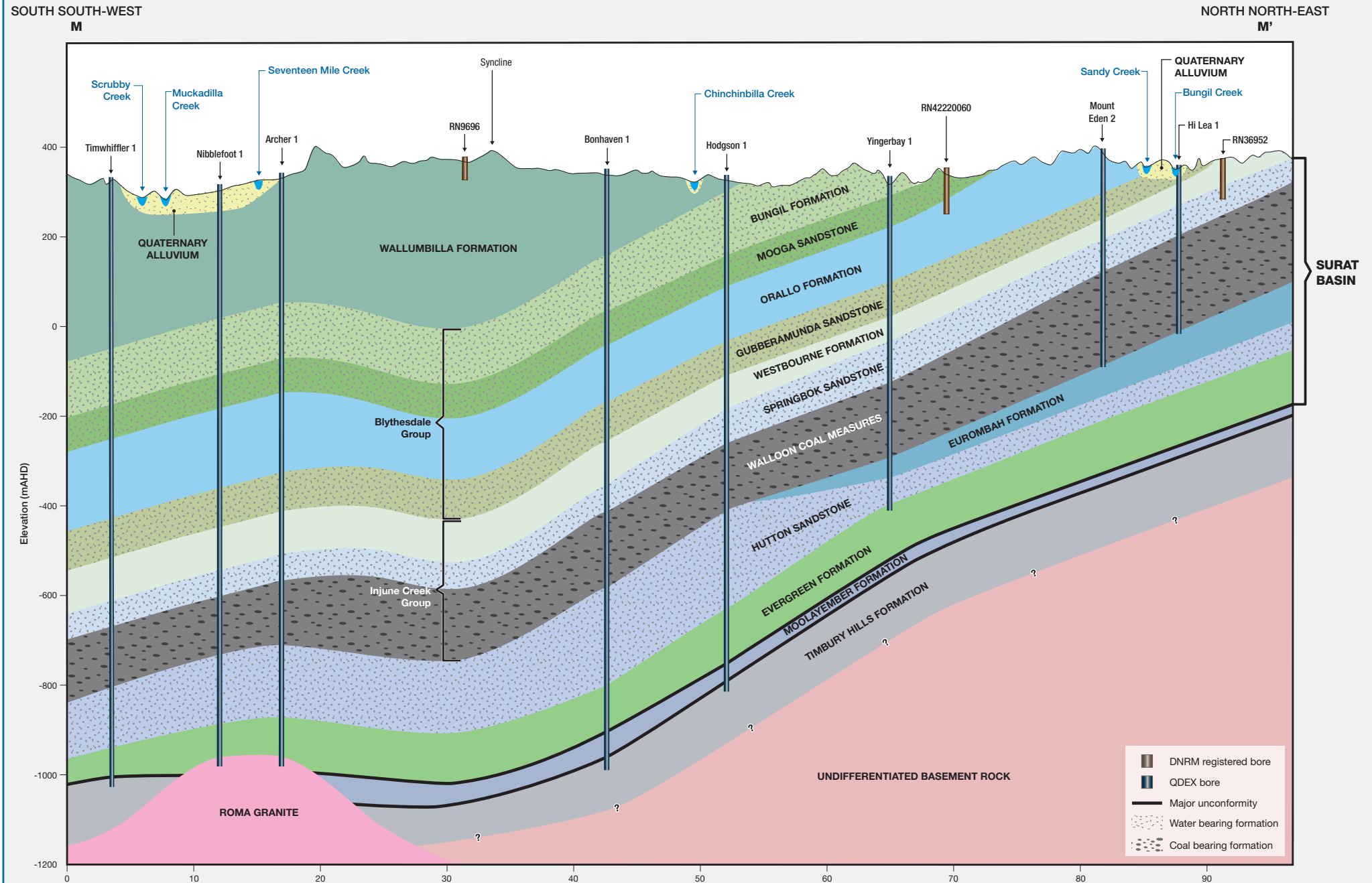
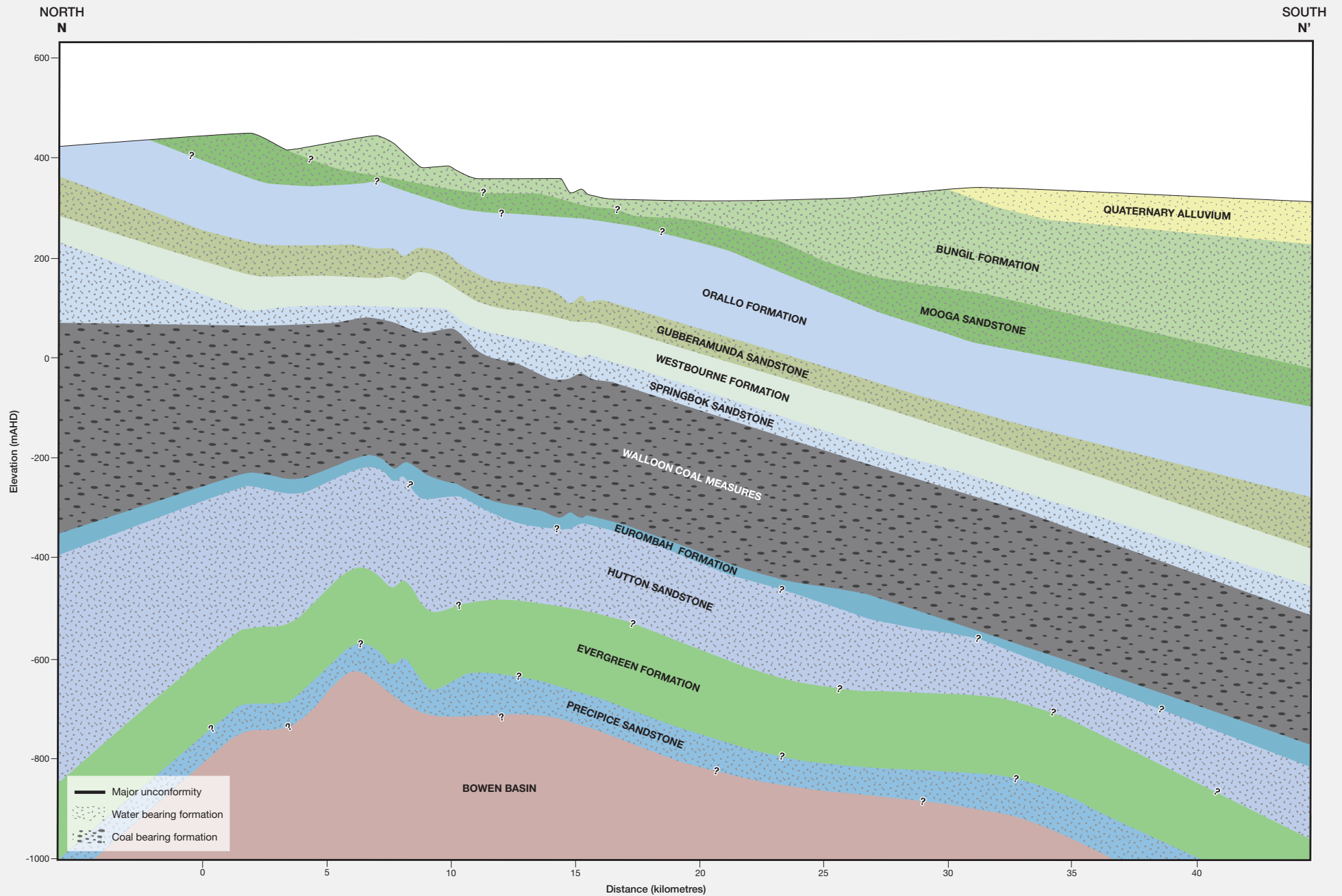
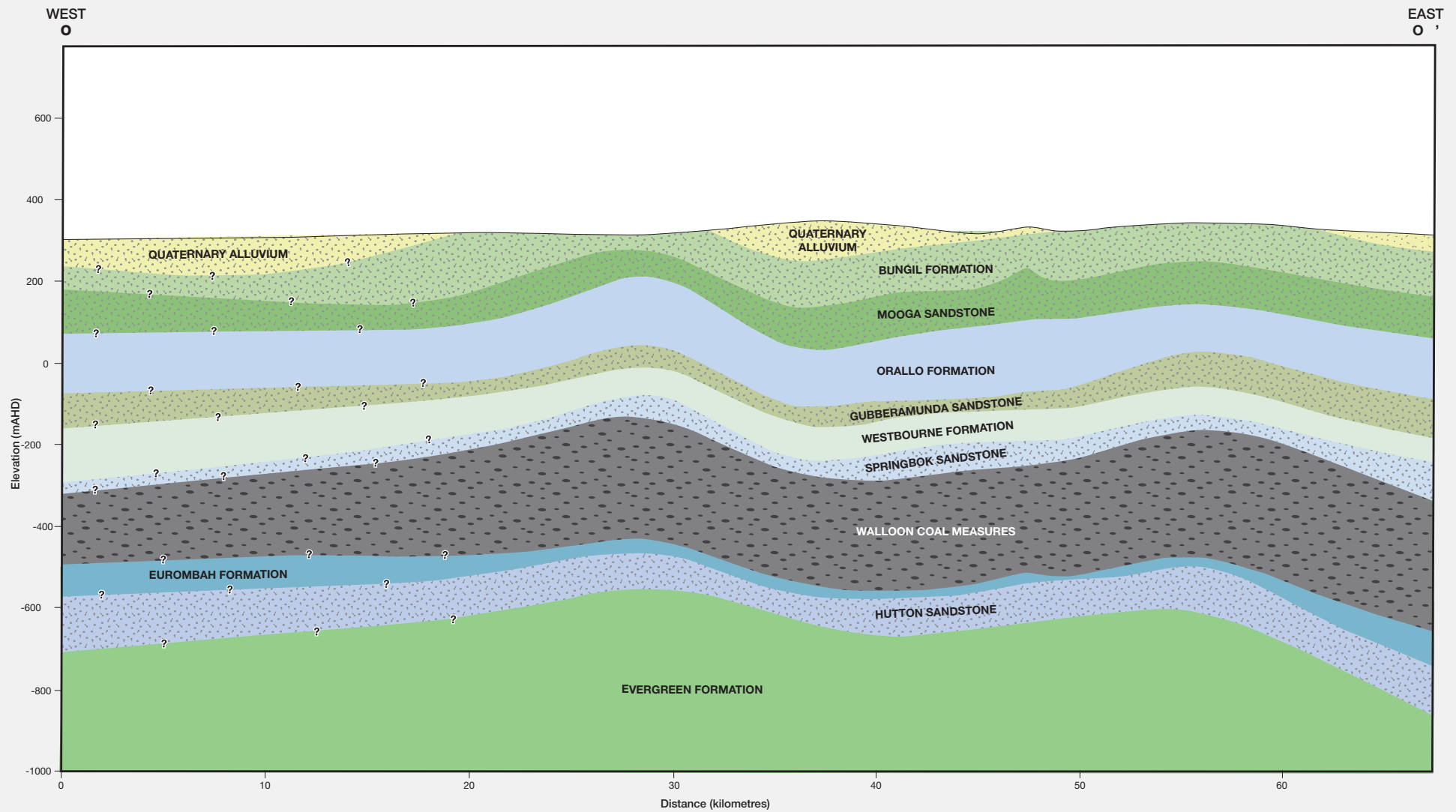


Figure A.13 CONCEPTUAL HYDROGEOLOGICAL CROSS-SECTION M - M'





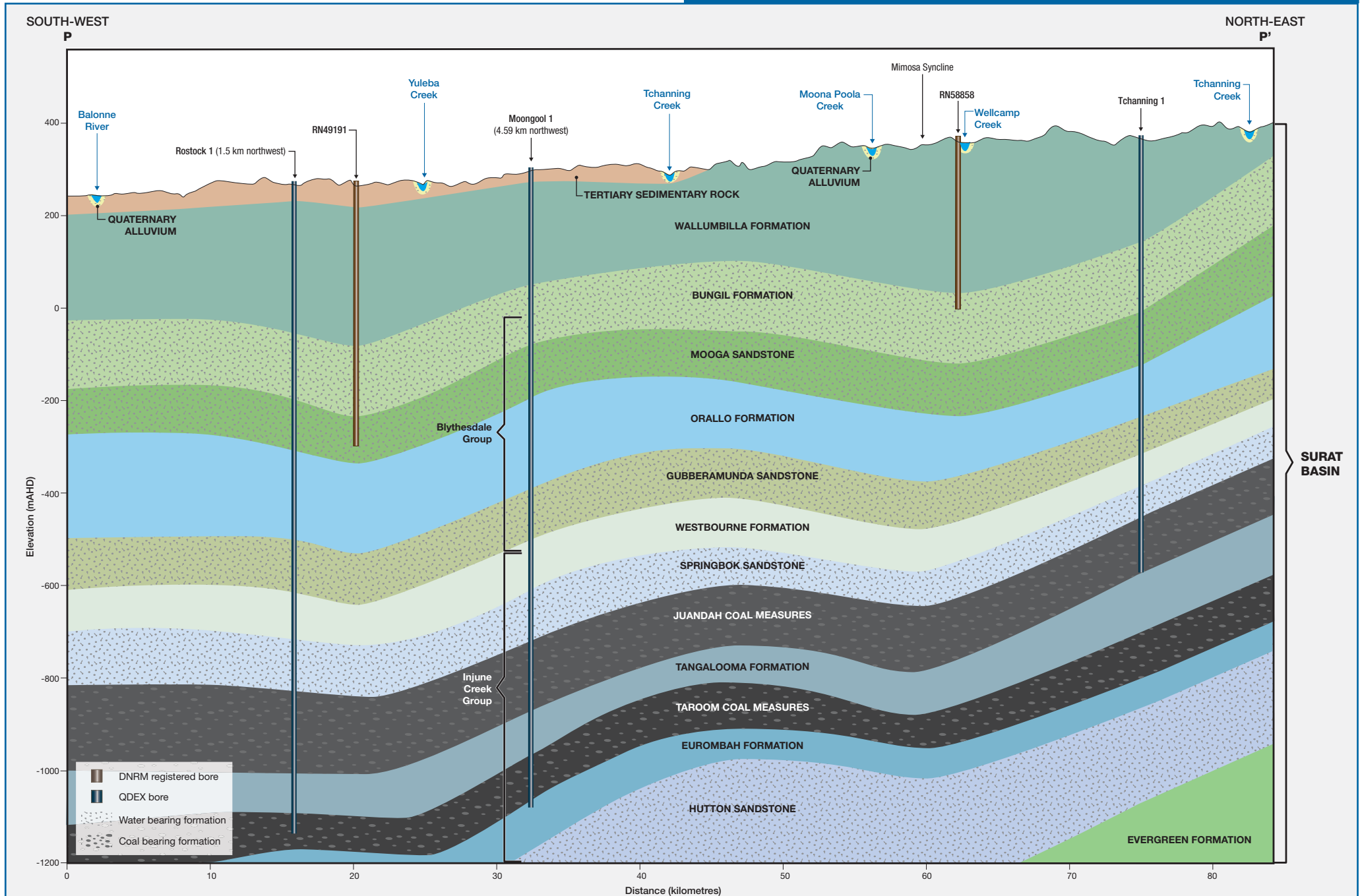
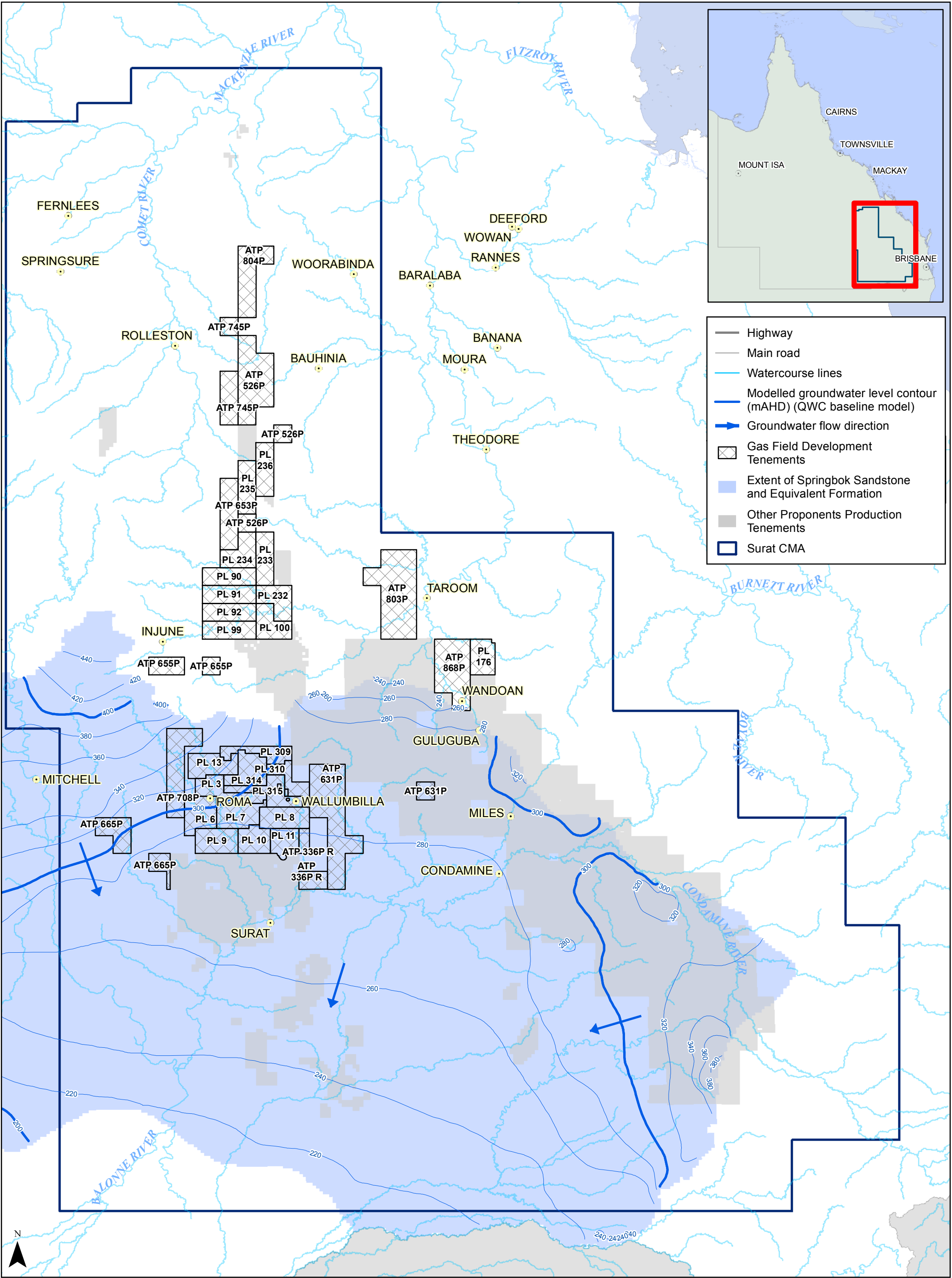


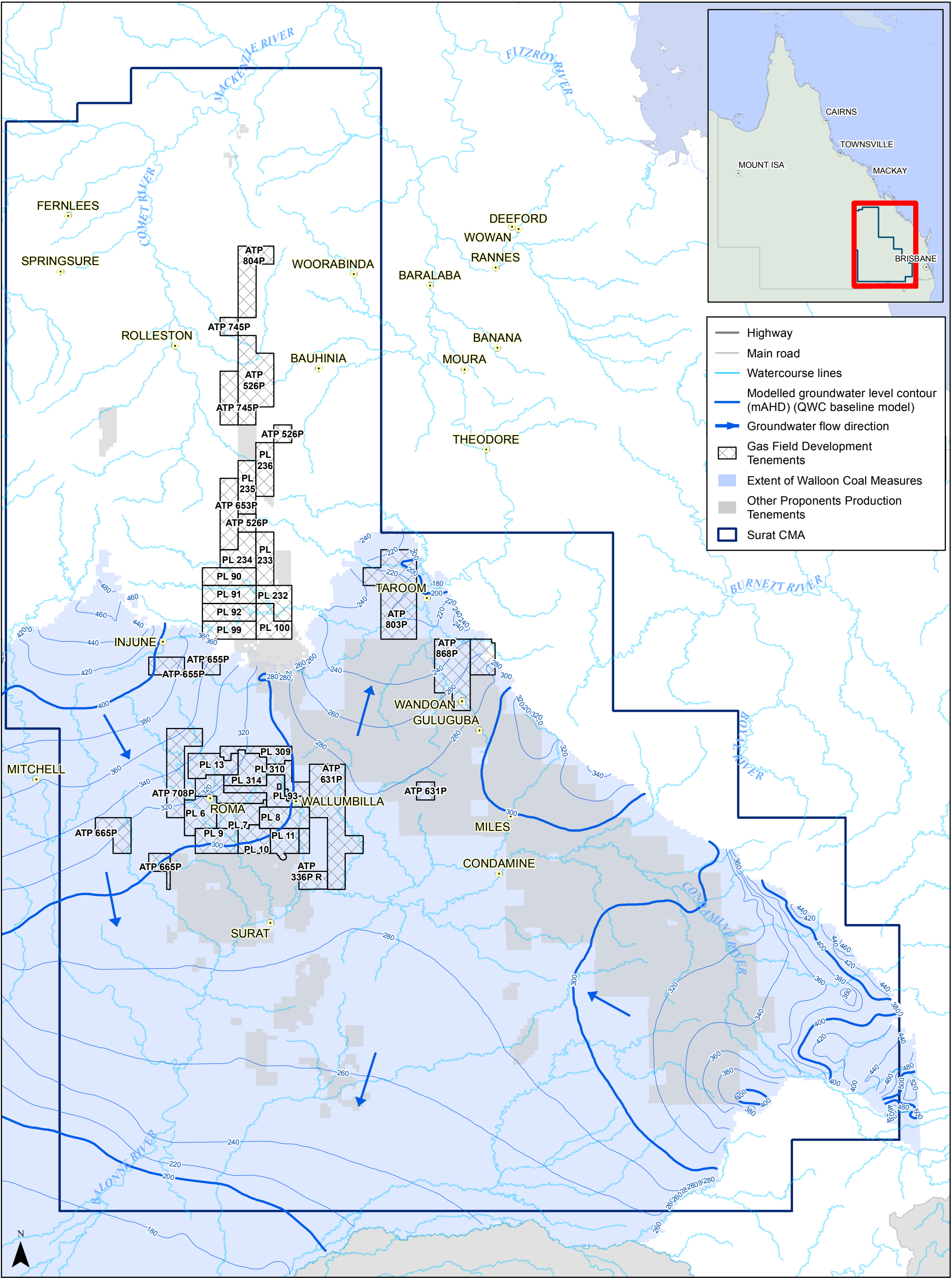
Figure A.16 CONCEPTUAL HYDROGEOLOGICAL CROSS-SECTION P-P'

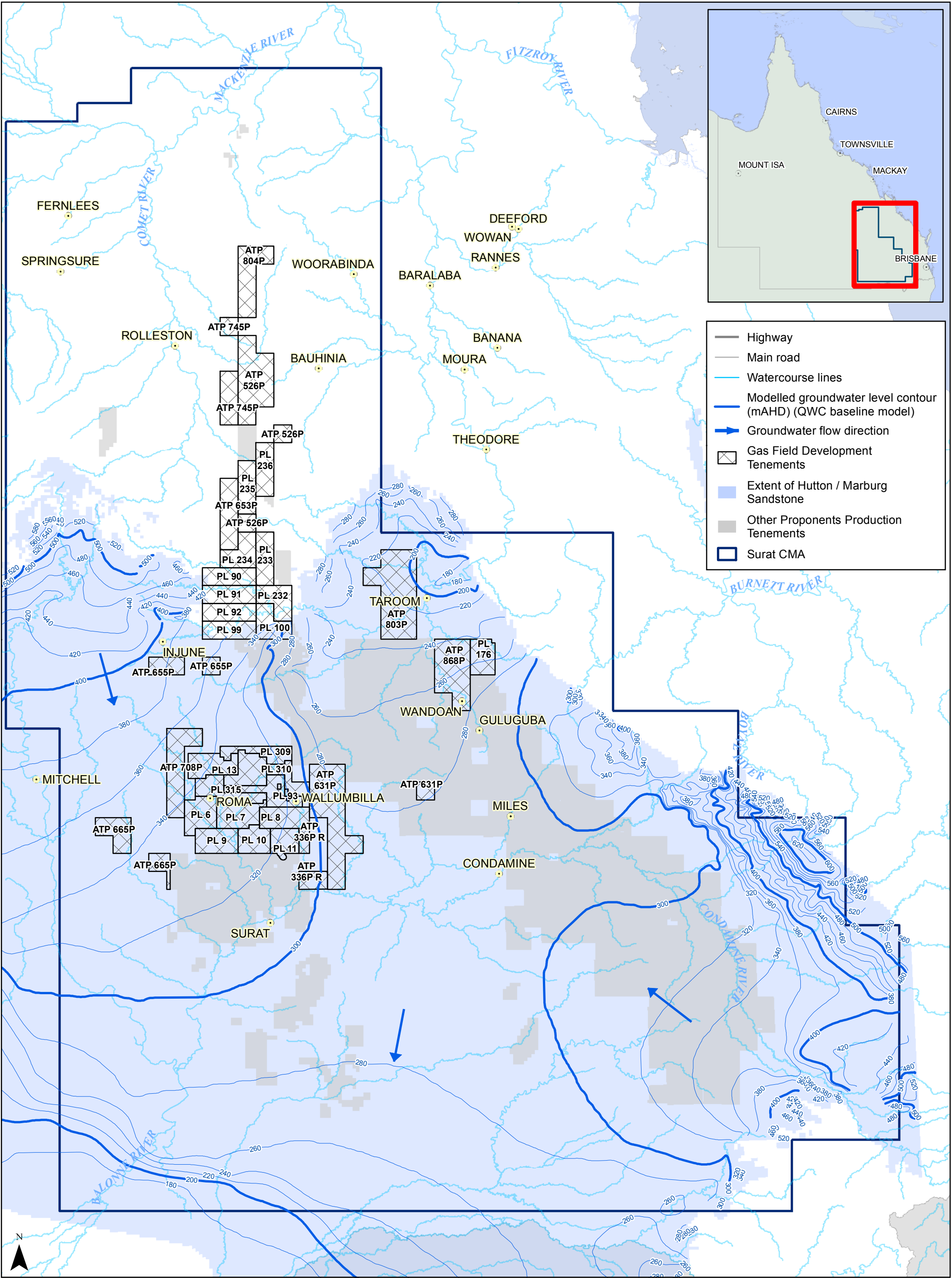
Appendix B

Groundwater level data









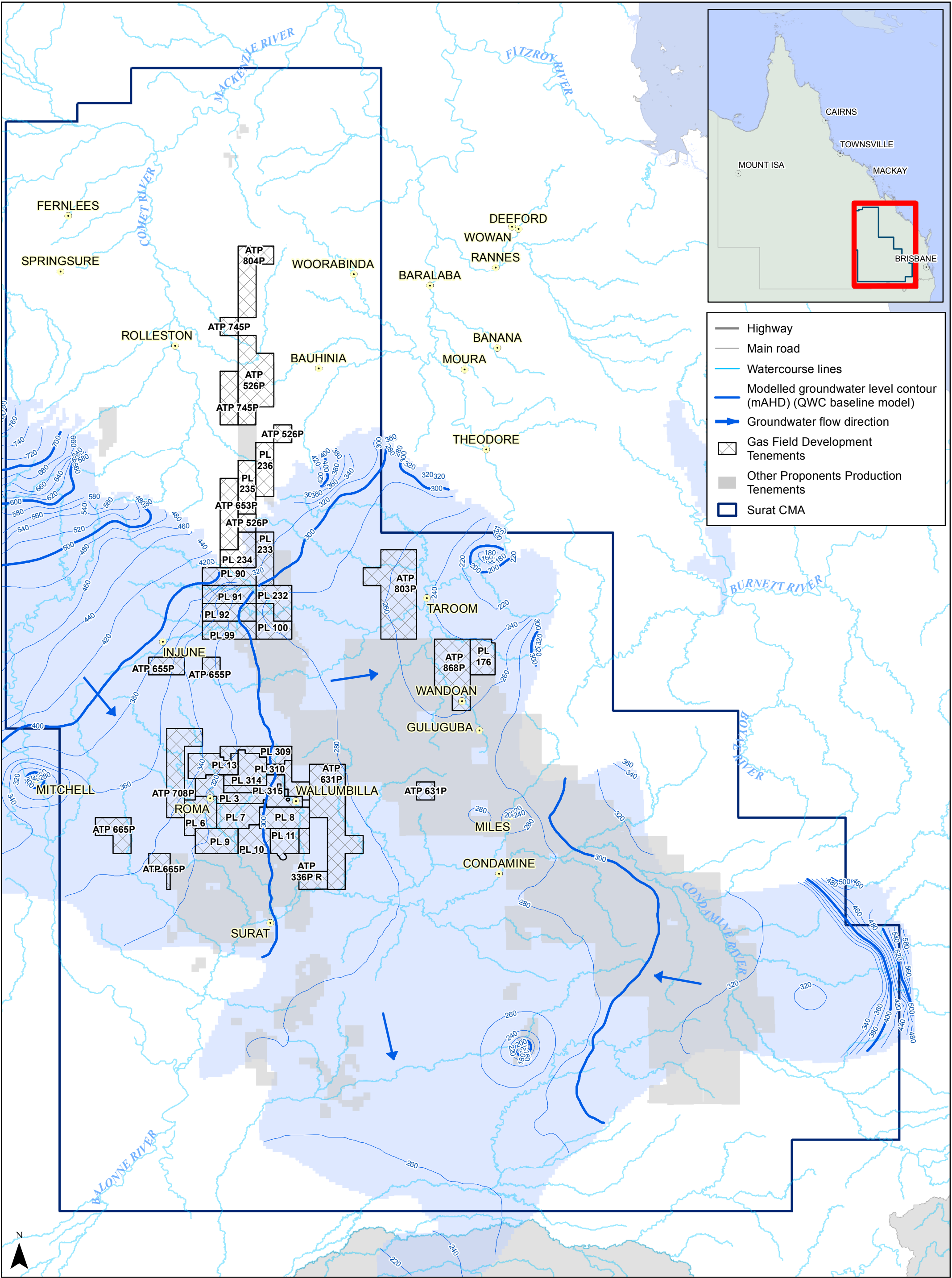


Figure B.10 Groundwater levels at Bendemere 1

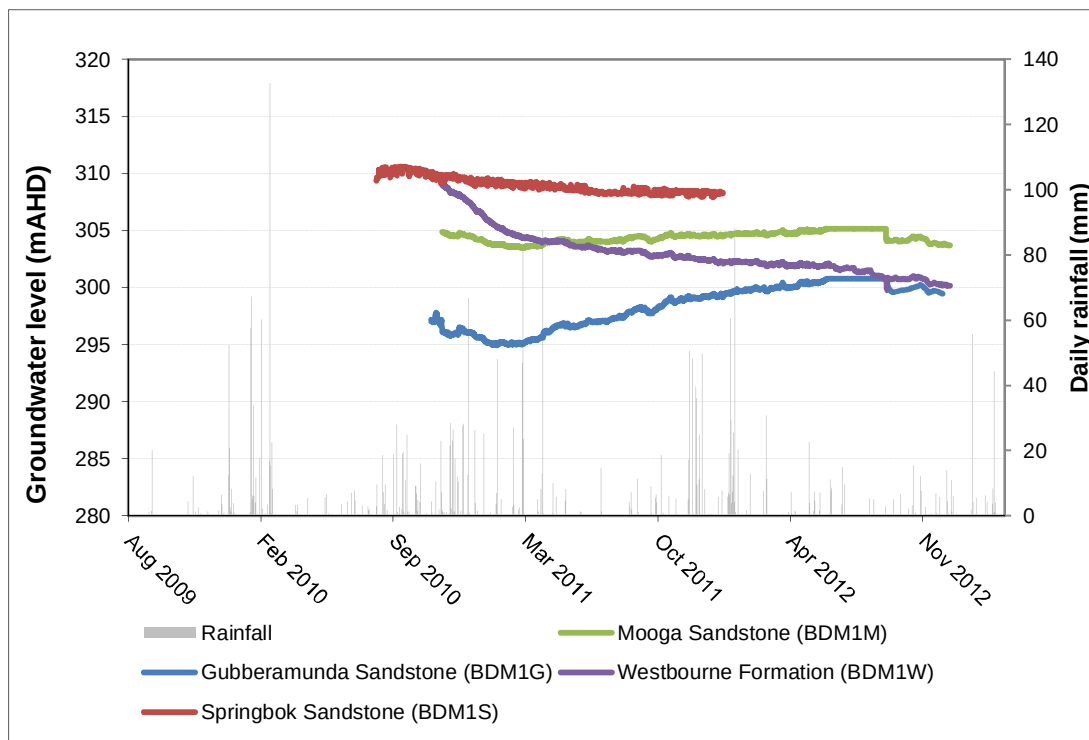


Figure B.11 Groundwater levels at Lettermore South 2

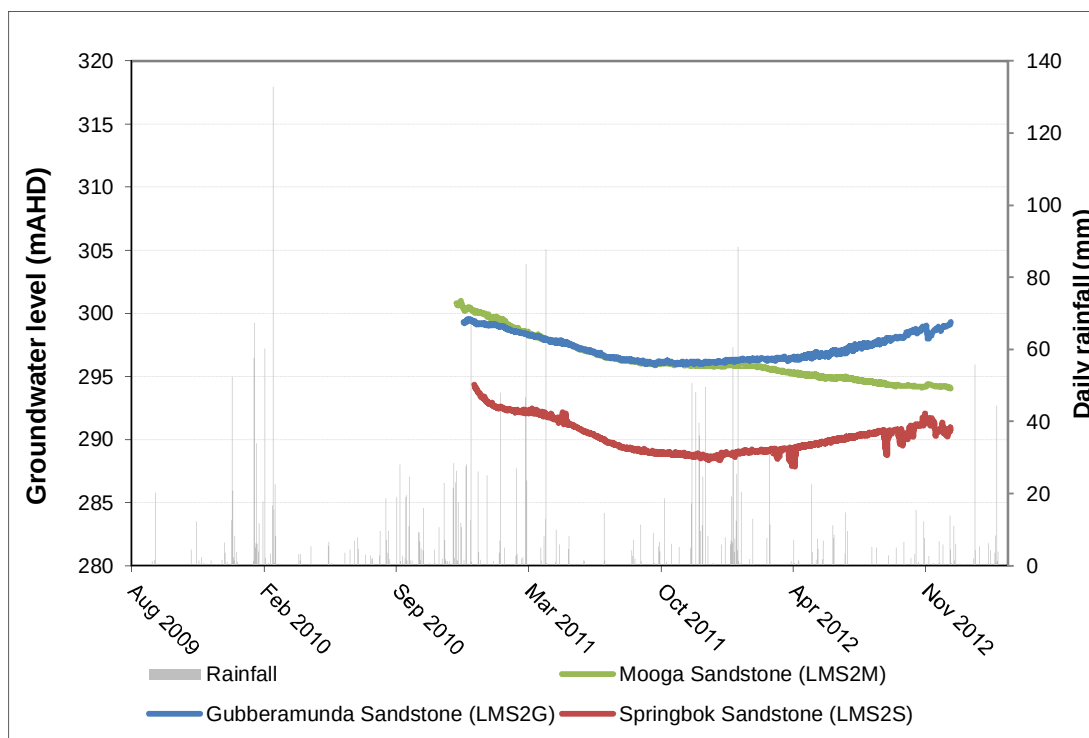


Figure B.12 Groundwater levels at Stakeyard East 1

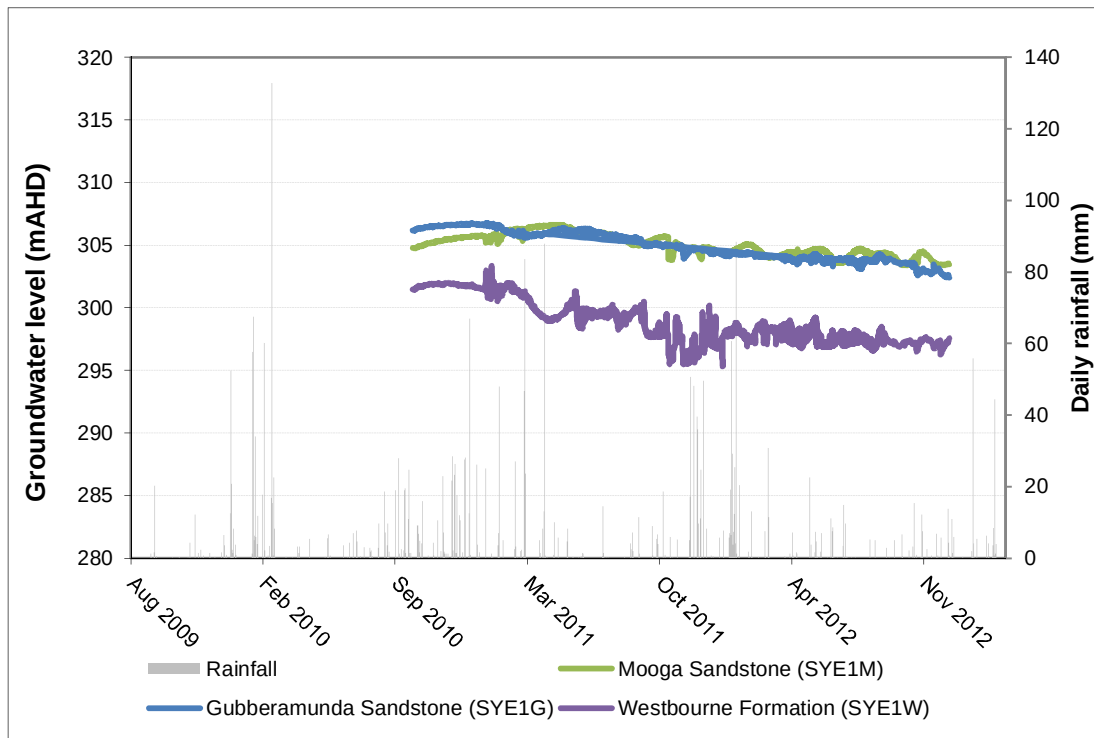


Figure B.13 Groundwater levels at Coonardoo 2

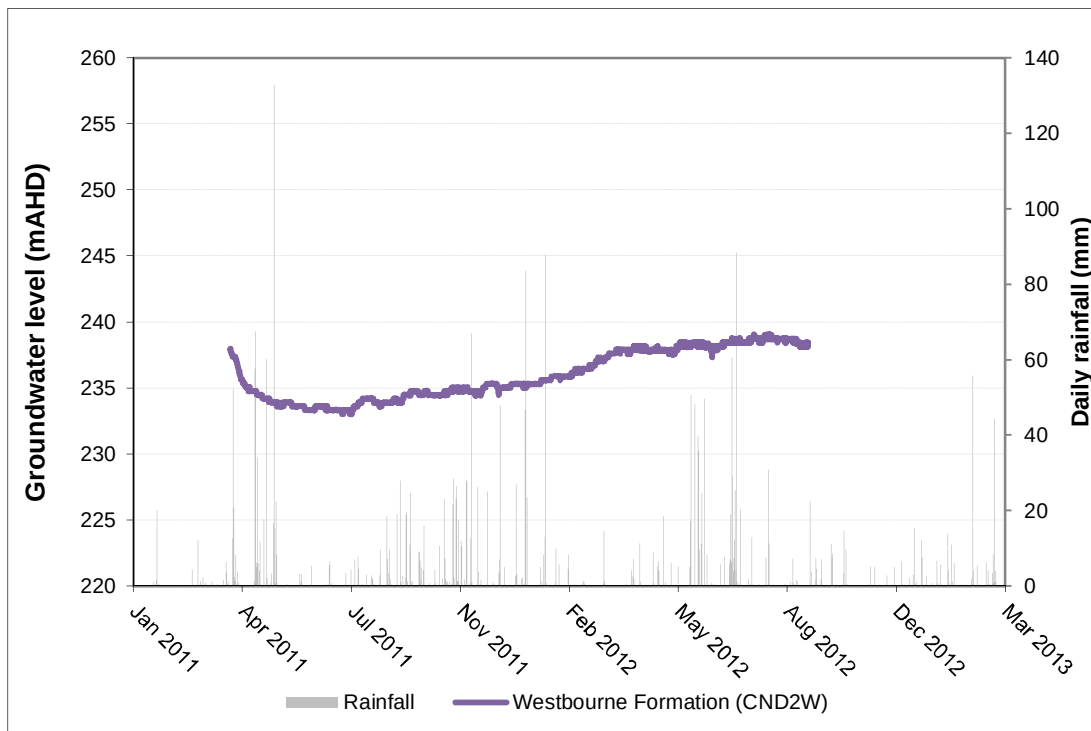


Figure B.14 Groundwater levels at Mt Eden 1

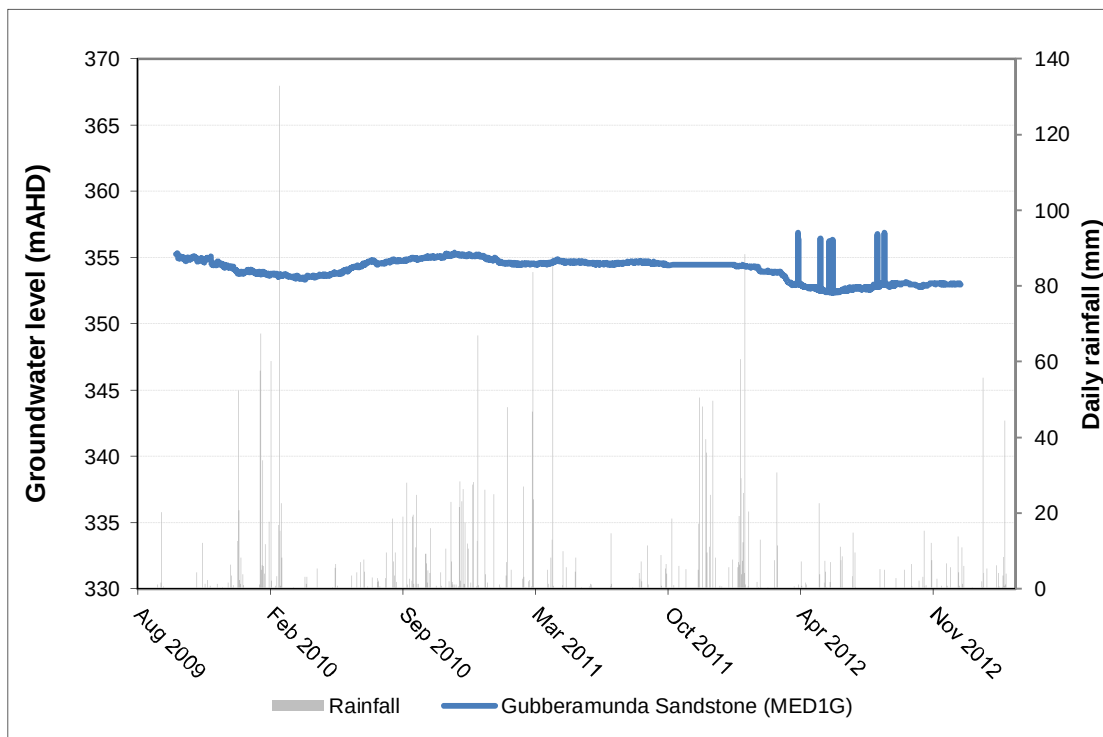


Figure B.15 Groundwater levels at Montana 1

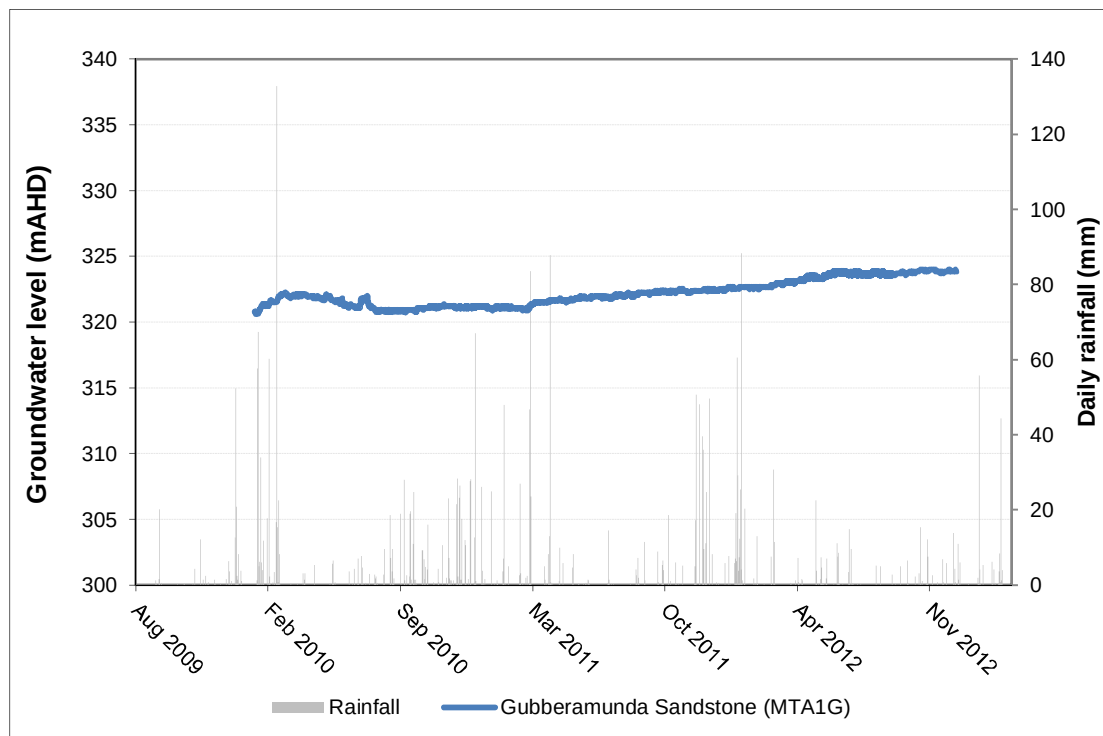


Figure B.16 Groundwater levels at Navarra 1

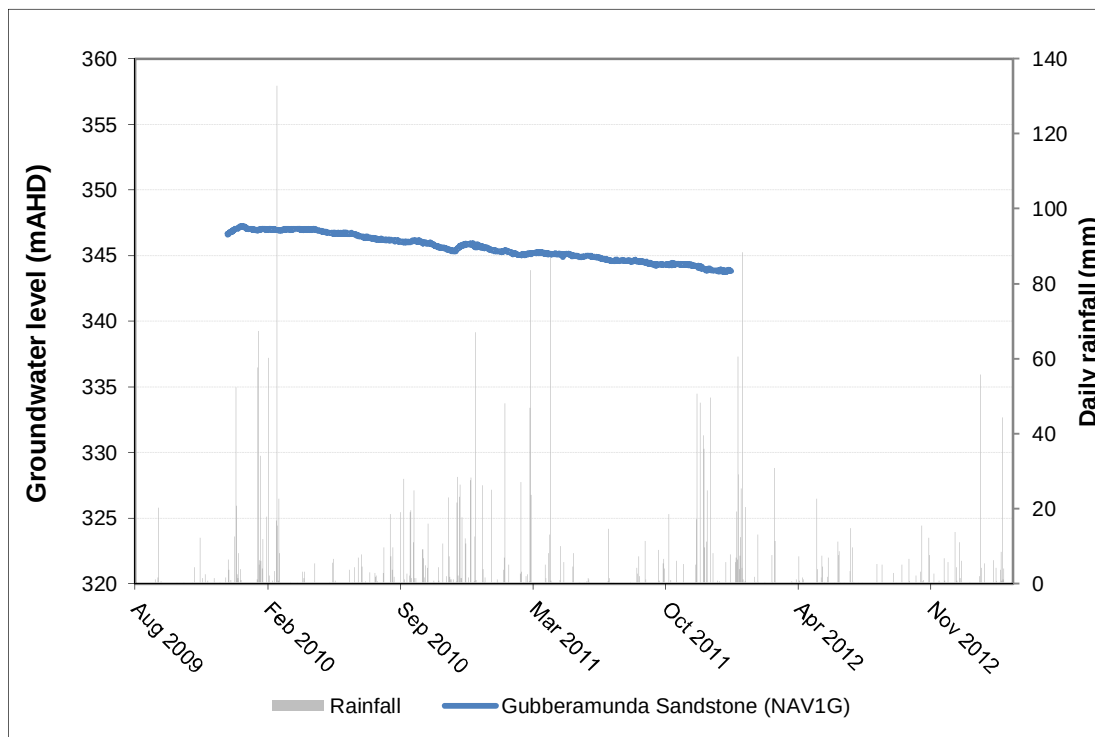


Figure B.17 Groundwater levels at Wingnut 3

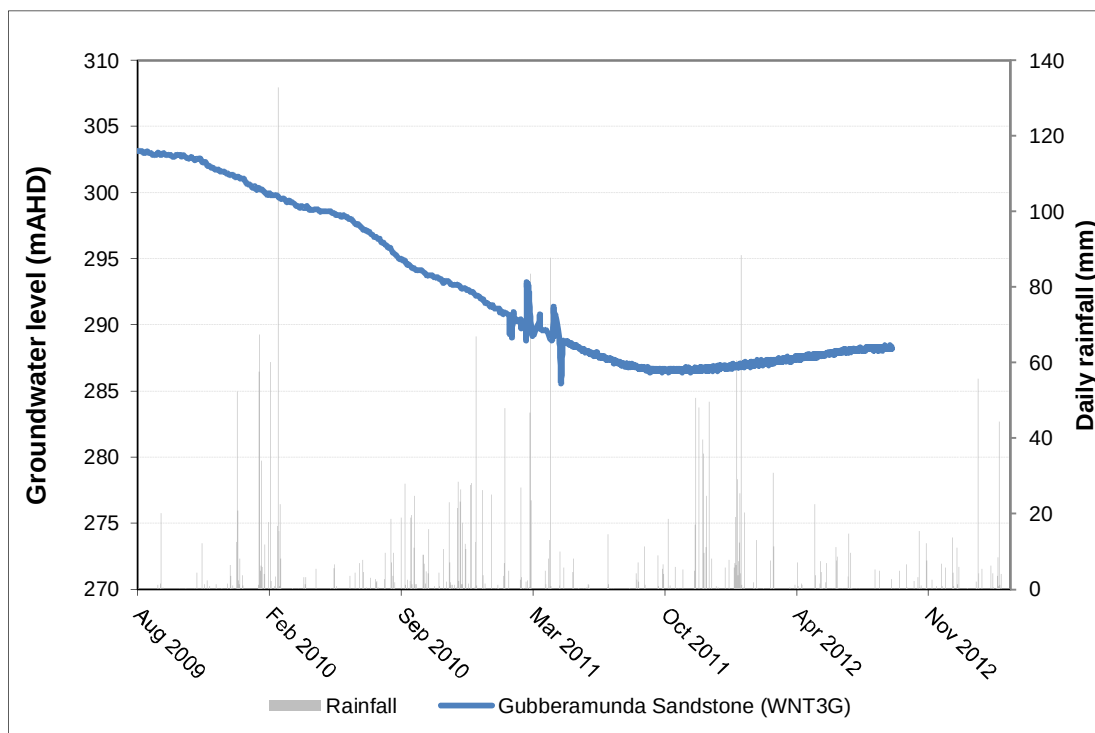


Figure B.18 Groundwater levels at Duarran VWP

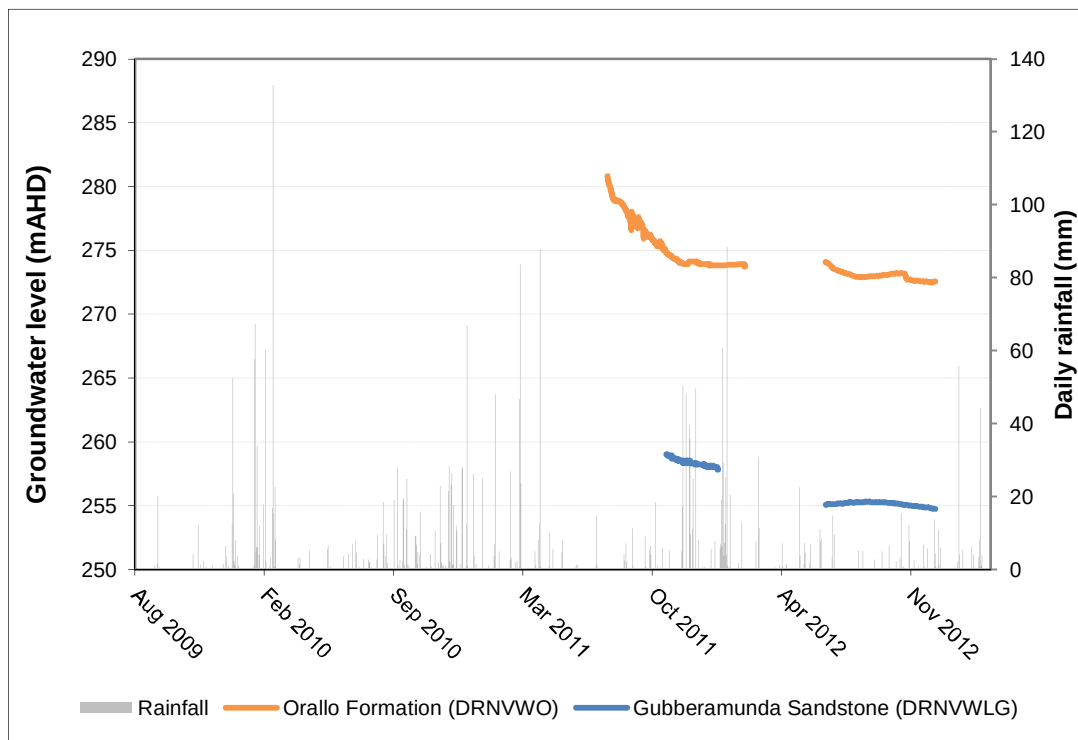


Figure B.19 Groundwater levels at Hutton Creek monitoring bore

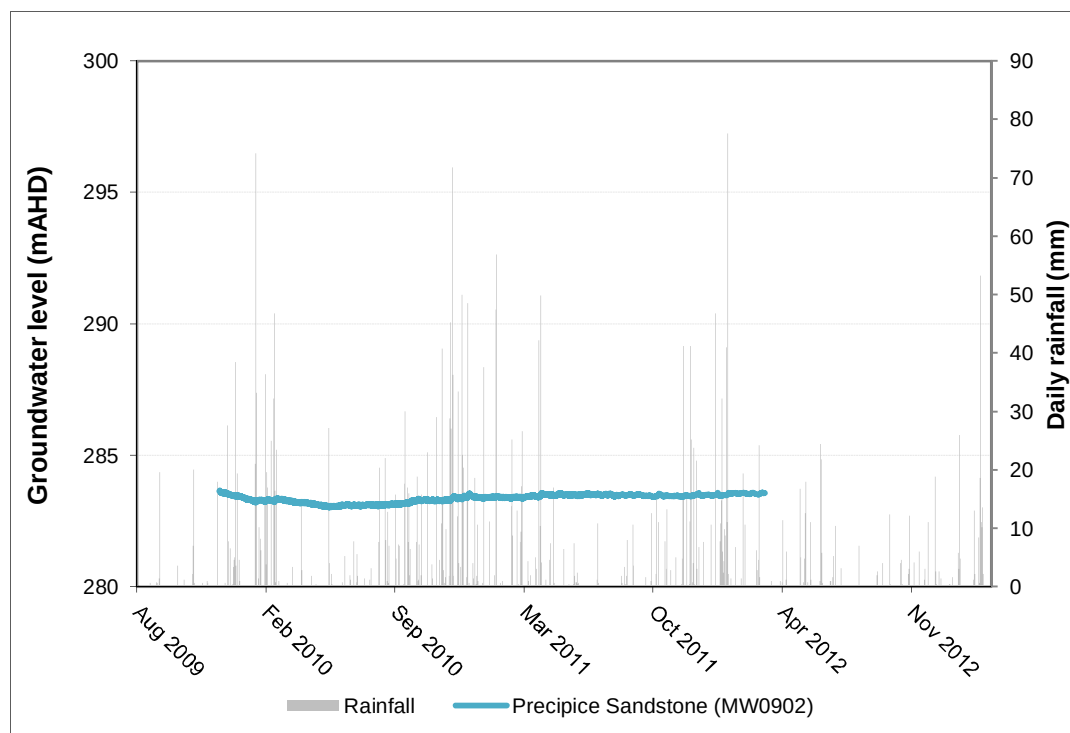


Figure B.20 Groundwater levels at Springwater West Plateau monitoring bore

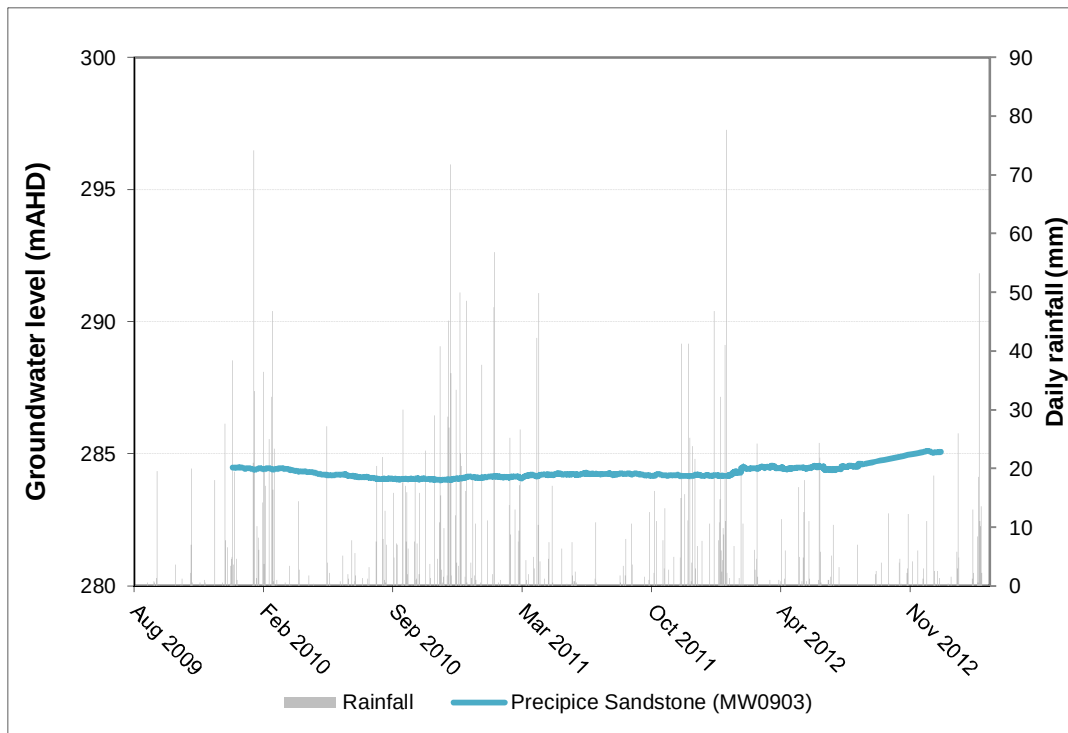


Figure B.21 Groundwater levels at Springwater Central Plateau monitoring bore

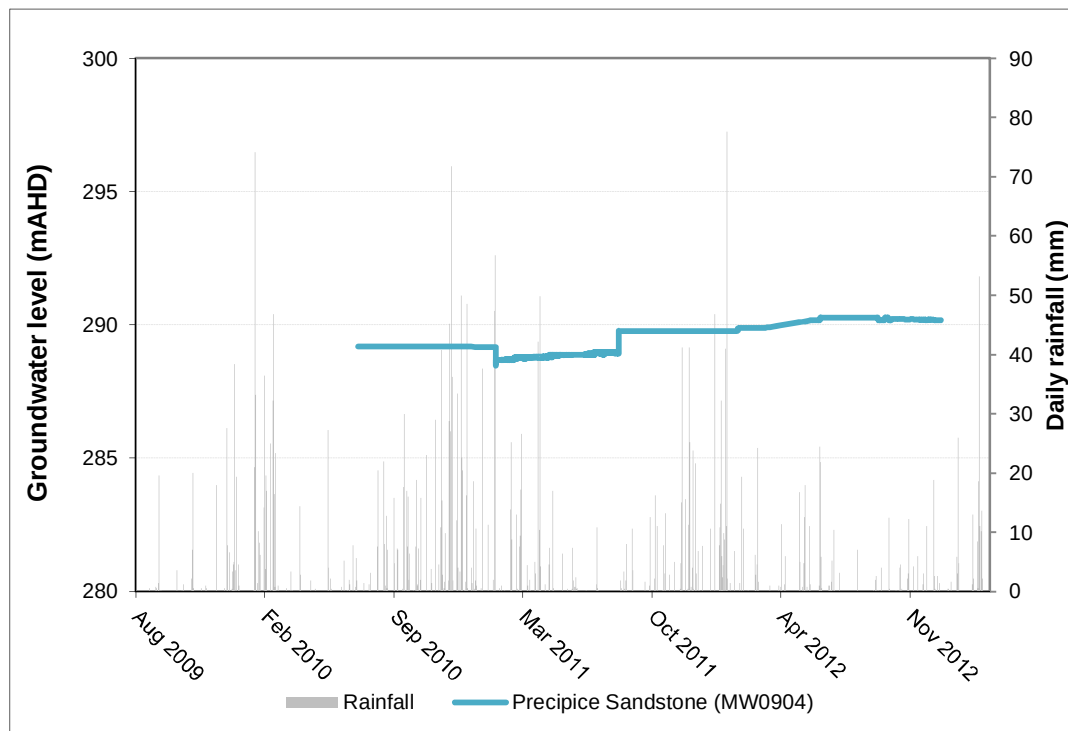
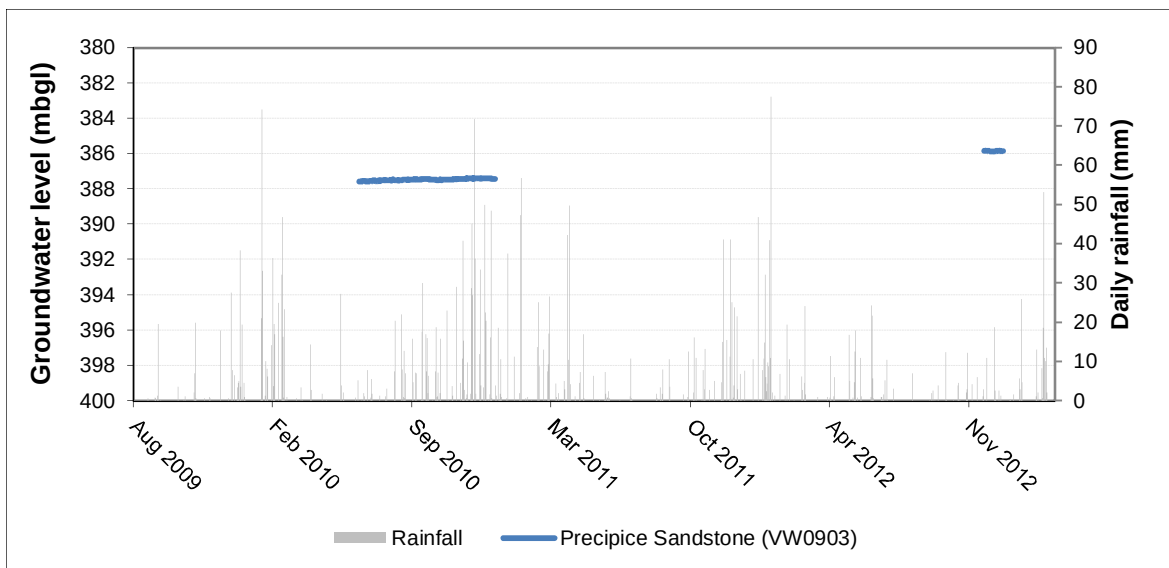
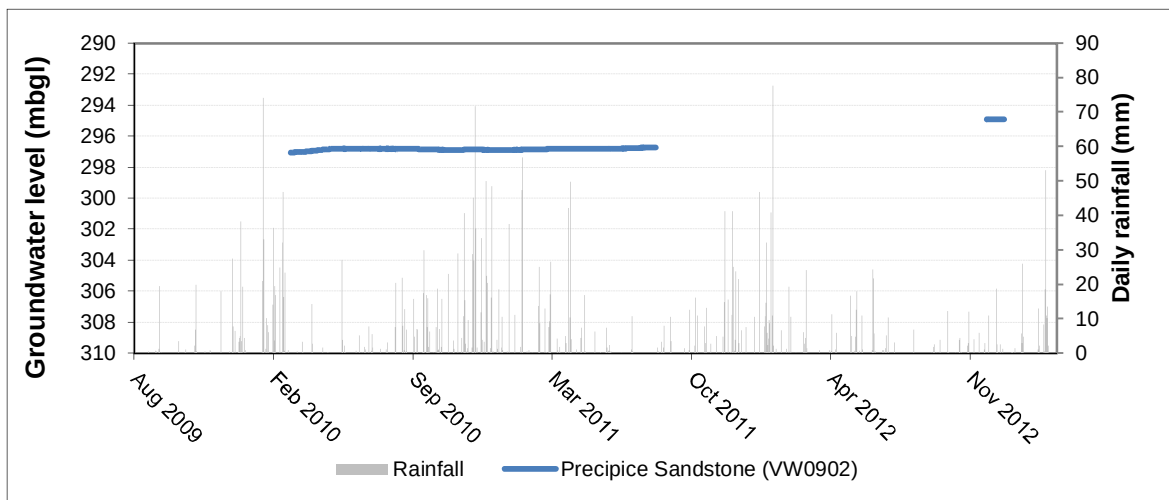
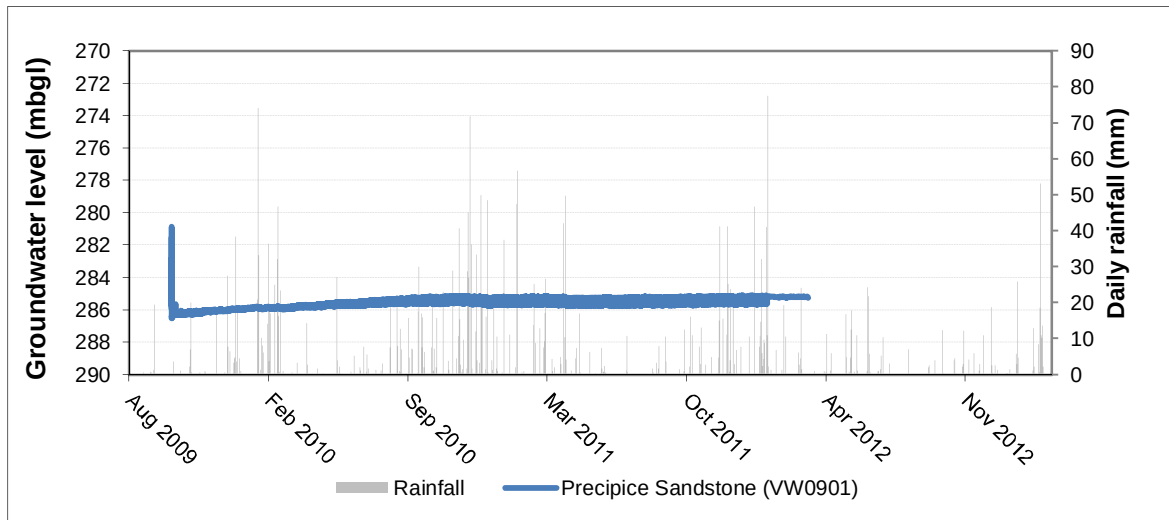


Figure B.22 Groundwater levels at Springwater Central Plateau VWPs
(Note the surface elevation was not known, so data is in mbgl)



Appendix C

Vent and watercourse springs in the Surat CMA



Table C.1 Details of spring vents within the Surat CMA

Complex number	Complex name	Site number	Latitude (decimal degrees)	Longitude (decimal degrees)	Estimated spring flow (L/min)	Source aquifer(s)	Model layer	EBPC	Conservation ranking (complex)
1	Rainbow Spring	549	-23.861427	149.100102	61.4	Precipice Sandstone	14	No	2
		550	-23.759428	149.104101	0.2	Precipice Sandstone	14	No	2
		nv337	-23.919	149.114	8.3	Precipice Sandstone, Clematis Sandstone	14,16	No	2
		nv339	-23.732739	149.082686	8.3	Precipice Sandstone, Clematis Sandstone	14,16	No	2
		nv340	-23.917	149.019	8.3	Precipice Sandstone, Clematis Sandstone	14,16	No	2
		nv343	-23.923	149.027	133.3	Precipice Sandstone, Clematis Sandstone	14,16	No	2
		nv365	-23.911	149.085	8.3	Precipice Sandstone	14	No	2
		nv366	-23.918	149.104	8.3	Precipice Sandstone, Clematis Sandstone	14,16	No	2
		nv368	-23.839	149.111	5.0	Precipice Sandstone, Clematis Sandstone	14,16	No	2
		nv369	-23.829	149.111	5.0	Precipice Sandstone, Clematis Sandstone	14,16	No	2
2	DawsonRiver2	nv4	-23.8	149.07	5.0	Precipice Sandstone	14	No	2
		42	-25.51502355	150.0586082	7.0	Evergreen Formation, Precipice Sandstone	13,14	Yes	2
3	DawsonRiver3	16	-25.448418	150.1541	72.0	Precipice Sandstone	14	No	2
		17	-25.460418	150.1331	136.5	Precipice Sandstone	14	No	2
		18	-25.46033	150.130112	18.0	Precipice Sandstone	14	No	2
		19	-25.456418	150.1341	21.7	Precipice Sandstone	14	No	2
		20	-25.461418	150.1321	63.1	Precipice Sandstone	14	No	2
		21	-25.455418	150.1351	11.2	Precipice Sandstone	14	No	2
		34	-25.458418	150.1231	108.9	Precipice Sandstone	14	No	2
		35	-25.459418	150.1251	79.4	Precipice Sandstone	14	No	2
		36	-25.456418	150.1261	79.4	Precipice Sandstone	14	No	2
		69	-25.464418	150.1221	23.0	Precipice Sandstone	14	No	2
4	DawsonRiver4	45	-25.471418	150.1221	0.1	Precipice Sandstone	14	No	2
		46	-25.47133	150.120113	0.0	Precipice Sandstone	14	No	2
		47	-25.47091677	150.117523	1.5	Precipice Sandstone	14	No	2
		47.1	-25.4710457	150.1180573	0.3	Precipice Sandstone	14	No	2
		47.2	-25.47114251	150.1181125	0.0	Precipice Sandstone	14	No	2
		47.3	-25.47124118	150.1181988	0.0	Precipice Sandstone	14	No	2
		47.4	-25.47136122	150.1182559	0.0	Precipice Sandstone	14	No	2
		47.5	-25.47098956	150.1184065	0.0	Precipice Sandstone	14	No	2
		47.6	-25.47049227	150.1182705	0.1	Precipice Sandstone	14	No	2
		47.7	-25.47045172	150.1176825	0.0	Precipice Sandstone	14	No	2
		47.8	-25.46987159	150.1177979	0.2	Precipice Sandstone	14	No	2
		47.9	-25.46964622	150.117768	0.1	Precipice Sandstone	14	No	2
		48	-25.47212557	150.1186713	0.1	Precipice Sandstone	14	No	2
		49	-25.471418	150.1191	0.4	Precipice Sandstone	14	No	2
		50	-25.46964199	150.1186245	0.0	Precipice Sandstone	14	No	2
		51	-25.468418	150.1201	0.0	Precipice Sandstone	14	No	2
		690	-25.43700833	150.0879637	0.2	Precipice Sandstone	14	No	2
5	Boggomoss	2	-25.4576017	150.02148	6.3	Precipice Sandstone	14	Yes	1b
		3	-25.45254651	150.0292412	1.6	Precipice Sandstone	14	Yes	1b
		7	-25.42675664	150.0281648	9.3	Precipice Sandstone	14	Yes	1b
		8	-25.41540657	150.0236539	13.4	Precipice Sandstone	14	Yes	1b
		9	-25.41483661	150.023632	1.3	Precipice Sandstone	14	Yes	1b
		10	-25.41246512	150.0209163	2.2	Precipice Sandstone	14	Yes	1b
		11	-25.45118343	150.0435847	7.4	Precipice Sandstone	14	Yes	1b
		12	-25.44135435	150.0563478	1.0	Precipice Sandstone	14	Yes	1b
		13	-25.44085157	150.0563245	1.3	Precipice Sandstone	14	Yes	1b
		14	-25.44762943	150.0427044	1.4	Precipice Sandstone	14	Yes	1b
		15	-25.44349858	150.0337326	1.2	Precipice Sandstone	14	Yes	1b
		29	-25.45161256	150.0204894	0.1	Precipice Sandstone	14	Yes	1b
		33	-25.45913631	150.0285987	22.8	Precipice Sandstone	14	Yes	1b
		37	-25.46079838	150.0796957	0.0	Precipice Sandstone	14	Yes	1b
		37.1	-25.46083753	150.0798116	0.0	Precipice Sandstone	14	Yes	1b
		44	-25.45863392	150.0475805	9.1	Precipice Sandstone	14	Yes	1b
		53	-25.45486721	150.0210337	0.9	Precipice Sandstone	14	Yes	1b
		54	-25.44534961	150.0591455	0.2	Precipice Sandstone	14	Yes	1b
		55	-25.42186255	150.0227037	1.8	Precipice Sandstone	14	Yes	1b
		56	-25.42472495	150.0217385	2.5	Precipice Sandstone	14	Yes	1b
		56.1	-25.4245658	150.021045	1.6	Precipice Sandstone	14	Yes	1b
		57	-25.42017349	150.0265028	36.6	Precipice Sandstone	14	Yes	1b
		58	-25.42250065	150.0271392	2.9	Precipice Sandstone	14	Yes	1b
		61	-25.45435894	150.0274468	10.6	Precipice Sandstone	14	Yes	1b
		62	-25.43112764	150.0251739	0.5	Precipice Sandstone	14	Yes	1b
		63	-25.45020088	150.0463916	1.1	Precipice Sandstone	14	Yes	1b
		68	-25.4311504	150.0269657	3.0	Precipice Sandstone	14	Yes	1b
		68.1	-25.43120943	150.0266768	8.0	Precipice Sandstone	14	Yes	1b
		683	-25.45312751	150.0205662	0.5	Precipice Sandstone	14	Yes	1b
		691	-25.48731898	150.0471372	2.3	Precipice Sandstone	14	Yes	1b
6	DawsonRiver6	1	-25.43409526	150.025268	11.7	Precipice Sandstone	14	Yes	1b
		4	-25.44578102	150.0236943	975.0	Precipice Sandstone	14	Yes	1b
		5	-25.44554528	150.0260319	69.5	Precipice Sandstone	14	Yes	1b
		6	-25.42748095	150.0227381	20.7	Precipice Sandstone	14	Yes	1b
		22	-25.4280454	150.0274794	6.1	Precipice Sandstone	14	Yes	1b
		23	-25.43585637	150.0256214	13.3	Precipice Sandstone	14	Yes	1b
		24	-25.43837566	150.0256315	132.9	Precipice Sandstone	14	Yes	1b
		25	-25.4368412	150.023329	5.0	Precipice Sandstone	14	Yes	1b
		27	-25.43227654	150.0253622	2.5	Precipice Sandstone	14	Yes	1b
		30	-25.44227155	150.0055029	1.6	Precipice Sandstone	14	Yes	1b
		31	-25.44085753	150.0048892	122.7	Precipice Sandstone	14	Yes	1b
		32	-25.44119617	150.0260088	35.1	Precipice Sandstone	14	Yes	1b
		43	-25.46326113	150.0567337	0.3	Precipice Sandstone	14	Yes	1b
		59	-25.44208309	150.0234976	4.3	Precipice Sandstone	14	Yes	1b
		60	-25.43021577	150.0215641	5.5	Precipice Sandstone	14	Yes	1b
		681	-25.43604964	150.0229777	22.5	Precipice Sandstone	14	Yes	1b

Complex number	Complex name	Site number	Latitude (decimal degrees)	Longitude (decimal degrees)	Estimated spring flow (L/min)	Source aquifer(s)	Model layer	EBPC	Conservation ranking (complex)
8	DawsonRiver8	26	-25.55242	149.807105	0.6	Hutton Sandstone	12	Yes	3
		28	-25.55242	149.807105	0.0	Hutton Sandstone	12	Yes	3
		38	-25.56850966	149.8021111	58.1	Hutton Sandstone	12	Yes	3
9	CockatooCrk	64	-25.7176972	150.2409226	34.2	Precipice Sandstone	14	Yes	1b
		64.1	-25.71781297	150.2407025		Precipice Sandstone	14	Yes	1b
		65	-25.71645643	150.2390982	3.7	Precipice Sandstone	14	Yes	1b
		65.1	-25.71628444	150.2390233		Precipice Sandstone	14	Yes	1b
		65.2	-25.71621969	150.2391317		Precipice Sandstone	14	Yes	1b
		66	-25.719417	150.238101	0.0	Precipice Sandstone	14	Yes	1b
		319	-25.72546831	150.2688961	3.8	Precipice Sandstone	14	Yes	1b
		320	-25.73178874	150.2518877	0.4	Precipice Sandstone	14	Yes	1b
		320.1	-25.73194259	150.2519747	0.1	Precipice Sandstone	14	Yes	1b
		321	-25.72941864	150.2500176	0.0	Precipice Sandstone	14	Yes	1b
		321.1	-25.72965807	150.2498677	0.0	Precipice Sandstone	14	Yes	1b
		321.2	-25.72971516	150.2500017	0.0	Precipice Sandstone	14	Yes	1b
		321.3	-25.72976047	150.2501178	0.0	Precipice Sandstone	14	Yes	1b
		321.4	-25.72955732	150.2498508	0.0	Precipice Sandstone	14	Yes	1b
		321.5	-25.72944292	150.2498188	0.0	Precipice Sandstone	14	Yes	1b
		321.6	-25.7293432	150.2500551	0.0	Precipice Sandstone	14	Yes	1b
		321.7	-25.72893178	150.2501139	0.0	Precipice Sandstone	14	Yes	1b
		321.8	-25.72871228	150.2502401	0.0	Precipice Sandstone	14	Yes	1b
		684	-25.72583114	150.2694099	0.1	Precipice Sandstone	14	Yes	1b
16	16	548	-23.775427	149.1751	0.6	Clematis Sandstone	16	No	3
35	35	nv367	-23.888	149.28	8.3	Clematis Sandstone	16	No	
		nv386	-23.859	149.317	8.3	Clematis Sandstone	16	No	
68	SF212	547	-23.817427	149.2231	6.3	Clematis Sandstone	16	No	2
		nv341	-23.842211	149.227732	5.0	Clematis Sandstone	16	No	2
74	Yebna	nv329	-25.65	149.2	8.3	Evergreen Formation, Precipice Sandstone, Clematis Sandstone	13,14,16	No	
76	Eden Vale	700	-25.21072737	148.1189283	3.2	Hutton Sandstone	12	No	3
		701	-25.20427479	148.2292392		Evergreen Formation (Boxvale Sandstone)	13	No	
		nv600	-25.1312397	148.131227		Hutton Sandstone	12	No	3
		nv601	-25.1762348	148.1181965		Evergreen Formation (Boxvale Sandstone)	13	No	3
		nv602	-25.1554645	148.0844437		Evergreen Formation (Boxvale Sandstone)	13	No	3
		nv603	-25.1477037	148.1189979		Hutton Sandstone	12	No	3
		nv605	-25.1285902	148.1972325		Evergreen Formation (Boxvale Sandstone)	13	No	3
		nv607	-25.1104266	148.1370552		Hutton Sandstone	12	No	3
78	78	551	-24.034428	149.022104	0.6	Clematis Sandstone	16	No	3
		552	-24.035428	149.035104	1.1	Clematis Sandstone	16	No	3
84	Conom	nv356	-24.378323	149.142415	16.8	Clematis Sandstone	16	No	
		nv357	-24.387182	149.141579	16.8	Clematis Sandstone	16	No	
		nv358	-24.406553	149.125146	16.8	Clematis Sandstone	16	No	
85	Newton	538	-25.354423	149.36311	12.2	Hutton Sandstone	12	No	2
		nv328	-25.367	149.358	5.0	Hutton Sandstone	12	No	2
		nv331	-25.4	149.4		Hutton Sandstone	12	No	2
		nv332	-25.41667	149.366668		Hutton Sandstone	12	No	2
229	Ponies	284	-25.82954964	149.0413821	1.8	Hutton Sandstone	12	No	2
230	LuckyLast	287	-25.79806535	148.7755795	32.7	Evergreen Formation (Boxvale Sandstone), Precipice Sandstone	13,14	Yes	1b
		340	-25.79399184	148.7731738	2.7	Evergreen Formation (Boxvale Sandstone), Precipice Sandstone	13,14	Yes	1b
		686	-25.79477826	148.7734076	1.0	Evergreen Formation (Boxvale Sandstone), Precipice Sandstone	13,14	Yes	1b
		687	-25.794811	148.7737796	0.8	Evergreen Formation (Boxvale Sandstone), Precipice Sandstone	13,14	Yes	1b
		687.1	-25.79462441	148.773846		Evergreen Formation (Boxvale Sandstone), Precipice Sandstone	13,14	Yes	1b
		687.2	-25.794561	148.7737828		Evergreen Formation (Boxvale Sandstone), Precipice Sandstone	13,14	Yes	1b
		687.3	-25.79420224	148.7736134		Evergreen Formation (Boxvale Sandstone), Precipice Sandstone	13,14	Yes	1b
		687.4	-25.79411808	148.7735415		Evergreen Formation (Boxvale Sandstone), Precipice Sandstone	13,14	Yes	1b
		687.5	-25.79367953	148.7732965		Evergreen Formation (Boxvale Sandstone), Precipice Sandstone	13,14	Yes	1b
		687.6	-25.79359458	148.7733188		Evergreen Formation (Boxvale Sandstone), Precipice Sandstone	13,14	Yes	1b
		688	-25.79511407	148.7737482	2.9	Evergreen Formation (Boxvale Sandstone), Precipice Sandstone	13,14	Yes	1b
		689	-25.79398988	148.7728387	0.1	Evergreen Formation (Boxvale Sandstone), Precipice Sandstone	13,14	Yes	1b
232	CrystalBall	317	-25.505433	147.977131	597.9	Hutton Sandstone	12	No	2
		317.1	-25.508064	147.976852	3.3	Hutton Sandstone	12	No	2
		317.2	-25.51	147.9722	3.3	Hutton Sandstone	12	No	2
		318	-25.508433	147.977131	68.4	Hutton Sandstone	12	No	2
233	Moolayember	408	-25.17953097	148.5704143	16.8	Clematis Sandstone	16	No	2
		675	-25.17917444	148.5640373	16.2	Clematis Sandstone	16	No	2
		676	-25.17954119	148.5635078	1.4	Clematis Sandstone	16	No	2
235	Moffat	316	-25.106433	148.078126	16.8	Hutton Sandstone	12	No	2
		316.1	-25.0617	148.0539	15.0	Tertiary Volcanics		No	2
		316.2	-25.0619	148.0333	15.0	Tertiary Volcanics, Evergreen Formation (Boxvale Sandstone)	13	No	2
236	Marlong	309	-24.943434	147.961126	16.8	Precipice Sandstone	14	No	2
		310	-24.946434	147.958126	29.8	Precipice Sandstone	14	No	2
		315	-24.942434	147.960126	37.1	Precipice Sandstone	14	No	2
254	254	nv5	-24.92	148.94	5.0	Clematis Sandstone	16	No	
256	DamDyke	nv9	-24.75	147.88	0.1	Tertiary Volcanics		No	

Complex number	Complex name	Site number	Latitude (decimal degrees)	Longitude (decimal degrees)	Estimated spring flow (L/min)	Source aquifer(s)	Model layer	EBPC	Conservation ranking (complex)
260	Scotts Creek	189	-25.89150945	149.2859827	50.5	Hutton Sandstone	12	Yes	1b
		190	-25.8884365	149.2874154	1.2	Hutton Sandstone	12	Yes	1b
		191	-25.89175501	149.2874838	56.2	Hutton Sandstone	12	Yes	1b
		192	-25.88895774	149.279041	1.5	Hutton Sandstone	12	Yes	1b
		192.1	-25.88811432	149.2791888		Hutton Sandstone	12	Yes	1b
267	267	nv6	-25.233336	148.33333	5.0	Hutton Sandstone	12	No	
		nv7	-25.233329	148.350007	5.0	Hutton Sandstone	12	No	
283	Barton	702	-26.27030324	149.2432849	1.1	Gubberamunda Sandstone	5	No	3
		703	-26.28533269	149.234459	0.0	Gubberamunda Sandstone	5	No	3
296	Carnarvon Gorge	553	-25.07936689	148.2295515		Evergreen Formation (Boxvale Sandstone)	13	No	1a
		554	-25.04348221	148.2009444	6.3	Precipice Sandstone	14	No	1a
		554.3	-25.03540237	148.2041927		Precipice Sandstone	14	No	1a
		555	-25.057432	148.210124	11.2	Precipice Sandstone	14	No	1a
		556	-25.057345	148.213618	0.2	Precipice Sandstone	14	No	1a
		677	-25.03776376	148.1999831	20.0	Precipice Sandstone	14	No	1a
		678	-25.03716647	148.201275	20.0	Precipice Sandstone	14	No	1a
		712	-25.13115551	148.1903936	40.0	Hutton Sandstone	12	Yes	1a
		713	-25.09066805	148.2289839	20.0	Evergreen Formation, Precipice Sandstone	13,14	No	1a
		714	-25.07743161	148.2301236	20.0	Tertiary Volcanics		No	1a
		715	-25.03378204	148.2045532		Precipice Sandstone	14	No	1a
		nv387	-24.950009	148.134167	16.8	Tertiary Volcanics		No	1a
		nv388	-24.96699	148.157106	16.8	Tertiary Volcanics		No	1a
		nv389	-24.982208	148.174091	16.8	Tertiary Volcanics		No	1a
		nv390	-25.002689	148.209956	16.8	Tertiary Volcanics		No	1a
		nv391	-24.961112	148.098609	16.8	Tertiary Volcanics		No	1a
		nv392	-25.052308	148.215399	16.8	Precipice Sandstone	14	No	1a
		nv394	-25.033387	148.210257	16.8	Evergreen Formation (Boxvale Sandstone)	13	No	1a
		nv395	-25.075904	148.20076	16.8	Tertiary Volcanics		No	1a
		nv396	-25.029872	148.19833	16.8	Hutton Sandstone, Evergreen Formation (Boxvale Sandstone)	12,13	No	1a
		nv399	-25.056402	148.154971	16.8	Hutton Sandstone, Tertiary Volcanics	12	No	1a
		nv400	-25.06087	148.16096	16.8	Evergreen Formation (Boxvale Sandstone), Hutton Sandstone	12,13	No	1a
		nv401	-25.046547	148.144966	16.8	Precipice Sandstone	14	No	1a
		nv435	-25.077	148.23	6.3	Tertiary Volcanics		No	1a
		nv8	-25.033	148.13	16.7	Tertiary Volcanics, Hutton Sandstone	12	No	1a
302	302	539	-25.099424	149.273109	163.6	Precipice Sandstone	14	No	2
		539.1	-25.115	149.232	0.2	Precipice Sandstone	14	No	2
304	ExpedRange	541	-24.316426	149.168104	3.1	Clematis Sandstone, Cainozoic Sediments	1,16	No	2
		542	-24.298426	149.179104	0.6	Clematis Sandstone, Cainozoic Sediments	1,16	No	2
		543	-24.314426	149.155105	0.0	Clematis Sandstone, Cainozoic Sediments	1,16	No	2
		544	-24.308426	149.174104	0.2	Clematis Sandstone, Cainozoic Sediments	1,16	No	2
		544.1	-24.311	149.169	0.2	Clematis Sandstone, Cainozoic Sediments	1,16	No	2
		544.2	-24.311	149.17329	0.2	Clematis Sandstone, Cainozoic Sediments	1,16	No	2
		544.3	-24.31	149.174	0.2	Clematis Sandstone, Cainozoic Sediments	1,16	No	2
		545	-24.172427	149.156103	108.9	Clematis Sandstone	16	No	2
		546	-24.257427	149.135104	65.8	Clematis Sandstone, Cainozoic Sediments	1,16	No	2
		nv2	-24.183	149.15	5.0	Clematis Sandstone	16	No	2
		nv3	-24.285	149.133	5.0	Clematis Sandstone	16	No	2
		nv348	-24.163077	149.137824	16.8	Clematis Sandstone	16	No	2
		nv349	-24.208709	149.134844	16.8	Clematis Sandstone, Cainozoic Sediments	1,16	No	2
		nv350	-24.230422	149.131564	16.8	Clematis Sandstone, Cainozoic Sediments	1,16	No	2
		nv351	-24.25711	149.127578	16.8	Clematis Sandstone, Cainozoic Sediments	1,16	No	2
		nv352	-24.285367	149.14036	16.8	Clematis Sandstone	16	No	2
		nv353	-24.212	149.145	16.8	Clematis Sandstone, Cainozoic Sediments	1,16	No	2
		nv354	-24.284	149.148	16.8	Clematis Sandstone, Cainozoic Sediments	1,16	No	2
306	306	nv355	-24.324	149.131	16.8	Clematis Sandstone, Cainozoic Sediments	1,16	No	2
		nv371	-24.092	149.216	16.8	Clematis Sandstone	16	No	
307	Elgin	nv359	-24.466912	149.114816	16.8	Clematis Sandstone	16	No	
		nv372	-24.466	149.111	16.8	Clematis Sandstone	16	No	
		nv373	-24.474	149.132	16.8	Clematis Sandstone	16	No	
		nv375	-24.499487	149.12868	16.8	Clematis Sandstone	16	No	
		nv376	-24.530298	149.120318	16.8	Clematis Sandstone	16	No	
		nv377	-24.56372	149.118906	16.8	Clematis Sandstone	16	No	
		nv378	-24.583395	149.132071	16.8	Clematis Sandstone	16	No	
		nv379	-24.595236	149.085867	16.8	Clematis Sandstone	16	No	
308	308	nv383	-25.002466	148.9867	16.8	Clematis Sandstone	16	No	
309	309	nv384	-25.062552	148.878645	16.8	Clematis Sandstone	16	No	
310	310	nv370	-25.015	149.223	16.8	Precipice Sandstone	14	No	
311	311	499	-25.70023983	149.1289353		Precipice Sandstone	14	No	2
		500	-25.71975802	149.1048357		Precipice Sandstone	14	No	2
		500.1	-25.72817478	149.1004509		Precipice Sandstone	14	No	2
		535	-25.7202	149.0275078		Precipice Sandstone	14	No	2
		536	-25.71449917	149.0654313	0.2	Precipice Sandstone	14	No	2
		536.1	-25.71362345	149.0653911		Precipice Sandstone	14	No	2
		536.2	-25.71554437	149.0648192		Precipice Sandstone	14	No	2
		537	-25.72834046	149.0939031	0.3	Precipice Sandstone	14	No	2
		692	-25.72598643	149.1037402		Precipice Sandstone	14	No	2
		693	-25.72066565	149.0296327	0.3	Precipice Sandstone	14	No	2
		694	-25.71239372	149.0726224	0.0	Precipice Sandstone	14	No	2
		695	-25.7254151	149.0869461	0.0	Precipice Sandstone	14	No	2
		696	-25.72547095	149.086885	0.0	Precipice Sandstone	14	No	2
		697	-25.72559901	149.0867477	0.0	Precipice Sandstone	14	No	2
		698	-25.72562963	149.086671	0.0	Precipice Sandstone	14	No	2
		699	-25.72578972	149.0866167	0.2	Precipice Sandstone	14	No	2
		704	-25.67971845	149.1272668	0.0	Precipice Sandstone	14	No	2

Complex number	Complex name	Site number	Latitude (decimal degrees)	Longitude (decimal degrees)	Estimated spring flow (L/min)	Source aquifer(s)	Model layer	EBPC	Conservation ranking (complex)
325	325	nv363	-24.817	147.983		Precipice Sandstone, Tertiary Volcanics	14	No	
326	326	705	-25.23031169	148.6591471	3.1	Clematis Sandstone	16	No	3
327	327	nv385	-25.501	148.982	16.8	Precipice Sandstone	14	No	
328	328	nv374	-24.958	149.402	16.8	Precipice Sandstone	14	No	
331	331	nv402	-25.394441	150.147457	66.7	Precipice Sandstone	14	No	
		nv404	-25.394882	150.170295	66.7	Precipice Sandstone	14	No	
334	334	nv405	-25.425066	150.191451	66.7	Precipice Sandstone	14	No	
335	335	nv406	-25.096007	149.541327	66.7	Hutton Sandstone	12	No	
339	LonelyEddie	706	-25.47908835	148.731527	0.2	Precipice Sandstone	14	No	2
		707	-25.4787368	148.7321002	0.4	Precipice Sandstone	14	No	2
		708	-25.47852975	148.7326468	20L/min	Precipice Sandstone	14	No	2
		709	-25.47851881	148.7335345	0.4	Precipice Sandstone	14	No	2
506	SprRidge	184	-26.23335247	148.8685837	3.3	Gubberamunda Sandstone	5	No	4b
		185	-26.23209094	148.8693863	0.7	Gubberamunda Sandstone	5	No	4b
		186	-26.23671634	148.8689719	8.1	Gubberamunda Sandstone	5	No	4b
507	VI_mile	187	-26.21895625	148.6703018	10.7	Gubberamunda Sandstone	5	No	4b
		188	-26.26947584	148.7054377		Gubberamunda Sandstone	5	No	4b
		679	-26.27848265	148.6958733	2.1	Gubberamunda Sandstone	5	No	4b
		680	-26.27313503	148.6868238	2.0	Gubberamunda Sandstone	5	No	4b
		680.1	-26.27362732	148.6873191	1.6	Gubberamunda Sandstone	5	No	4b
510	Cleanskins	nv417	-23.933	149.186	163.6	Clematis Sandstone	16	No	
561	SpRockCrk	285	-25.76267665	148.769787		Evergreen Formation (Boxvale Sandstone), Precipice Sandstone	13,14	No	3
580	Prices	39	-25.476418	150.1271	0.0	Precipice Sandstone	14	No	2
		40	-25.47528611	150.1287009	2.3	Precipice Sandstone	14	Yes	1b
		41	-25.47671662	150.1309371	2.9	Precipice Sandstone	14	Yes	1b
		52	-25.4772879	150.1256939	3.4	Precipice Sandstone	14	Yes	1b
		67	-25.47553915	150.1272052	1.8	Precipice Sandstone	14	Yes	1b
583	Lenore Hills	nv621	-24.63173926	149.062935		Clematis Sandstone, Tertiary Volcanics	16	No	3
		nv622	-24.62247999	149.1018211		Clematis Sandstone	16	No	3
		710	-24.65965513	149.1140606	0.3	Clematis Sandstone, Tertiary Volcanics	16	No	3
584	Wambo	711	-26.87419522	150.4371375	1.8	Cainozoic Sediments	1	No	3
		711.1	-26.8739598	150.4371718		Cainozoic Sediments	1	No	3
585	Bowenville	SP4	-27.32777327	151.4569981		Tertiary Volcanics		No	3
586	Boxvale	nv437	-25.307	148.448		Evergreen Formation (Boxvale Sandstone)	13, 14	No	
587	Timor	x436	-25.672	148.455		Hutton Sandstone	12	No	
588	Springwood	nv609	-24.57775377	148.2525338		Tertiary Volcanics		No	
		nv610	-24.5632663	148.2463668		Tertiary Volcanics		No	
		nv611	-24.56795637	148.2305752		Tertiary Volcanics		No	
		nv612	-24.52524855	148.2210281		Tertiary Volcanics		No	
		nv613	-24.52755837	148.2367847		Tertiary Volcanics		No	
		nv614	-24.53240691	148.206774		Tertiary Volcanics		No	
		nv615	-24.5515971	148.1758283		Tertiary Volcanics		No	
		nv616	-24.53235196	148.1989455		Tertiary Volcanics		No	
		nv617	-24.50830032	148.2141037		Tertiary Volcanics		No	
		nv618	-24.49870521	148.2102121		Tertiary Volcanics		No	
		nv619	-24.49667209	148.2193507		Tertiary Volcanics		No	
		nv620	-24.48112681	148.2119976		Tertiary Volcanics		No	
589	Merivale	nv438	-25.478	148.216	0.0	Hutton Sandstone	12	No	
590	Non-GAB Carnarvon basalt	174	-24.803435	147.859126	0.6	Tertiary Volcanics		No	2
		175	-24.789435	147.846127	2.4	Tertiary Volcanics		No	2
		304	-24.853434	147.863127	16.8	Tertiary Volcanics		No	2
		311	-24.868434	147.939126	1.1	Tertiary Volcanics		No	2
		312	-24.824434	147.911126	0.2	Tertiary Volcanics		No	2
		313	-24.815434	147.889126	1.1	Tertiary Volcanics		No	2
		314	-24.889433	148.026125	1.1	Tertiary Volcanics		No	2
591	Yebna2	534	-25.73264193	149.1027786	0.0	Evergreen Formation, Precipice Sandstone	14	Yes	3
592	Abyss	286	-25.79817442	148.7691414	0.8	Hutton Sandstone	12	Yes	1b
		286.1	-25.79815318	148.7702873	0.2	Hutton Sandstone	12	No	1b
		286.2	-25.79795094	148.7701929	0.3	Hutton Sandstone	12	No	1b
		286.3	-25.79762097	148.7687133	0.0	Hutton Sandstone	12	No	1b
		682	-25.80809736	148.7341988	2.7	Hutton Sandstone	12	No	3
		716	-25.80768618	148.7339995	0.1	Hutton Sandstone	12	No	3
593	Cockatoo3	685	-25.72314015	150.2665099	45.0	Precipice Sandstone	14	No	3
594	Elgin2	540	-24.53411959	149.1695497	19.6	Clematis Sandstone, Tertiary Basalt	16	Yes	3
595	MoffatBasalt	nv604	-25.0794978	148.1230371		Tertiary Volcanics		No	
		nv606	-25.0812701	148.1262955		Tertiary Volcanics		No	
		nv608	-25.096214	148.1626368		Tertiary Volcanics		No	
596	Bunya1	SP2	-26.877082	151.595896		Main Range Volcanics	1	No	
597	Oaky1	SP5	-27.218628	151.760925		Main Range Volcanics	1	No	
598	Marburg1	SP44	-27.426521	151.907104		Main Range Volcanics	1	No	
599	MainRangeVolc1	SP45	-27.439267	151.956073		Main Range Volcanics	1	No	
600	MainRangeVolc2	SP1	-27.602449	151.939516		Main Range Volcanics	1	No	
		SP15	-27.570052	151.847562		Main Range Volcanics	1	No	
		SP42	-27.60362	151.911021		Main Range Volcanics	1	No	
		SP43	-27.58148	151.889894		Main Range Volcanics	1	No	
601	MainRangeVolc3	SP3	-27.394642	151.573569		Main Range Volcanics	1	No	
602	MainRangeVolc4	SP6	-27.621252	151.620827		Main Range Volcanics	1	No	
		SP7	-27.685393	151.623519		Main Range Volcanics	1	No	
		SP8	-27.66508	151.574915		Main Range Volcanics	1	No	
603	MainRangeVolc5	SP9	-27.710738	151.725352		Main Range Volcanics	1	No	
604	MainRangeVolc6	SP10	-27.899825	151.945607		Main Range Volcanics	1	No	
		SP11	-28.025302	151.979354		Main Range Volcanics	1	No	
		SP37	-27.95212	151.992832		Main Range Volcanics	1	No	
		SP38	-27.95962	151.999758		Main Range Volcanics	1	No	
605	Kangaroo Creek	nv717	-26.17175	149.3718	5.0	Springbok Sandstone, Cainozoic Sediments	1,8	No	
		nv718	-26.16348	149.36325	5.0	Springbok Sandstone, Cainozoic Sediments	1,8	No	
		nv719	-26.18709	149.37807	5.0	Springbok Sandstone, Cainozoic Sediments	1,8	No	

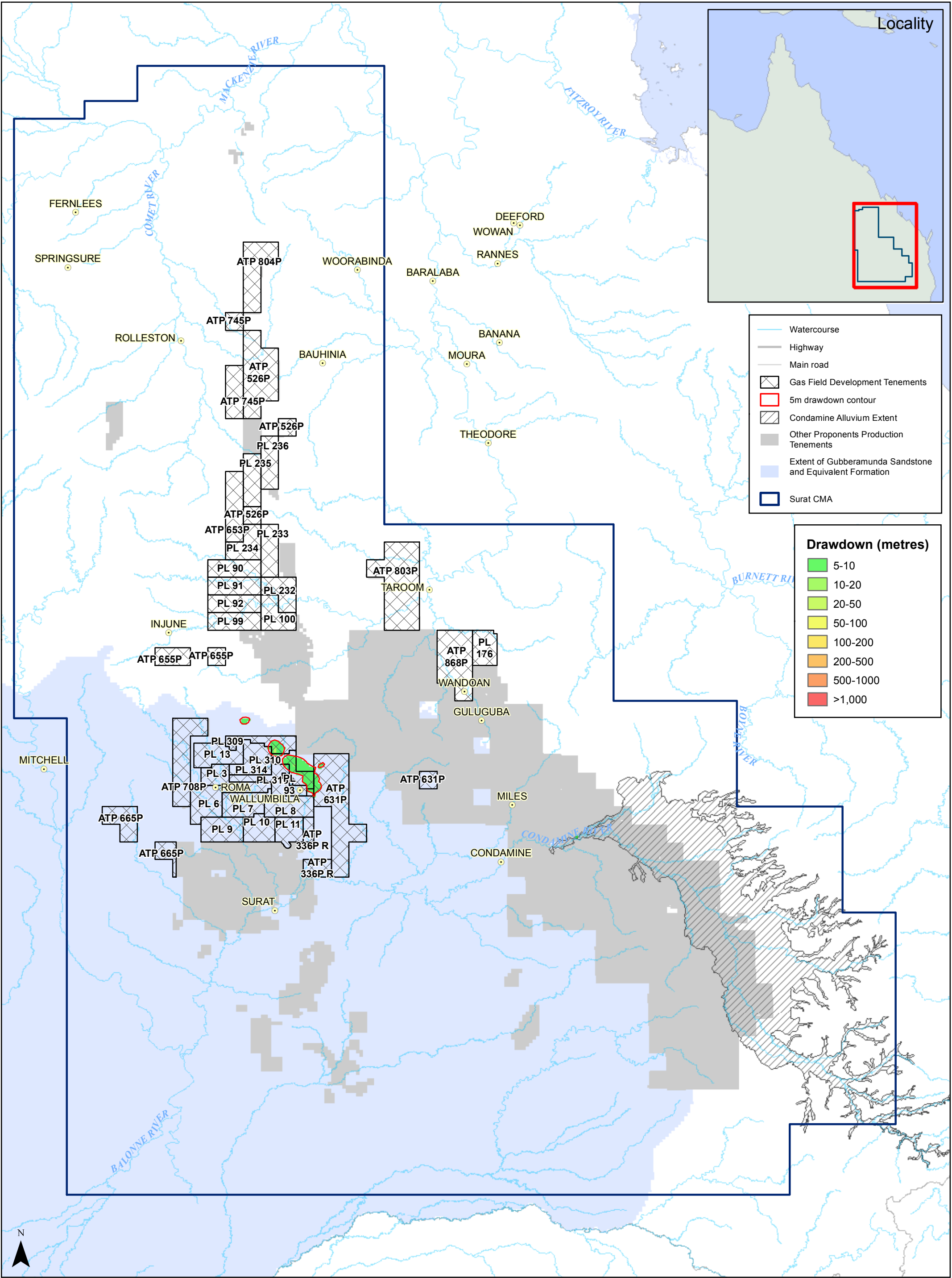
Table C.2 Details of watercourse springs within the Surat CMA

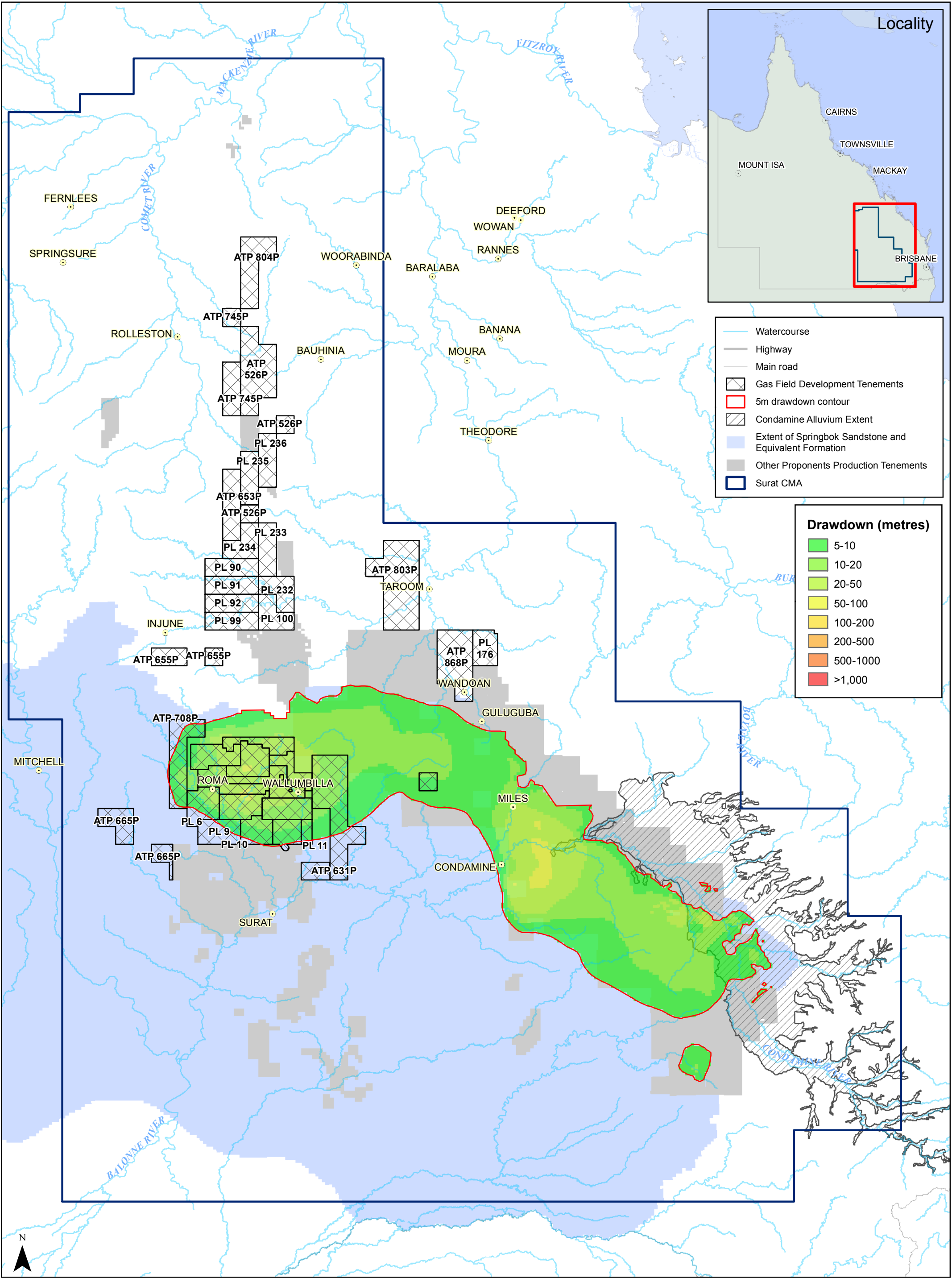
Site number	Watercourse reach start latitude	Watercourse reach start longitude	Watercourse reach finish latitude	Watercourse reach finish longitude	Source aquifer(s)	River
W6	-28.47082	150.54052	-28.45634162	150.5582964	Kumbarilla Beds	Bethecurriba Creek
W7	-28.45634162	150.5582964	-28.44577	150.58419	Kumbarilla Beds	Bethecurriba Creek
W10	-26.42471219	149.0838375	-26.47332954	149.0169652	Mooga Sandstone, Gubberamunda Sandstone	Blyth Creek
W14	-25.83663454	150.0612381	-25.92242	150.23495	Hutton Sandstone	Bungaban Creek
W15	-25.92242	150.23495	-25.90361441	150.2610792	Hutton Sandstone	Bungaban Creek (North)
W16	-26.21044718	148.4428536	-26.22838028	148.4744799	Gubberamunda Sandstone	Bungeworgorai Creek
W17	-26.39537781	148.6509133	-26.41800266	148.6438287	Mooga Sandstone	Bungeworgorai Creek
W18	-26.25520873	148.7095084	-26.30972286	148.7359845	Gubberamunda Sandstone	Bungil Creek
W19	-26.42196662	148.7874036	-26.45004641	148.8050478	Mooga Sandstone	Bungil Creek
W22	-25.0088	148.13407	-25.05176703	148.215057	Precipice Sandstone	Carnarvon Creek
W26	-25.00309	148.9985231	-24.92232915	148.8553936	Clematis Sandstone	Clematis Creek
W28	-25.72104166	150.2644189	-25.71078489	150.3286089	Precipice Sandstone	Cockatoo Creek
W29	-25.71824	150.22261	-25.72104166	150.2644189	Precipice Sandstone	Cockatoo Creek
W35	-24.625503	149.1288969	-24.64565	149.07425	Clematis Sandstone	Conciliation Creek
W39	-25.72558012	149.3030749	-25.6767222	149.2350559	Hutton Sandstone	Dawson River
W40	-25.67946031	149.1373406	-25.68479278	149.0664513	Precipice Sandstone	Dawson River (Cen)
W41	-25.4138029	150.1645459	-25.46614043	150.1095446	Precipice Sandstone	Dawson River (NE)
W42	-25.38224	148.6562884	-25.30424616	148.5904825	Precipice Sandstone	Dawson River (NW)
W50	-24.86795264	147.8492006	-24.83173699	147.8927038	Precipice Sandstone	Dooloogarah Creek Trib
W51	-24.84580301	147.8821576	-24.83916998	147.8900257	Precipice Sandstone	Dooloogarah Creek Trib
W59	-25.97985502	149.1941075	-25.98241233	149.1452382	Hutton Sandstone	Eurombah Creek
W76	-26.2017	149.5936	-26.22019489	149.6195567	Gubberamunda Sandstone	Horse Creek (East Branch)
W77	-26.26426187	149.6521547	-26.3062	149.66797	Mooga Sandstone, Gubberamunda Sandstone	Horse Creek (East Branch)
W78	-26.30970428	149.6747807	-26.34436603	149.6578244	Mooga Sandstone, Gubberamunda Sandstone	Horse Creek (East Branch) Tributary
W79	-26.3062	149.66797	-26.30970428	149.6747807	Mooga Sandstone, Gubberamunda Sandstone	Horse Creek (East Branch) Tributary
W80	-25.74343804	148.6856819	-25.69769506	148.4272692	Hutton Sandstone	Hutton Creek
W81	-25.71268	149.08368	-25.715116	149.0282812	Hutton Sandstone	Hutton Creek
W82	-25.80381235	148.7798978	-25.81189	148.7326914	Hutton Sandstone	Injune Creek
W99	-28.4393	150.99137	-28.63505	150.75147	Kumbarilla Beds	MacIntyre Brook
W100	-28.42319578	151.1355142	-28.41378684	151.0548292	Kumbarilla Beds	Macintyre Brook
W105	-26.12940273	147.9079293	-26.15722822	147.8954374	Gubberamunda Sandstone	Maranoa River
W106	-26.15722822	147.8954374	-26.29335852	147.92415	Mooga Sandstone, Gubberamunda Sandstone	Maranoa River
W108	-25.16160236	147.8375695	-25.28869	147.76752	Hutton Sandstone	Maranoa River (West)
W110	-25.34835116	148.0864674	-25.19238089	148.0939448	Hutton Sandstone	Merivale River
W111	-25.78833517	147.9608571	-25.34835116	148.0864674	Hutton Sandstone	Merivale River
W112	-25.85041372	147.8465135	-25.78439922	147.9272557	Hutton Sandstone	Murri Murri Creek
W122	-28.44224288	150.4040798	-28.47082	150.54052	Kumbarilla Beds	Merivale River (South Section)
W113	-23.80363	149.09999	-23.92110142	149.2383053	Clematis Sandstone	Mimosa Creek
W114	-23.79367139	149.0680085	-23.80363	149.09999	Clematis Sandstone	Mimosa Creek Tributary
W141	-25.45351869	149.4792696	-25.4336982	149.3693947	Hutton Sandstone	Robinson Creek
W146	-25.59519	148.15584	-25.54720833	148.1834157	Hutton Sandstone	Sandy Creek
W160	-27.75252	150.68218	-27.7935699	150.6963639	Kumbarilla Beds	Western Creek
W164	-26.36411053	149.4378862	-26.47228	149.40031	Mooga Sandstone	Yuleba Creek

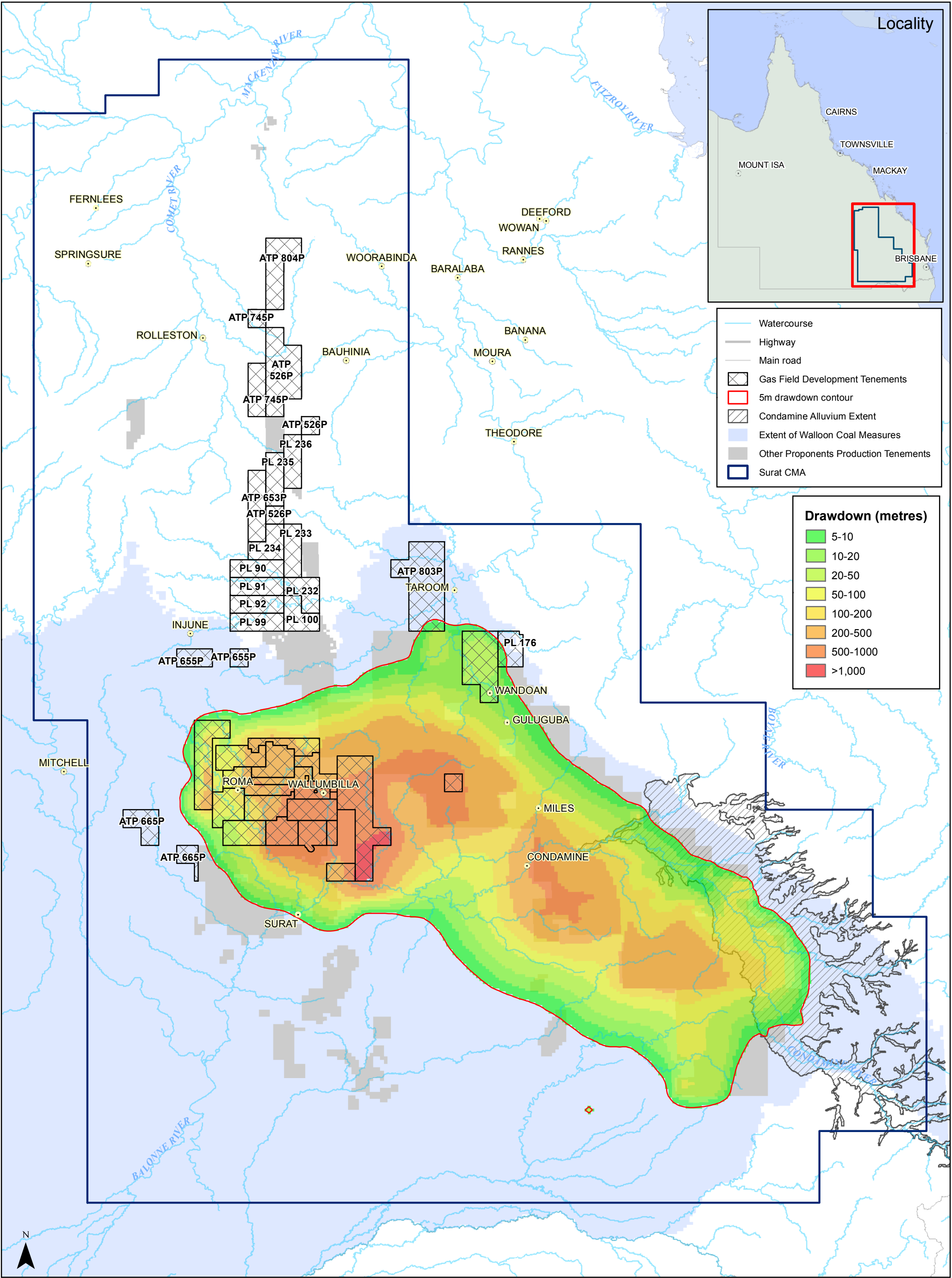
Appendix D

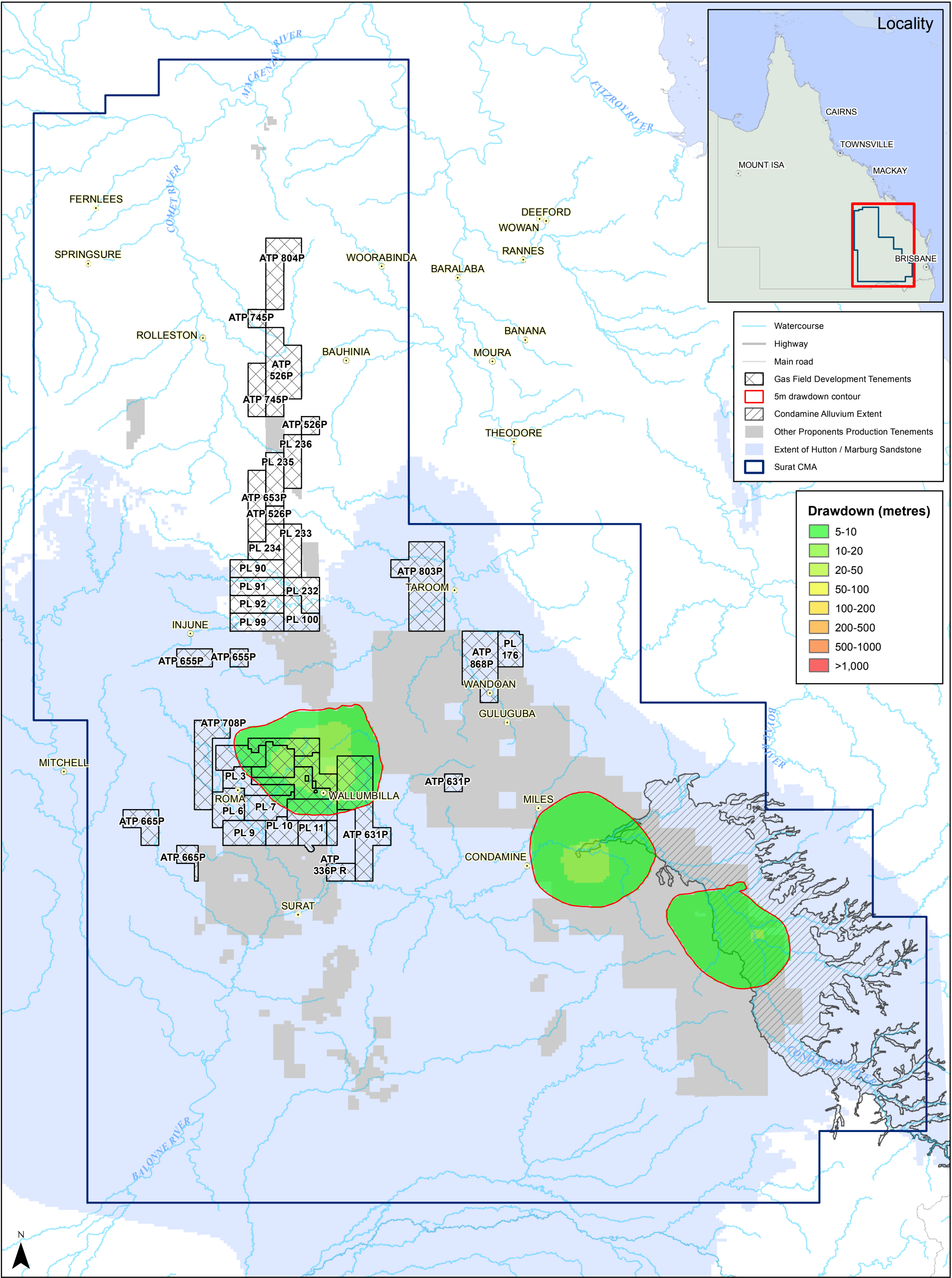
Potential impact maps

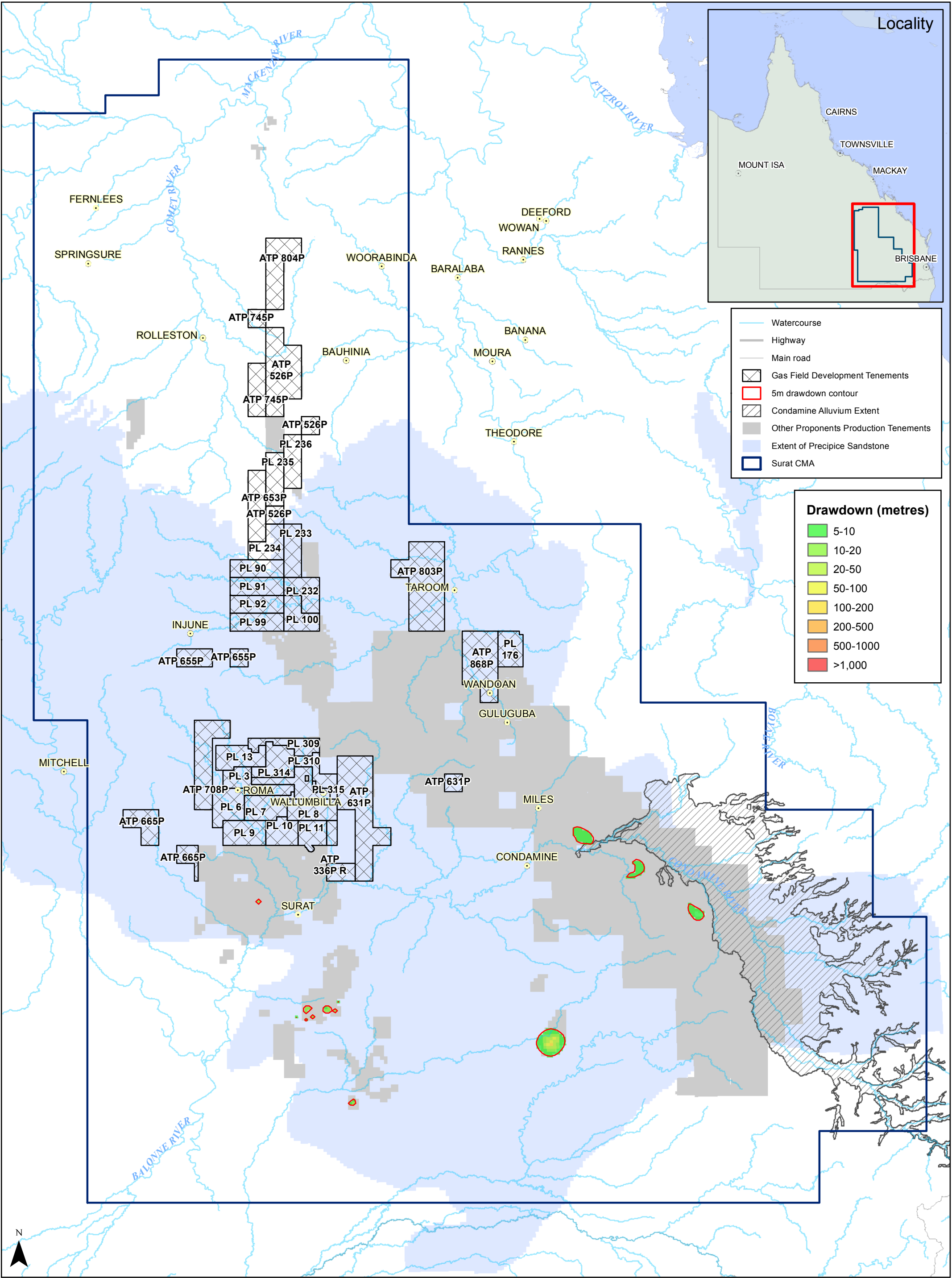


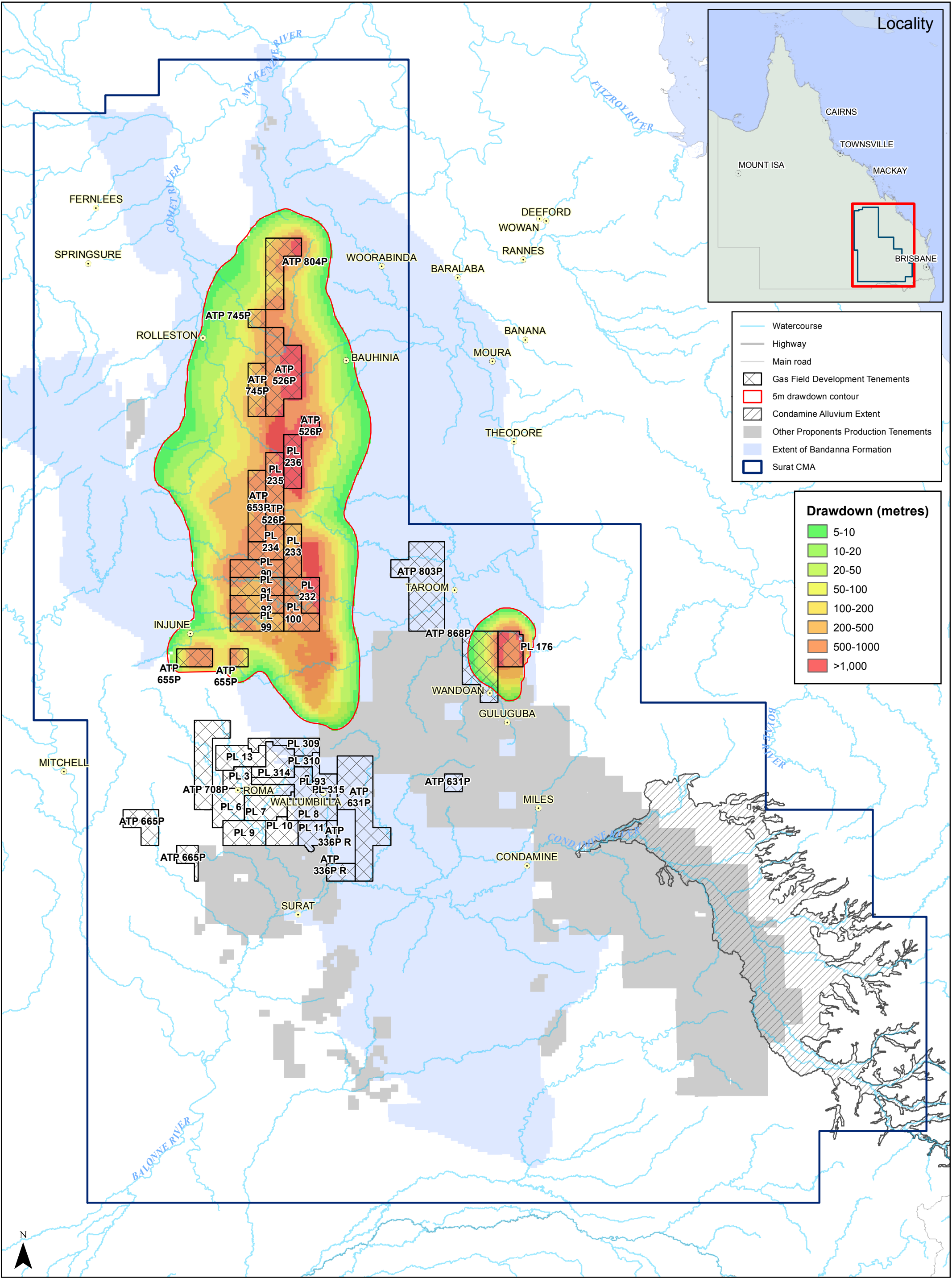










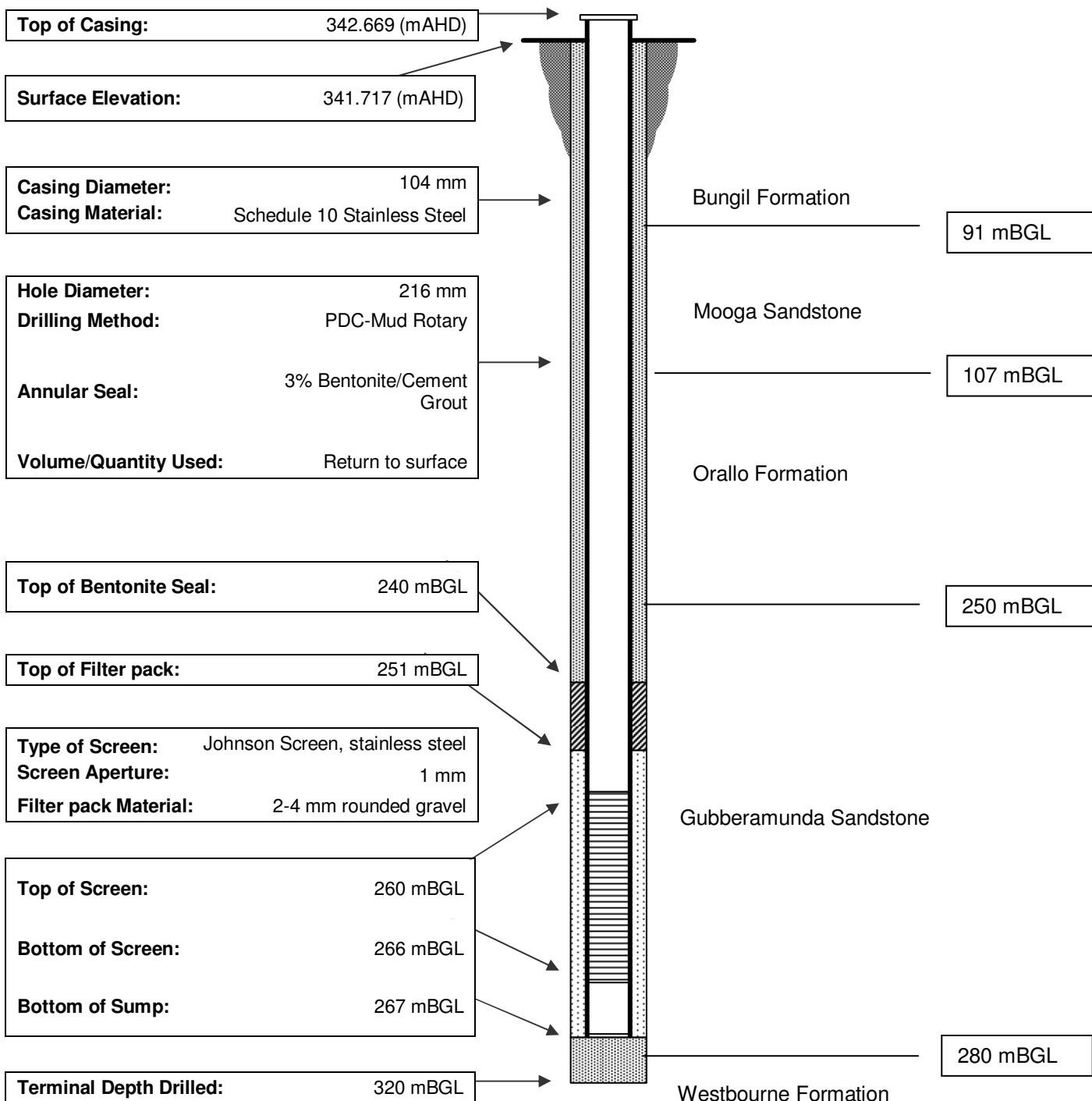


Appendix E

Monitoring bore logs



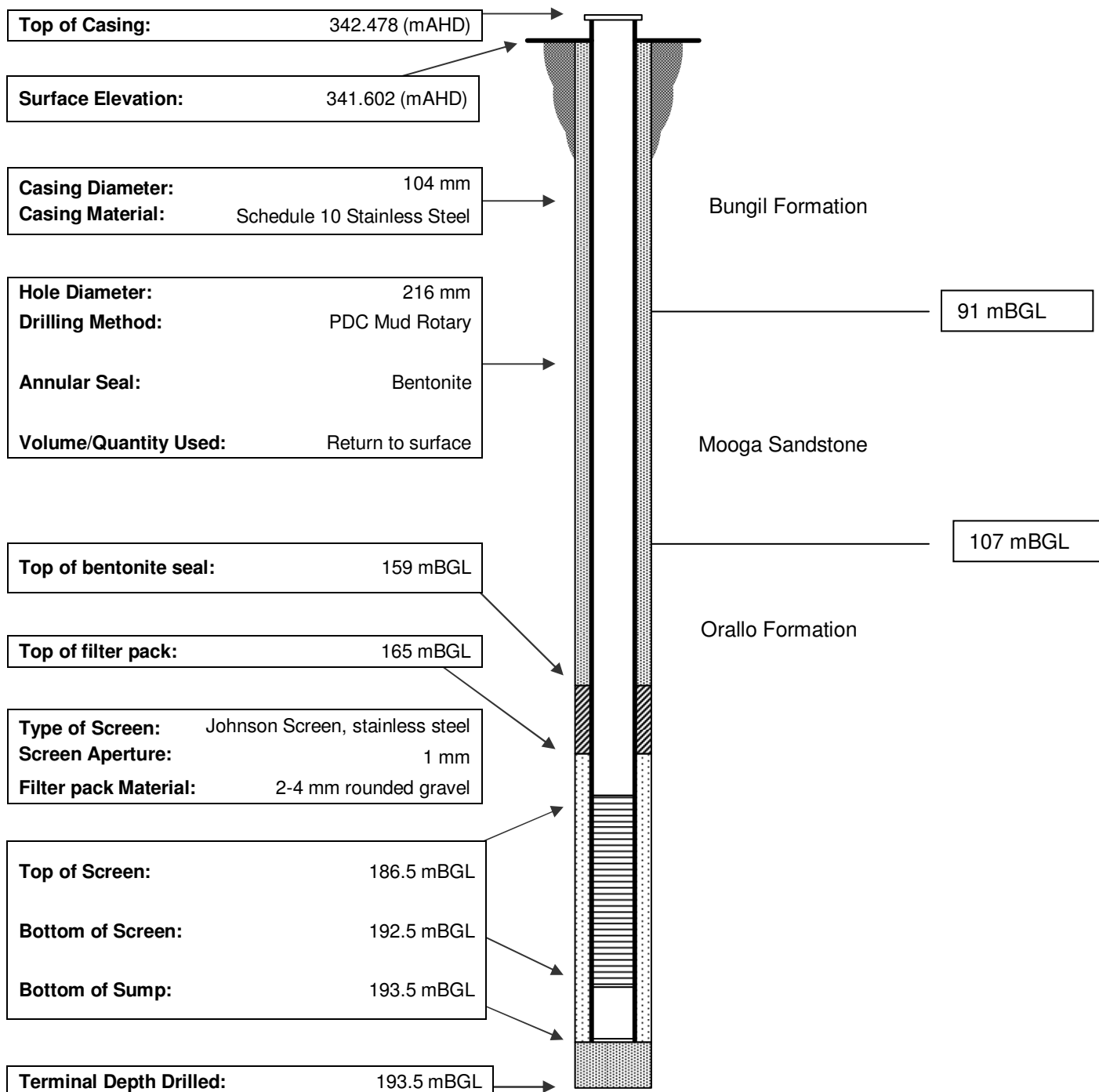
Project Name	Roma Deep Monitoring Bore Programme		Document ID	7699-URS-4-3.3-0010
Location	Ben Bow		Santos Bore ID	ROM_BBWGWG03_BORE_W
Coordinates	-26.430241	149.338663	URS Project	42626577
URS Supervisor	Matthew Ryan, Finnigan Johnson		Date Installed	03/02/11
Driller's Name	Peter Adams		Drilling Method	Mud Rotary
Drilling Company	Adams Drilling			



Groundwater parameters after bore development:

SWL: 47.65, EC: 1376µS/cm, pH: 9.10, TDS: 894 mg/L, Temperature: 27.8 °C, Redox: -53.8 mV

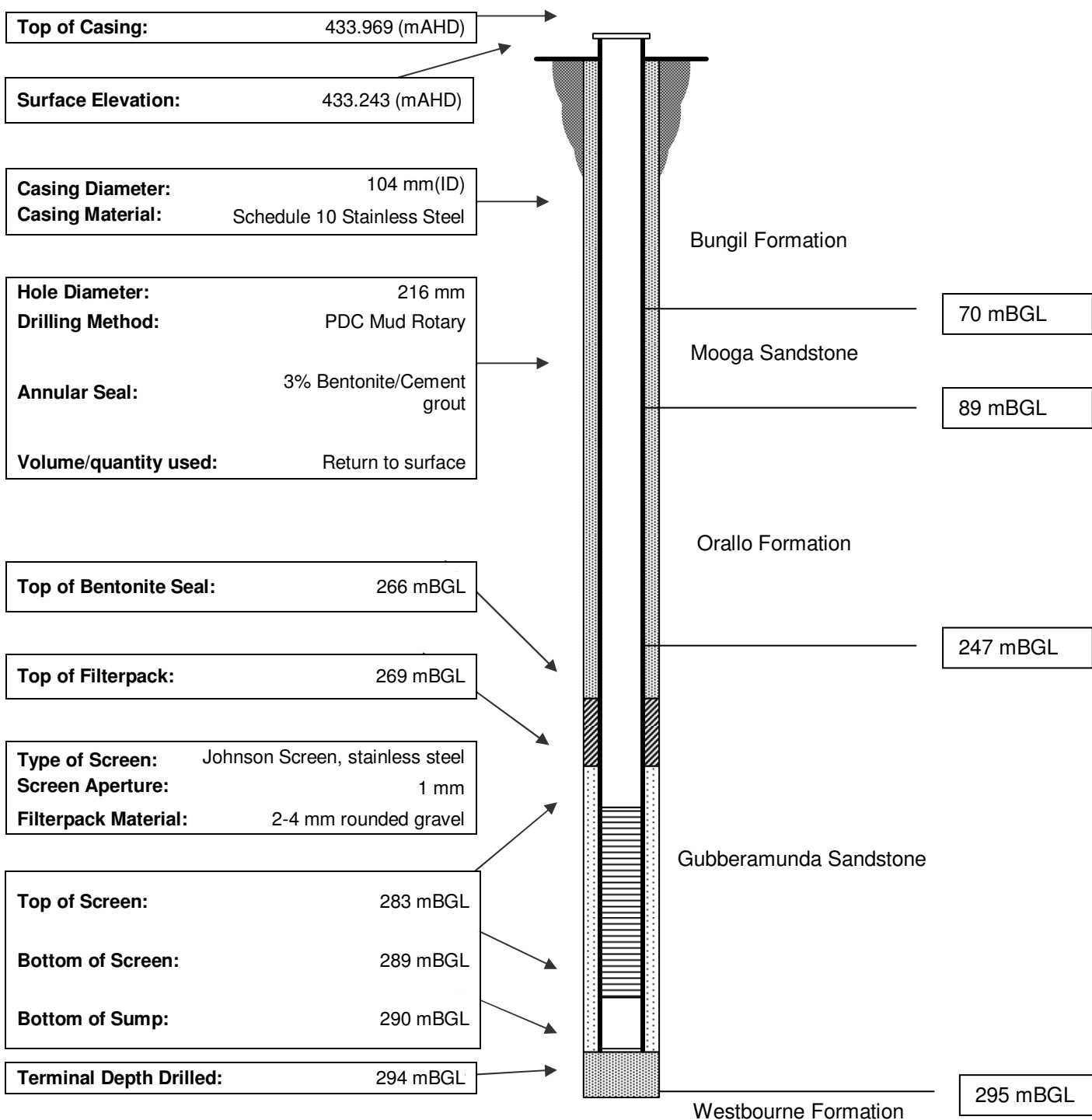
Project Name	Roma Deep Monitoring Bore Programme		Document ID	7699-URS-4-3.3-0012
Location	Ben Bow		Santos Bore ID	ROM_BBWGWO01_BORE_W
Coordinates	-26.430227	149.338830	URS Project	42626577
URS Supervisor	Matthew Ryan		Date Installed	4/02/2011
Driller's Name	Peter Adams		Drilling Method	Mud Rotary
Drilling Company	Adams Drilling			



Groundwater parameters after bore development:

SWL: 25.28mBGL, EC: 2087µS/cm, pH: 9.01, TDS: 1360 mg/L, Temperature: 26.50 degC, Redox: 6.9 mV

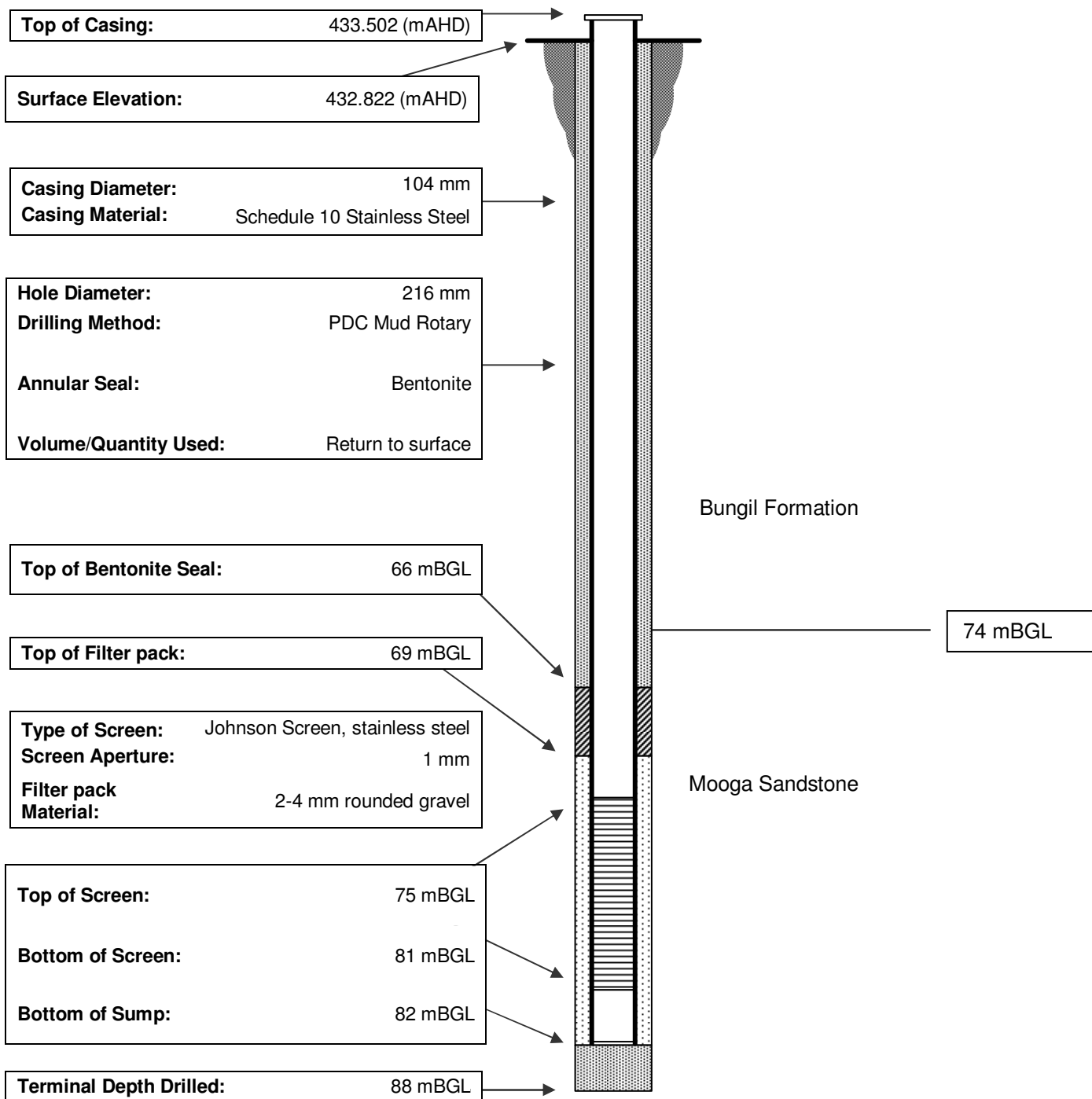
Project Name	Roma Deep Monitoring Bore Programme		Document ID	7699-URS-4-3.3-0002
Location	Bel Bri		Santos Bore ID	ROM_BLBGWG01_BORE_W
Coordinates	-26.378797	148.936575	URS Project	42626577
URS Supervisor	Sian Smith, Tom Mackie		Date Installed	4/04/2011
Driller's Name	Peter Adams		Drilling Method	Mud Rotary
Drilling Company	Adams Drilling			



Groundwater parameters after bore development:

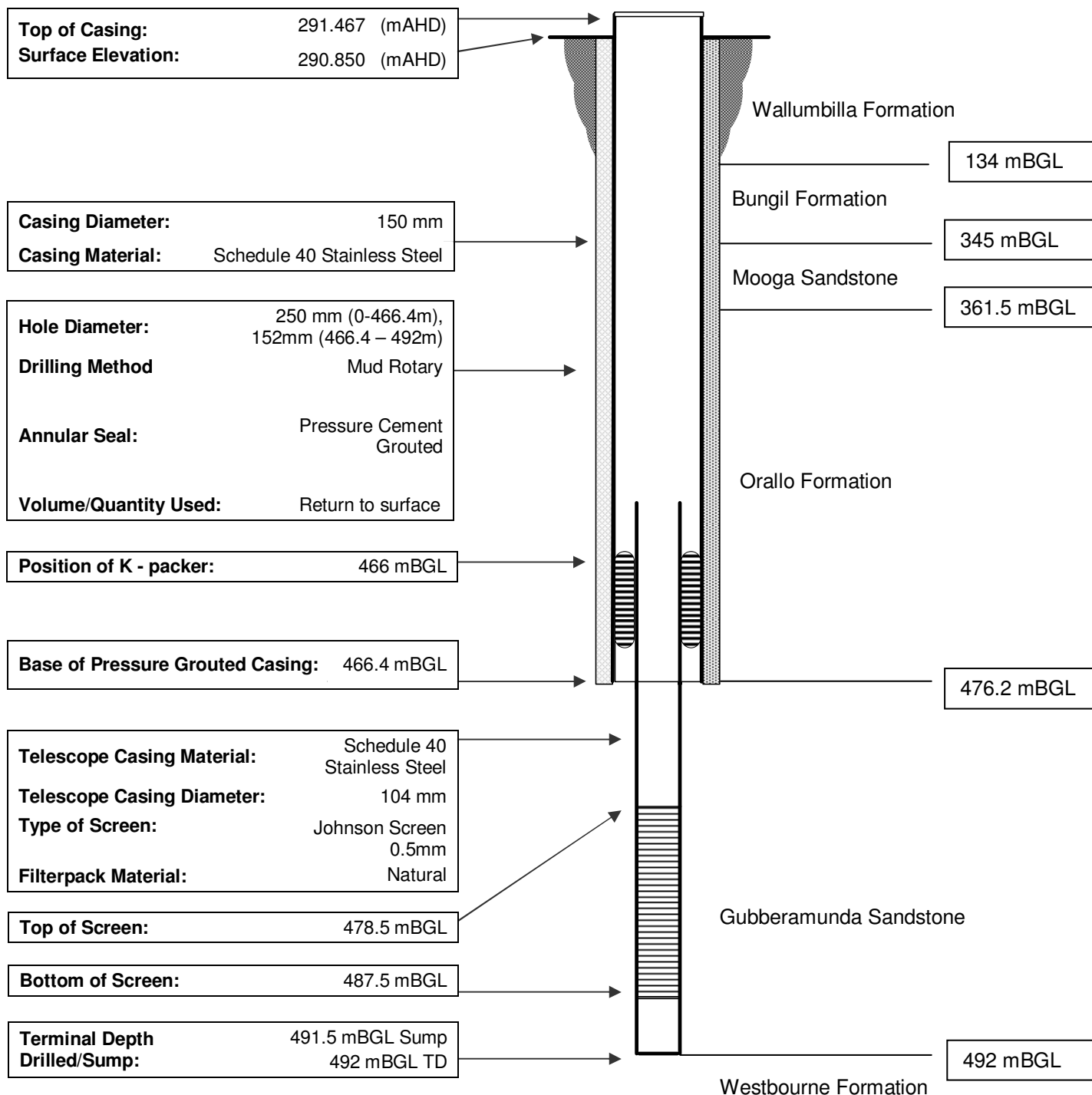
SWL: 119.3 mBGL, EC: 1267uS/cm, pH: 8.26, Temperature: 29.6 °C, Redox: -48.8 mV

Project Name	Roma Deep Monitoring Bore Programme		Document ID	7699-URS-4-3.3-0004
Location	Bel Bri		Santos Bore ID	ROM_BLBGWM01_BORE_W
Coordinates	-26.378927	148.936361	URS Project	42626577
URS Supervisor	Sian Smith, Tom Mackie		Date Installed	29/03/2011
Driller's Name	Marc Adams		Drilling Method	Mud Rotary
Drilling Company	Adams Drilling			



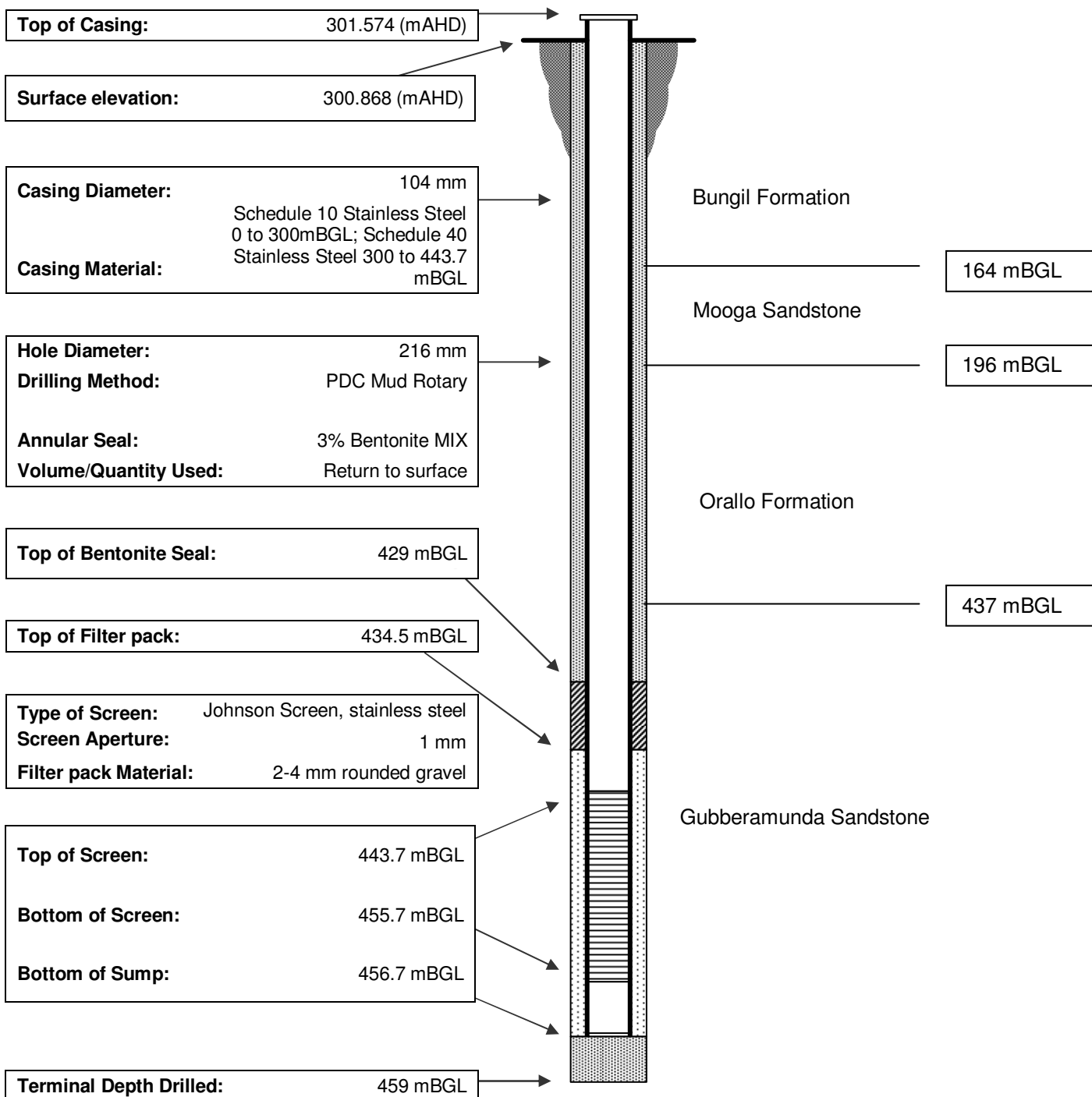
Groundwater parameters after bore development:
 SWL: Dry

Project Name	Roma Deep Monitoring Bore Programme		Document ID	7699-URS-4-3.3-0030
Location	Duarran		Santos Bore ID	ROM_DRNGWG08_BORE_W
Coordinates	-26.681192	148.736275	URS Project	42626577
URS Supervisor	Tom Mackie		Date Installed	11/12/11
Driller's Name	Marc Adams		Drilling Method	Mud Rotary
Drilling Company	Adams Drilling			



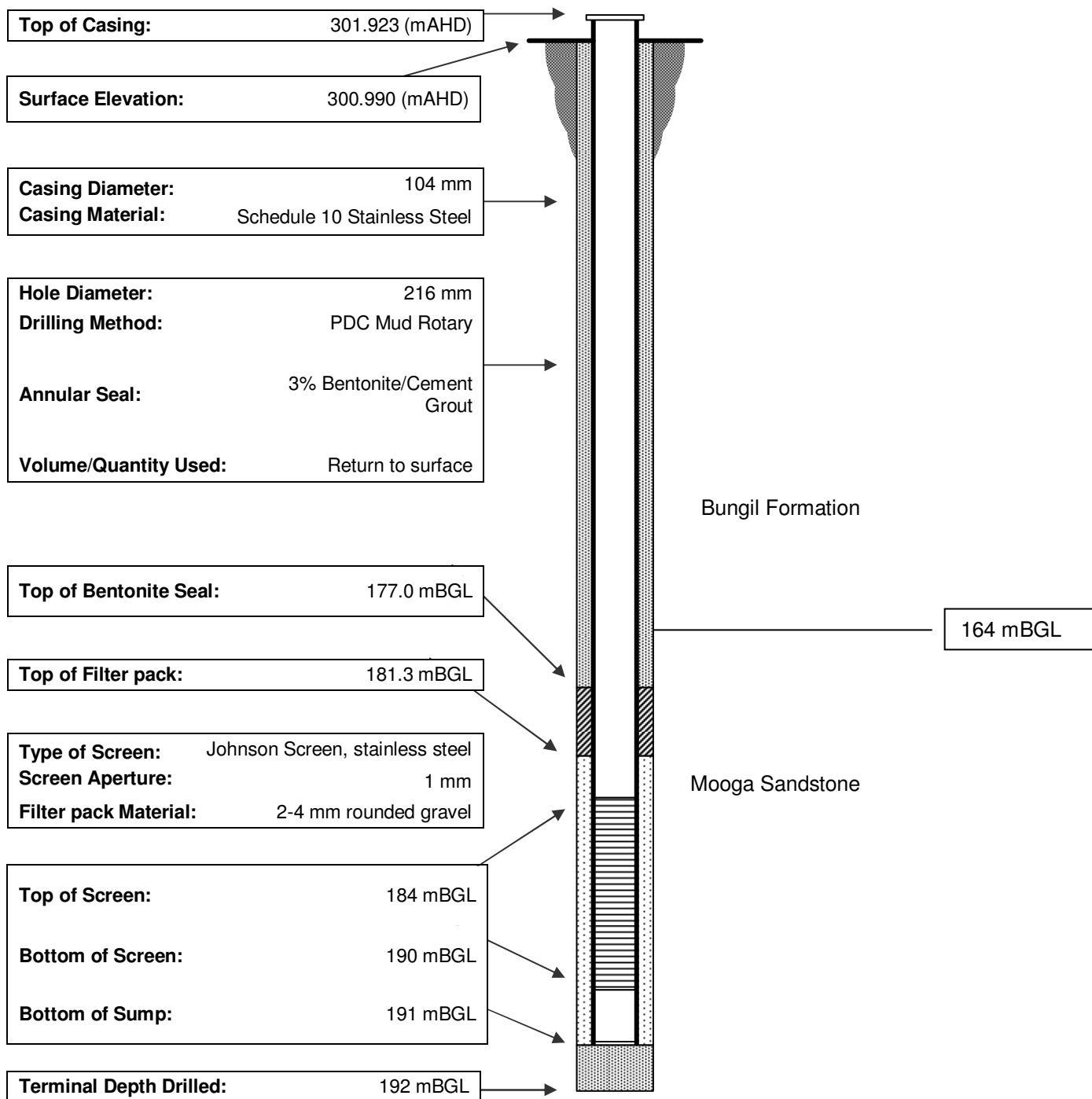
Groundwater parameters after bore development: SWL: 37 mBGL, EC: 988 μ S/cm, pH: 9.01, 36.1 $^{\circ}$ C, Redox: 0.1 mV

Project Name	Roma Deep Monitoring Bore Programme		Document ID	7699-URS-4-3.3-0016
Location	Boxgrove		Santos Bore ID	ROM_BXGGWG04_BORE_W
Coordinates	-26.603497	149.373586	URS Project	42626577
URS Supervisor	Kitty van Cuylenburg		Date Installed	1/03/2011
Driller's Name	Marc Adams		Drilling Method	Mud Rotary
Drilling Company	Adams Drilling			



Groundwater parameters after bore development:
 SWL: 28.30mBGL, EC: 1107µS/cm, pH: 8.62, Temperature: 33.92 °C, Redox: -2.8 mV

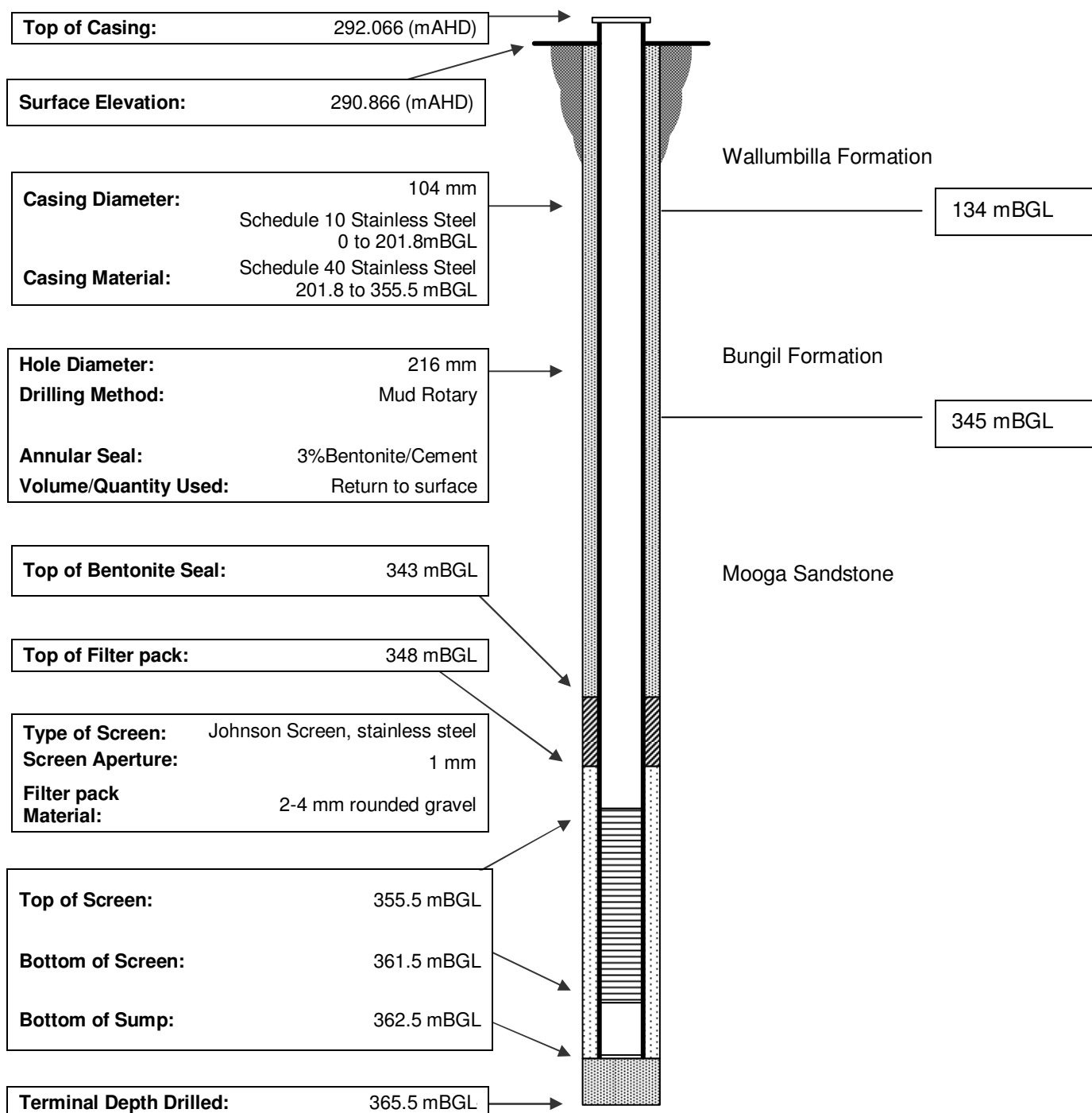
Project Name	Roma Deep Monitoring Bore Programme		Document ID	7699-URS-4-3.3-0018
Location	Boxgrove		Santos Bore ID	ROM_BXGGWM02_BORE_W
Coordinates	-26.603333	149.373497	URS Project	42626577
URS Supervisor	Kitty van Cuylenburg		Date Installed	5/3/2011
Driller's Name	Marc Adams		Drilling Method	Mud Rotary
Drilling Company	Adams Drilling			



Groundwater parameters after bore development:

SWL: Artesian, EC: 1674µS/cm, pH: 8.67, Temperature: 24.23 °C, Redox: 95.1 mV

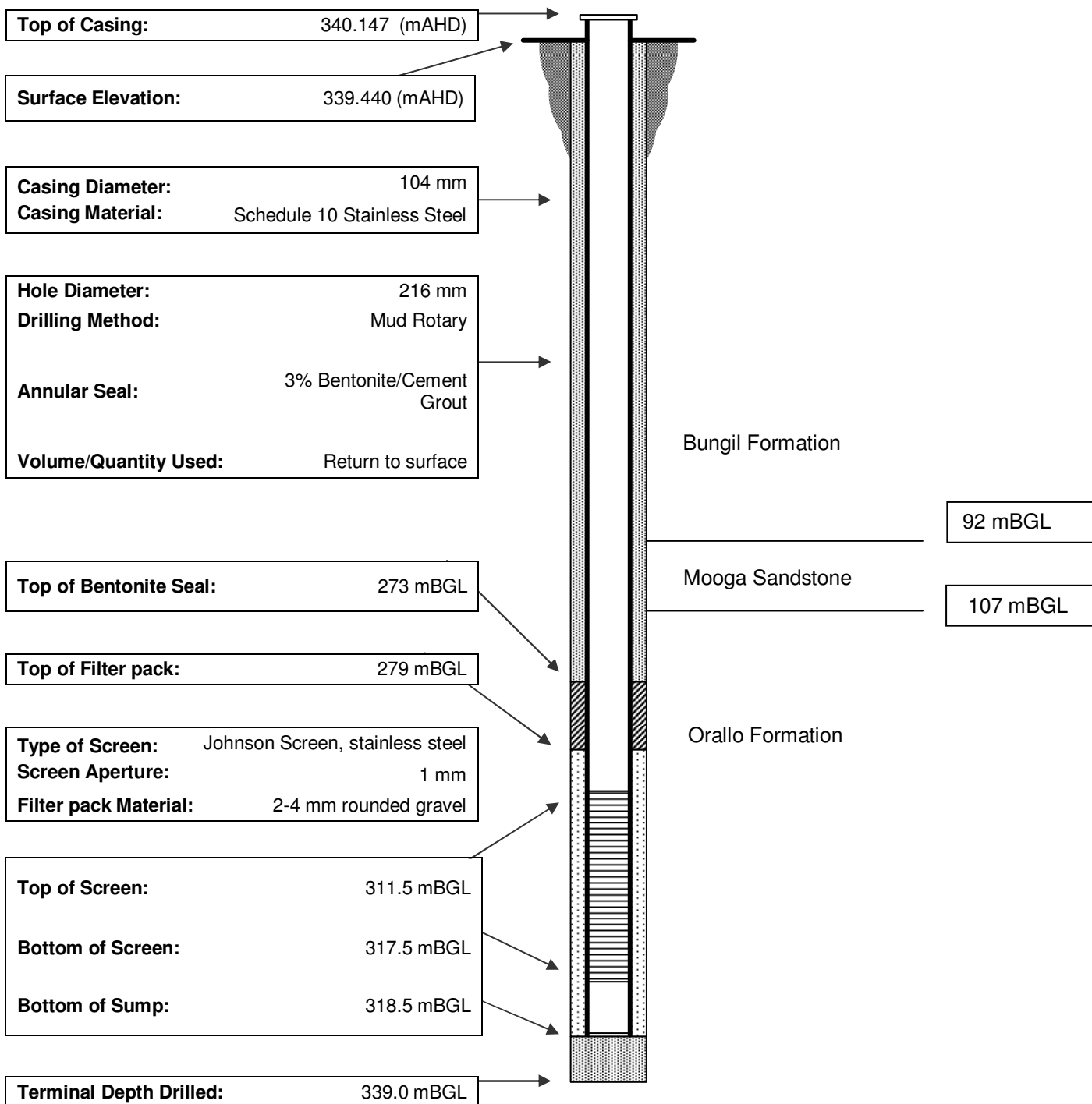
Project Name	Roma Deep Monitoring Bore Programme		Document ID	7699-URS-4-3.3-0032
Location	Duarran		Santos Bore ID	ROM_DRNGWM04_BORE_W
Coordinates	-26.681403	148.736315	URS Project	42626577
URS Supervisor	Tom Mackie		Date Installed	21/01/2012
Driller's Name	Marc Adams		Drilling Method	Mud Rotary
Drilling Company	Adams Drilling			



Groundwater parameters after bore development:

SWL: 13.72 mBGL, EC: 1481 μ S/cm, pH: 8.67, Temperature: 32.4 $^{\circ}$ C, Redox: -134 mV

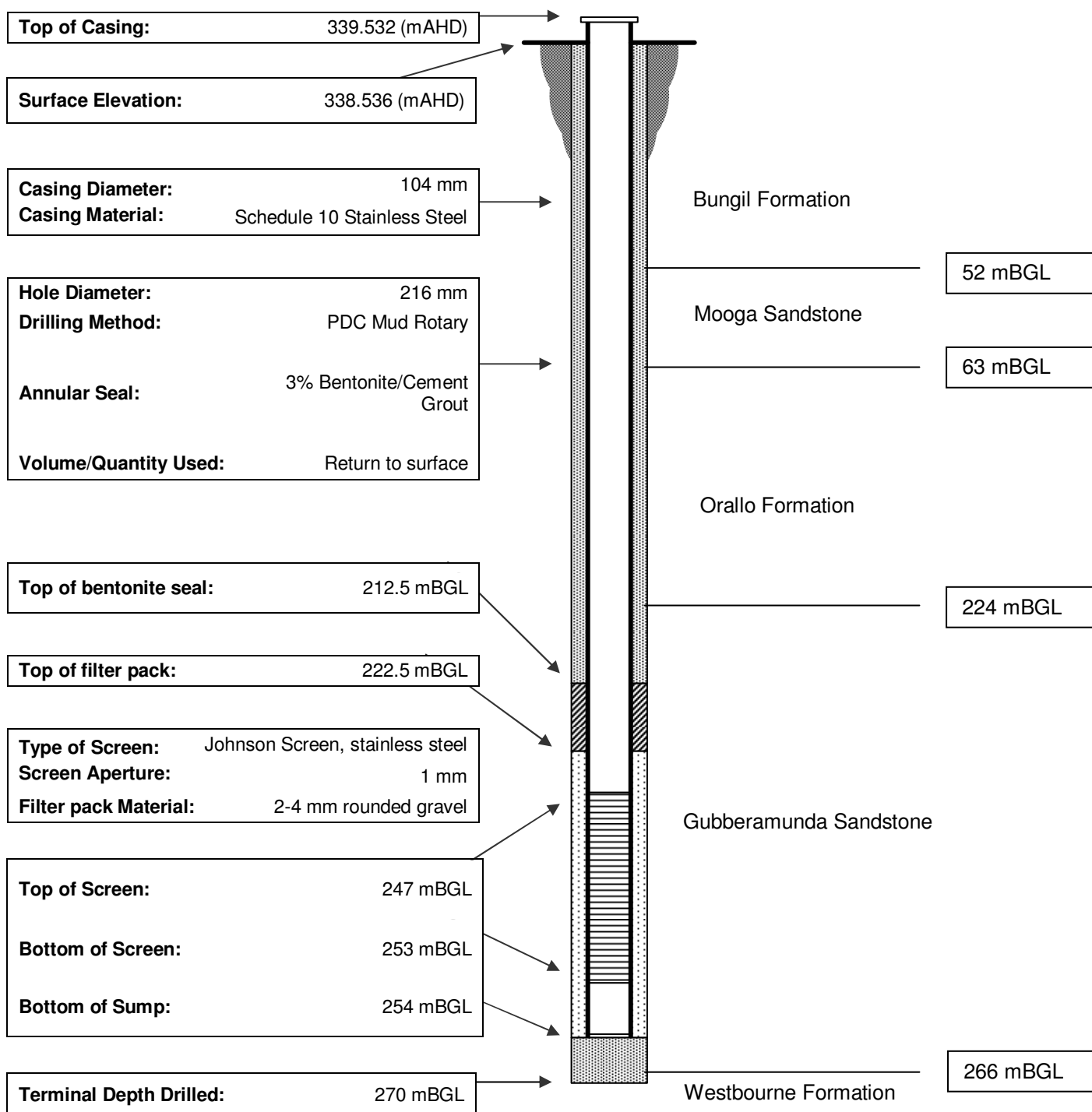
Project Name	Roma Deep Monitoring Bore Programme		Document ID	7699-URS-4-3.3-0036
Location	Pasadena		Santos Bore ID	ROM_PASGWO03_BORE_W
Coordinates	-26.577938	149.066142	URS Project	42626577
URS Supervisor	Hayden Seear		Date Installed	16/02/2011
Driller's Name	Peter Adams		Drilling Method	Mud Rotary
Drilling Company	Adams Drilling			



Groundwater parameters after bore development:

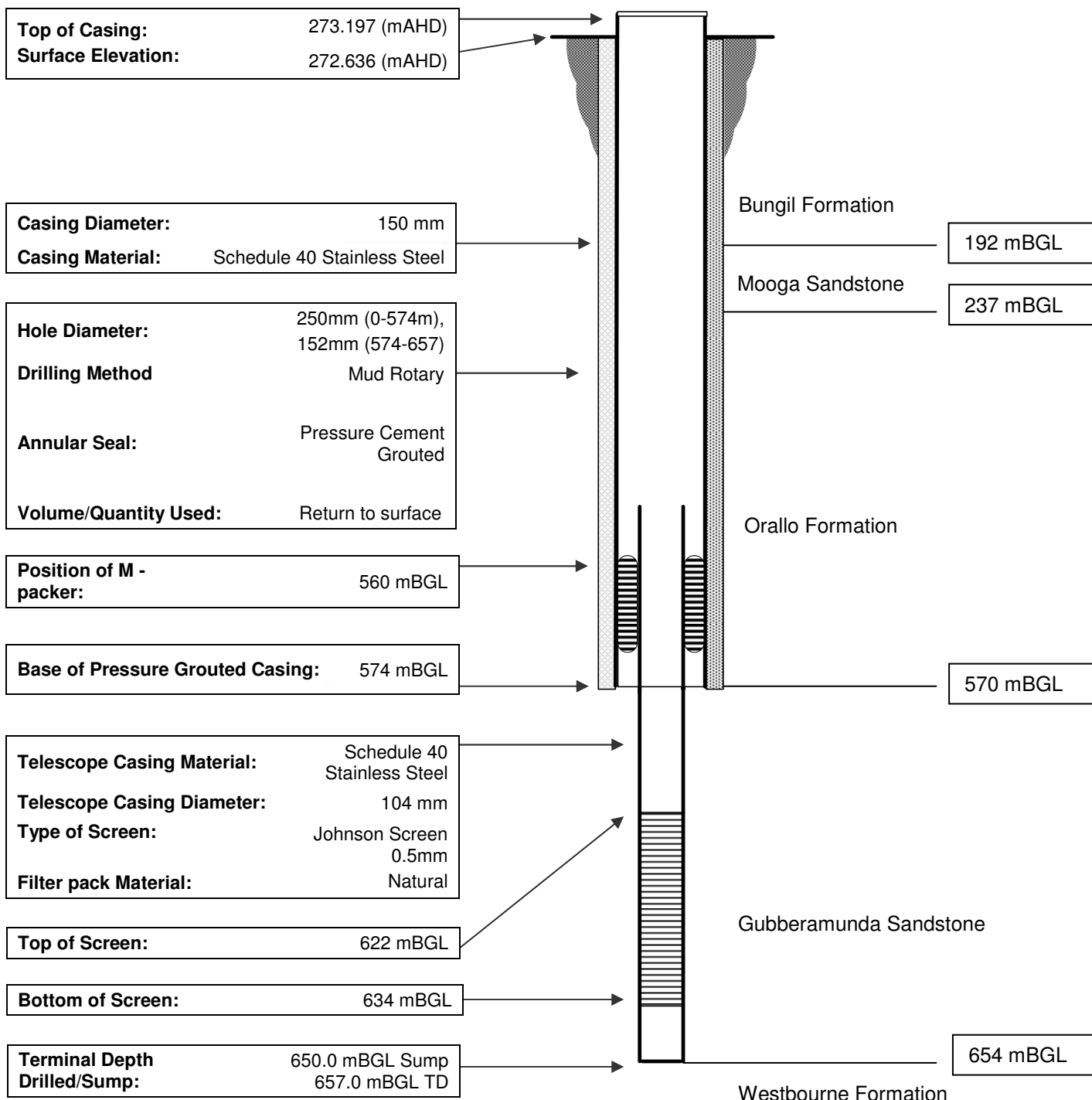
SWL: 44.20mBGL, EC: 1295µS/cm, pH: 8.77, Temperature: 30.7 °C, Redox: 73.5 mV

Project Name	Roma Deep Monitoring Bore Programme		Document ID	7699-URS-4-3.3-0006
Location	The Bend		Santos Bore ID	ROM_TBDGWG02_BORE_W
Coordinates	-26.465027	149.014594	URS Project	42626577
URS Supervisor	Tom Mackie, Hayden Seear		Date Installed	5/05/2011
Driller's Name	Marc and Peter Adams		Drilling Method	Mud Rotary
Drilling Company	Adams Drilling			



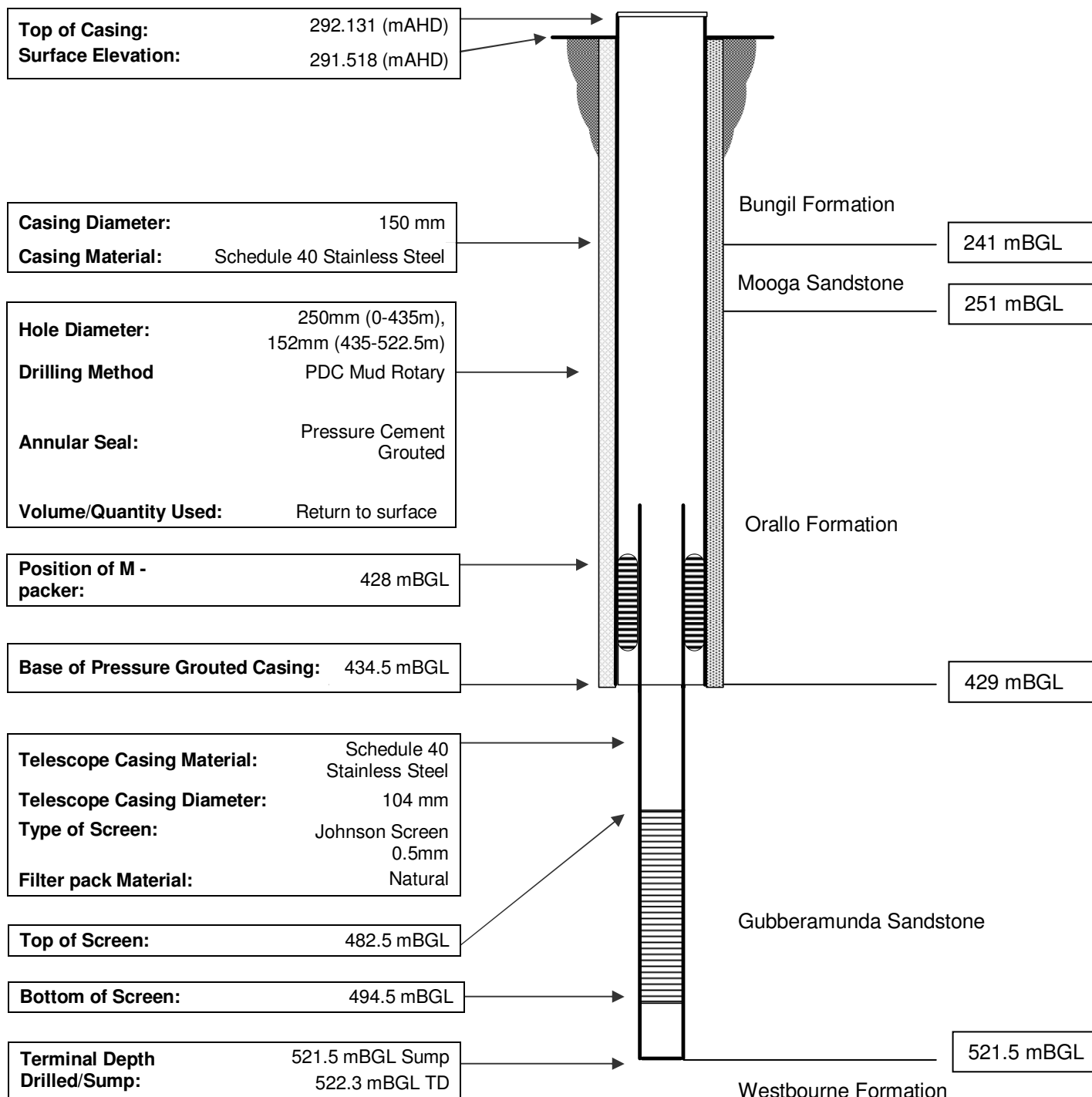
Groundwater parameters after bore development:
 SWL: 40.82 mBGL, EC: 640 μ S/cm, pH: 8.49, Temperature: 27.7 $^{\circ}$ C, Redox: 176 mV

Project Name	Roma Deep Monitoring Bore Programme		Document ID	7699-URS-4-3.3-0024
Location	Wallabella		Santos Bore ID	ROM_WBLGWG06_BORE_W
Coordinates	-26.782535	149.196870	URS Project	42626577
URS Supervisor	Sian Smith		Date Installed	25/10/11
Driller's Name	Marc Adams		Drilling Method	Mud Rotary
Drilling Company	Adams Drilling			



Groundwater parameters after bore development: SWL: ND mBGL, EC: 1085 µS/cm, pH: 9.04, 31.9 °C, Redox:-66.4 mV
--

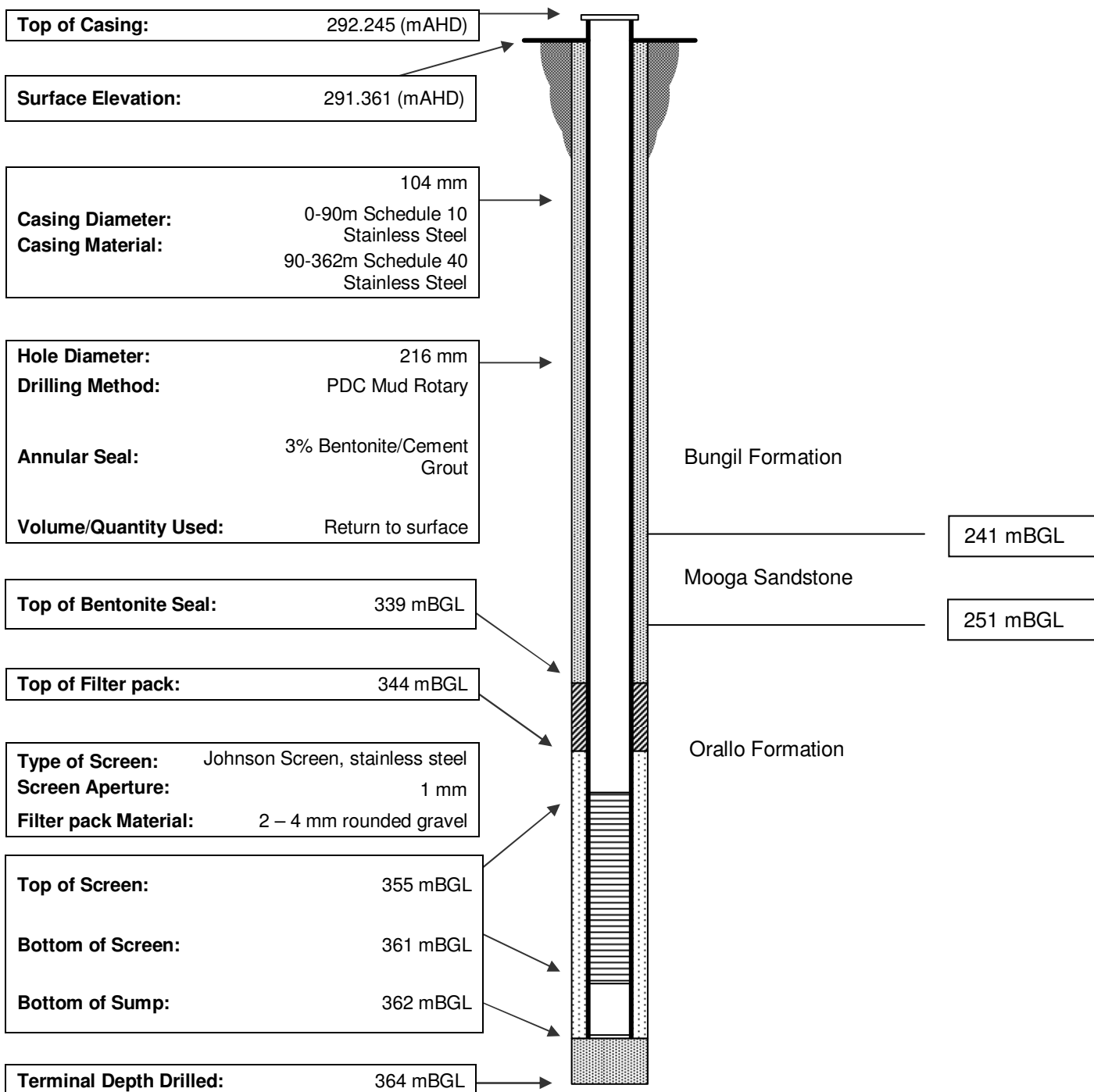
Project Name	Roma Deep Monitoring Bore Programme		Document ID	7699-URS-4-3.3-0020
Location	Wonga Park		Santos Bore ID	ROM_WOPGWG05_BORE_W
Coordinates	-26.639432	149.224799	URS Project	42626577
URS Supervisor	Tom Mackie		Date Installed	11/9/2011
Driller's Name	Marc Adams		Drilling Method	Mud Rotary
Drilling Company	Adams Drilling			



Groundwater parameters after bore development:

SWL: 24.15 mBGL, EC: 1485 μ S/cm, pH: 9.17, 33.7 °C, Redox:-262.6 mV

Project Name	Roma Deep Monitoring Bore Programme		Document ID	7699-URS-4-3.3-0022
Location	Wonga Park		Santos Bore ID	ROM_WOPGWO02_BORE_W
Coordinates	-26.639544	149.224491	URS Project	42626577
URS Supervisor	Matthew Ryan		Date Installed	20/07/2011
Driller's Name	Peter Adams		Drilling Method	Mud Rotary
Drilling Company	Adams Drilling			



Groundwater parameters after bore development:

SWL: ND, EC: 1844 μ S/cm, pH: 8.78, Temperature: 32.1 $^{\circ}$ C, Redox: -72.2mV

URS Australia Pty. Ltd.
Level 17, 240 Queen St, Brisbane QLD 4000

Phone: (07) 3243 2111
Phone: (07) 3243 2199

Project Name: **2010-12 Roma Drilling Programme**

Client: **Santos Ltd**

Document ID:

Drilling Contractor: **Adams Drillers**

Project No.: **42626577**

Location: **Roma, QLD**

N/A

Logged By: **SC, TM**

Bore Size: **350 mm**

Casing RL: **279.466 mAHD**

Drill Type: **Mud Rotary**

Checked By: **MR**

Total Depth: **605.2 m**

Coordinates: **Lat: -26.744016**

Drill Model: **Atlas Copco T3W**

Date Started: **26-7-12**

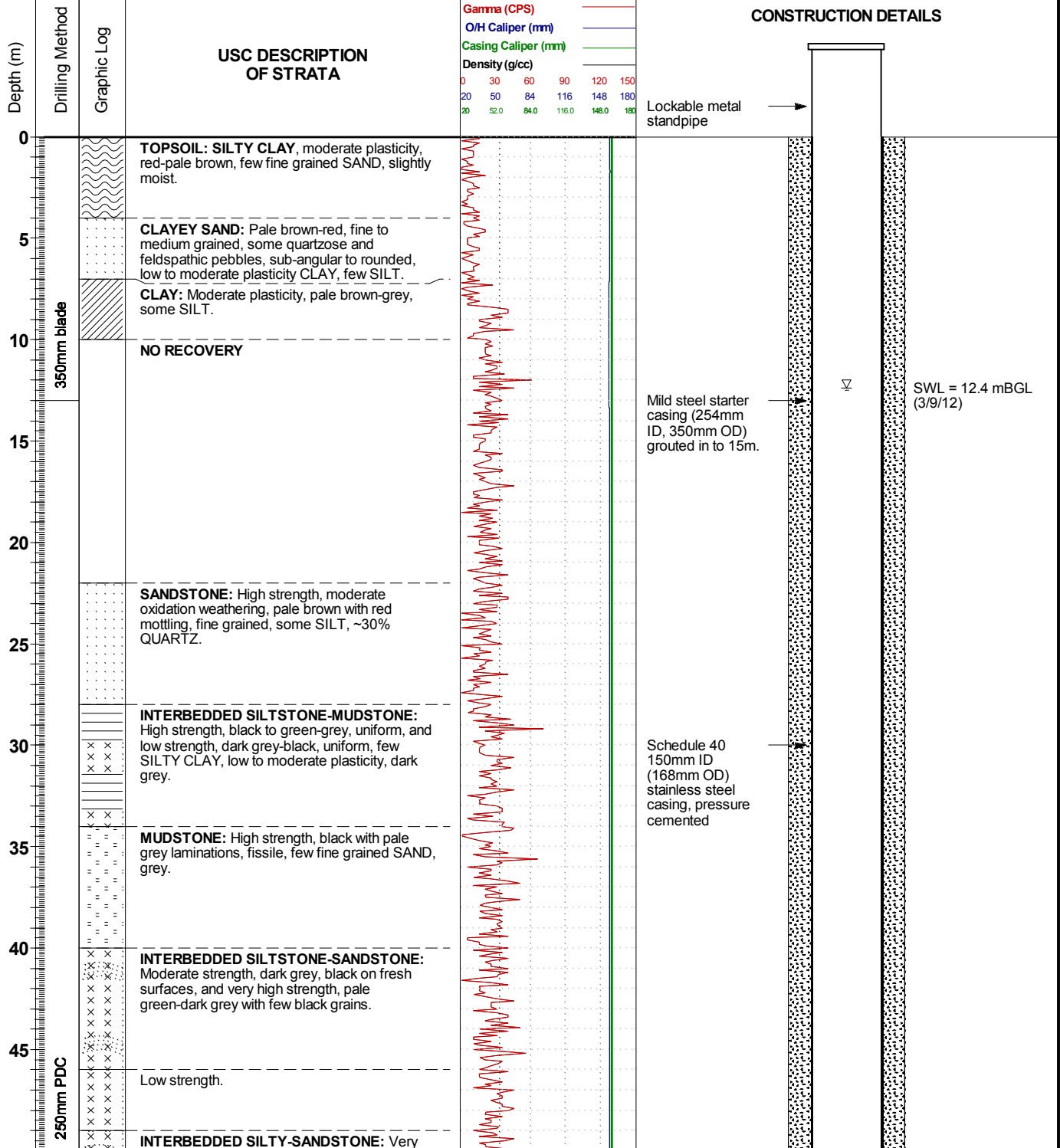
Casing Size: **150 mm**

Long: 148.916279

Drill Fluid: **Mud (bentonite and PAC)**

Date Finished: **14-8-12**

Permit No: **0020-GLNG-4-1.2-0011**

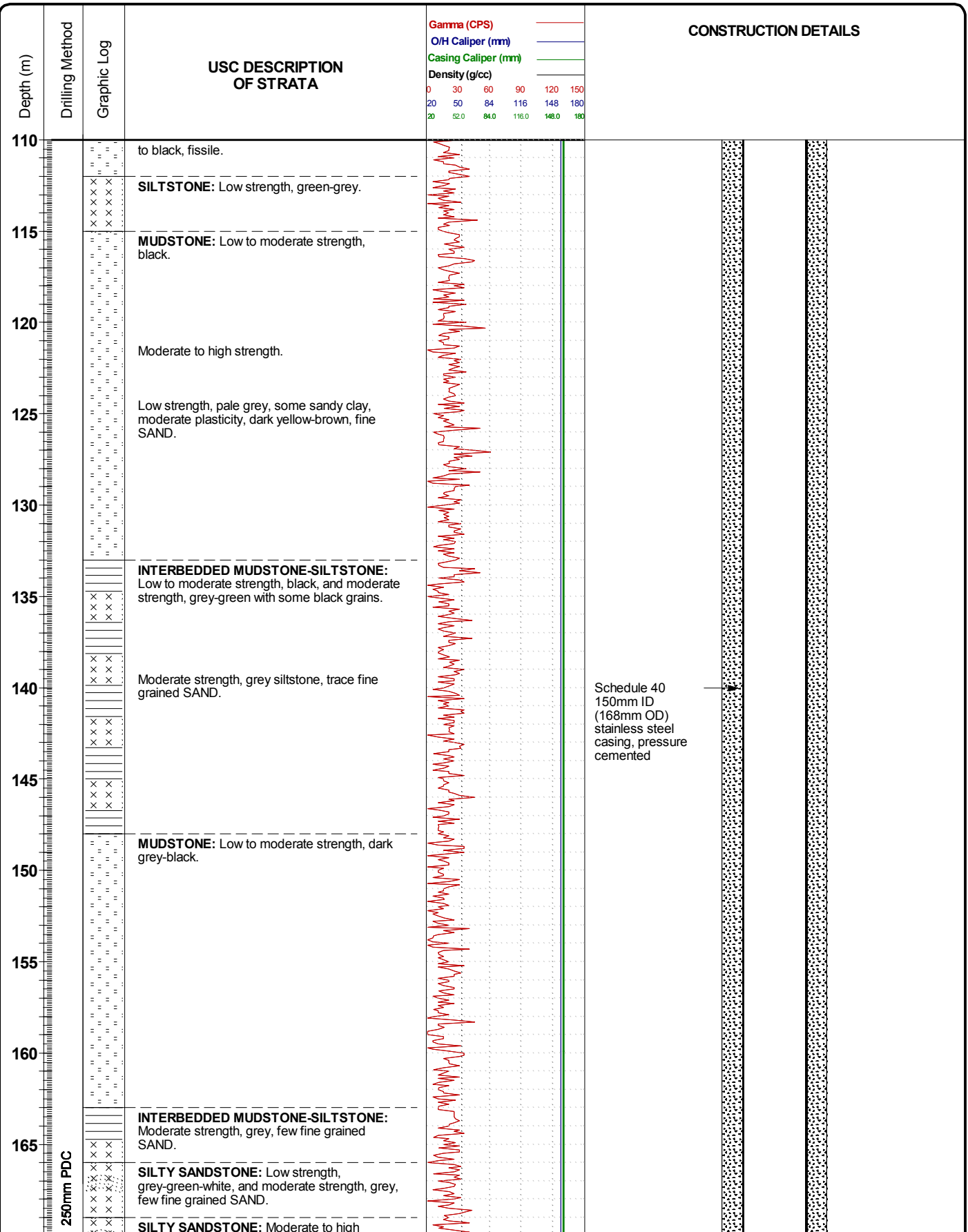


URS Australia Pty. Ltd.
Level 17, 240 Queen St, Brisbane QLD 4000

Phone: (07) 3243 2111
Phone: (07) 3243 2199

Project No.: **42626577**

Document ID: **N/A**



Document ID: N/A

[illegible]

ROM_PRSGWG07_BORE_W (FINAL)

URS Australia Pty. Ltd.
Level 17, 240 Queen St, Brisbane QLD 4000

Phone: (07) 3243 2111
Phone: (07) 3243 2199

Project
No.: 42626577

Document
ID: N/A

Depth (m)	Drilling Method	Graphic Log	USC DESCRIPTION OF STRATA	Gamma (CPS)		O/H Caliper (mm)		Casing Caliper (mm)		Density (g/cc)		CONSTRUCTION DETAILS
				0	30	60	90	120	150	20	50	
230												
235												
240			Lower strength.									
245												
250												
255			INTERBEDDED SANDSTONE-SILTSTONE: Moderate to high strength, small platy chips, white with some black grains, fine grained, quartzose, and moderate strength, pale grey with dark grey-black mottling, some SAND. Higher strength.									
260			SILTY SANDSTONE: Medium strength, pale grey with black carbonaceous specks and minor black laminae, fine grained, trace COAL, black (~3mm thick). White with black carbonaceous specks, low strength, very fine grained.									
265			Trace MUDDY SILTSTONE layers, brown, and trace SANDSTONE, high strength, clean, fine grained, yellow matrix. No MUD.									
270			Trace high strength SILTSTONE layers and trace clean, fine grained SANDSTONE.									
275			No clean SANDSTONE. Minor black, carbonaceous laminae and trace SANDSTONE, high strength, grey-dark brown.									
280			Medium strength, pale grey.									
285			Minor SILTSTONE layers, high strength, dark brown-grey.									
			Low strength, pale grey, some layers containing									

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Project No.: **42626577**

Document ID: **N/A**

Depth (m)	Drilling Method	Graphic Log	USC DESCRIPTION OF STRATA	Gamma (CPS) O/H Caliper (mm) Casing Caliper (mm) Density (g/cc)	CONSTRUCTION DETAILS
290			brown, carbonaceous laminae.	0 30 60 90 120 150 20 50 84 116 148 180 20 52.0 84.0 116.0 148.0 180	
295					
300					
305			SILTSTONE: Medium strength, pale grey, black carbonaceous laminae, trace fine grained SAND, trace COAL (~1mm thick).		
310			SILTY SANDSTONE: Medium strength, pale grey, black carbonaceous laminae, very fine grained, trace mica specks. Minor high strength, dark grey shale layer (~0.5m thick). Trace mica specks, trace clean SANDSTONE, fine grained, medium QUARTZ clasts.		
315			Minor inclusions SILTSTONE, medium strength, grey-white, black carbonaceous specks, trace fine grained SAND.		
320			INTERBEDDED SILTY-SANDSTONE: Medium strength, pale grey, black carbonaceous laminae, and pale grey-white, trace pale yellow, platy, crystalline material.		
325			SILTY SANDSTONE: Medium strength, pale grey, black carbonaceous specks, very fine grained. Black laminae, trace shale layers, high strength, dark grey.		
330			SILTSTONE: Medium strength, pale grey, minor brown layers, black carbonaceous specks, clayey.		
335			Minor SILTSTONE layers, high strength, grey, uniform.		
340			SILTY SANDSTONE: Medium strength, pale grey, black carbonaceous laminae, very fine grained.		
345			SILTSTONE: Medium strength, pale grey-brown, black carbonaceous specks, minor CLAYEY SANDSTONE, pale grey, black specks, fine to medium grained, trace COAL (<3mm thick). Minor SILTSTONE, high strength, grey, uniform, trace COAL.		

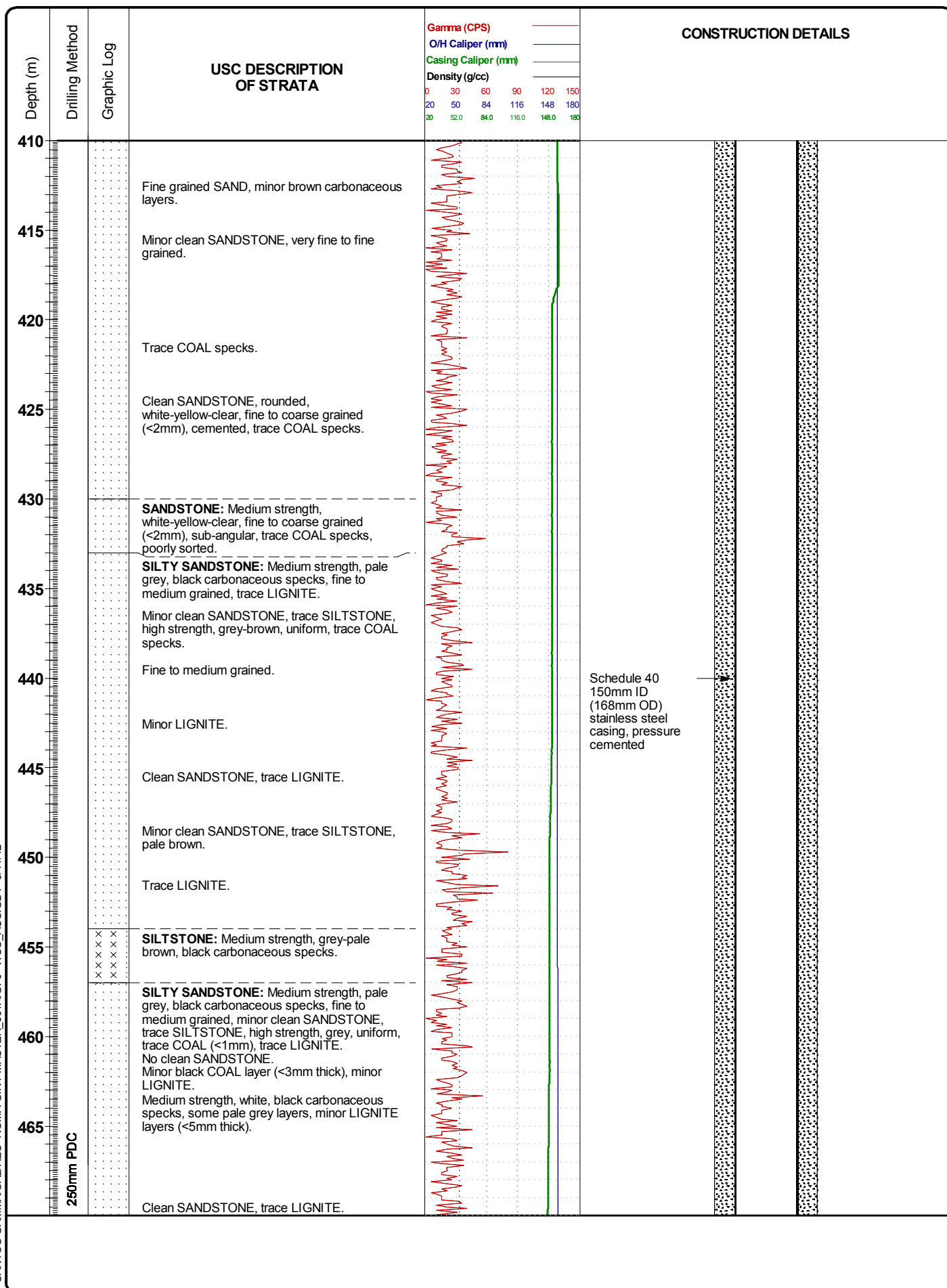
Schedule 40
150mm ID
(168mm OD)
stainless steel
casing, pressure
cemented

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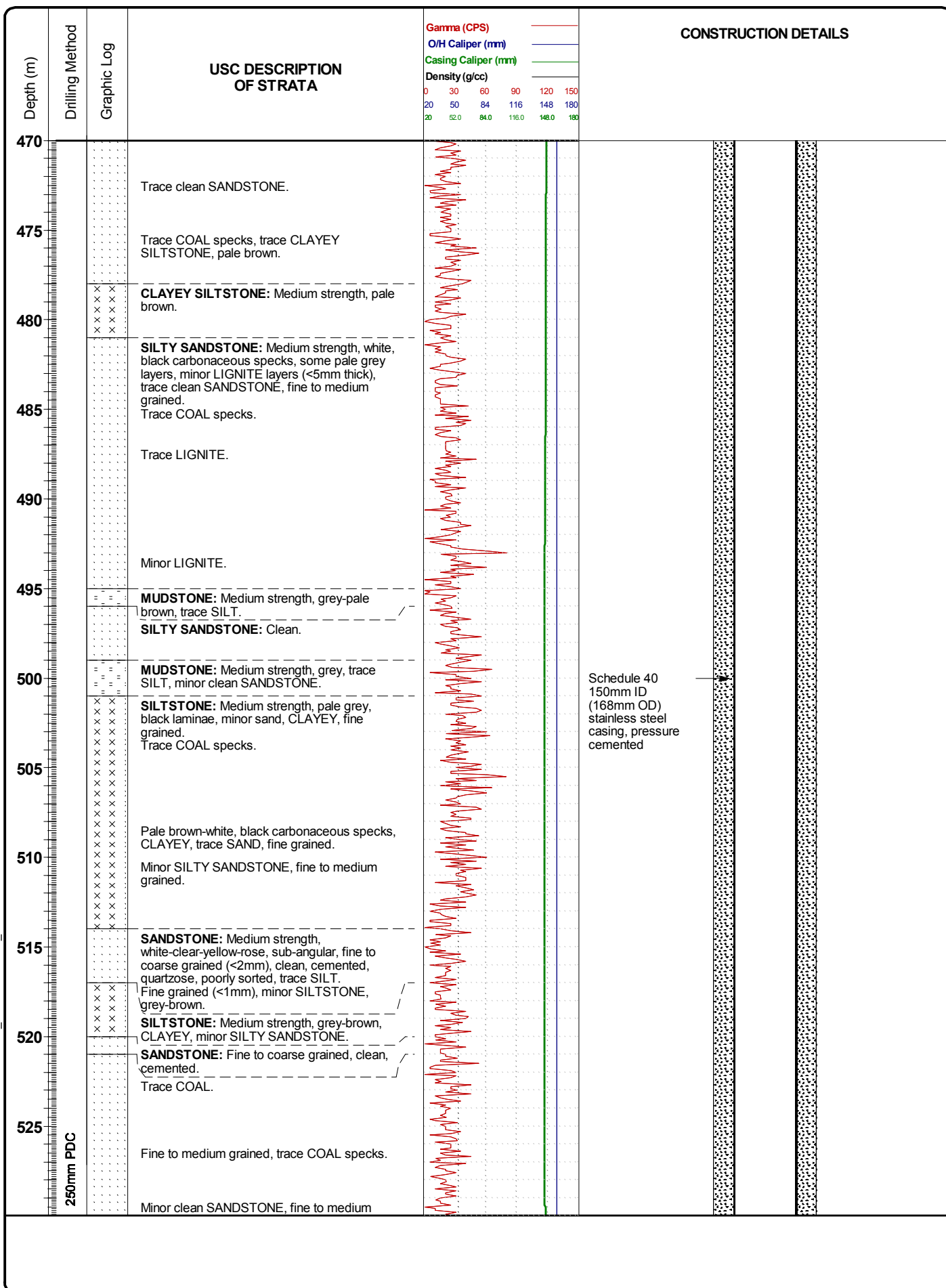


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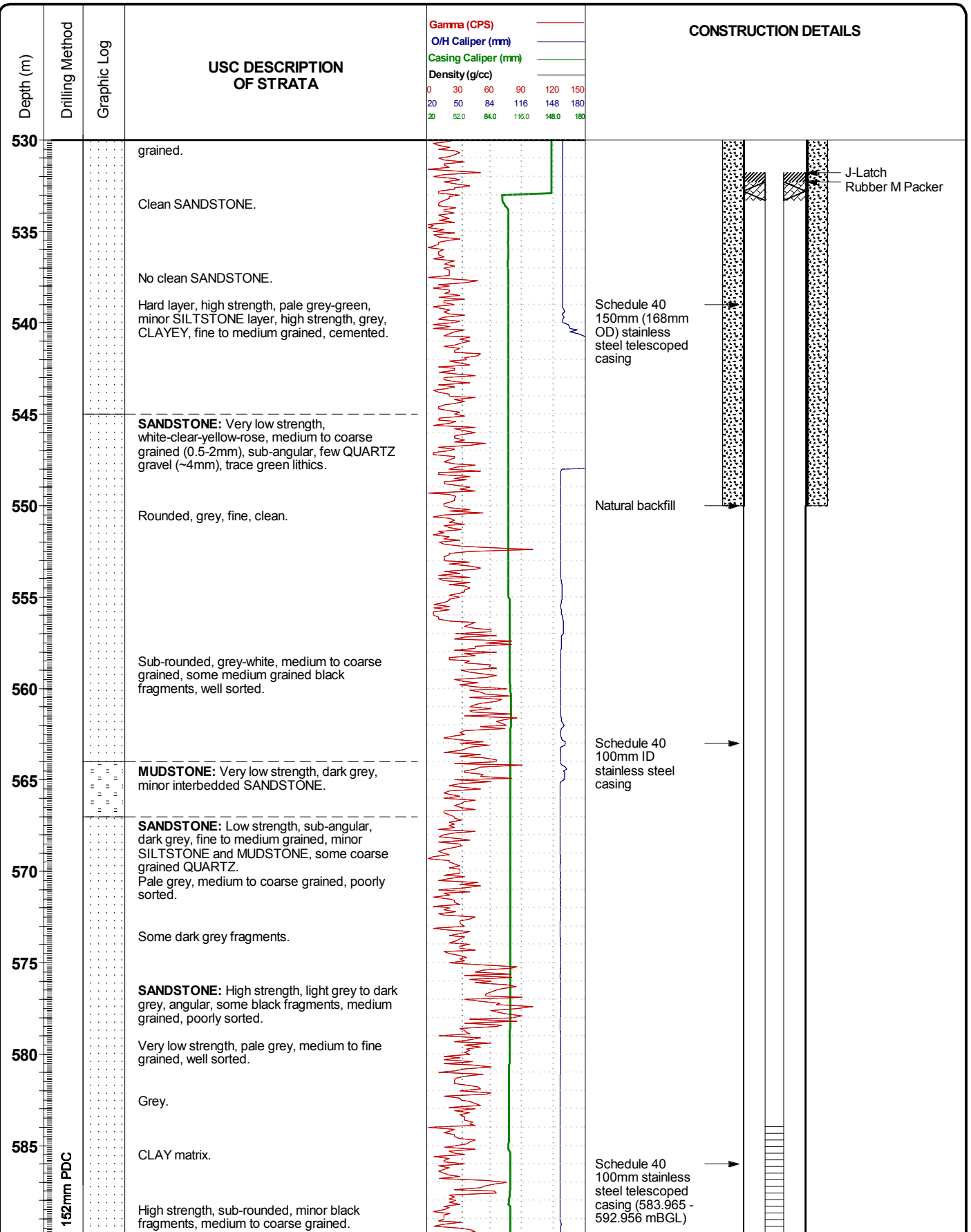


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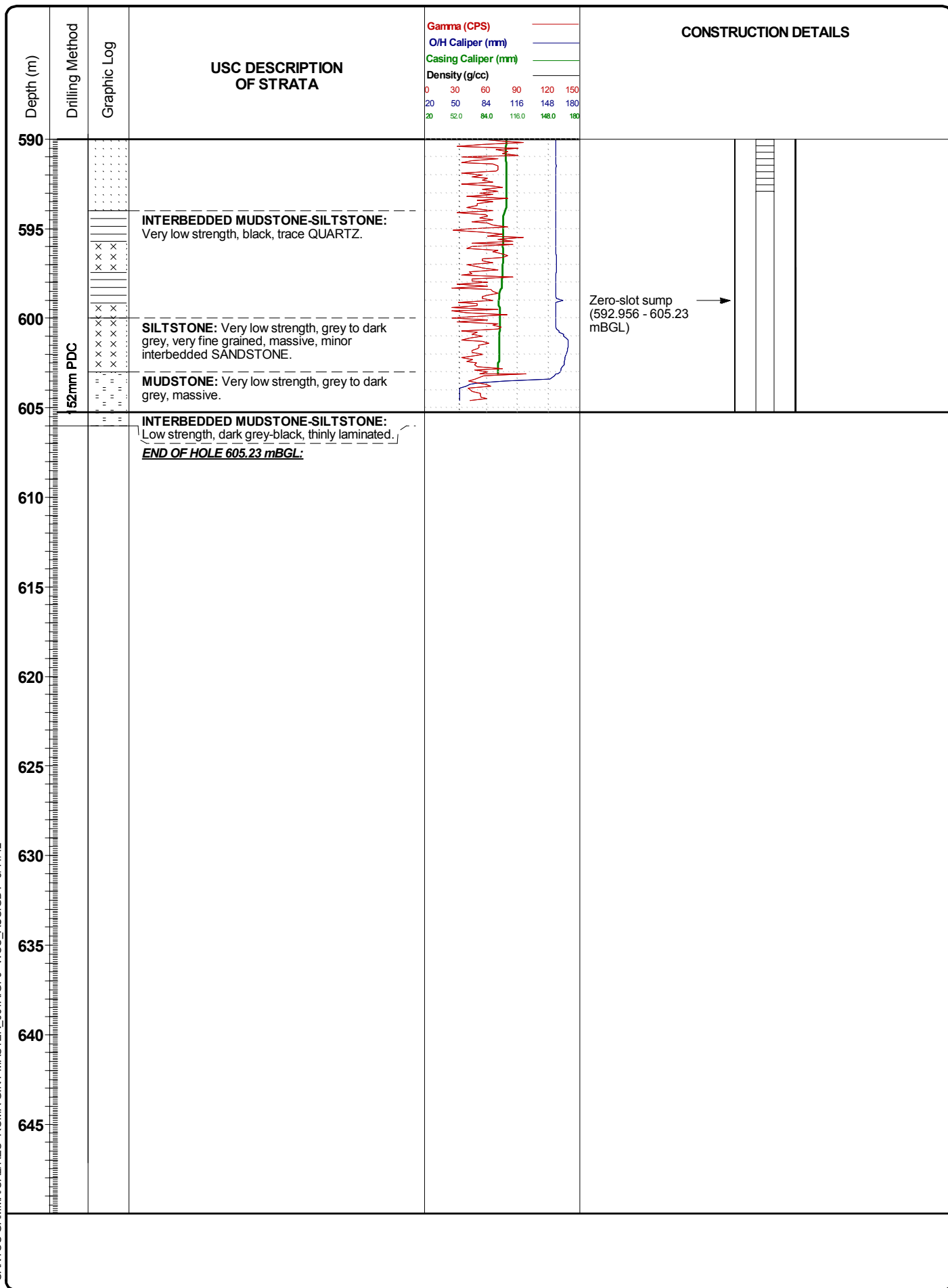


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ROM_PRSGWM03_BORE_W (FINAL)

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Phone: (07) 3243 2111
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Project Name: **2010-12 Roma Drilling Programme**

Client: **Santos Ltd**

Document ID:

Drilling Contractor: **Adams Drillers**

Project No.: **42626577**

Location: **Roma, QLD**

N/A

Logged By: **DP, PO**

Bore Size: **350 mm**

Casing RL: **279.281 mAHD**

Drill Type: **Mud Rotary**

Checked By: **MR**

Total Depth: **382.2 m**

Coordinates: **Lat: -26.743843**

Drill Model: **Atlas Copco T3W**

Date Started: **5-8-12**

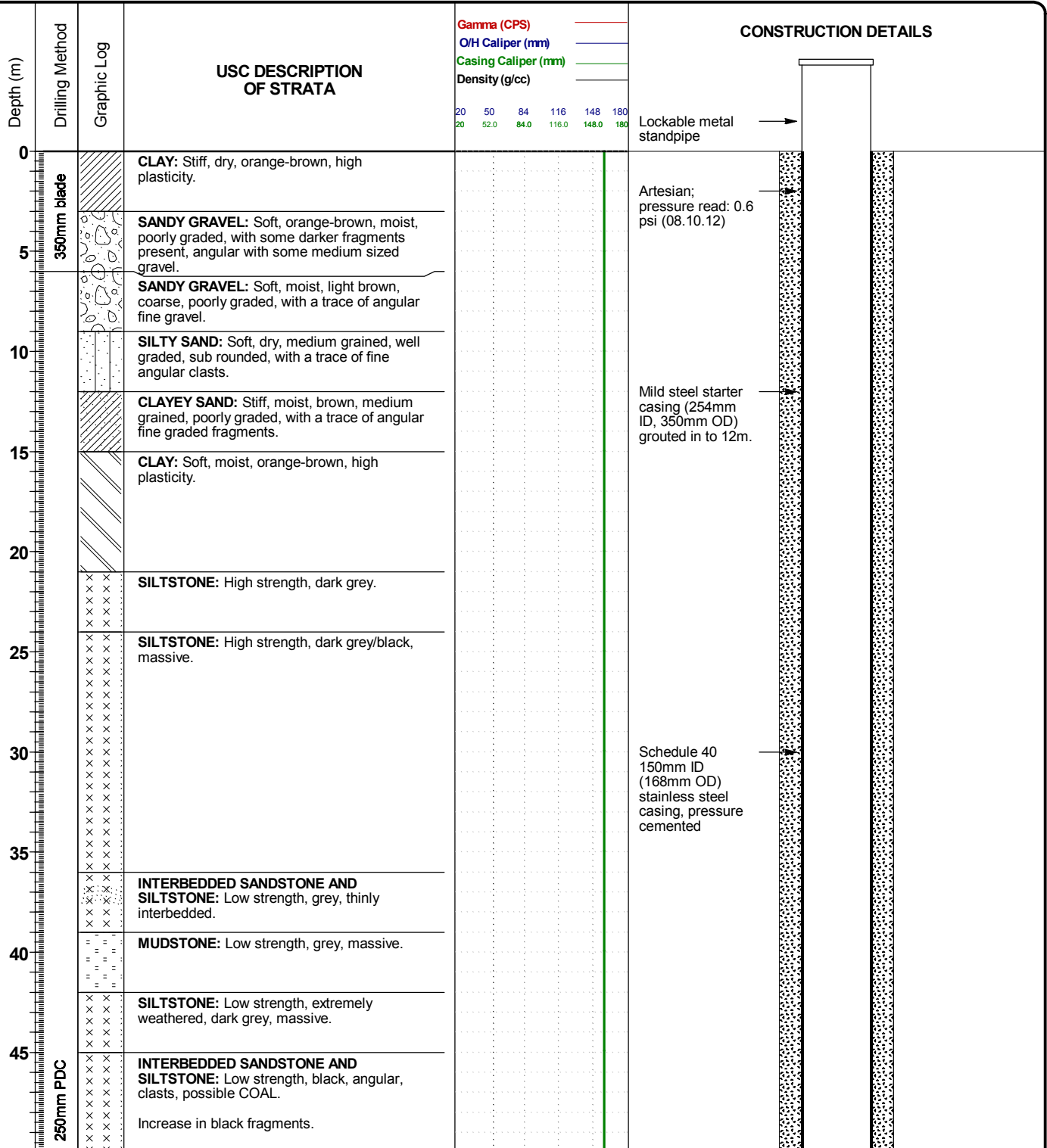
Casing Size: **150 mm**

Long: 148.916182

Drill Fluid: **Mud (bentonite & PAC)**

Date Finished: **19-9-12**

Permit No: **0020-GLNG-4-1.2-0011**



ROM_PRSGWM03_BORE_W (FINAL)

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Phone: (07) 3243 2111
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Project No.: **42626577**

Document ID: **N/A**

Depth (m)	Drilling Method	Graphic Log	USC DESCRIPTION OF STRATA	Gamma (CPS) O/H Caliper (mm) Casing Caliper (mm) Density (g/cc)						CONSTRUCTION DETAILS			
				20	50	84	116	148	180				
50		X X X	MUDSTONE: Low strength, dark grey, massive.										
55													
60			Increase in unconsolidated clay content throughout.										
65													
70													
75													
80													
85													
90													
95													
100			MUDSTONE: Very low strength, dark grey/black, poorly developed with some interbedded black fragments possibly COAL.										
105		X X X	INTERBEDDED MUDSTONE AND SILTSTONE: Very low strength, dark grey/black, with some medium strength SILTSTONE interbedded.										
			MUDSTONE: Very low strength, fresh, dark grey/black, massive.										
		X X X	SILTSTONE: Low strength, fresh, dark grey/black, massive.										

Schedule 40
150mm ID
(168mm OD)
stainless steel
casing, pressure
cemented

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Depth (m)	Drilling Method	Graphic Log	USC DESCRIPTION OF STRATA	Gamma (CPS) O/H Caliper (mm) Casing Caliper (mm) Density (g/cc)						CONSTRUCTION DETAILS			
				20	50	84	116	148	180				
110				20	52.0	84.0	116.0	148.0	180				
115			INTERBEDDED MUDSTONE AND SILTSTONE: Very low strength, fresh, thinly laminated, interbedded siltstone layers, poorly developed. MUDSTONE: Medium strength, dark grey/black, massive.										
120													
125			INTERBEDDED MUDSTONE AND SILTSTONE: Medium/high strength, dark grey/grey, with minor light brown clasts.										
130													
135			SILTSTONE: Medium strength, slight weathering, dark grey/grey with some green mottling on some fragments, some very fine SAND size black clasts throughout. INTERBEDDED MUDSTONE AND SILTSTONE: Low/medium strength, dark grey, massive.										
140			SILTSTONE: Low/medium strength, dark grey, thinly laminated.										
145													
150													
155			Increase in strength. INTERBEDDED SILTSTONE AND SANDSTONE: Low/medium strength, dark/light grey, SANDSTONE fine grained.										
160			SANDSTONE: Medium strength, slightly weathered, grey, interbedded SILT-MUDSTONE clasts. SANDSTONE: Medium strength, slightly weathered, grey, interbedded SILT-MUDSTONE clasts.										
165			Decrease in strength. INTERBEDDED SILTSTONE AND SANDSTONE: Medium strength, slightly										

Schedule 40
150mm ID
(168mm OD)
stainless steel
casing, pressure
cemented

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ROM_PRSGWM03_BORE_W (FINAL)

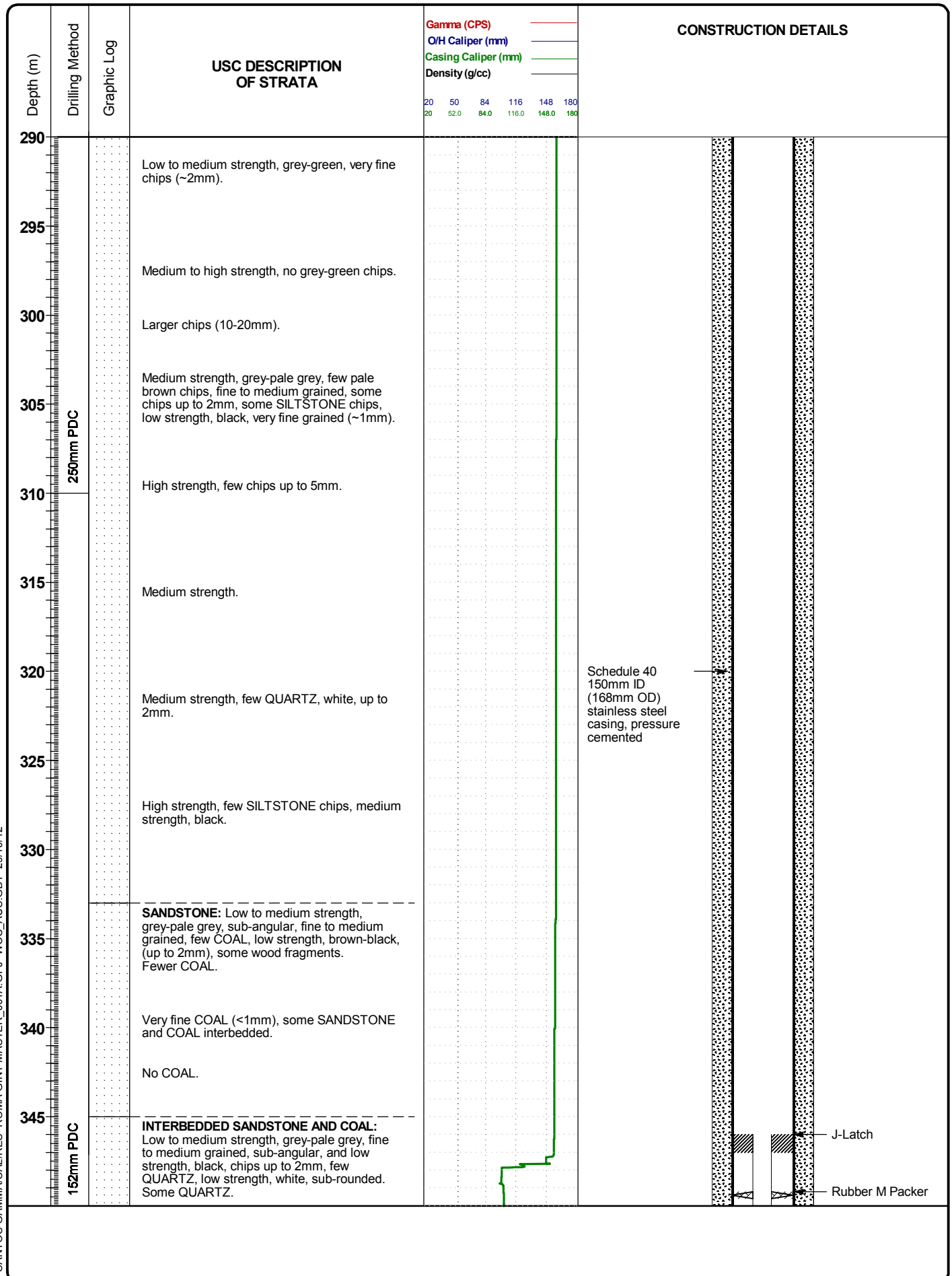
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Project
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Document
ID: N/A

Depth (m)	Drilling Method	Graphic Log	USC DESCRIPTION OF STRATA	Gamma (CPS)	O/H Caliper (mm)	Casing Caliper (mm)	Density (g/cc)	CONSTRUCTION DETAILS				
230			SILTSTONE, low strength, dark grey. No SILTSTONE.	20	50	84	116	148	180			
235			Low to medium strength, medium grained.	20	52.0	84.0	116.0	148.0	180			
240			Some SILTSTONE chips, medium strength, up to 2mm.									
245												
250			SANDSTONE: Low to medium strength, grey-pale grey, fine to medium grained, few SILTSTONE chips, low strength, dark grey.									
255			No SILTSTONE.									
260			Some COAL chips, low strength, black, vitreous, very fine (<1mm). Few COAL.							Schedule 40 150mm ID (168mm OD) stainless steel casing, pressure cemented		
265			Some SILTSTONE chips, low to medium strength, dark grey.									
270			Larger SILTSTONE chips, medium to high strength, sub-angular, fine to medium grained.									
275			Light brown-dark grey, fine chips (<3mm), no SILTSTONE.									
280												
285	250mm PDC		Low to medium strength, some brown-grey chips, few QUARTZ (<3mm), white, crystalline.									

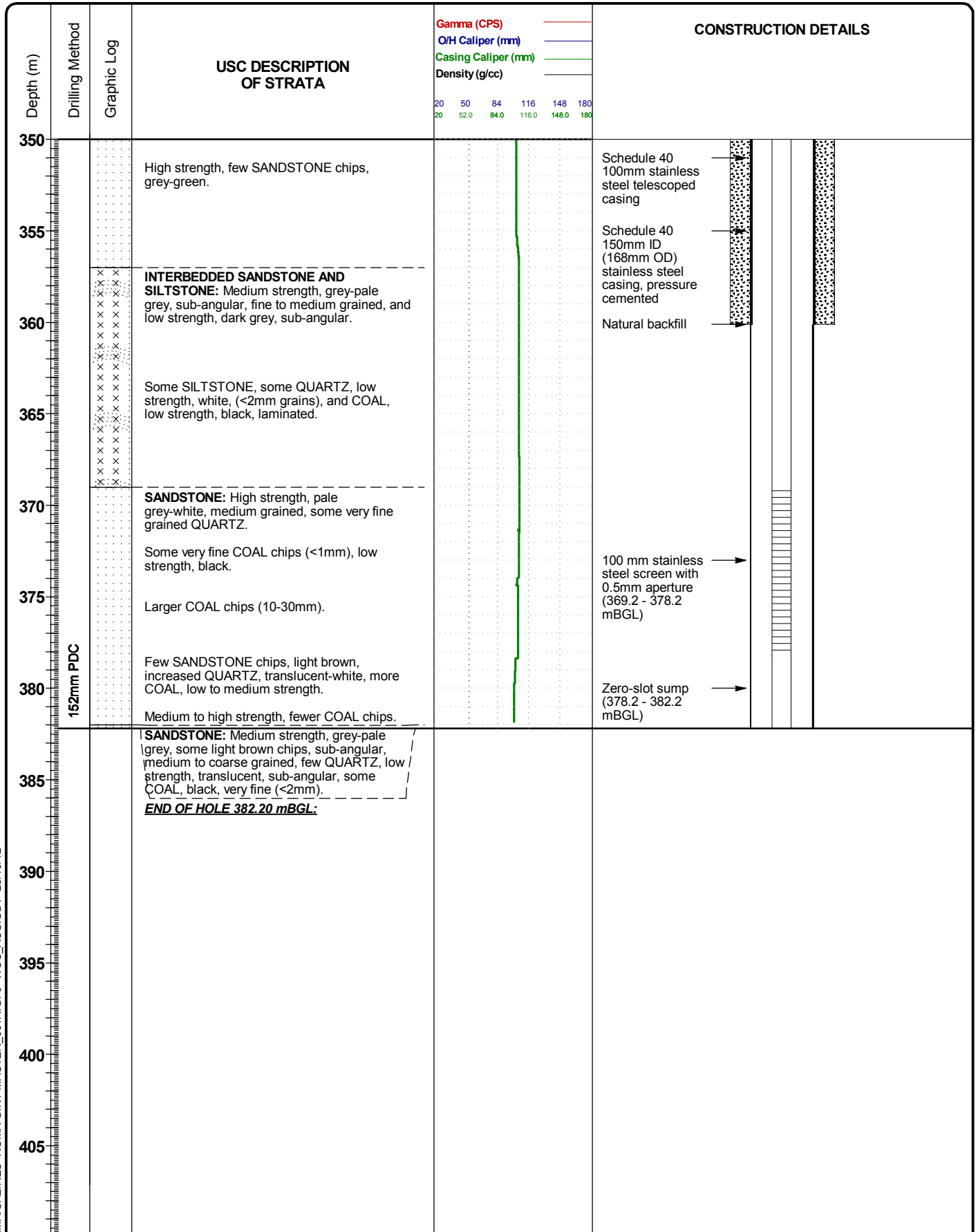


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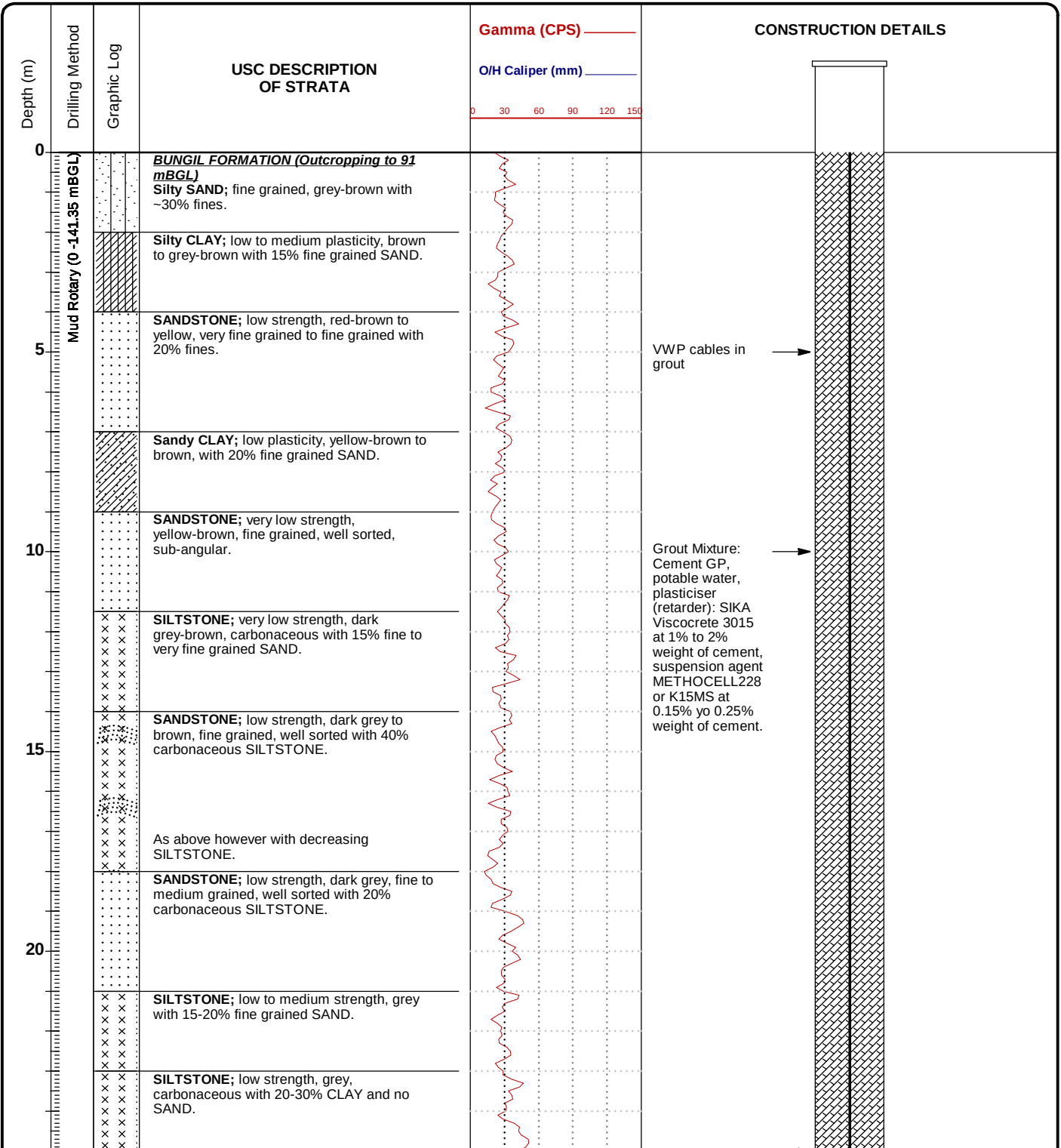
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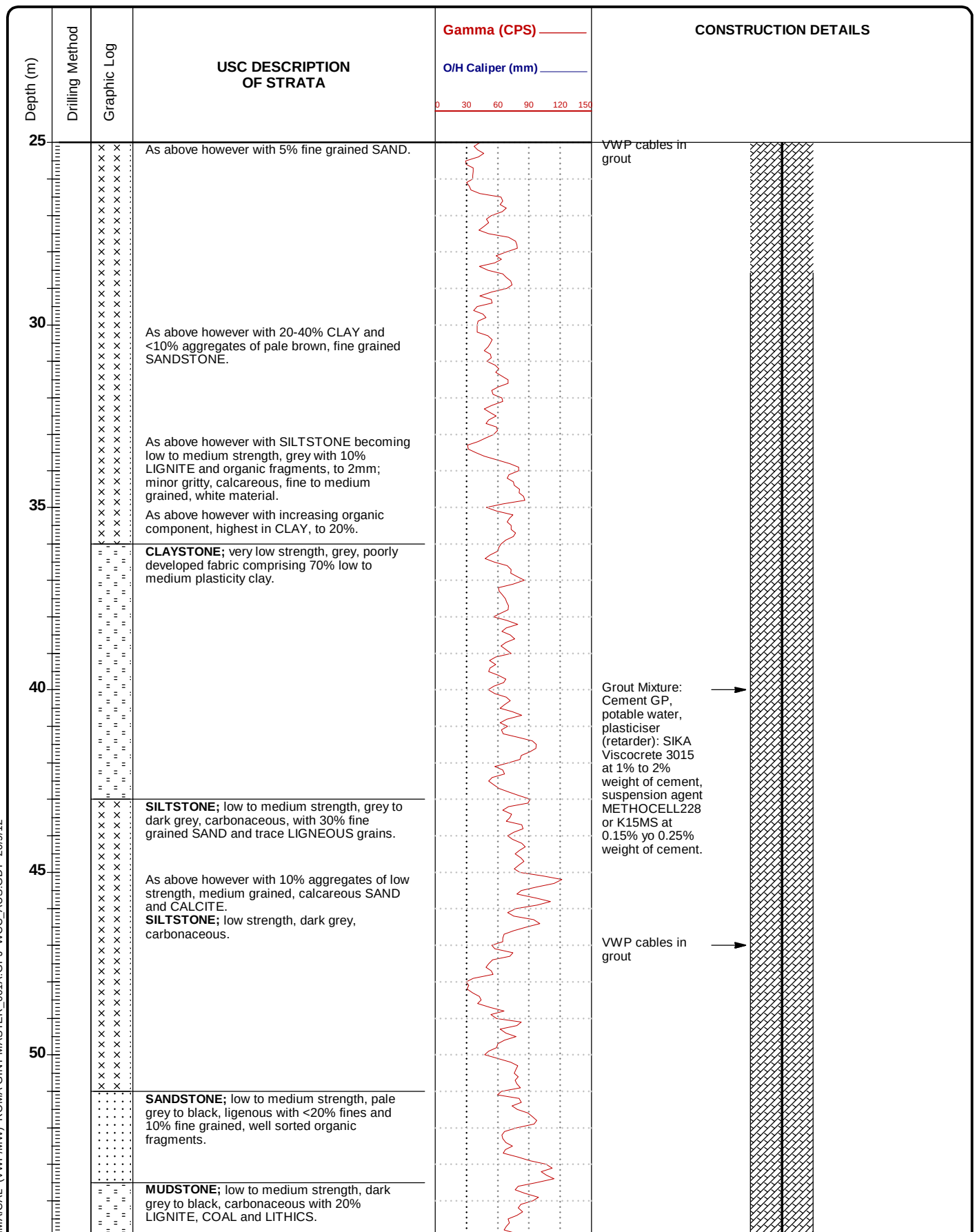


ROM_BBW_VWP_W (FINAL)

URS Australia Pty. Ltd. Level 17, 240 Queen St, Brisbane QLD 4000		Phone: (07) 3243 2111 Phone: (07) 3243 2199	Project Name: 2010/12 Roma Drilling Programme	Client: Santos Ltd	Document ID: 7699-URS-4-3.3-0013
Drilling Contractor: Boart Longyear / Spaulding Drillers					
Logged By: MR, MH, FC, HS, RP	Bore Size: HQ3 mm	Casing RL: 341.58 mAHD	Drill Type: Mud Rotary and Coring (HQ)	Drill Model: G&K 850	Drill Fluid: Mud (CR650)
Checked By: TS	Total Depth: 341.8 m	Coordinates: Lat: -26.430342 Long: 149.338833			
Date Started: 30-6-11	Casing Size: mm	Permit No: 2010-10-BB-Bore			
Date Finished: 11-7-11					



Remarks: This corehole log is the combination of core taken from three holes due to difficulties in the coring process, which resulted in the abandoning of the first 2 holes; all holes were within a 20 metre radius.
For a summary of cored sections please refer to notes on the last two pages of the log.

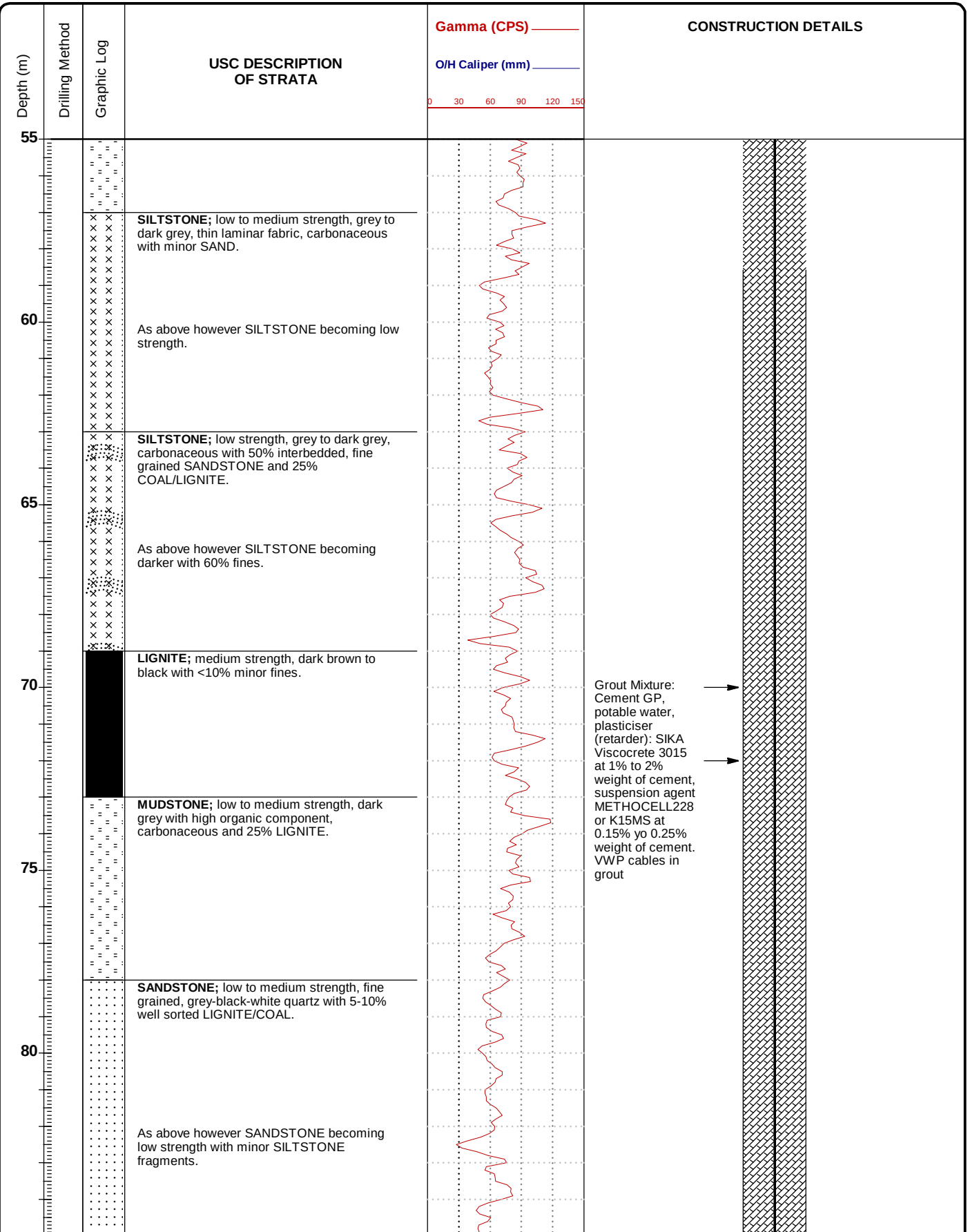


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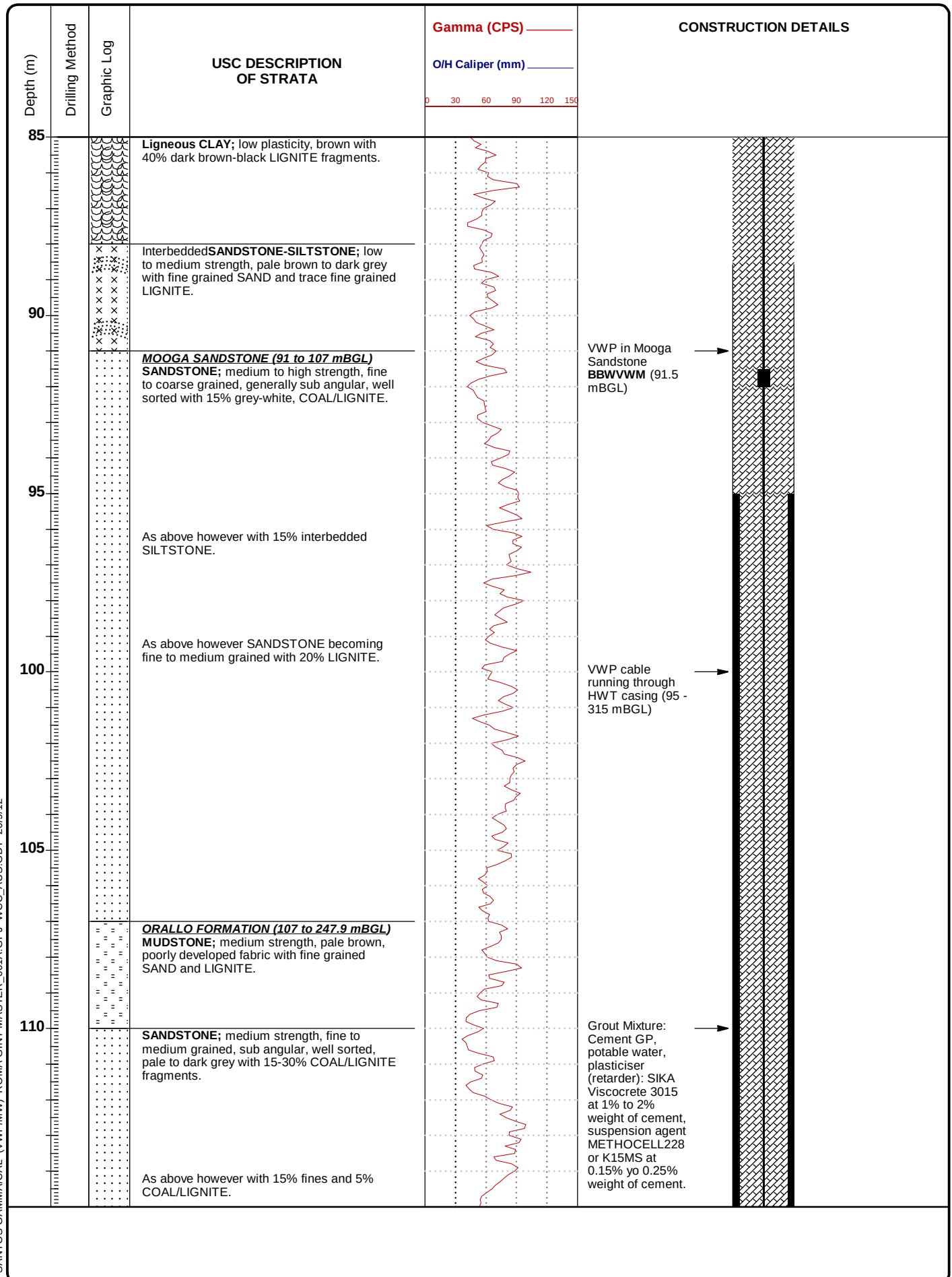


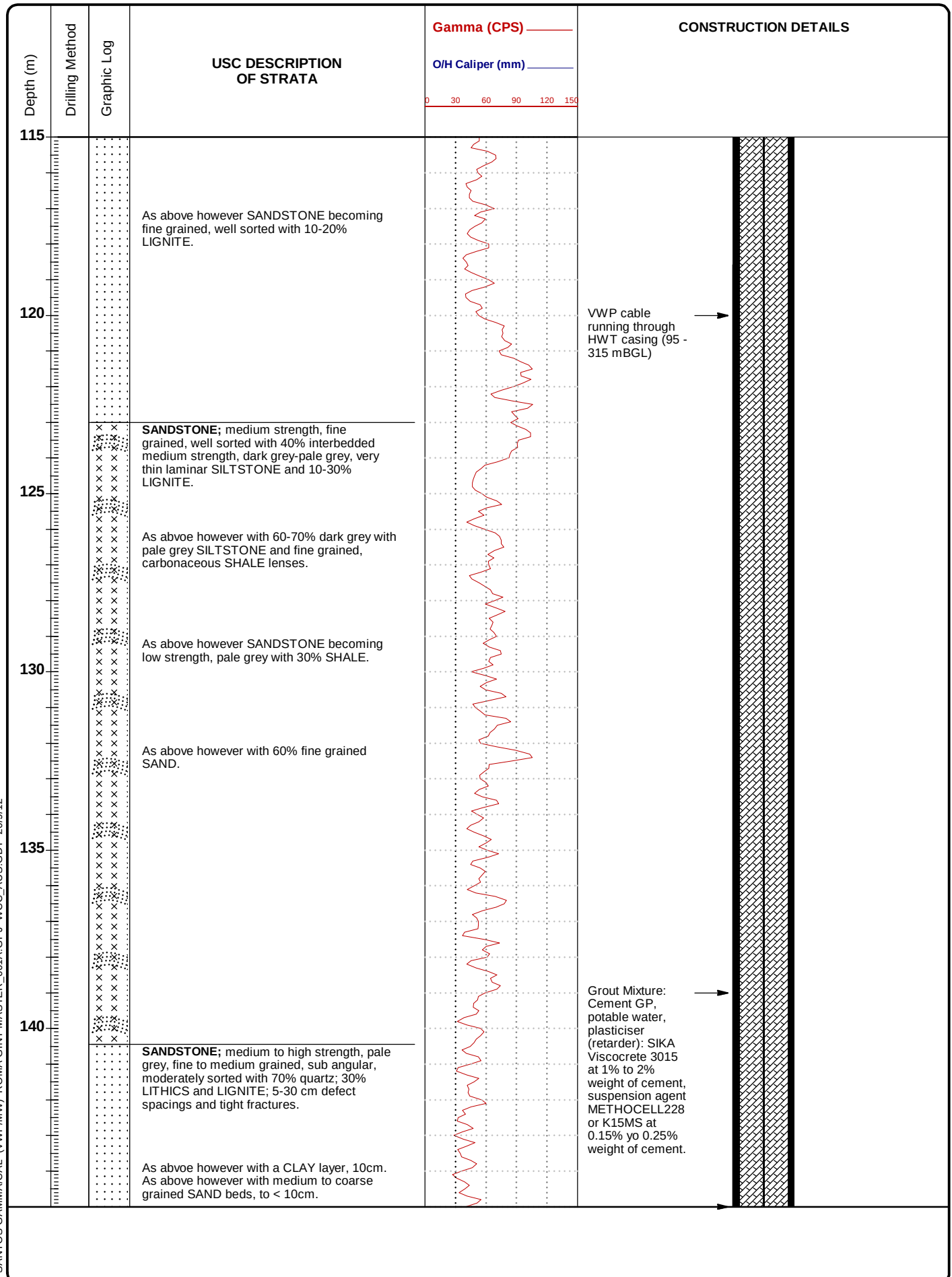
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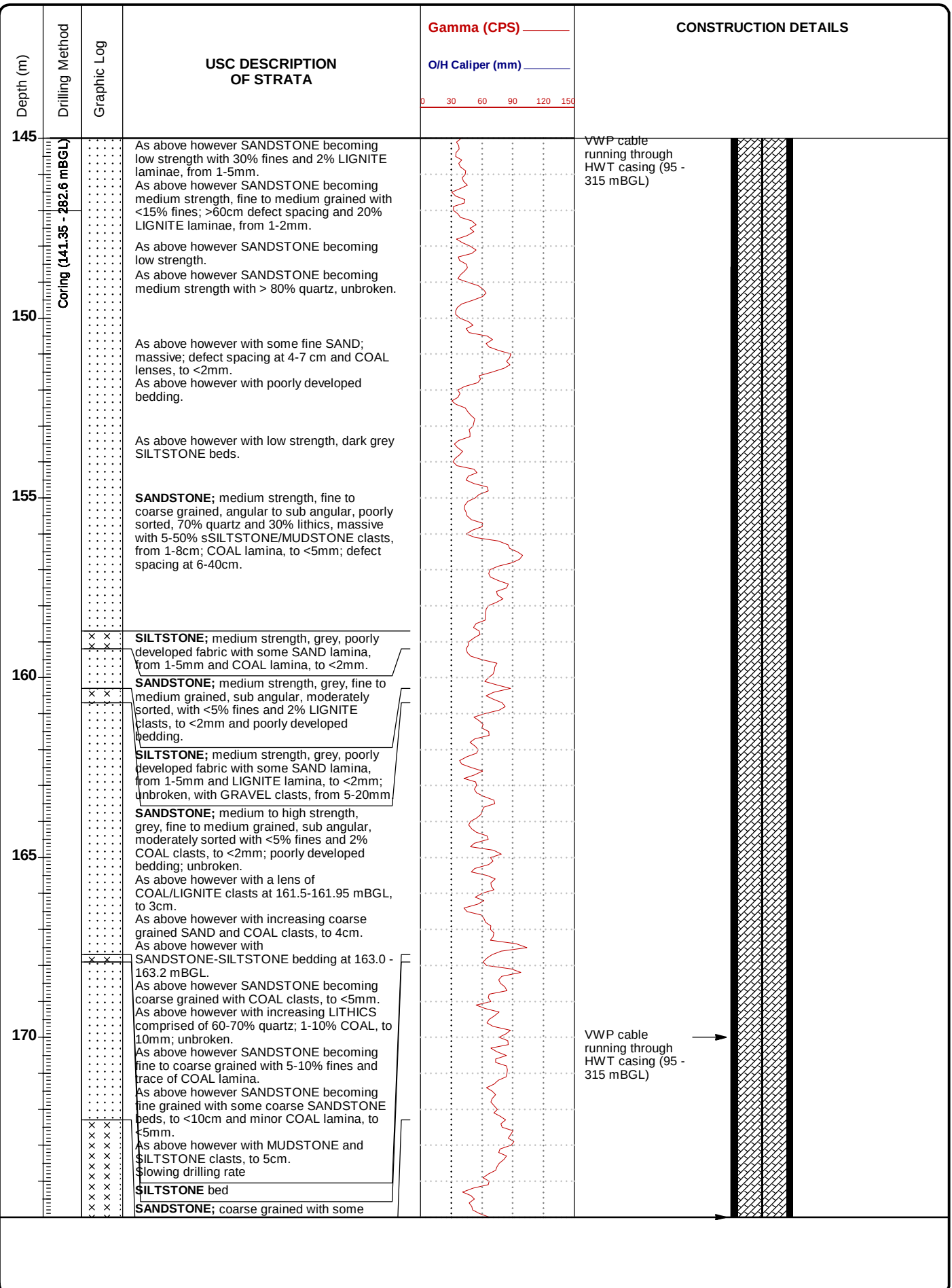


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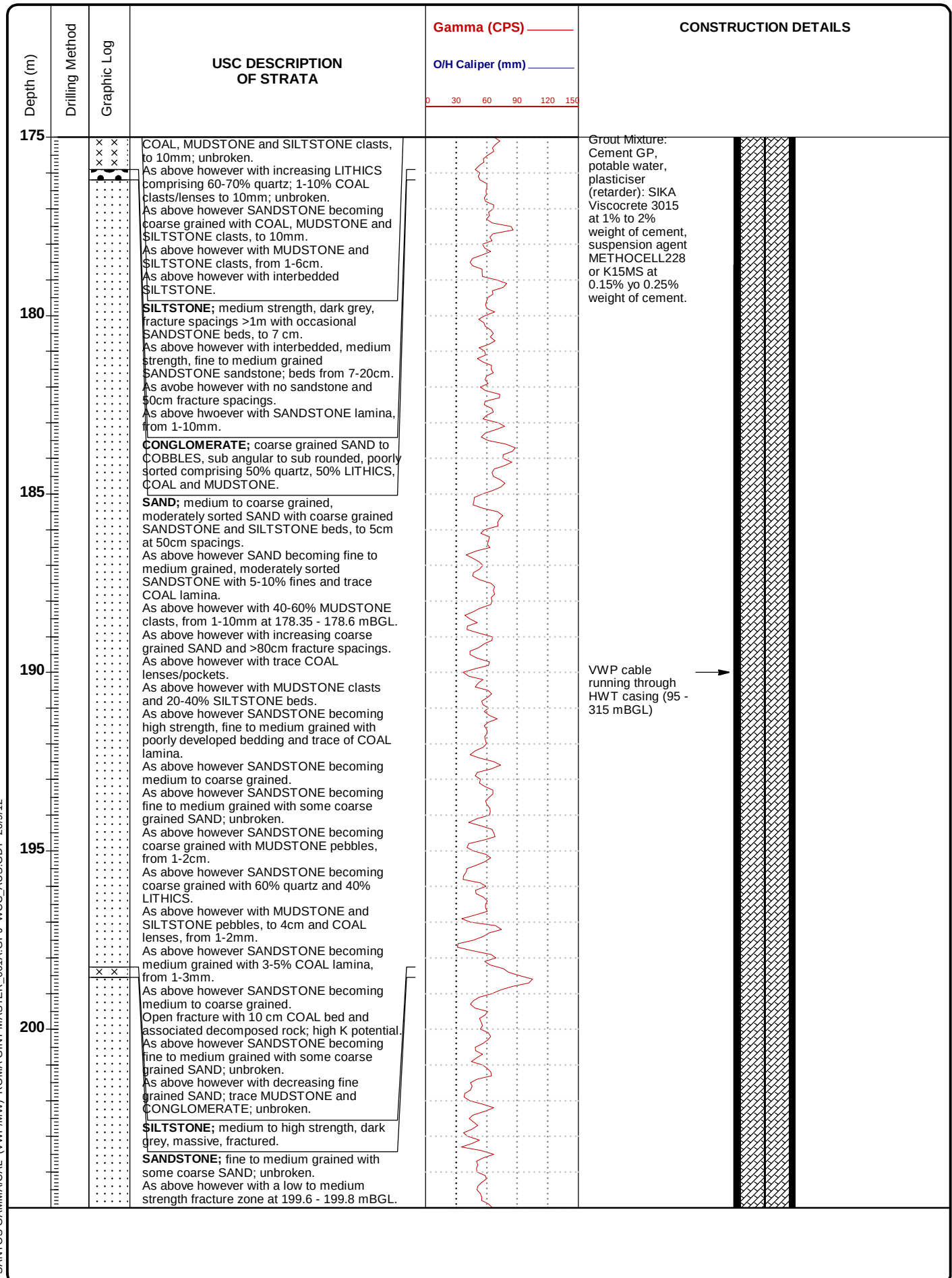


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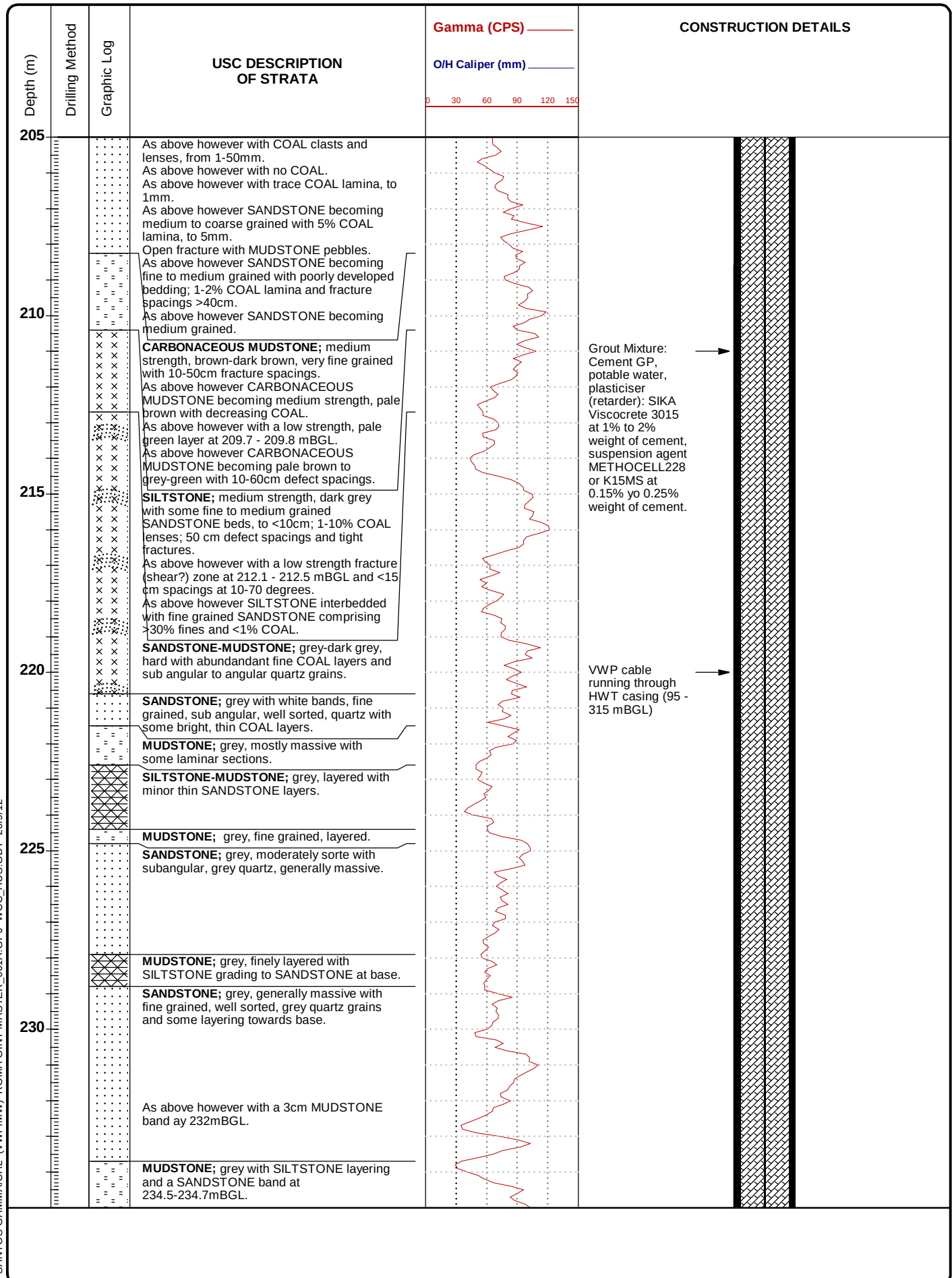


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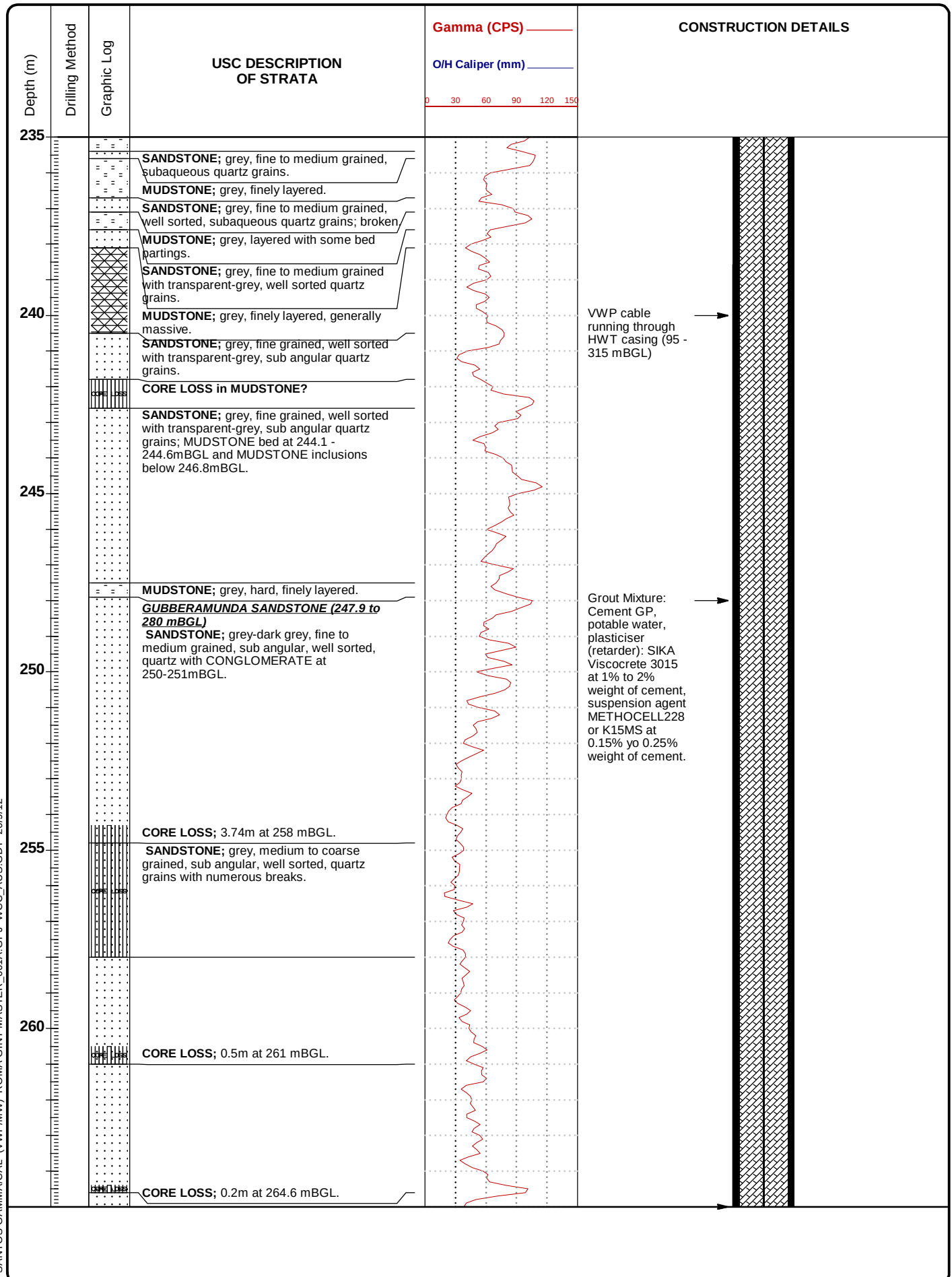


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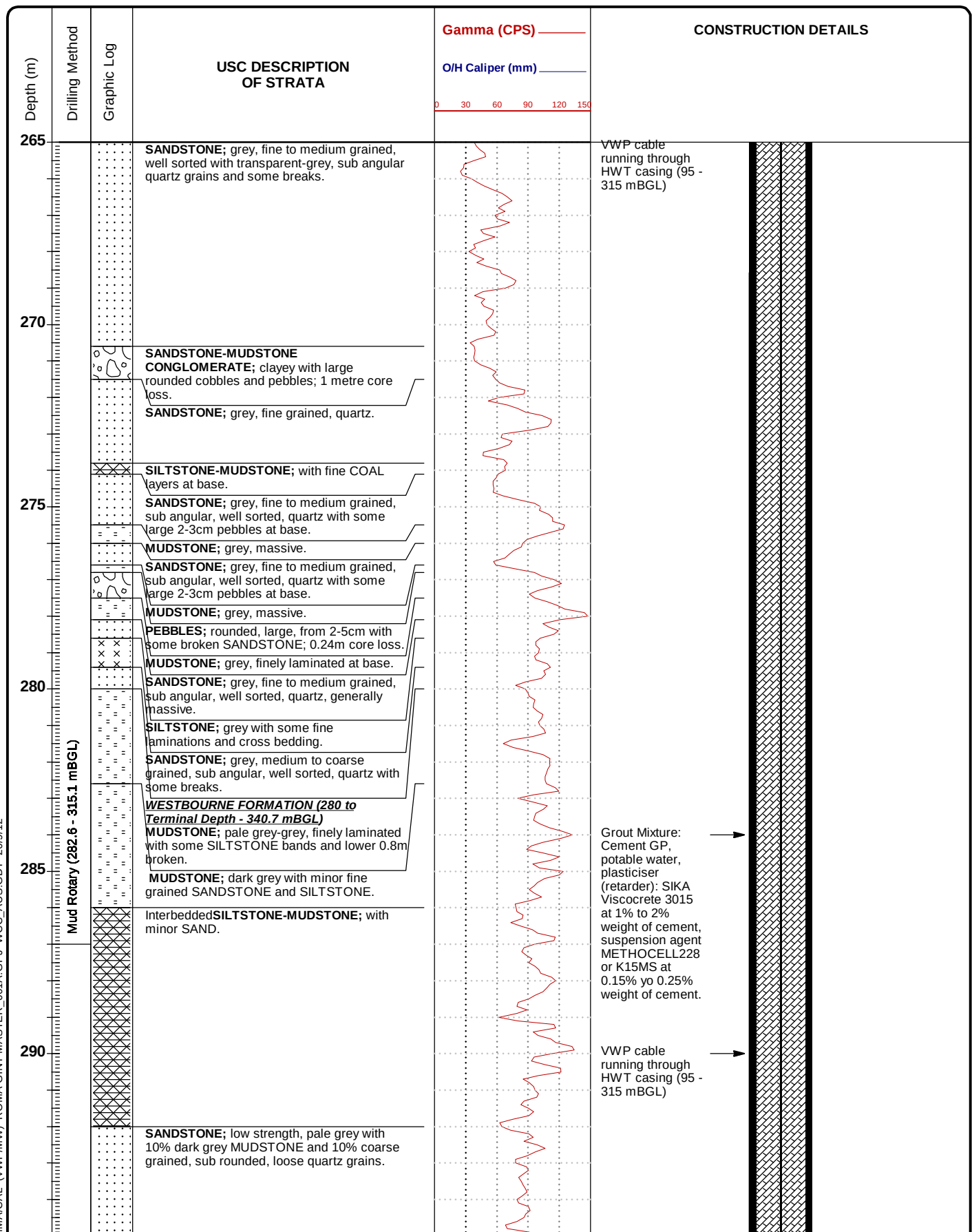


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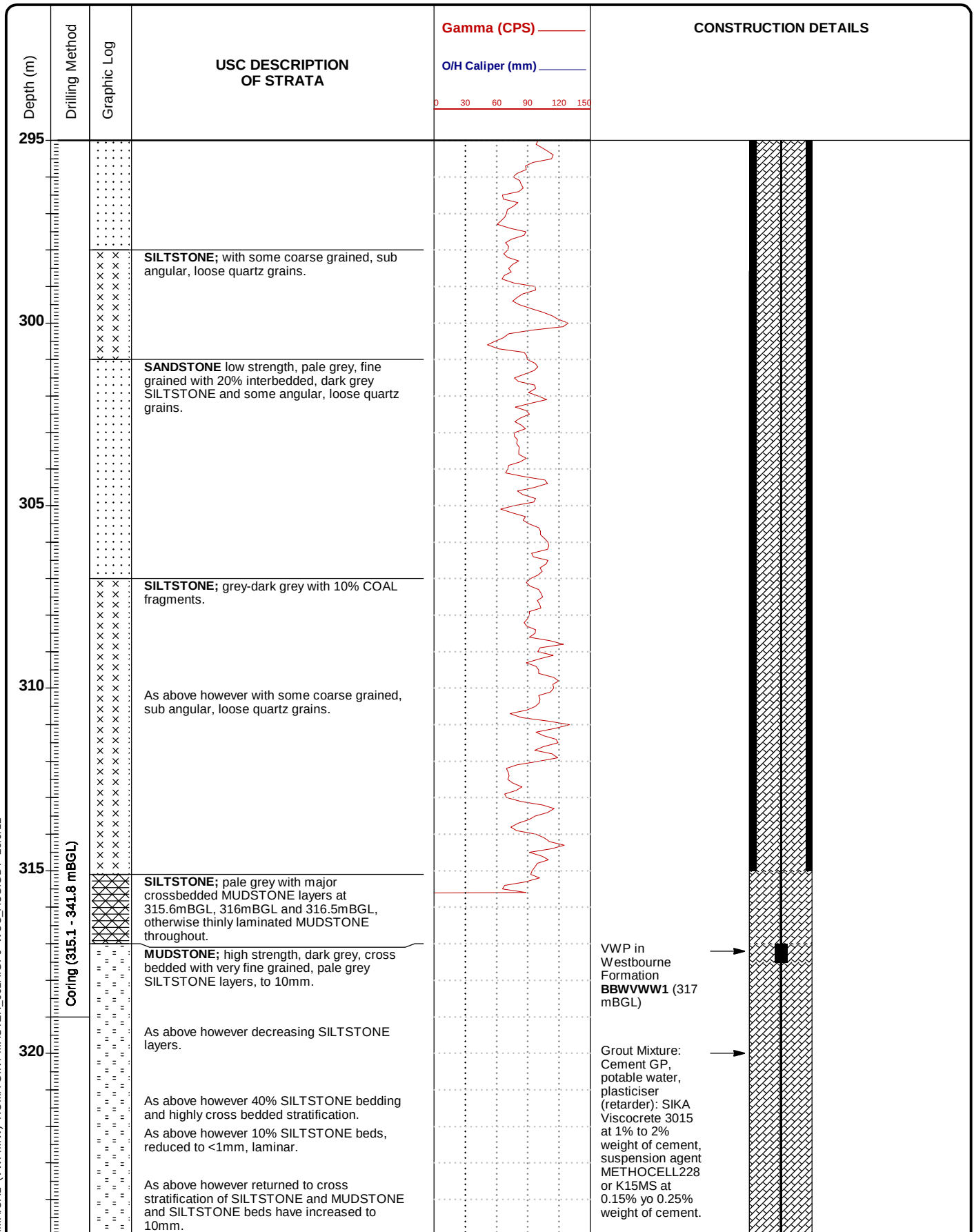
Remarks: In Summary the cored sections of the log were

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Remarks: 140.45 - 212.5 mBGL (Location C1)
220.6 - 282.6 mBGL (Location C2)
282.6 - 315.4 m BGL (Location C3)
The drilling difficulties are described in greater detail in the Report for the Coring Programme
The first hole was drilled by Boart Longyear, using mud rotary from surface to 140.45mBGL, then cored from 140.45mBGL to 212.5mBGL before the hole was abandoned when no further coring was possible.
The surface to 140.25 mBGL was taken from the log of the water monitoring bore 15metres from the corehole.
The chips at this location were a lot easier to log due to the different sized PDC drill bit and a thicker drilling mud which provided better chip returns.

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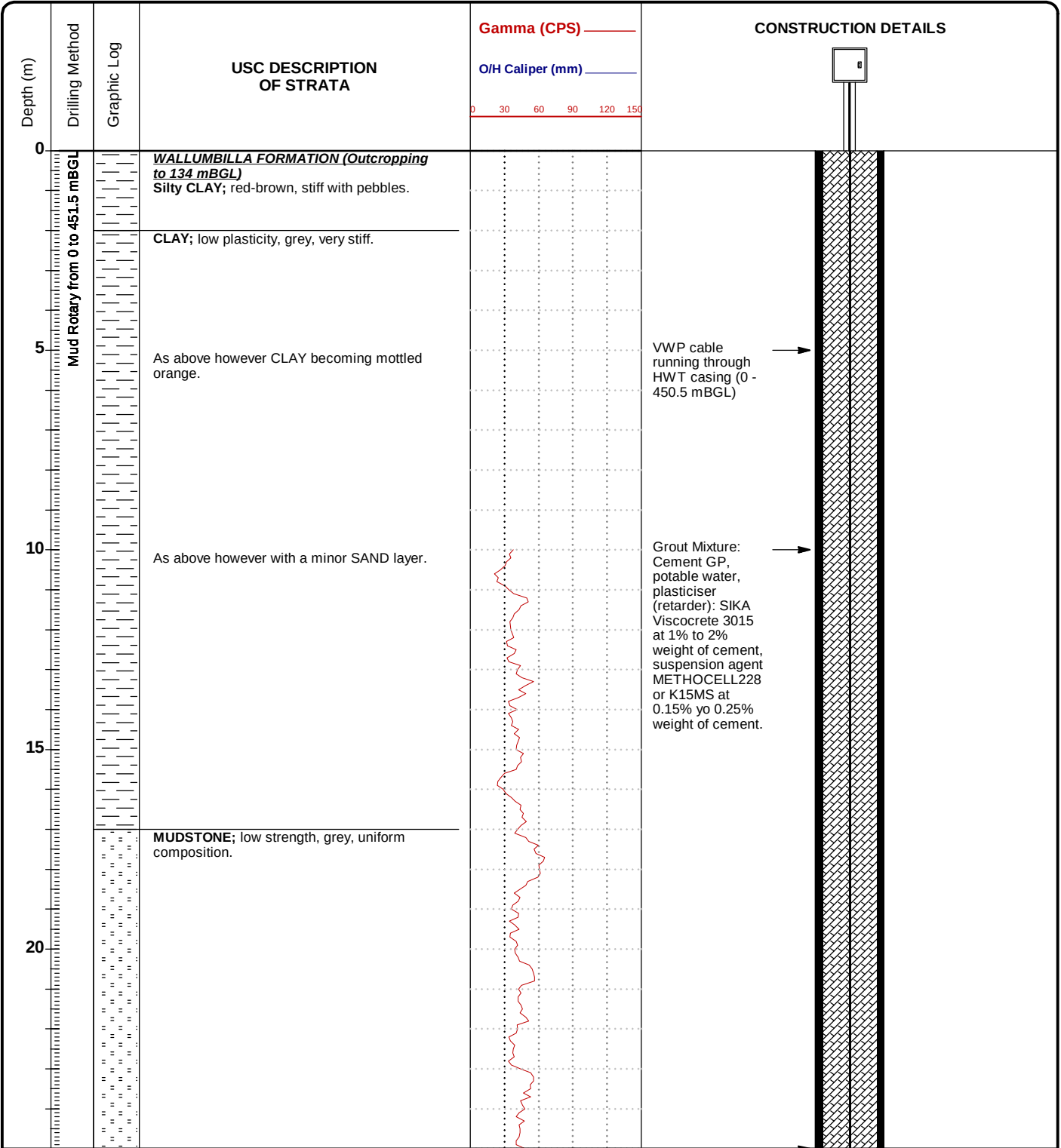
Project No.: **42626577**

Document ID: **7699-URS-4-3.3-0013**

Depth (m)	Drilling Method	Graphic Log	USC DESCRIPTION OF STRATA	Gamma (CPS) _____ O/H Caliper (mm) _____ 0 30 60 90 120 150	CONSTRUCTION DETAILS
325			As above however thin, laminated SILTSTONE beds. As above however with decreasing SILTSTONE laminae and banding; infilled fracture at 329.2mBGL, 45 degrees.		
330					
335			As above however MUDSTONE becoming very hard with trace SILTSTONE. As above however with cross bedded SILTSTONE bands, from 1-20mm with occasional very fine grained SANDSTONE, to 4cm; fracture at 335.7mBGL, 45 degrees.		VWP in Westbourne Formation BBWVWW2 (327 mBGL) Grout in sump below final VWP (327 mBGL)
340					
345			As above however with very thinly interbedded SILTSTONE and occasional very fine grained SANDSTONE.		
350			End of Hole, target depth achieved at 341.8 mBGL.		

Remarks: Spaulding Drillers were engaged to continue the coring at the site 10 metres away from the first location. The second location was drilled mud rotary from surface to 220.6mBGL then cored from 220.6mBGL to 282.6mBGL at which no further coring was possible. Spaulding Drillers drilled the final hole, 10 metres from the second mud rotary from surface to 282.6 - 315.4 (Terminal Depth). The Vibrating Wire Piezometers were installed in this final hole.

URS Australia Pty. Ltd. Level 17, 240 Queen St, Brisbane QLD 4000	Phone: (07) 3243 2111 Phone: (07) 3243 2199	Project Name: 2010/12 Roma Drilling Programme	Client: Santos Ltd	Document ID: 7699-URS-4-3.3-0033
Drilling Contractor: Spaulding Drillers		Project No.: 42626577	Location: Roma, QLD	
Logged By: HS, RP, FJ, RB	Bore Size: HQ3 mm	Casing RL: 290.92 mAHD	Drill Type: Mud Rotary and Coring (HQ)	
Checked By: TS	Total Depth: 600.0 m	Coordinates: Lat: -26.681261	Drill Model: G&K 850	
Date Started: 15-7-11	Casing Size: mm	Long: 148.730286	Drill Fluid: Mud (CR650)	
Date Finished: 23-7-11		Permit No: GDR11-008		



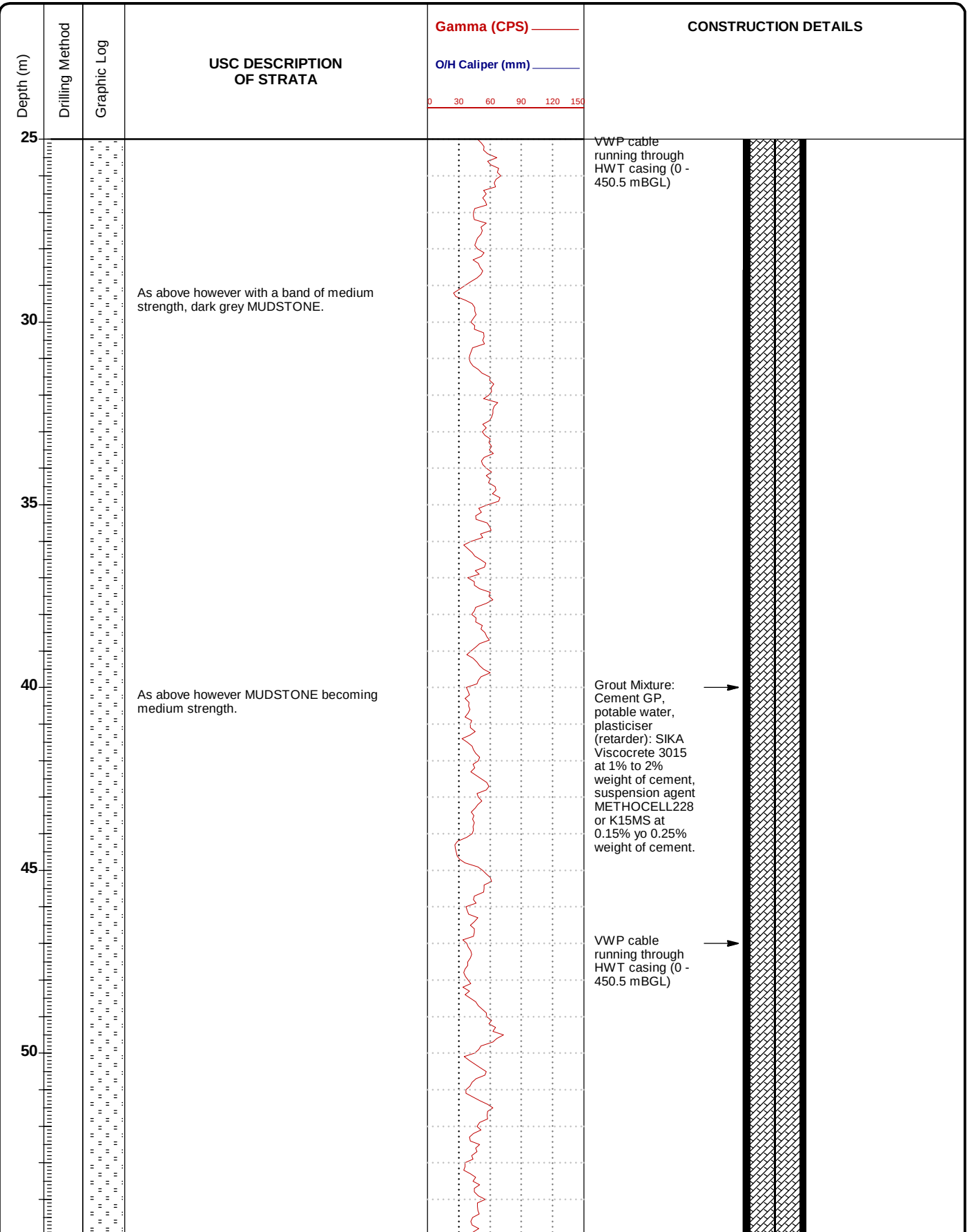
Remarks: HWT casing used to ensure the integrity of the hole during coring was not able to be removed at the completion of coring.

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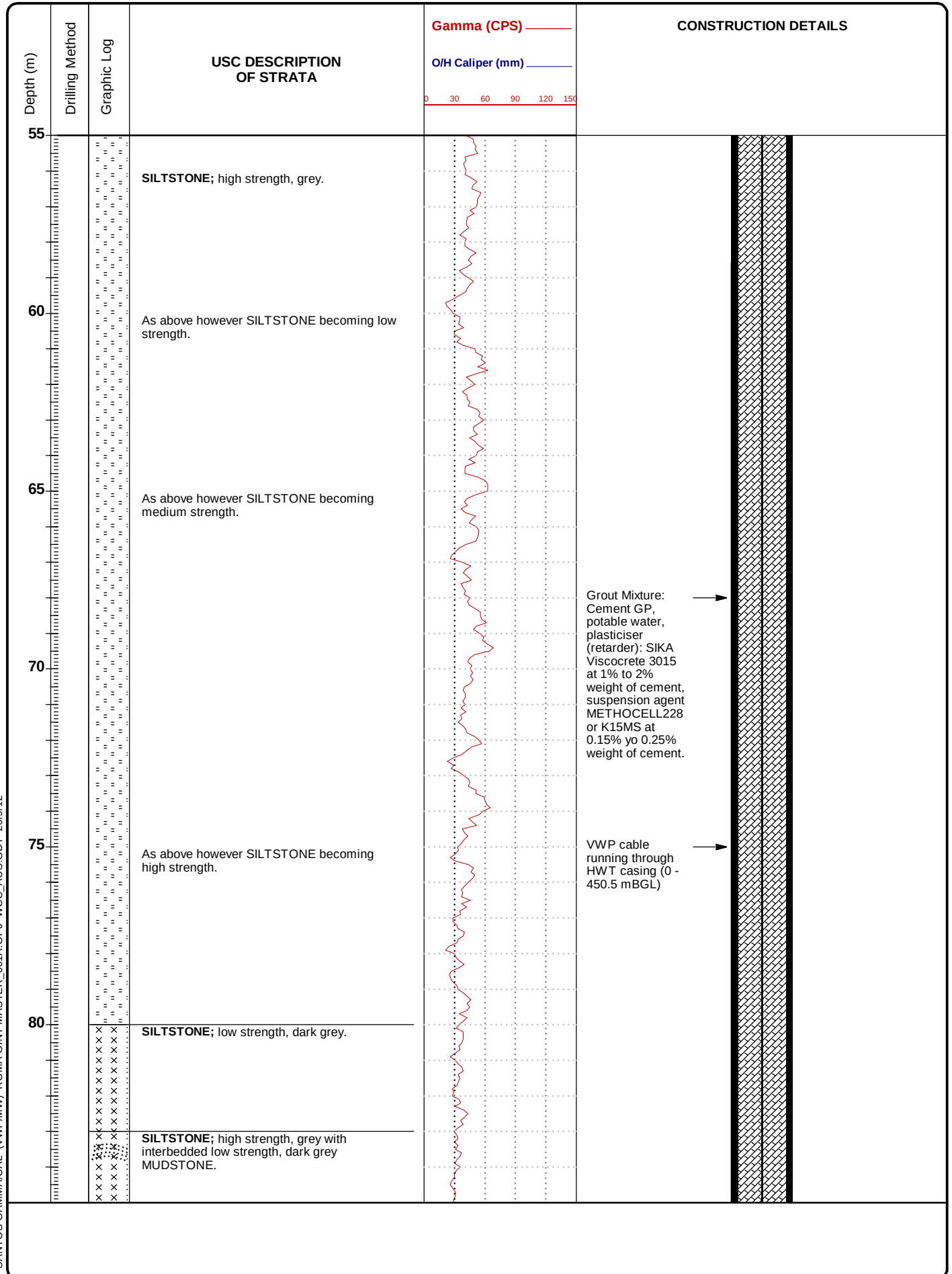


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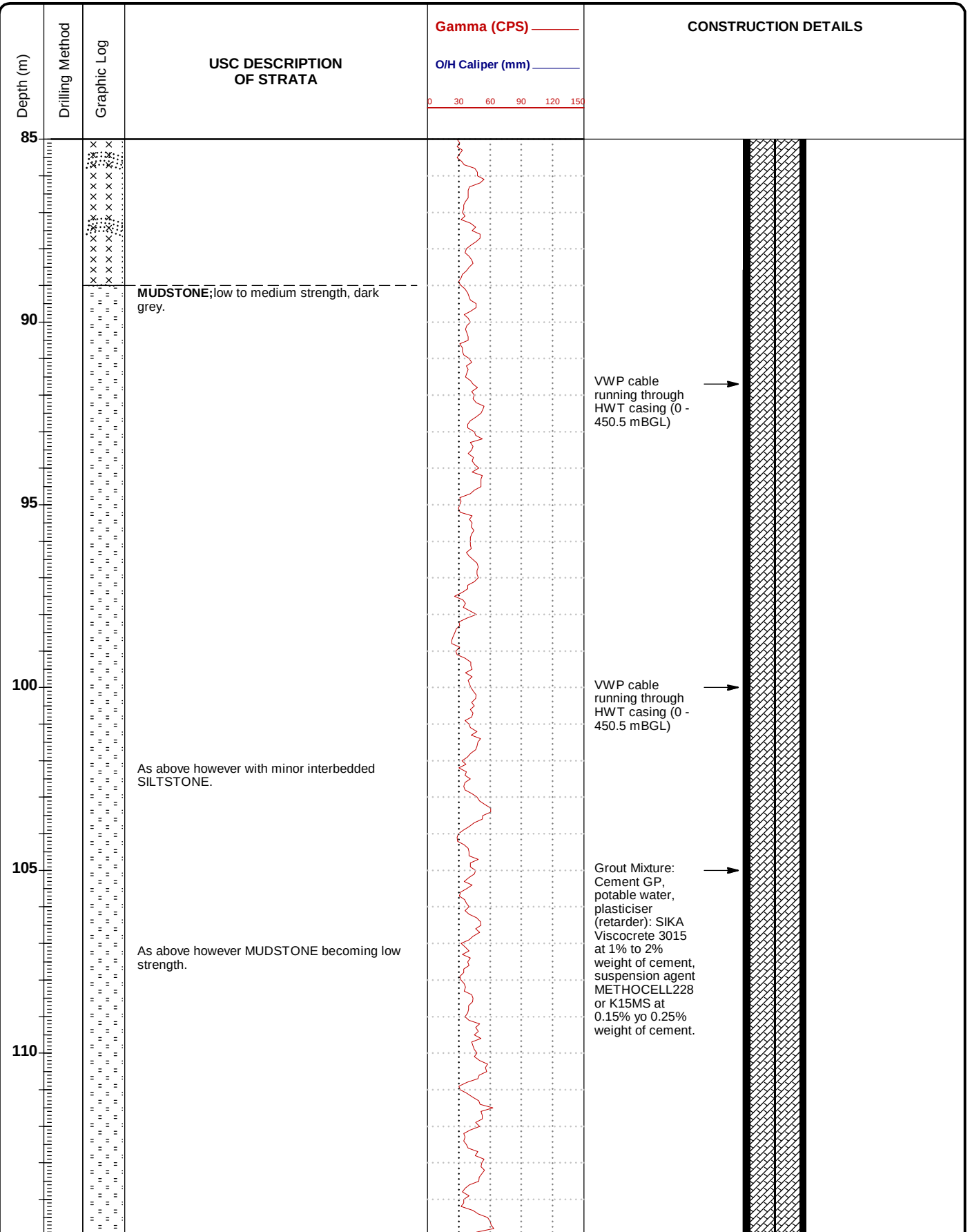


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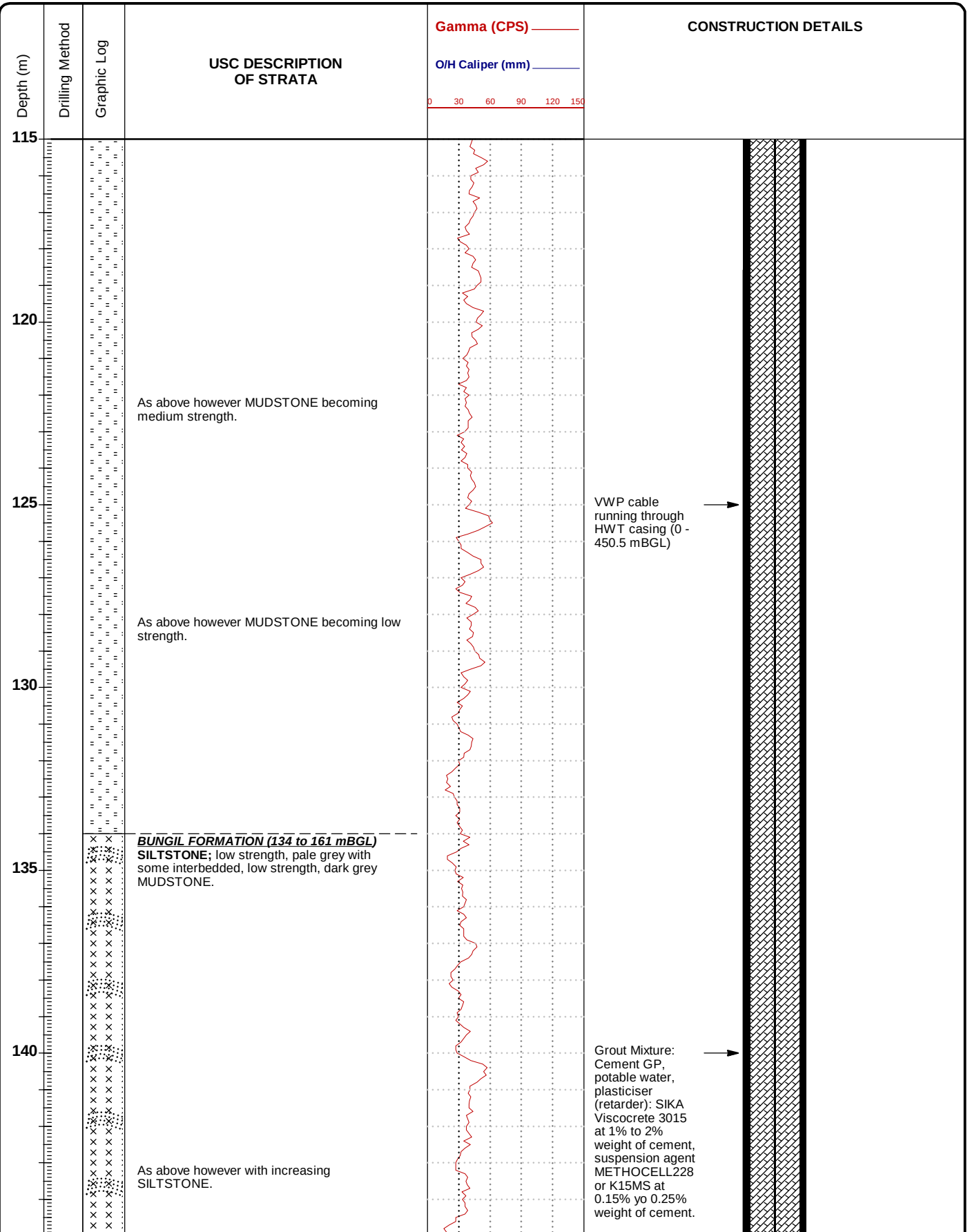


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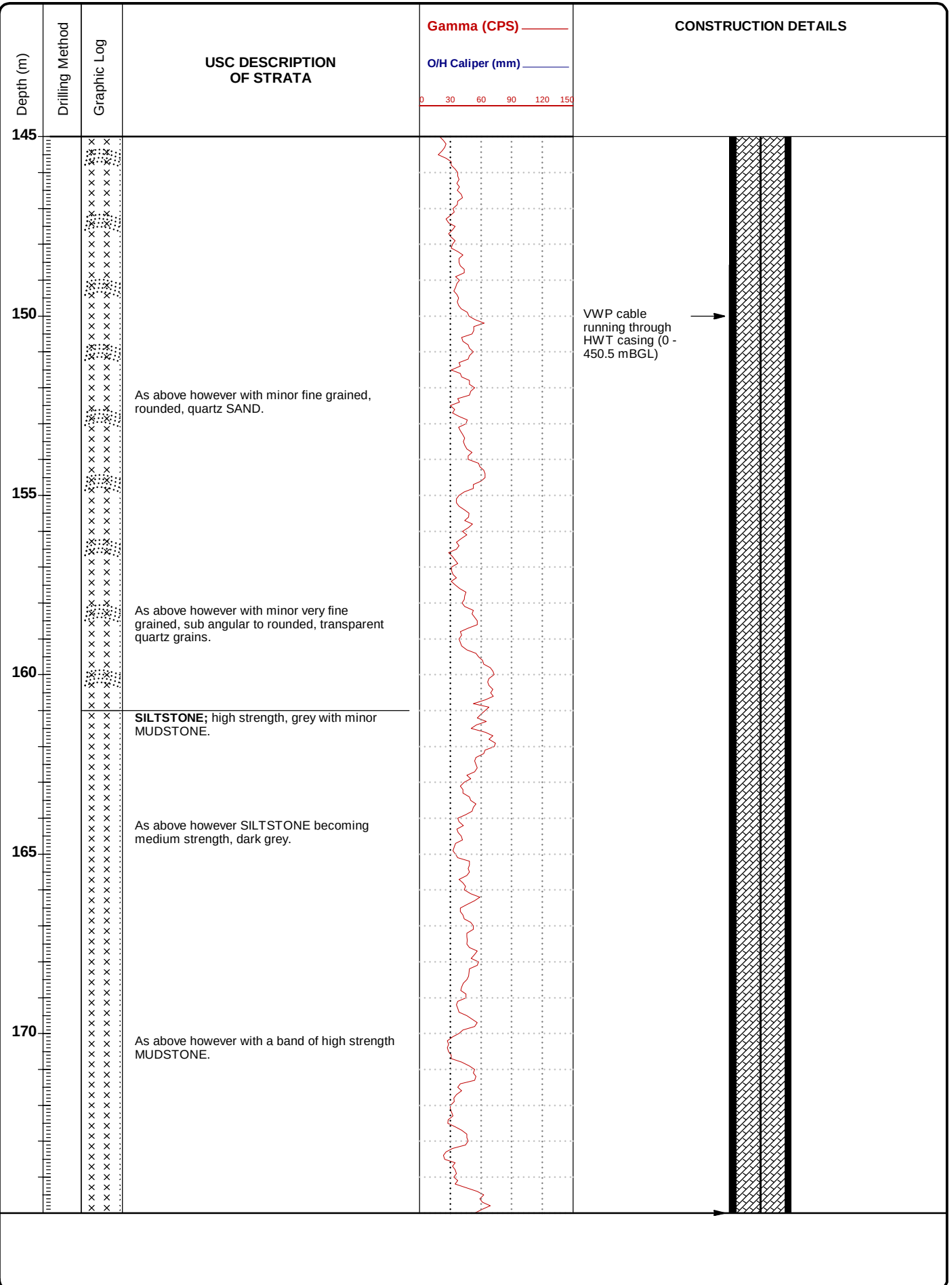


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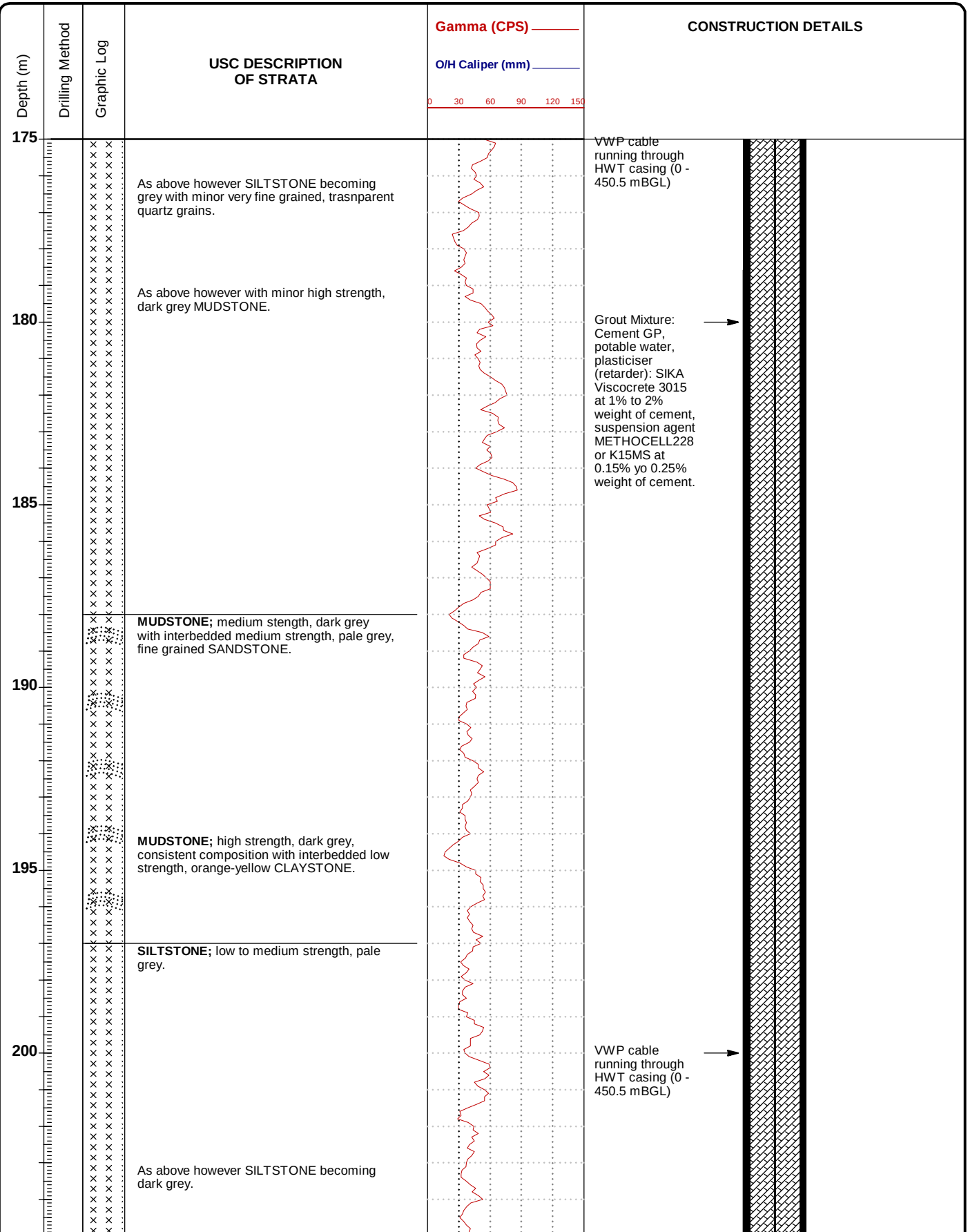


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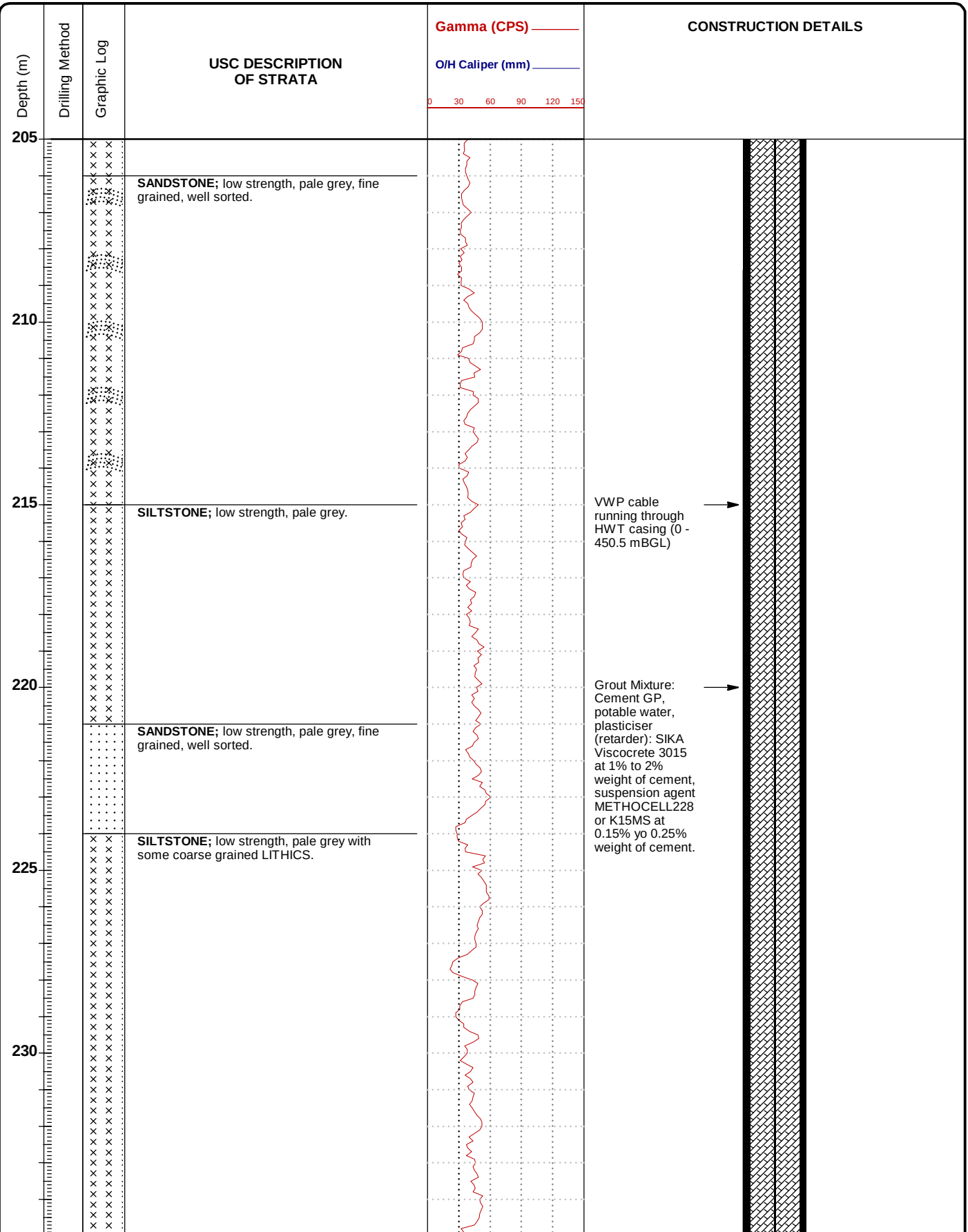


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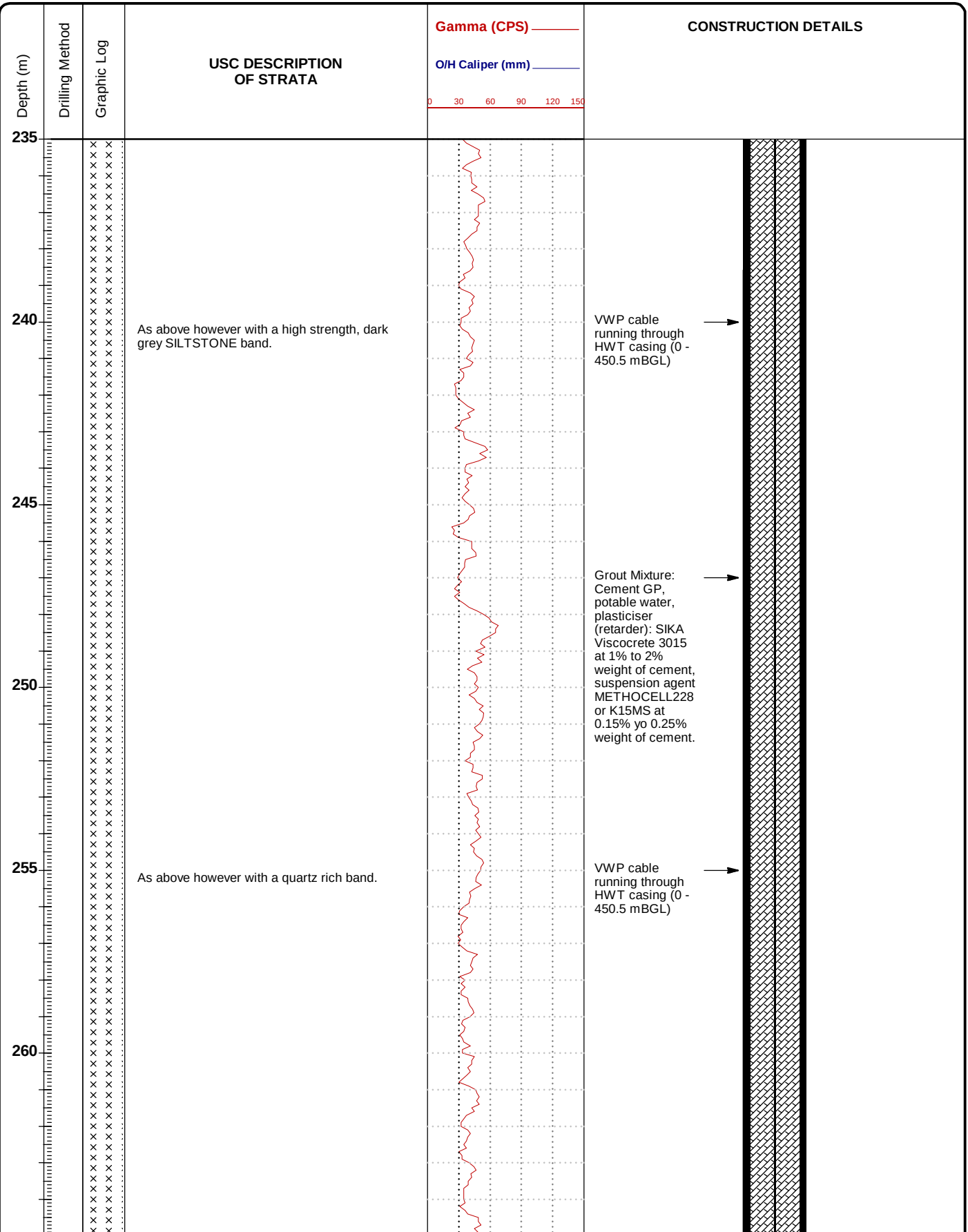


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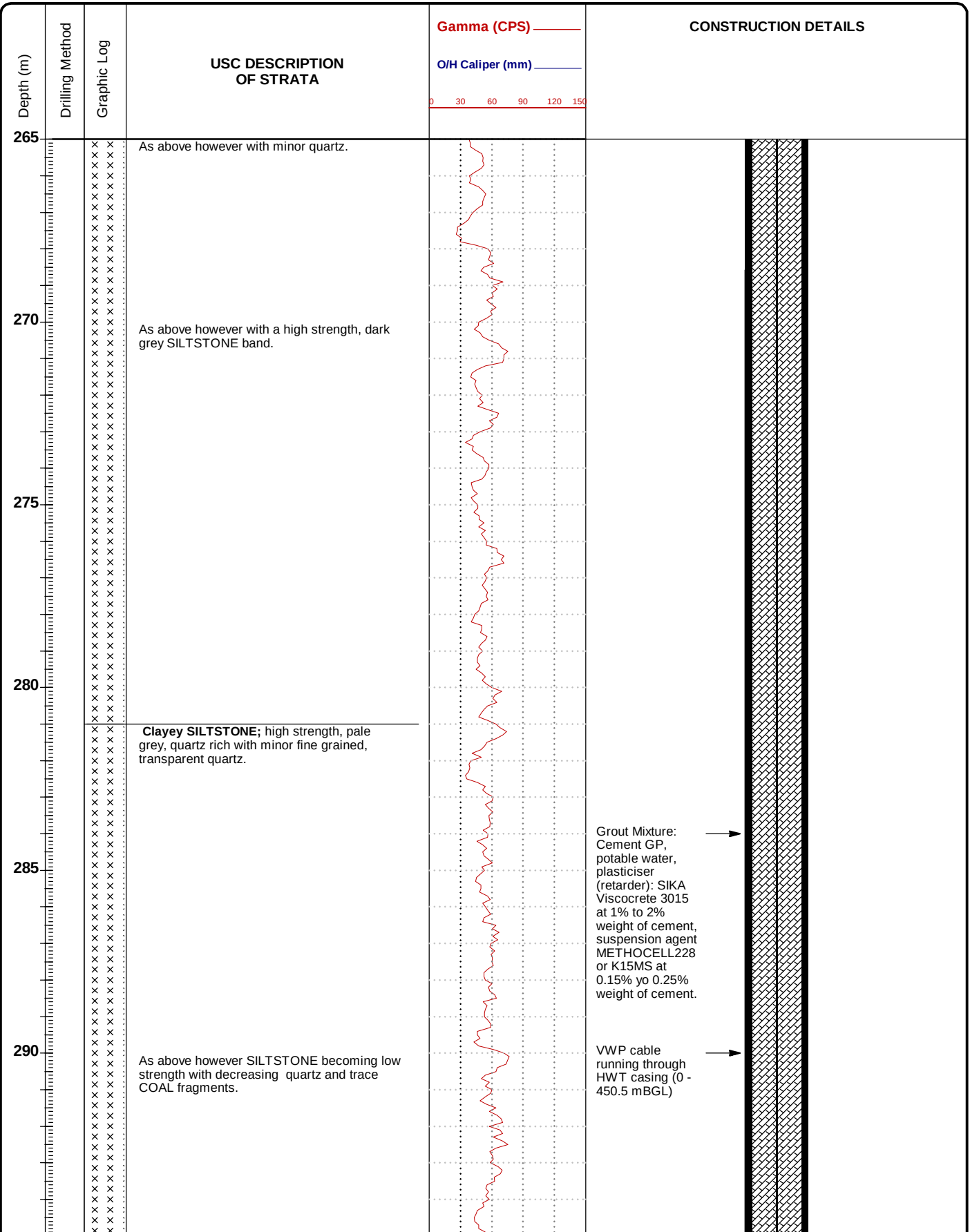


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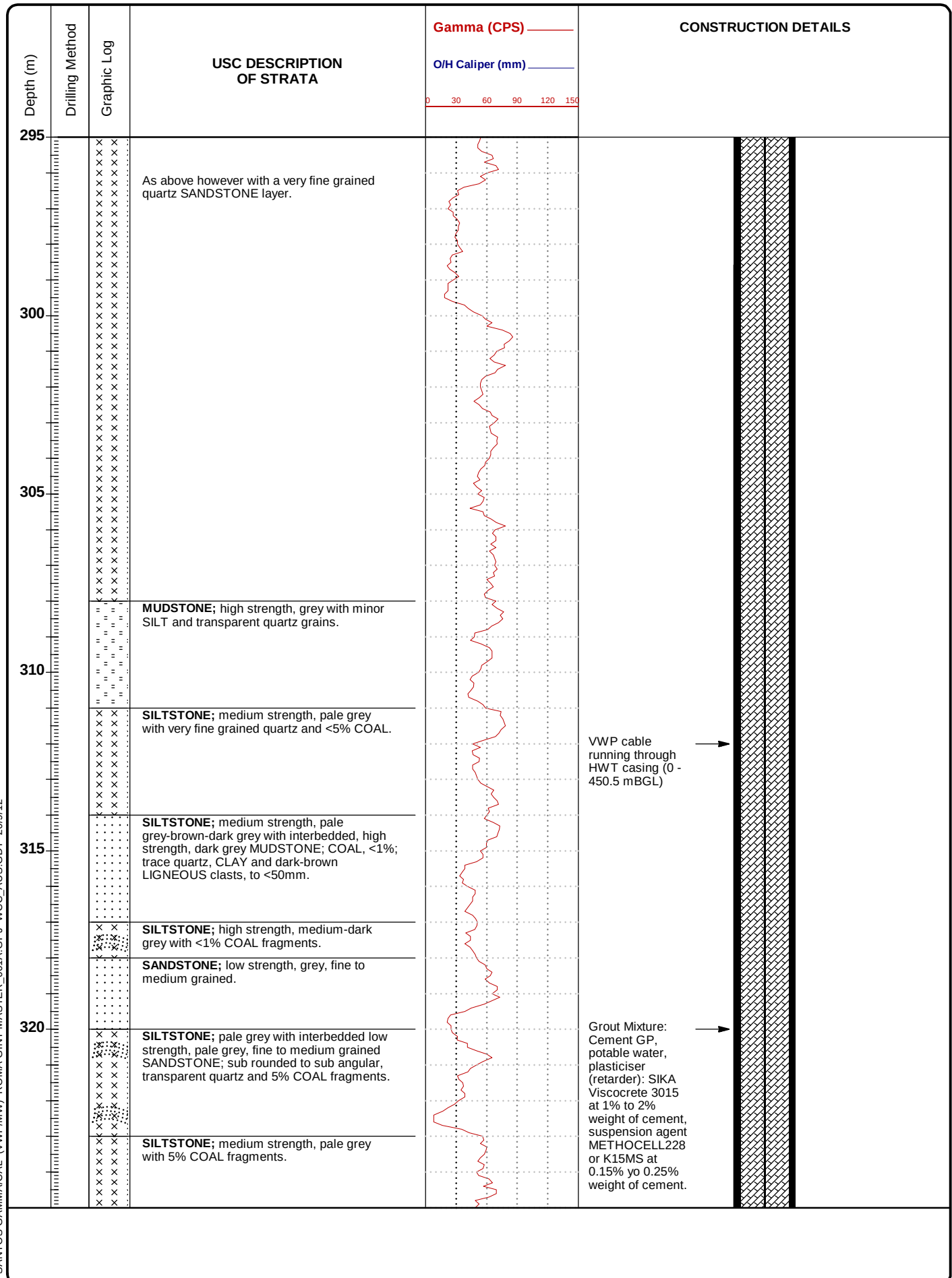


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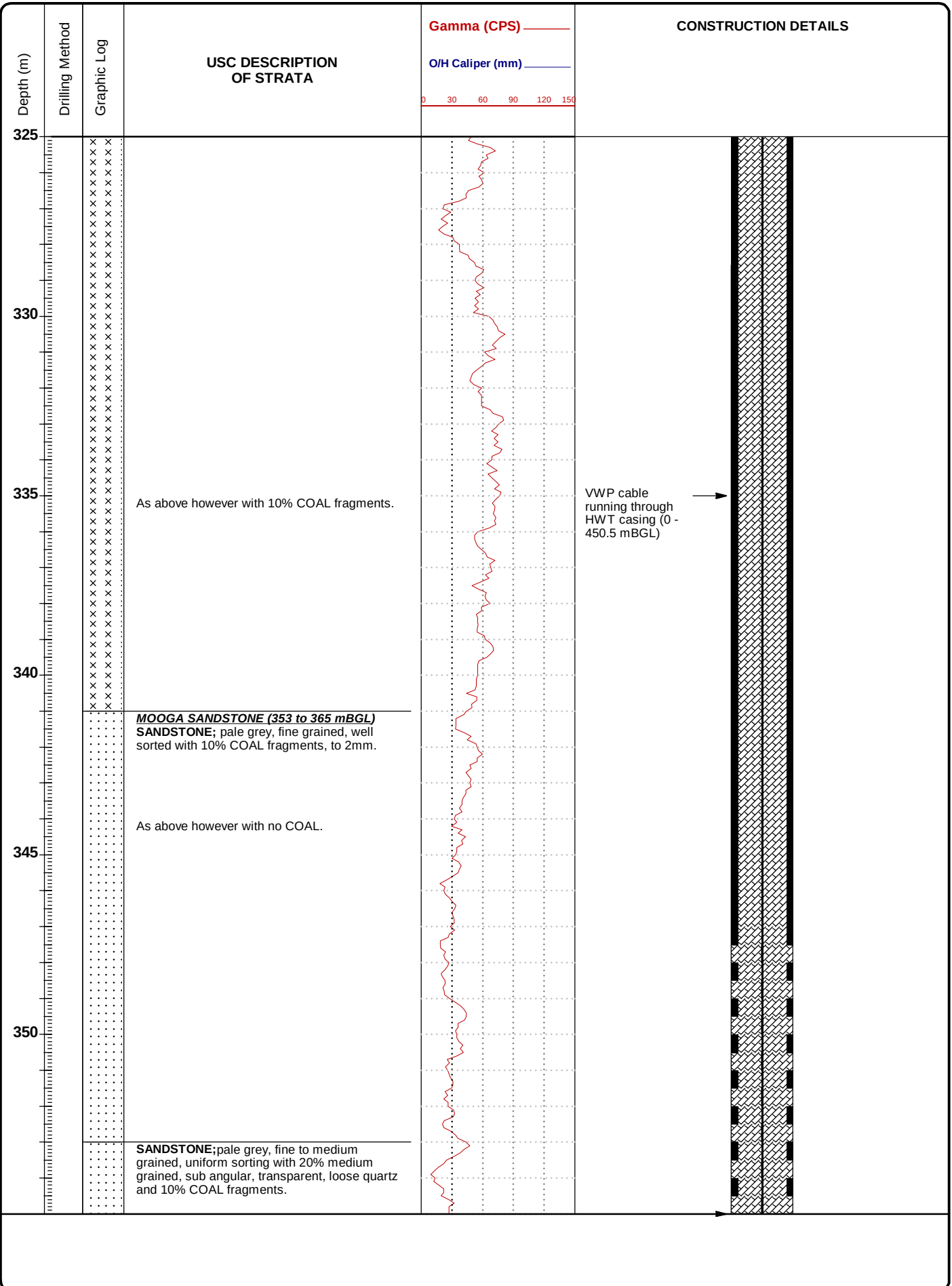


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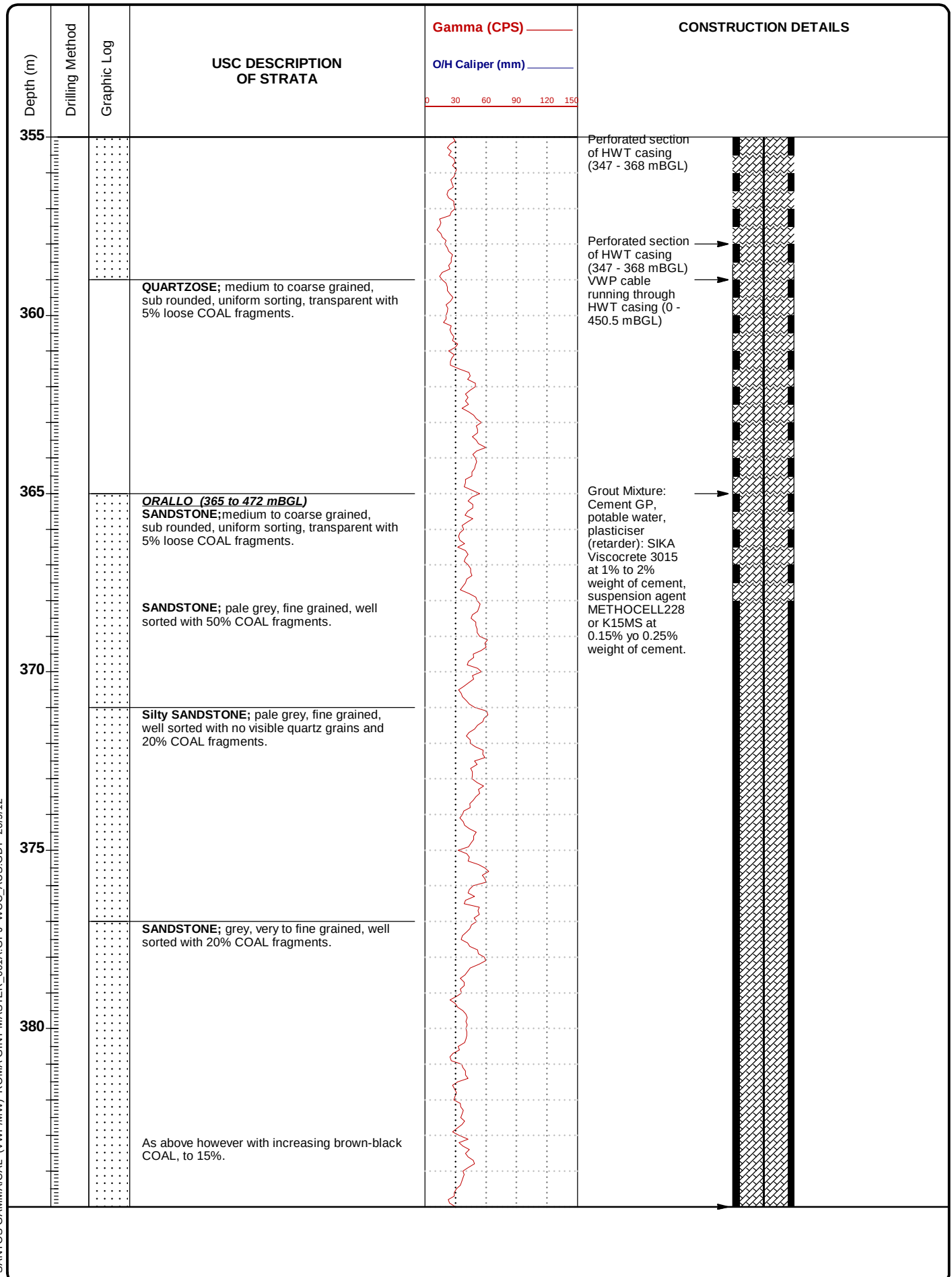


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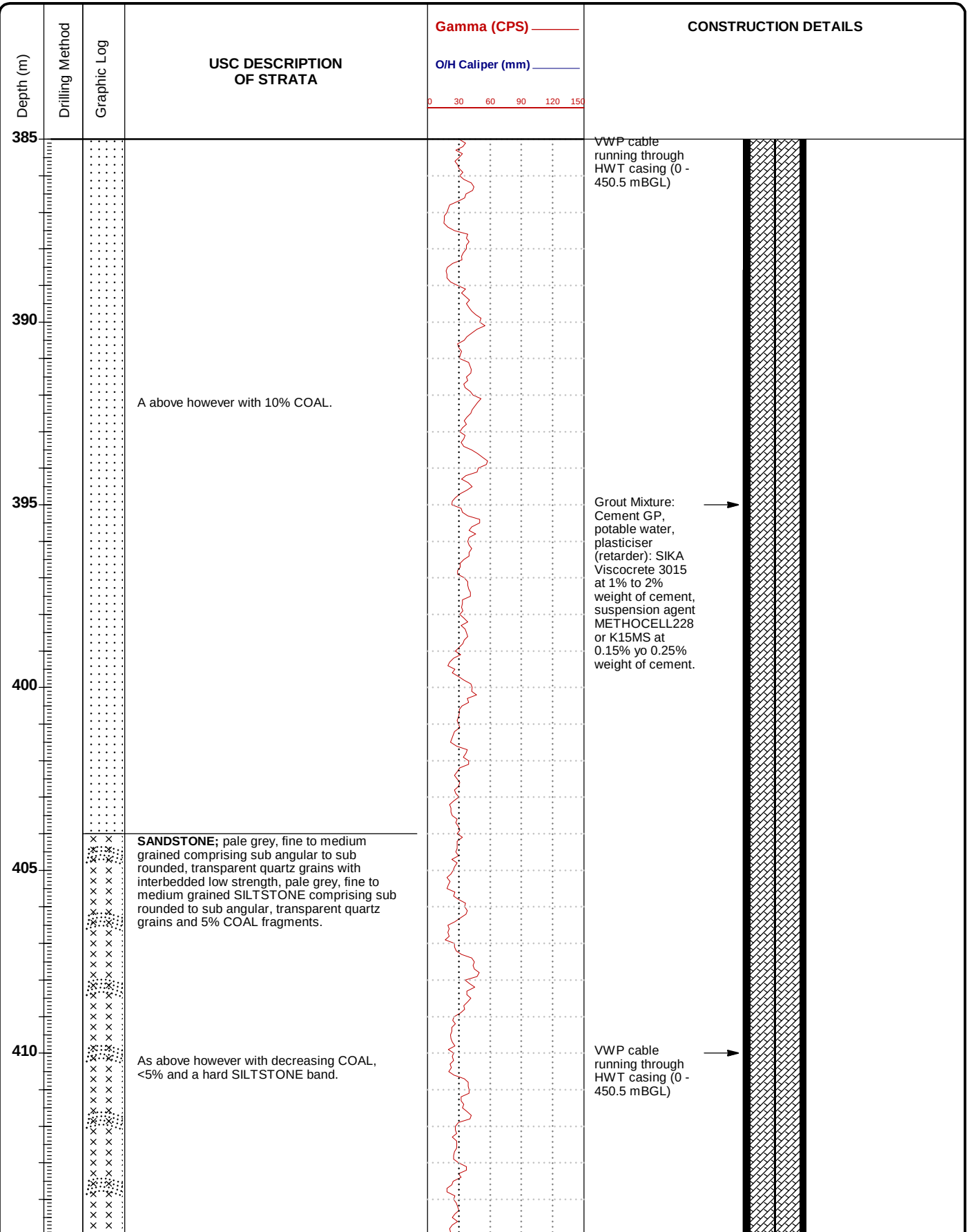


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Document ID: **7699-URS-4-3.3-0033**

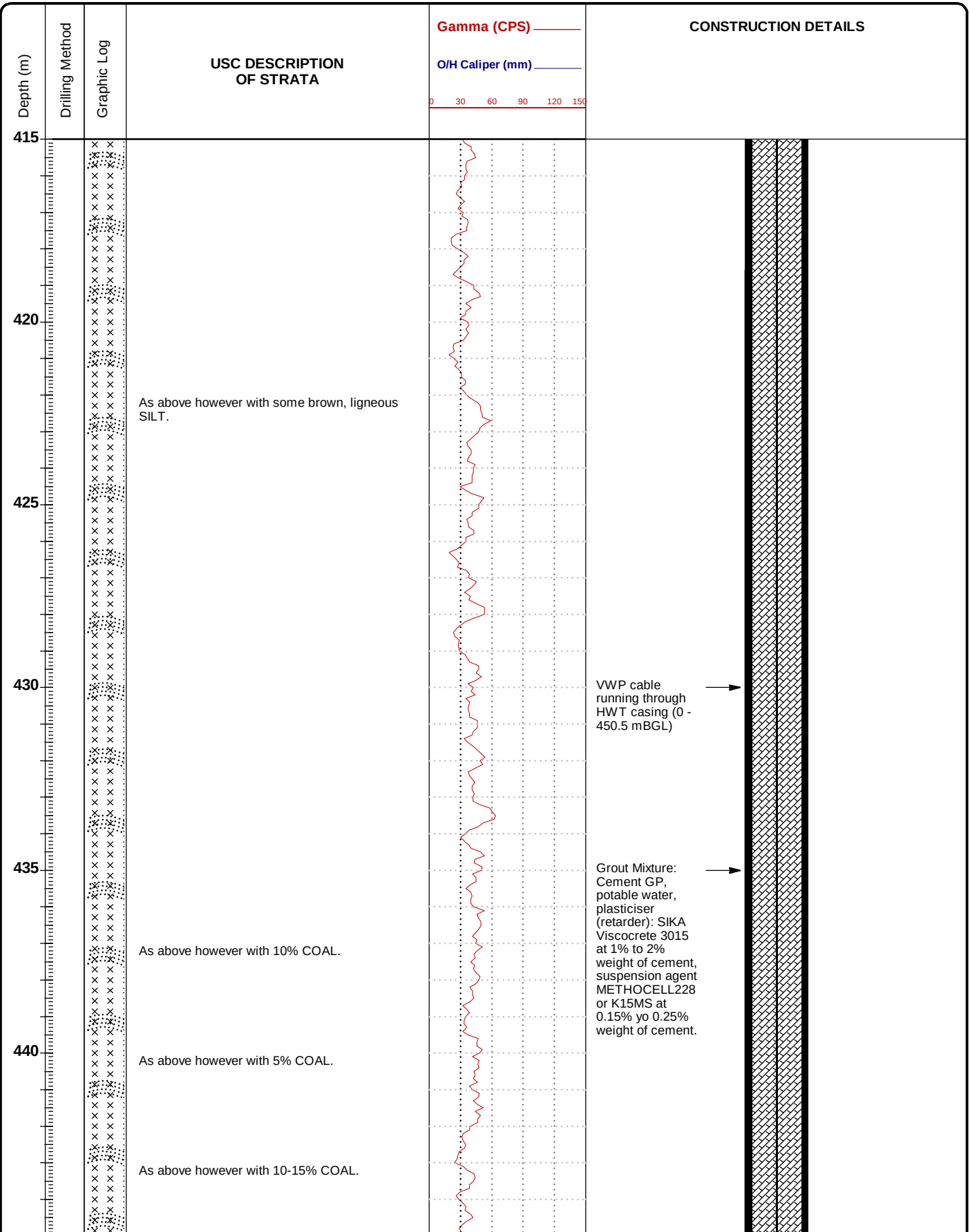


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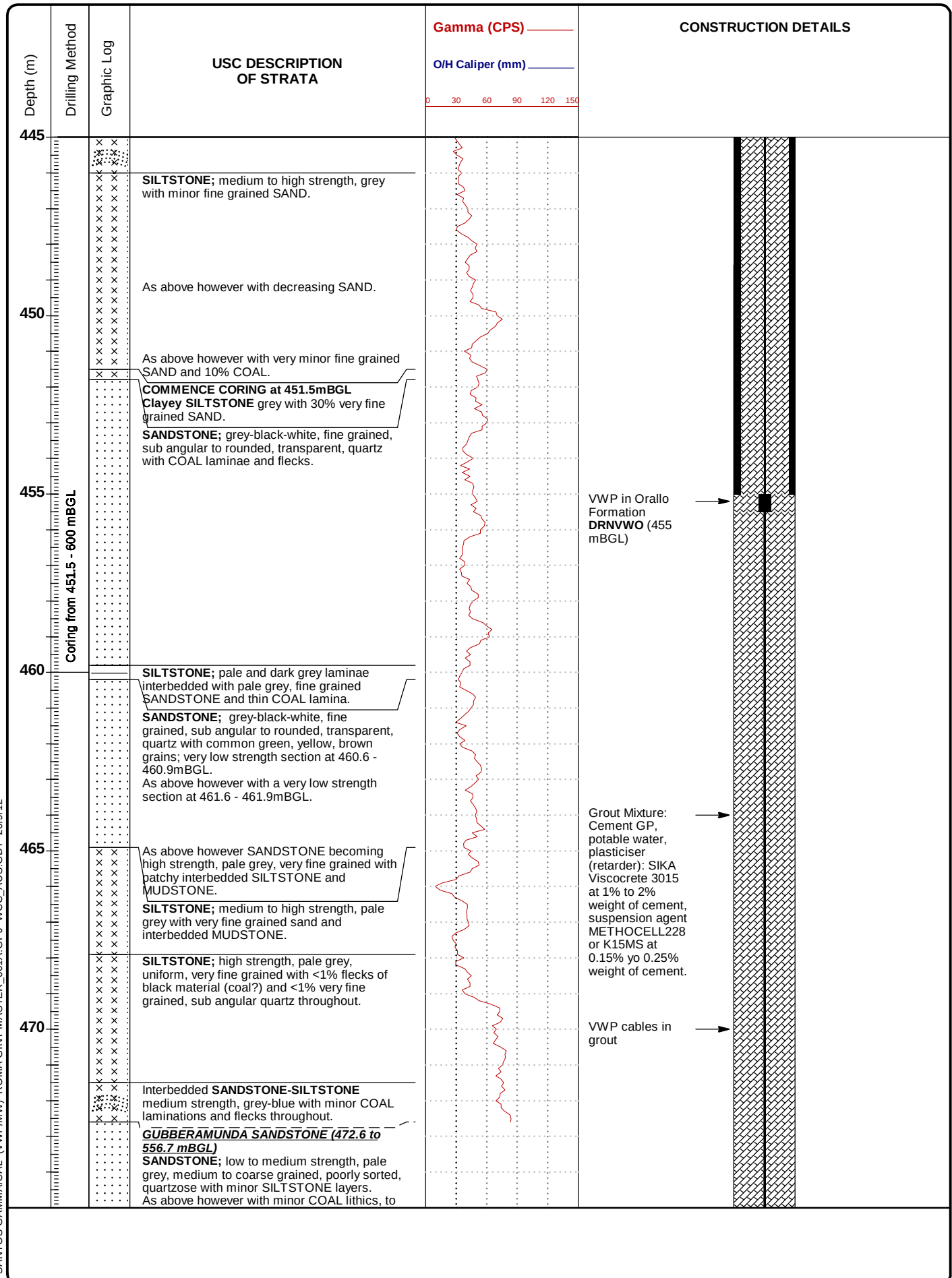


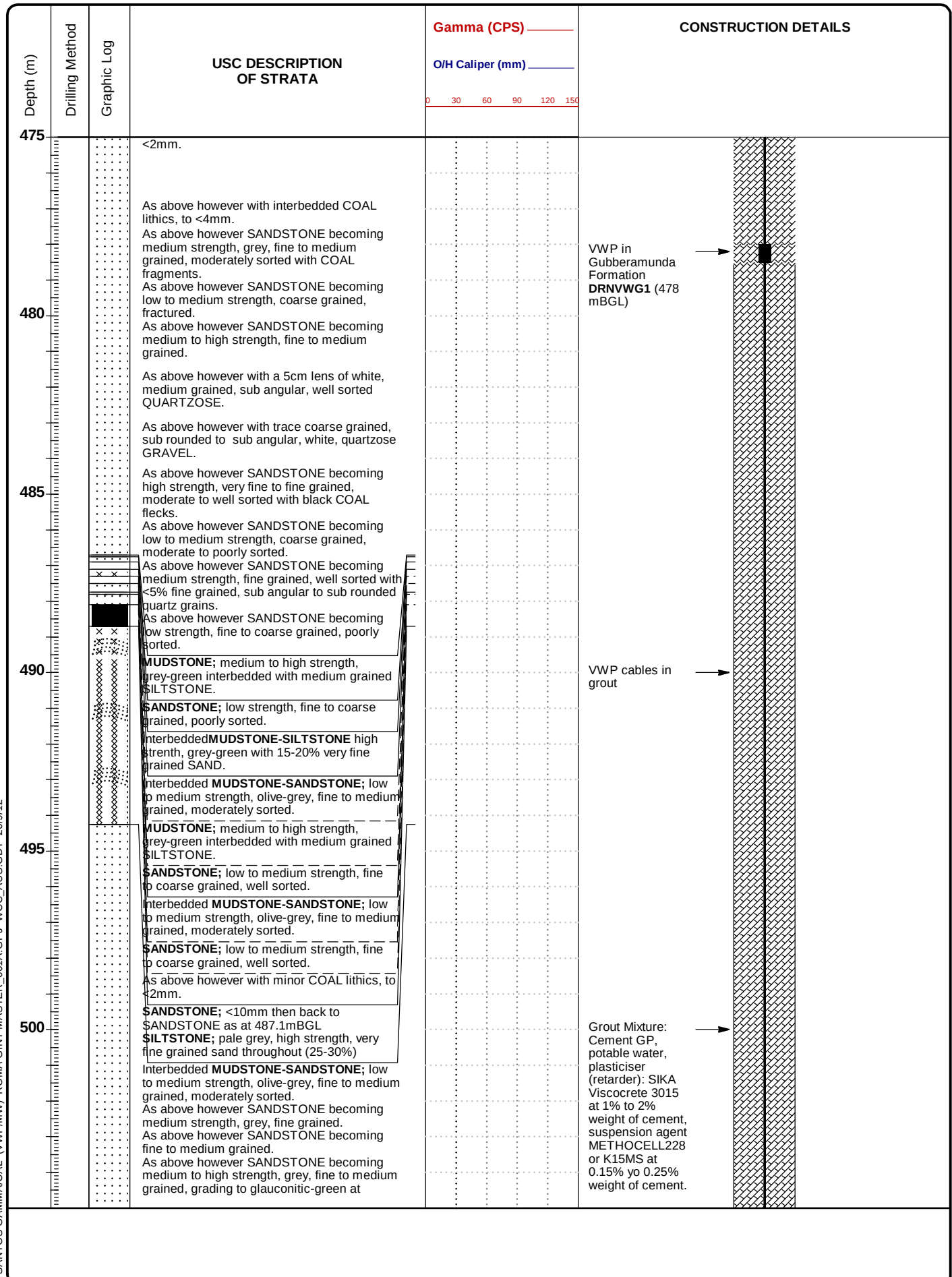
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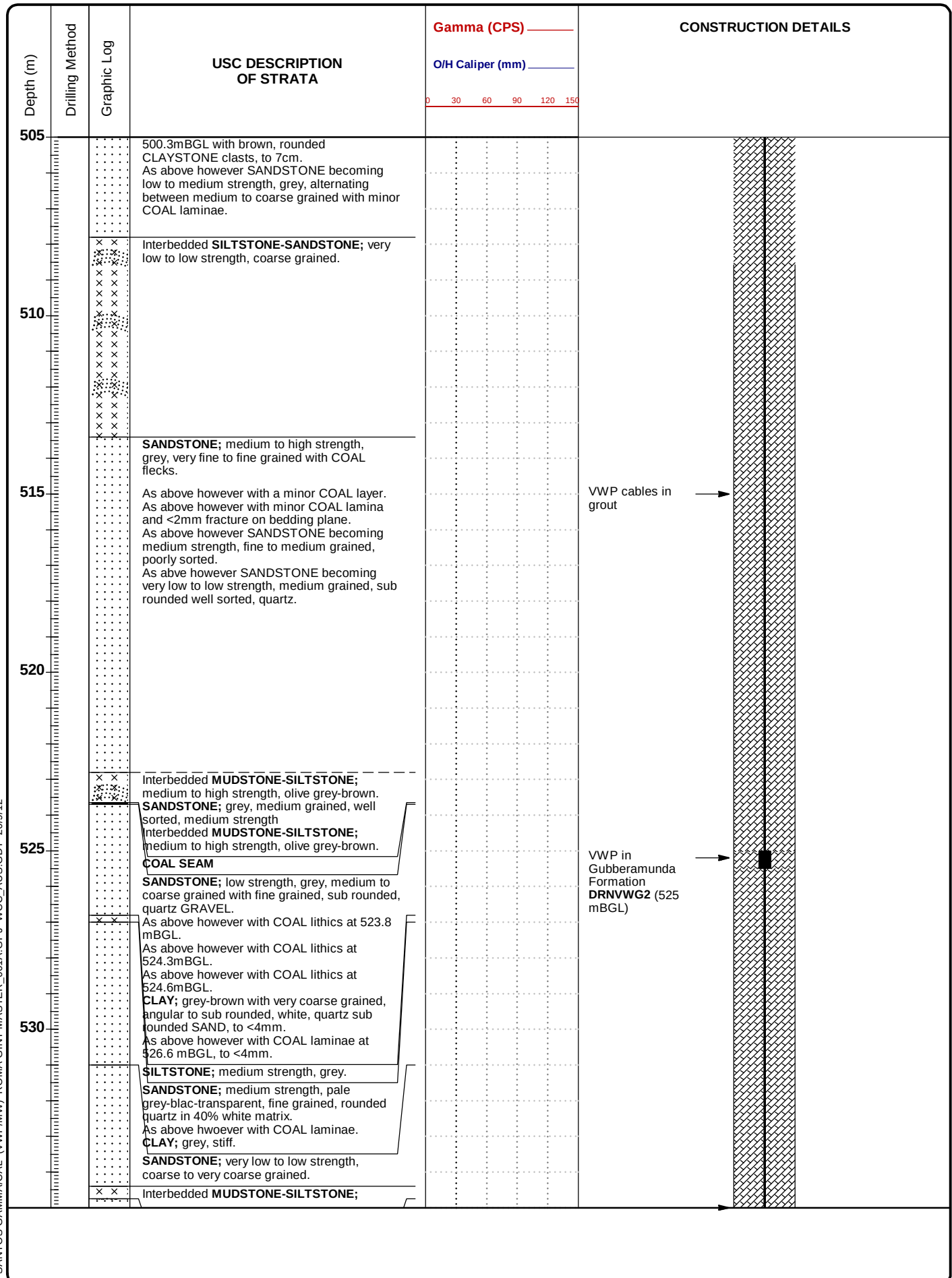


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Depth (m)	Drilling Method	Graphic Log	USC DESCRIPTION OF STRATA	Gamma (CPS)	CONSTRUCTION DETAILS	
				O/H Caliper (mm)		
				0 30 60 90 120 150		
535			medium to high strength, pale to dark grey. SANDSTONE ; medium to coarse grained grading to fine to very fine grained with thin COAL laminations and bedding. MUDSTONE ; dark grey, very hard with COAL layers at 536mBGL (0.1m) and 536.4mBGL (0.1m).		VWP cables in grout	
540			SANDSTONE high strength, fine to medium grained with very minor COAL flecks. As above however with 2% interbedded COAL grains/fragments. As above however SANDSTONE becoming medium strength, grey, fine grained with COAL flecks and seams; trace fine to medium grained, sub angular, transparent-opaque quartz grains. CLAY ; grey. As above however with increasing quartz. As above however with minor quartz and a 0.1m COAL seam at 541mBGL. As above however coarse grained quartz, sub angular, clear/white/opaque interbedded into grey SANDSTONE, with minor coal flecks throughout COAL seam layer (0.03m), 541.7mBGL As above however SANDSTONE becoming coarse to very coars with minor COAL flecks. As above however SANDSTONE becoming fine grained with very minor cross bedded COAL laminations and minor interbedded grey, hard SILTSTONE.		Grout Mixture: Cement GP, potable water, plasticiser (retarder): SIKA Viscocrete 3015 at 1% to 2% weight of cement, suspension agent METHOCELL228 or K15MS at 0.15% yo 0.25% weight of cement.	
545			As above however with a very minor COAL lens at 543.4 mBGL. As above however with a 0.02m grey, hard, cross bedded SILTSTONE. As above however with a 0.01m COAL seam at 545.2 mBGL.			
550			QUARTZOSE ; coarse to very coarse grained, sub angular, well sorted, opaque cemented with a very minor fine grained matrix. As above however with a 0.01m COAL seam at 547.4 mBGL. As above however with a 0.01m COAL seam at 548.1 mBGL. As above however with a 0.01m COAL seam at 548.5 mBGL. As above however with a 0.01m COAL seam at 548.7mBGL. As above however with a 0.01m COAL seam at 550 mBGL. As above however with a 0.02m COAL seam at 550.4 mBGL.		VWP cables in grout	
555			Interbedded SANDSTONE ; medium to high strength, grey, fine grained with interbedded, fine grained COAL interbedded laminations and SILTSTONE. WESTBOURNE FORMATION (556.7 to Terminal Depth - 600 mBGL) Interbedded SILTSTONE-MUDSTONE ; high strength, grey-green. As above however SILTSTONE-MUDSTONE becoming fine grained quartzose with minor fine grained, sub rounded COAL, to <2mm; mica flecks observed in horizontal fractures.			
560			Interbedded SILTSTONE-SANDSTONE ; high strength, grey-green with thin laminae. As above however with a thin COAL			

VWP cables in
grout

Grout Mixture:
Cement GP,
potable water,
plasticiser
(retarder): SIKA
Viscocrete 3015
at 1% to 2%
weight of cement,
suspension agent
METHOCELL228
or K15MS at
0.15% yo 0.25%
weight of cement.

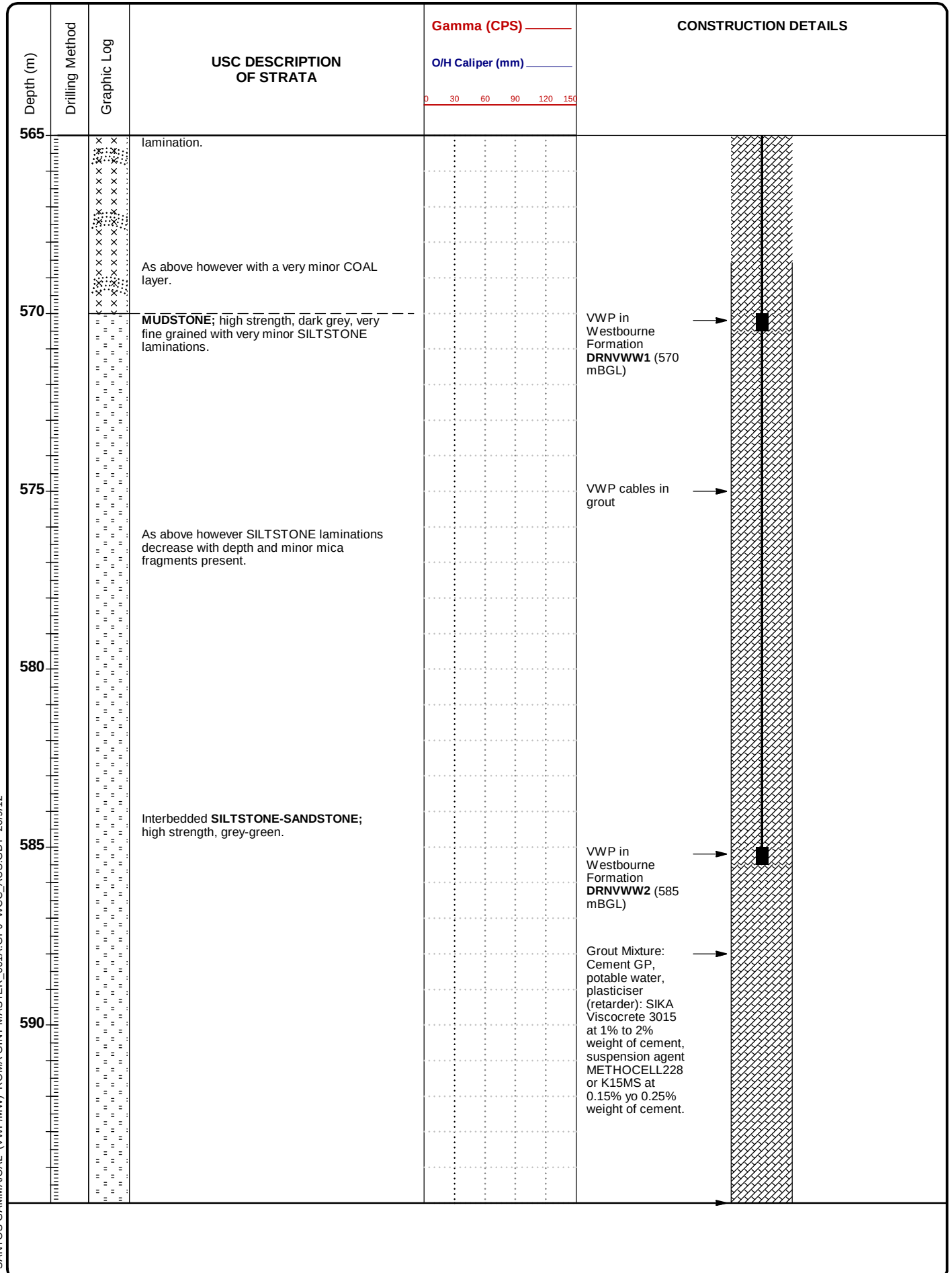
VWP cables in
grout

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ROM_DRN_VWP_W (FINAL)

Sheet 21 of 21

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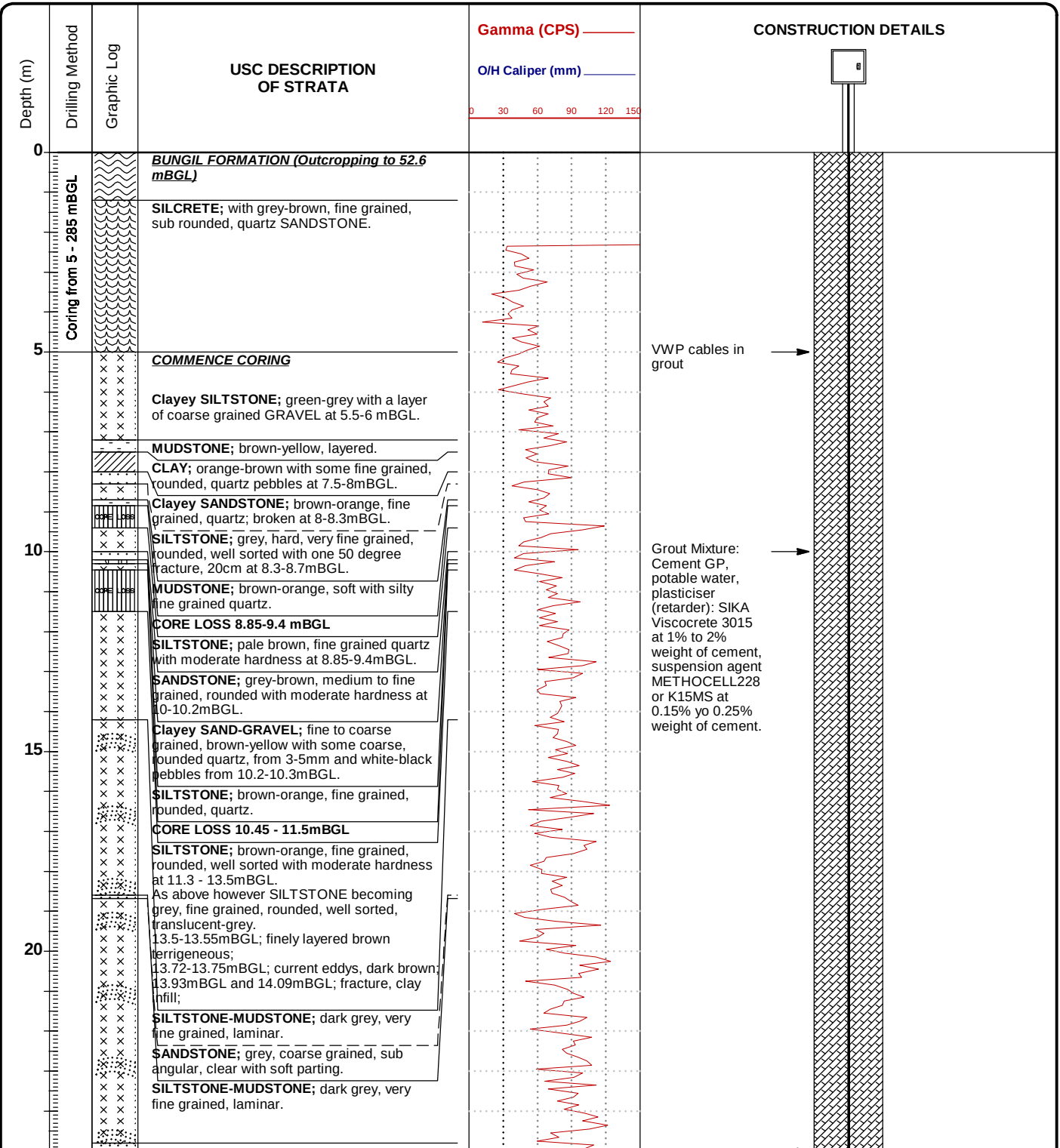
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Project No.: **42626577**

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Depth (m)	Drilling Method	Graphic Log	USC DESCRIPTION OF STRATA	Gamma (CPS) _____	CONSTRUCTION DETAILS
				O/H Caliper (mm) _____	
				0 30 60 90 120 150	
595					GROUT in sump below final VWP (585 mBGL)
600					
605			TARGET DEPTH ACHIEVED. End of Hole at 600 mBGL.		
610					
615					
620					

URS Australia Pty. Ltd. Level 17, 240 Queen St, Brisbane QLD 4000	Phone: (07) 3243 2111 Phone: (07) 3243 2199	Project Name: 2010/12 Roma Drilling Programme	Client: Santos Ltd	Document ID: 7699-URS-4-3.3-0007
Drilling Contractor: Spaulding Drillers		Project No.: 42626577	Location: Roma, QLD	
Logged By: FC, KVC	Bore Size: HQ3 to 150 mm	Casing RL: 337.98 mAHD	Drill Type: Coring (HQ)	
Checked By: TS	Total Depth: 299.0 m	Coordinates: Lat: -26.465228 Long: 149.014403	Drill Model: G&K 850	
Date Started: 10-6-11	Casing Size: mm	Permit No: GDRF11-002	Drill Fluid: Mud (CR650)	
Date Finished: 27-6-11				



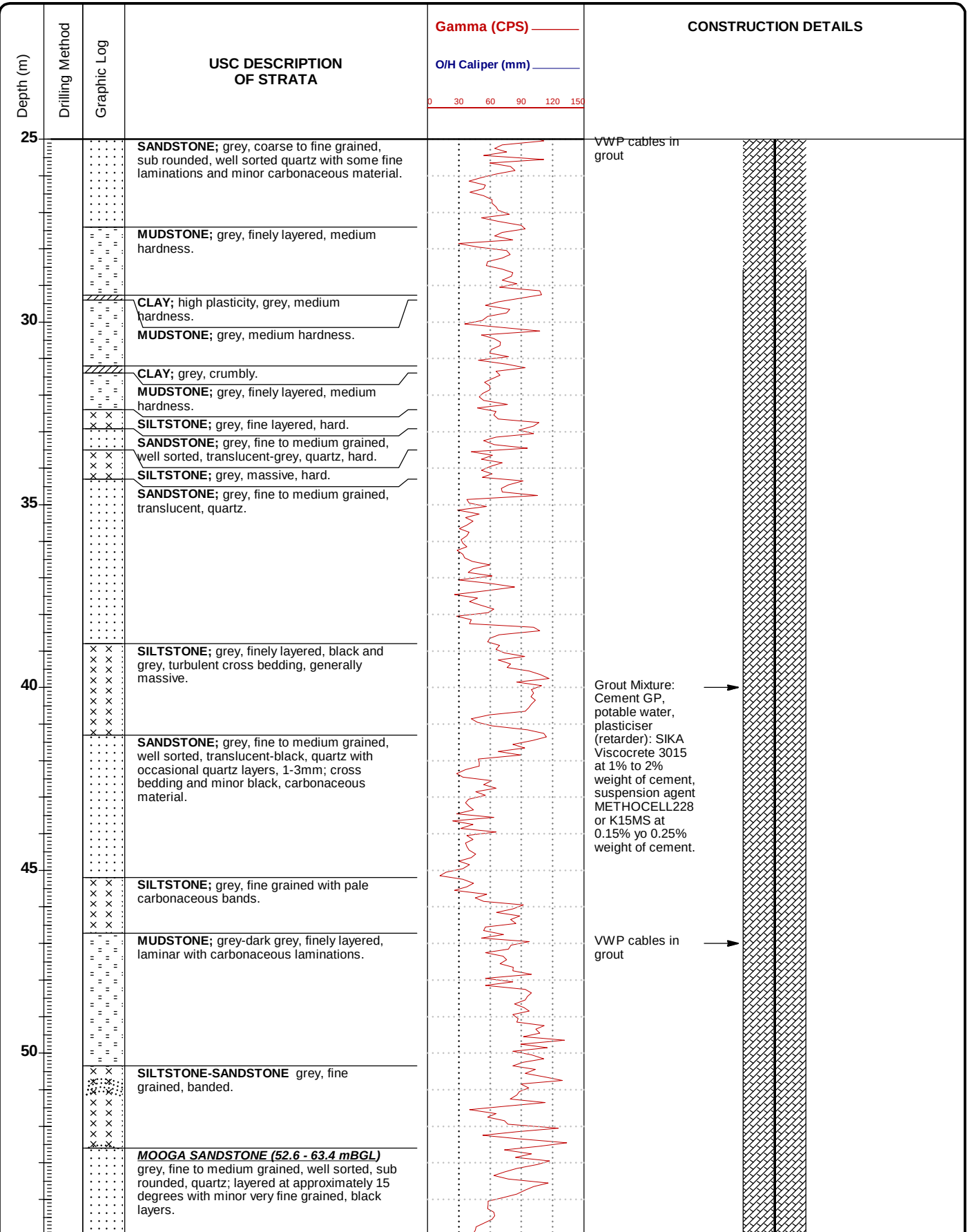
Remarks: Significant washouts of the formation occurred throughout the Gubberamunda Sandstone and the drilling was completed using mud rotary from 285 to 299 mBGL.
A 12 metre length of the HWT casing came unscrewed and it was not possible to remove it from the borehole, it fell down the hole through the washouts and remains at 251.4 - 264.4 mBGL.
Downhole geophysics is from the groundwater monitoring bore approximately 40 metres from the corehole.

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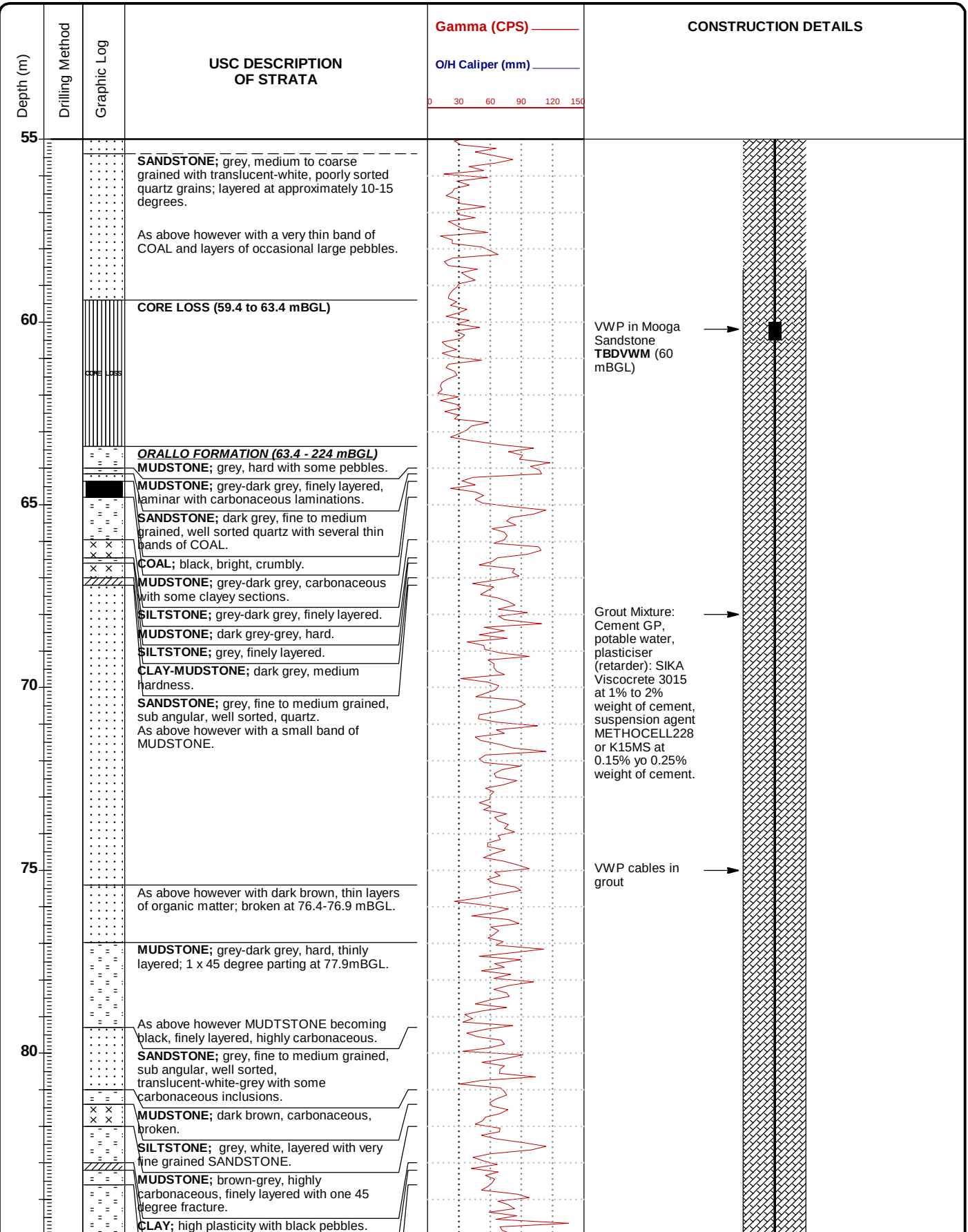


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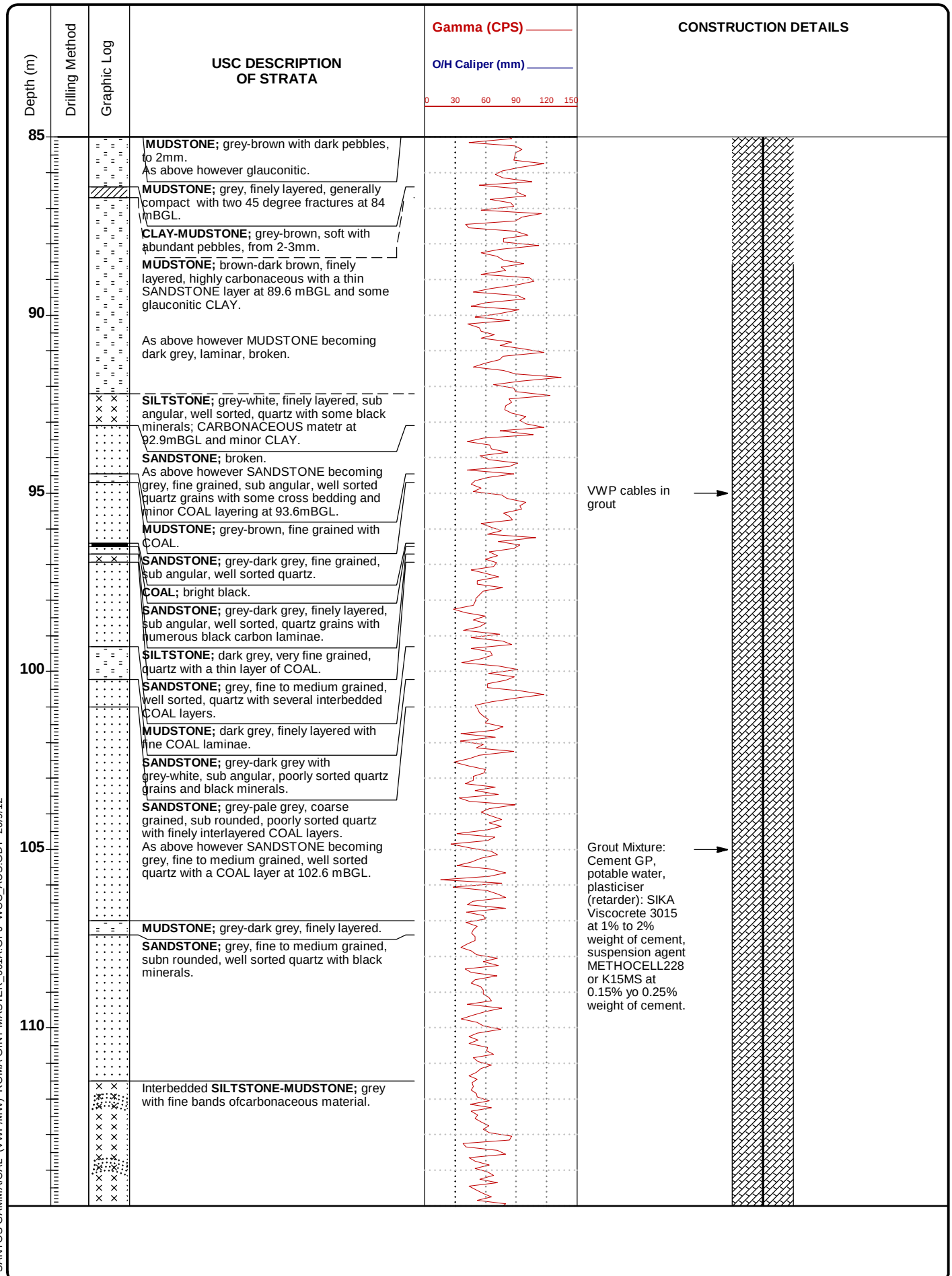


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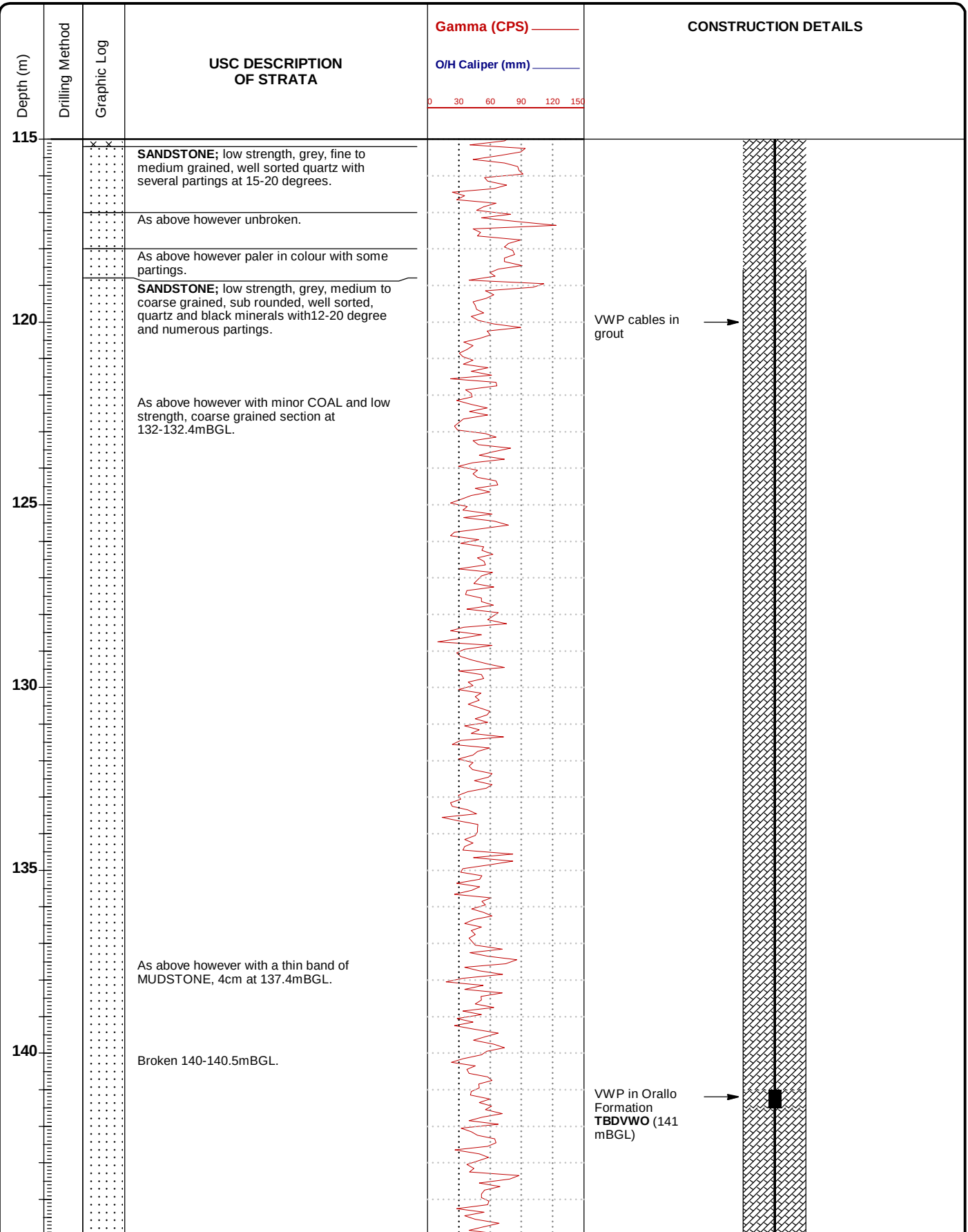


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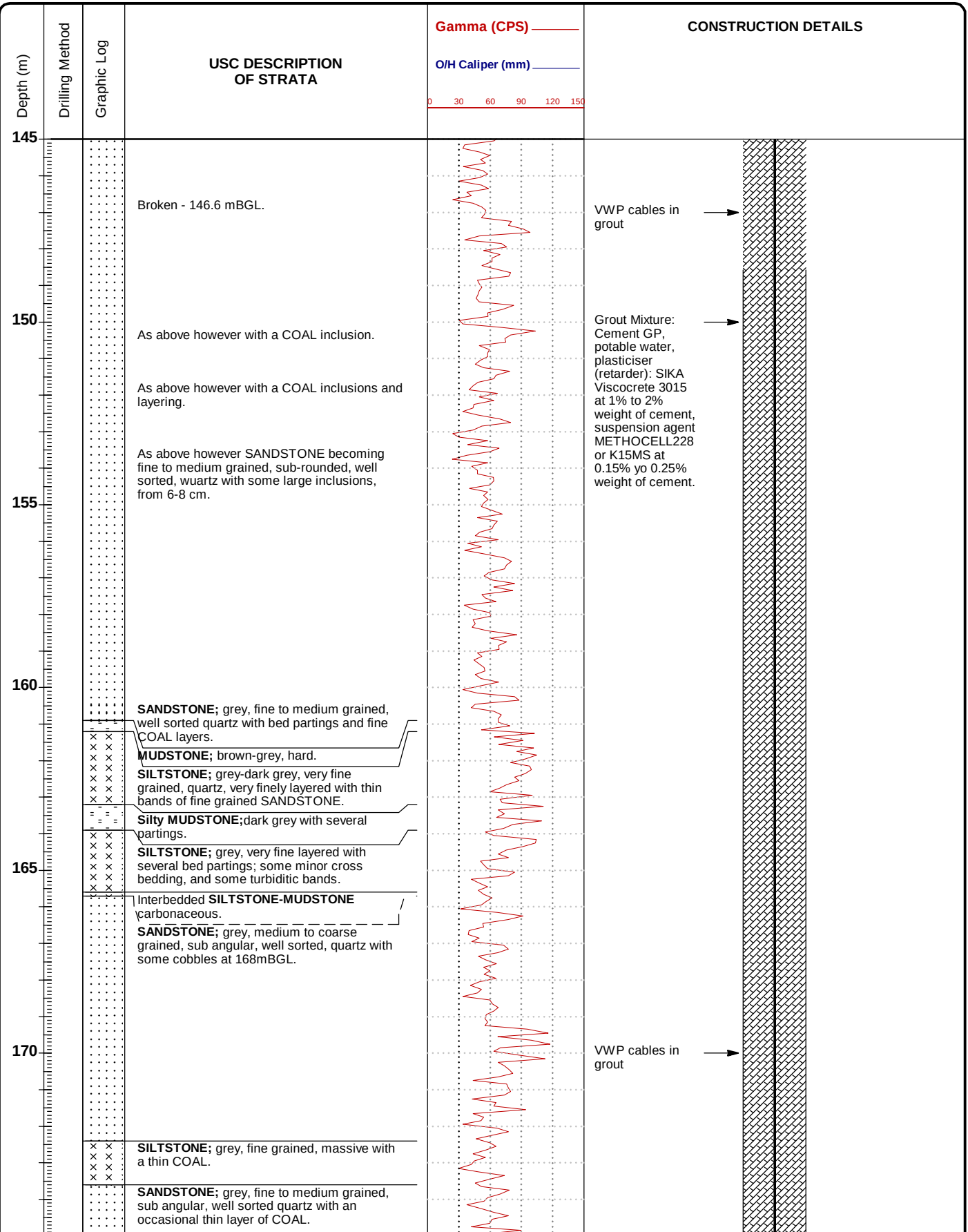


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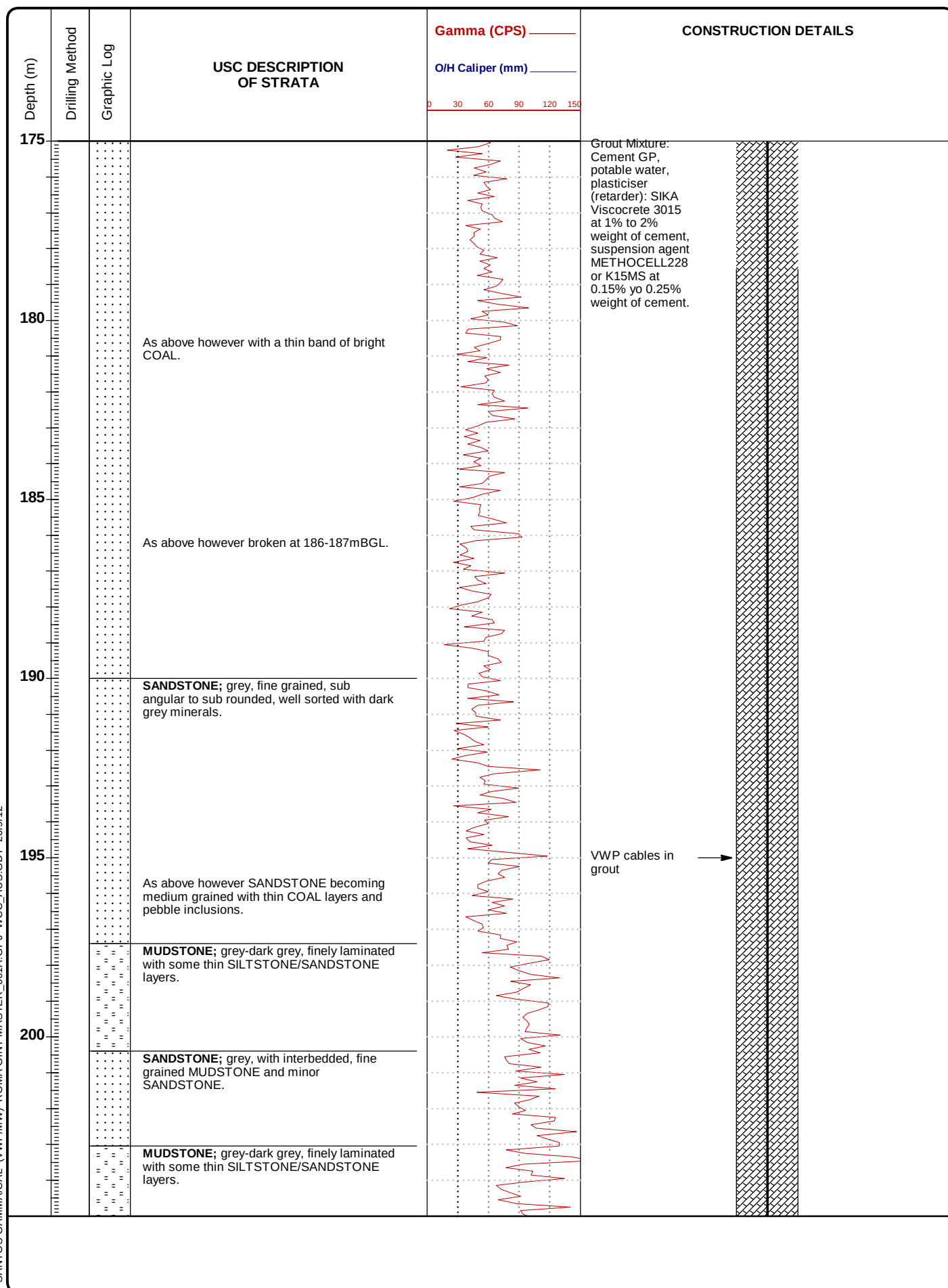


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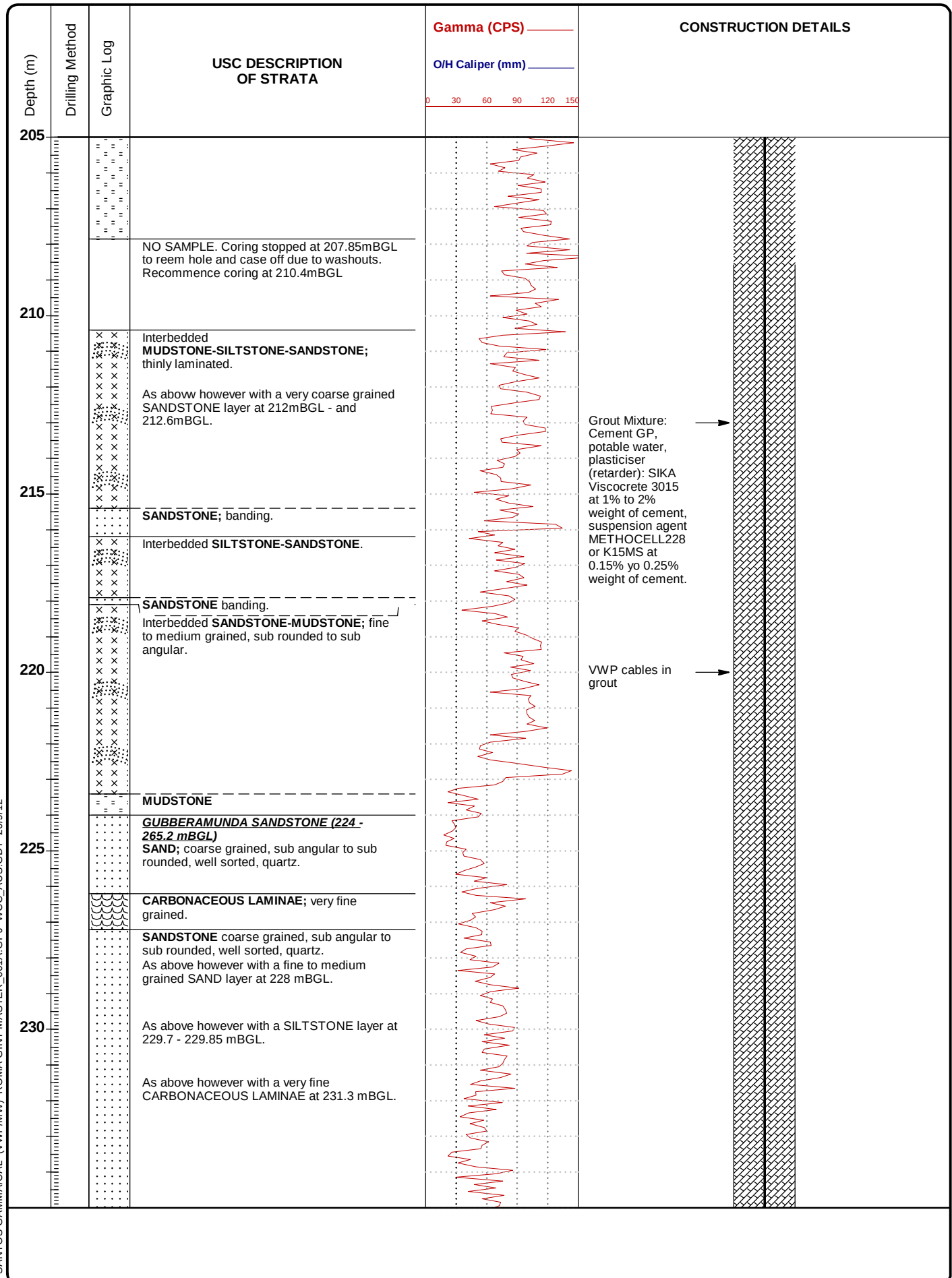


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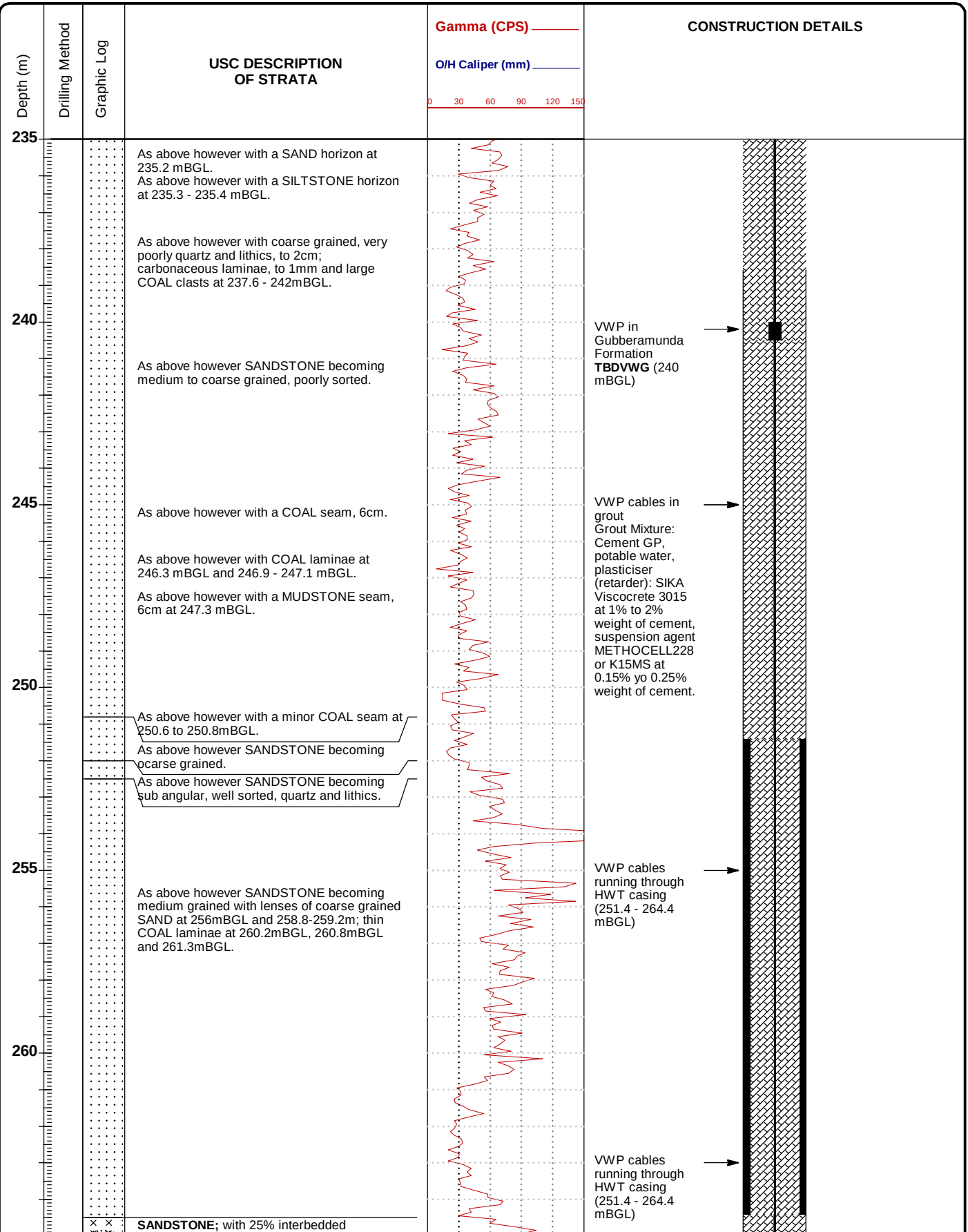


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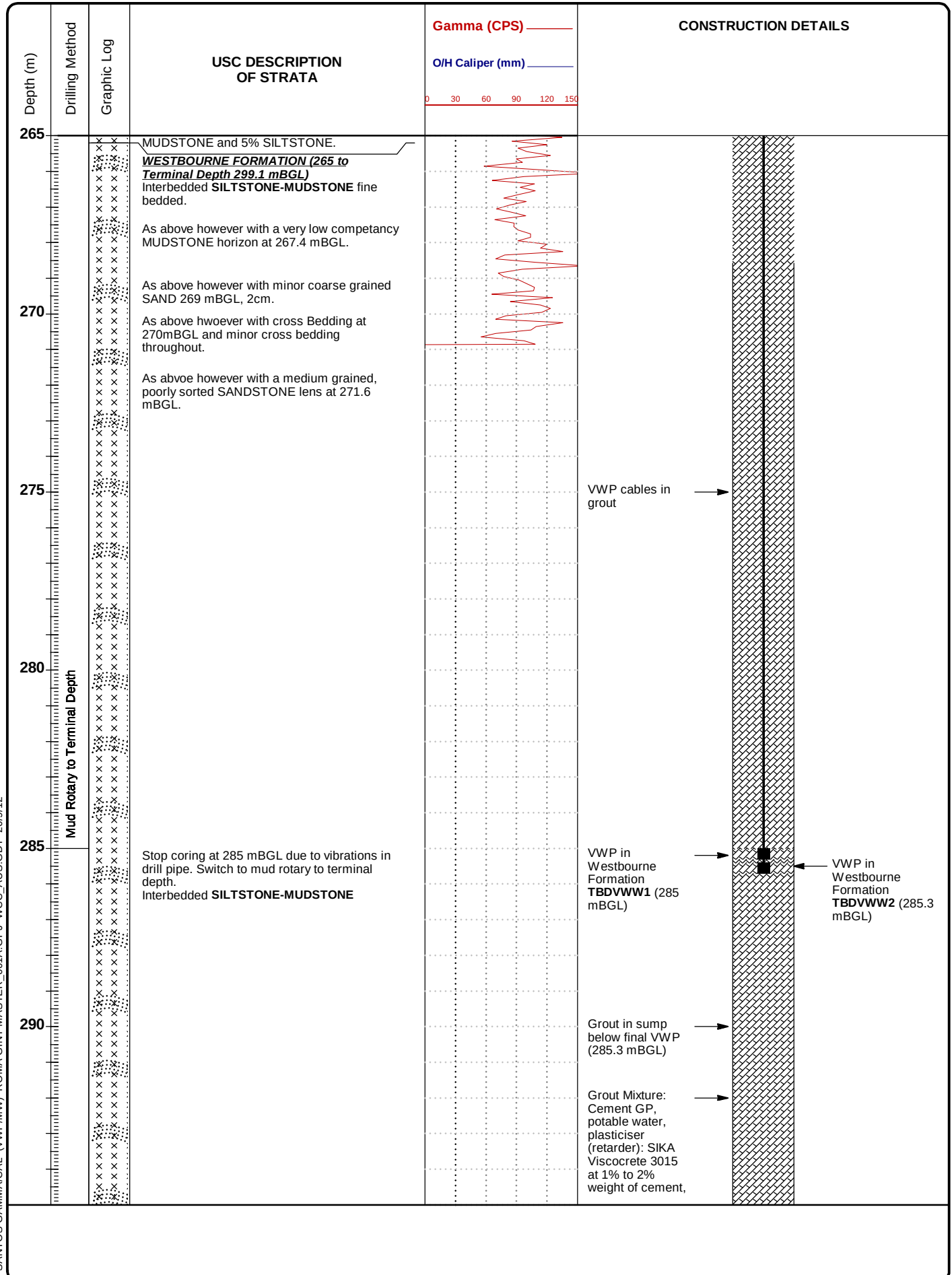


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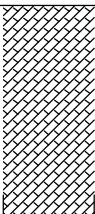


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Project No.: **42626577**

Document ID: **7699-URS-4-3.3-0007**

Depth (m)	Drilling Method	Graphic Log	USC DESCRIPTION OF STRATA	Gamma (CPS) _____	CONSTRUCTION DETAILS
				O/H Caliper (mm) _____	
295					Suspension agent METHOCELL228 or K15MS at 0.15% to 0.25% weight of cement. 
300			End of Hole. Target depth achieved at 299 mBGL		
305					
310					
315					
320					

URS Australia Pty. Ltd.
Level 17, 240 Queen St, Brisbane QLD 4000Phone: (07) 3243 2111
Phone: (07) 3243 2199Project Name: **Santos Deep
Drilling Programme**Client: **Santos Ltd**

Document ID:

130228_BBNGWH02_DRILLLOG_FINAL_REV1

Drilling Contractor: **Spaulding Drillers**Project No.: **42626910**Location: **Roma**Logged By: **DGP, CF, SC, RF**Bore Dia.: **177.8 mm**Casing RL: **360.53 mAHD**Drill Type: **Mud Rotary**Checked By: **MR**Total Depth: **950.0 m**Coordinates: **Lat: -26.533140**Drill Model: **Foremost 24 HD**Date Started: **6-2-13**Casing I.D.: **102.3 mm****Long: 149.054771**Drill Fluid: **MUD (refer to mud programme)**Date Finished: **22-2-13**Permit No: **GDEQGW12-76**

Depth (m)

Drilling Method

Graphic Log

DESCRIPTION
OF STRATA

CONSTRUCTION DETAILS

Lockable metal
standpipe with
flange

CELLAR

NO SAMPLE

12 1/4" TRICONE

SANDY CLAY: High plasticity, light brown to black with orange mottle, sand is grey, poorly graded, subangular to subrounded, with trace silt

18m: Clay orange to brown, sand is subangular

CLAY: Low to medium plasticity, dark grey, with some siltstone, low strength, grey**SANDY SILTSTONE:** Low strength, white to grey, poorly graded, sand is medium grained, with clay, dark grey

27m: Increasing clay component, very low strength

SILTY MUDSTONE: Very low strength, dark grey, thinly laminated, trace sand, fine grained, grey, subroundedSurface casing
(OZCON;
MWBCF; J55, 7"
OD; 22.6lb/ft)Class A Cement,
36.0 bbls, Cement
slurry density of 15.6
ppg, yield
1.18cuft/sk**SANDY SILTSTONE:** Low strength, pale grey to dark grey, massive, with clay, high plasticity, dark grey

45m: Becoming medium strength, increasing clay component

8 1/2" TRICONE

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Project
No.: **42626910**

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Depth (m)	Drilling Method		DESCRIPTION OF STRATA	CONSTRUCTION DETAILS			
	Drilling Method	Graphic Log					
50			SANDY SILTSTONE: Medium strength, light grey, massive, sand is fine to medium grained, subrounded 54m: Trace clay, high plasticity, grey				SWL = 51.12 mBGL (10/11/13)
60			Mooga Sandstone - 60 mBGL SILTY SANDSTONE: Medium to high strength, orange to white to grey, massive, sand is fine to medium grained, subrounded 63m: Becoming high strength				
70			SANDY MUDSTONE: Very low strength, dark grey, medium grained, subrounded, with trace silt SILTY SANDSTONE: Low to medium strength, grey, massive, sand is fine to medium grained, subrounded, orange to white to grey 75m: Trace coal 78m: Becoming low strength 81m: Trace coal, increasing mudstone component 84m: Medium strength, trace mudstone 87m: Thinly laminated				
80							
90			SANDSTONE: Low strength, grey, very fine grained, trace clay SILTY SANDSTONE: Low strength, highly weathered, grey, massive, sand is fine grained SILTY SANDSTONE: Low strength, highly weathered, grey, massive, sand is very fine grained, trace coal 108m: Becoming coarse grained, subangular				
100							

Surface casing
(OZCON;
MWBCF; J55, 7"
OD; 22.6lb/ft)

Class A Cement,
36.0 bbls, Cement
slurry density of 15.6
ppg, yield
1.18cuft/sk

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
110			SILTY SANDSTONE: Medium strength, grey, massive, sand is very fine grained 117m: High strength, grey, massive, very fine grained, with some quartz	
120			SANDSTONE: High strength, fresh, grey, massive, fine to medium grained, quartzose SANDSTONE: Medium strength, grey, very fine grained, trace silt	
130				
140			SILTY SANDSTONE: Low to medium strength, grey, sand is very fine grained, trace siltstone, medium strength, large chips INTERBEDDED SILTSTONE AND MUDSTONE: Very low strength, moderately weathered, light grey to white, massive INTERBEDDED SANDSTONE AND SILTSTONE: Sandstone is low strength, grey, very fine grained, siltstone is medium strength, dark grey, massive SANDSTONE: Medium strength, grey, massive, very fine grained, medium grained, trace quartz SILTY SANDSTONE: Low strength, highly weathered, grey, very fine grained	Surface casing (OZCON; MWBCF; J55, 7" OD; 22.6lb/ft) Class A Cement, 36.0 bbls, Cement slurry density of 15.6 ppg, yield 1.18cuft/sk
150			INTERBEDDED SILTSTONE AND MUDSTONE: Siltstone is low strength, dark grey, massive, mudstone is low strength, highly weathered, dark grey, massive INTERBEDDED SILTSTONE AND SANDSTONE: Sandstone is medium strength, light grey, siltstone is low strength, dark grey, massive, trace coal SILTSTONE: Low to medium strength, moderately weathered, grey to light grey, massive, trace clay	
160			SILTSTONE: Low to medium strength, moderately weathered, grey, with coal, trace quartz Orallo Formation - 169 mBGL SANDSTONE: Medium strength, fresh, light grey, medium grained, subangular, trace coal 168m: White to grey, subangular to subrounded, quartzose	

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Project
No.: **42626910**

Document
ID: **130228_BBNGWH02_DRILLLOG_FINAL_REV1**

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
170			171m: Trace coal	
			SANDY SILTSTONE: Low strength, highly weathered, light to dark grey, sand is fine to medium grained, white to grey, subrounded	
180			177m: White to orange-grey, medium to coarse grained, subrounded to subangular, trace coal	
			SANDSTONE: Medium to high strength, white to dark grey, medium to coarse grained, trace silt, light grey, trace organic matter, trace coal	
			SILTY SANDSTONE: Low to medium strength, white to dark grey, fine to medium grained, silt is light to dark grey, trace organic matter, trace coal	
190			SILTSTONE: Medium strength, fresh, light grey to dark grey, thinly laminated, trace sand, poorly graded, white to grey, trace organic fragments (25mm)	
			195m: Medium to high strength (35mm)	
			198m: Trace coal	
200			INTERBEDDED MUDSTONE AND SILTSTONE: Very low strength, light grey, massive, trace organic matter	
			SILTSTONE: High strength, fresh, dark grey, laminated, trace sand, white to grey, moderately graded, fine to medium grained, trace mudstone, trace coal	
			INTERBEDDED SANDSTONE AND SILTSTONE: Low strength, white to grey, massive	
210			210m: Brown to dark brown, trace mudstone, very low strength, light grey to dark grey	
			SANDSTONE: Very low strength, light grey to dark grey, fine to medium grained, trace mudstone, low strength, light grey, trace coal	
220			219m: Trace siltstone, medium strength, dark brown to grey, thinly laminated	
			222m: Trace coal, fragments up to 7mm	
			SANDY SILTSTONE: Low strength, grey to dark grey, sand is white to grey, moderately graded, fine to medium grained, trace coal	

Surface casing
(OZCON;
MWBCF; J55, 7"
OD; 22.6lb/ft)

Class A Cement,
36.0 bbls, Cement
slurry density of 15.6
ppg, yield
1.18cuft/sk

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
230			231m: Trace mudstone, very low strength, white	
			SANDSTONE: Low to very low strength, grey to white, trace silt, trace coal	
240			SILTY SANDSTONE: Low strength, light grey to dark grey, massive, fine to medium grained, trace mudstone, trace coal	
			SANDSTONE: Medium strength, white to grey, fine to coarse grained, trace silt, trace coal	
250			SILTY SANDSTONE: Low to medium strength, grey to dark grey, fine to coarse grained, silt is dark grey, trace coal	
			INTERBEDDED SANDSTONE AND SILTSTONE: Sandstone is Low strength, light grey, fine to coarse grained, siltstone is medium strength, dark grey, finely laminated, trace coal	
260			SILTY SANDSTONE: Low to medium strength, grey to dark grey, fine to coarse grained, silt is dark grey, trace coal	
			INTERBEDDED SILTSTONE AND SANDSTONE: Low strength, light grey, fine to coarse grained, siltstone is medium strength, dark grey, finely laminated, trace coal	
			SILTY SANDSTONE: Very low strength, light grey to grey, fine to medium grained, silt is dark grey, trace coal	
270			SANDSTONE: Medium strength, highly weathered, white to light grey, medium to coarse grained, subrounded, trace mudstone, low strength, light grey, trace coal	
			279m: Low to medium strength, trace siltstone, medium strength, dark grey	
280			282m: Grey to light grey, medium grained, trace silt, trace coal	

Surface casing
(OZCON;
MWBCF; J55, 7"
OD; 22.6lb/ft)

Class A Cement,
36.0 bbls, Cement
slurry density of 15.6
ppg, yield
1.18cuft/sk

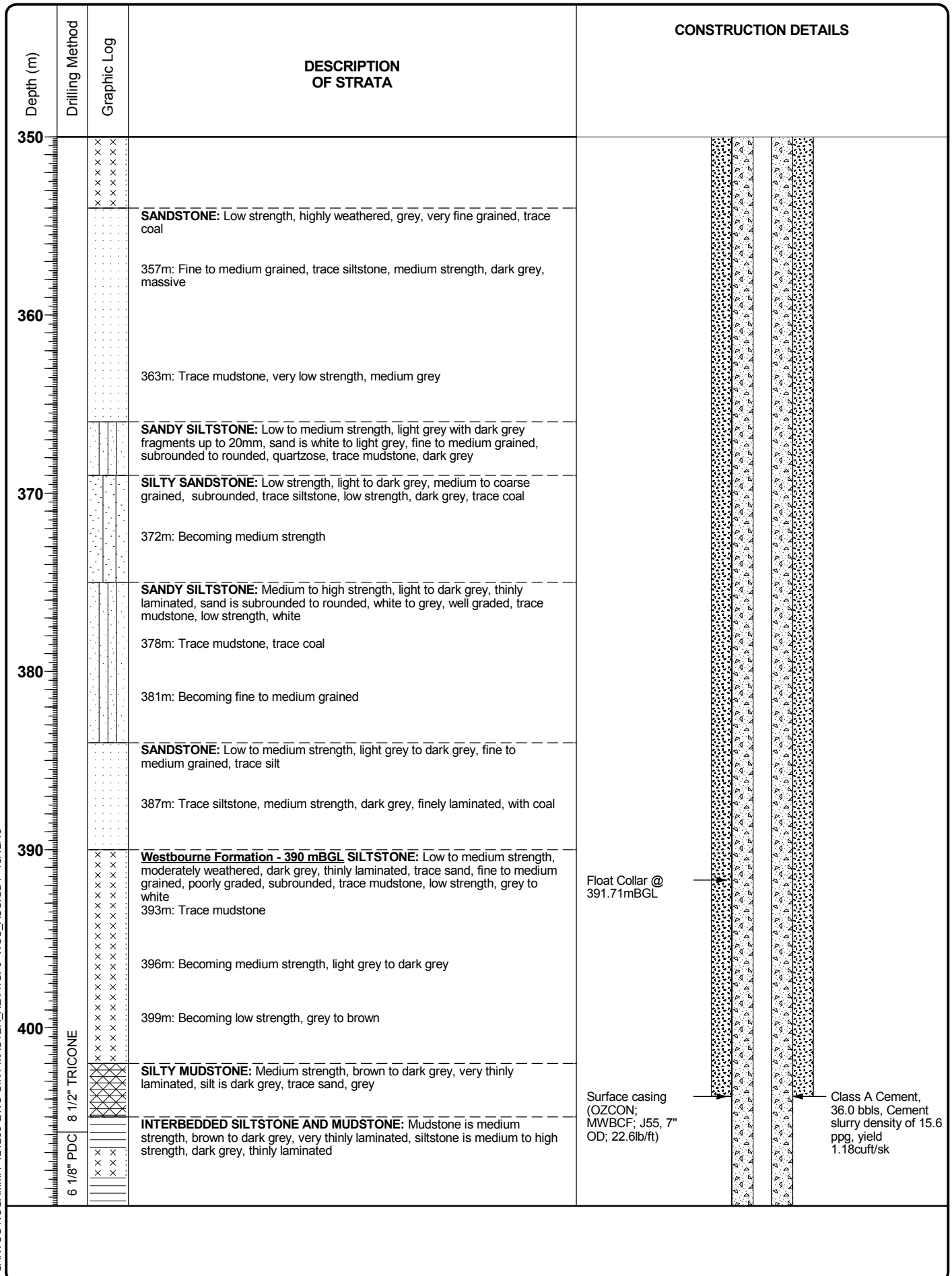
Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
290			291m: Grey, fine to medium grained, subrounded 294m: Trace coal	
300			SILTY SANDSTONE: Medium strength, highly weathered, grey, fine grained, trace quartz, trace siltstone, dark grey 306m: Trace coal	
310			SILTY SANDSTONE: Medium strength, grey, fine grained	
			SILTSTONE: Medium to high strength, slightly weathered, dark grey, massive, some clay, trace sand	Surface casing (OZCON; MWBCF; J55, 7" OD; 22.6lb/ft)
320			SANDY SILTSTONE: Medium strength, slightly, weathered, grey, with dark grey fragments	
			SILTY SANDSTONE: Medium strength, highly weathered, grey to light grey, very fine grained, with quartz	
			Gubbermunda Sandstone - 325 mBGLSILTSTONE: Medium strength, grey to dark grey, massive, trace sand, trace clay	
			SANDY SILTSTONE: Medium strength, grey to dark grey, massive, very fine grained	
330			SANDSTONE: Low to medium strength, slightly weathered, grey, massive, fine to very fine grained, trace silt 336m: Becoming low strength, fresh, medium grained, quartzose	
340			INTERBEDDED SILTSTONE AND SANDSTONE: Sandstone is low to medium strength, grey, siltstone is dark grey	
			SILTSTONE: Medium to high strength, slightly weathered, dark grey, massive, trace sand	Class A Cement, 36.0 bbls, Cement slurry density of 15.6 ppg, yield 1.18cuft/sk

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Project
No.: **42626910**

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
410			411m: Becoming low strength, grey to brown		
			SILTSTONE: Low strength, fresh, dark grey, thinly laminated, trace mudstone, extremely low strength, light grey to white		
			Weald Sandstone - 417 mBGL SILTY SANDSTONE: Low to medium strength, light grey, fine to medium grained, silt is dark grey		
420			SANDY SILTSTONE: Low to medium strength, medium to dark grey, sand is medium grained, light grey, poorly graded		
			423m: Trace coal		
			SILTY SANDSTONE: Low to medium strength, light grey, fine to medium grained, silt dark grey (10mm), trace coal		
430			Springbok Sandstone - 432 mBGL SANDSTONE: Medium strength, fresh, light grey, massive, fine to medium grained, quartzose		
			435m: Trace silt		
440			444m: Medium to high strength		
			SILTSTONE: Low to medium strength, dark grey, massive, trace clay		
450			450m: Trace coal (10mm)		
			SILTY SANDSTONE: Low strength, highly weathered, light to medium grey, fine to medium grained, subrounded, silt dark grey, trace coal		
460			SILTSTONE: Low to medium strength, highly weathered, medium to dark grey, thinly laminated, trace sand, light grey, subangular, trace mudstone, light to medium grey		
			465m: Trace coal		
			SILTY SANDSTONE: Medium strength, light grey, fine to medium grained, subrounded, silt is light grey, trace coal (13mm)		

Completion casing
(OZCON; HWT;
5L; 4 1/2";
10.8lb/ft)

Class A Cement,
64.5 bbls, Cement
slurry density of 12
ppg, yield 2.15
cuft/sk

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Project
No.: 42626910

Document
ID: 130228_BBNGWH02_DRILLLOG_FINAL_REV1

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
470			SANDSTONE: Medium to high strength, light to medium grey, fine grained, subrounded to subangular, trace silt 474m: Trace coal	
480			INTERBEDDED SILTSTONE AND SANDSTONE: Sandstone is medium to high strength, light grey, subrounded to rounded, very fine to fine grained, siltstone is low strength, dark grey SANDSTONE: Medium to high strength, medium grey, fine to medium grained, subrounded, trace mudstone, medium strength, brown, thinly laminated SILTSTONE: Medium strength, dark grey to black, massive, with clay, trace coal	
490			MUDSTONE: Very low strength, highly weathered, dark grey to black, massive SANDSTONE: Very low strength, highly weathered, light grey, massive, very fine grained	
500			501m: Trace clay	Completion casing (OZCON; HWT; 5L; 4 1/2"; 10.8lb/ft) Class A Cement, 64.5 bbls, Cement slurry density of 12 ppg, yield 2.15 cuft/sk
510			SILTSTONE: Low strength, highly weathered, dark brown to dark grey, thinly laminated, trace sandstone, very low strength, pale grey, fine to medium grained SILTY SANDSTONE: Medium strength, light grey, fine to medium grained, subangular, silt is light grey SANDSTONE: Low to medium strength, light to medium grey, fine to medium grained, trace silt, dark grey, with coal 519m: Trace coal (<1mm)	
520			SILTSTONE: Low strength, highly weathered, pale grey, trace sand, light to medium grey to black, subrounded to subangular 525m: Grey to brown, trace sandstone, light grey, fine grained 528m: Becoming medium strength, trace mudstone, very low strength, medium brown, trace coal	

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
530			SANDY SILTSTONE: Very low strength, light grey, sand is grey, fine grained, trace coal Upper Juandah Coal Measures - 538 mBGL SANDSTONE: Low to medium strength, highly weathered, medium grey, fine to coarse grained, subrounded to subangular, with quartz, trace coal 537m: Coarse grained, no coal		
540			SILTSTONE: Medium to high strength, moderately weathered, dark grey, trace coal MUDSTONE: Low strength, highly weathered, grey to dark grey, with sand Proud Sandstone - 565 mBGL SANDSTONE: Very low strength, highly weathered, light grey, massive, very fine grained, with clay		
550					
560			564m: Trace coal, trace siltstone		
570					
580			Lower Juandah Coal Measures - 580 mBGL SILTY SANDSTONE: Low strength, moderately weathered, grey to light grey, fine to medium grained SANDY SILTSTONE: Low to medium strength, dark grey to black, fine grained SILTSTONE: Low strength, grey, minor sand, fine grained		

Completion casing
(OZCON; HWT;
5L; 4 1/2";
10.8lb/ft)

Class A Cement,
64.5 bbls, Cement
slurry density of 12
ppg, yield 2.15
cuft/sk

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
590			MUDSTONE: Medium strength, black, minor coal, low to medium strength, black, trace siltstone, low to medium strength, grey SILTY SANDSTONE: Low strength, dark grey to brown, fine grained SILTSTONE: Low strength, grey to black, with sandstone, low strength, grey, fine grained SILTY SANDSTONE: Low strength, fine to medium grained, grey to black, with quartz SILTSTONE: Low to medium strength, pale grey to brown, trace sandstone, fine grained 609m: Some coal (~50) medium strength, black, lustrous, trace mudstone, low strength, dark brown to grey, trace sand, fine grained 618m: Trace siltstone <u>Tangalooma Formation - 627 mBGL</u> SILTSTONE: Low strength, grey to dark grey, trace coal 636m: Trace mudstone, medium strength, black INTERBEDDED MUDSTONE AND SILTSTONE: Siltstone is low strength, grey to dark grey, mudstone is low to medium strength, pale grey	Completion casing (OZCON; HWT; 5L; 4 1/2"; 10.8lb/ft) Class A Cement, 64.5 bbls, Cement slurry density of 12 ppg, yield 2.15 cuft/sk

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
650			651m: Trace mudstone	
			MUDSTONE: Medium strength, dark grey to black, trace siltstone, grey to brown	
660			660m: Trace coal	
			666m: Trace siltstone	
670			669m: Medium to high strength, with siltstone	
			INTERBEDDED MUDSTONE AND SILTSTONE: Siltstone is medium strength, pale grey, mudstone is high strength, dark brown, larger fragments (~3mm), trace coal	
680			Taroom Coal Measures - 693 mBGL SILTSTONE: Medium strength, light brown, trace mudstone, high strength, dark brown, trace coal	
			684m: Trace mudstone, trace coal	
690			693m: Trace sandstone, very fine grained, subangular	
700			INTERBEDDED COAL AND SILTSTONE: Siltstone is low strength, grey to brown, coal is medium strength, black, lustrous	
			705m: Minor sand, fine grained, trace mudstone, black, medium strength, trace coal	
			708m: Low strength, grey-brown, trace coal, black	

Completion casing
(OZCON; HWT;
5L; 4 1/2";
10.8lb/ft)

Class A Cement,
64.5 bbls, Cement
slurry density of 12
ppg, yield 2.15
cuft/sk

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
710				
			INTERBEDDED MUDSTONE AND SANDY SILTSTONE: Siltstone is low strength, grey to white, mudstone is low strength, brown	
			SANDY SILTSTONE: Low strength, grey to white, subrounded, fine to medium grained	
720			723m: Becoming subangular sand	
730			SANDY SILTSTONE: Low strength, grey to white, trace quartz, trace coal	
740			747m: Becoming dark grey to brown, fine grained, trace mudstone, black	
750			INTERBEDDED MUDSTONE AND SILTSTONE: Siltstone is dark grey to brown, mudstone is low strength, black, trace sand	
			INTERBEDDED SILTSTONE AND SANDSTONE: Sandstone is low strength, pale grey, fine to medium grained, siltstone is dark grey to brown	
			INTERBEDDED MUDSTONE AND SILTSTONE: Siltstone is dark grey to brown, mudstone is low to medium strength, brown to black, trace coal	
760			Eurombah Formation - 760 mBGL. INTERBEDDED SANDSTONE AND SILTSTONE: Siltstone is dark grey to brown, Sandstone is low strength, grey to white, fine grained, trace quartz	
			762m: Siltstone becoming red to brown, trace quartz	

Completion casing
(OZCON; HWT;
5L; 4 1/2";
10.8lb/ft)

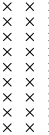
Class A Cement,
64.5 bbls, Cement
slurry density of 12
ppg, yield 2.15
cuft/sk

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
770			771m: Trace coal	
			SILTSTONE: Medium strength, grey to brown, trace sand, very fine grained, subangular	
780			780m: Light grey, with sand, trace subangular quartz	
			783m: Very fine to fine grained, subrounded quartz	
			791m: Trace mudstone, trace sand	
790			804m: Trace coal, trace sand, fine to medium grained	
			INTERBEDDED SANDSTONE AND SILTSTONE: Siltstone is medium strength, light grey, sandstone is high strength, light grey, medium to coarse grained, trace quartz, trace coal, trace mudstone	
			INTERBEDDED MUDSTONE AND SANDSTONE: Sandstone is high strength, light grey, medium to coarse grained, mudstone is medium to high strength, brown, trace coal	
			SANDY SILTSTONE: Medium strength, grey, subangular, fine to medium grained, trace coal	
820			Hutton Sandstone - 822 mBGL INTERBEDDED MUDSTONE AND SILTSTONE: Siltstone is medium strength, grey, mudstone is high strength, dark brown, trace laminar	
			SANDY SILTSTONE: Medium strength, grey, sand is medium grained, subangular, trace quartz	
			SANDSTONE: Low strength, light grey to white, fine to medium grained, quartzose, trace mudstone	

Completion casing
(OZCON; HWT;
5L; 4 1/2";
10.8lb/ft)

Class A Cement,
64.5 bbls, Cement
slurry density of 12
ppg, yield 2.15
cuft/sk

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
830			SILTY SANDSTONE: Low strength, grey to white, fine grained, trace quartz, trace coal 834m: Becoming fine to medium grained, trace quartz, coarse grained	
840			SANDY SILTSTONE: Low strength, light grey, sand is fine grained, quartzose, subrounded 840m: Becoming dark grey to brown, medium grained, trace mudstone, low strength, black 843m: Minor quartz, medium to fine grained	
850			852m: Fine to very fine grained, quartzose, subrounded	
			SILTY SANDSTONE: Low strength, grey to white, fine to very fine grained, quartzose, rounded to subrounded	Completion casing (OZCON; HWT; 5L; 4 1/2"; 10.8lb/ft)
860			SILTSTONE: Low strength, grey to brown, trace sand, very fine grained, trace quartz 864m: Trace sand, very fine grained	Class A Cement, 64.5 bbls, Cement slurry density of 12 ppg, yield 2.15 cuft/sk
870			MUDSTONE: Medium strength, brown	
			SILTSTONE: Medium strength, grey 878m: Trace sand, very fine grained 879m: Trace coal	
880			885m: Trace mudstone 888m: Trace sand, subrounded to subangular quartz, clean	

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
890			SILTY SANDSTONE: High strength, grey, very fine grained, silt is medium strength, grey, trace coal	
			SILTSTONE: Medium strength, grey, trace mudstone, high strength, dark grey to brown, trace very fine laminations, trace sand, fine grained	
900			MUDSTONE: Medium to high strength, brown, trace siltstone, low strength, pale grey, trace sand	
			SILTY MUDSTONE: low strength, brown to grey, few sand, fine grained, trace quartz	
			SILTY SANDSTONE: Low strength, grey, fine to very fine grained, quartzose, subangular	
910			915m: Grey to white, quartzose, subrounded, trace mudstone, very low strength	
			918m: Some fine grained, subangular quartz	
920			SILTSTONE: Very low strength, grey, trace sand, very fine grained	
			SANDY SILTSTONE: Low strength, dark grey, sand is fine to very fine grained, quartzose	
			SILTY SANDSTONE: Low strength, dark grey to black, very fine grained, quartzose	
930				
940			945m: Trace mudstone, high strength, brown	
			948m: Trace coal	
			EOH 950 mBGL - 22/02/13	

Completion casing
(OZCON; HWT;
5L; 4 1/2";
10.8lb/ft)

Class A Cement,
64.5 bbls, Cement
slurry density of 12
ppg, yield 2.15
cuft/sk

Float Collar @
935.84 mBGL

Rat hole from
948.95 mBGL to



BBNGWH02 (FINAL)

Sheet 17 of 17

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
950				950 mBGL
960				
970				
980				
990				
1000				

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Project Name: **Santos Deep Drilling Programme**

Client: **Santos Ltd**

Document ID:

Drilling Contractor: **Spaulding Drillers**

Project No.: **42626910**

Location: **Roma**

130307_BBNGWS02_DRILLLOG_FINAL_REV1

Logged By: **RF, SC**

Bore Dia.: **177.8 mm**

Casing RL: **360.50 mAHD**

Drill Type: **Mud Rotary**

Checked By: **MR**

Total Depth: **535.6 m**

Coordinates: **Lat: -26.533170**

Drill Model: **Foremost 24 HD**

Date Started: **21-1-13**

Casing I.D.: **102.3 mm**

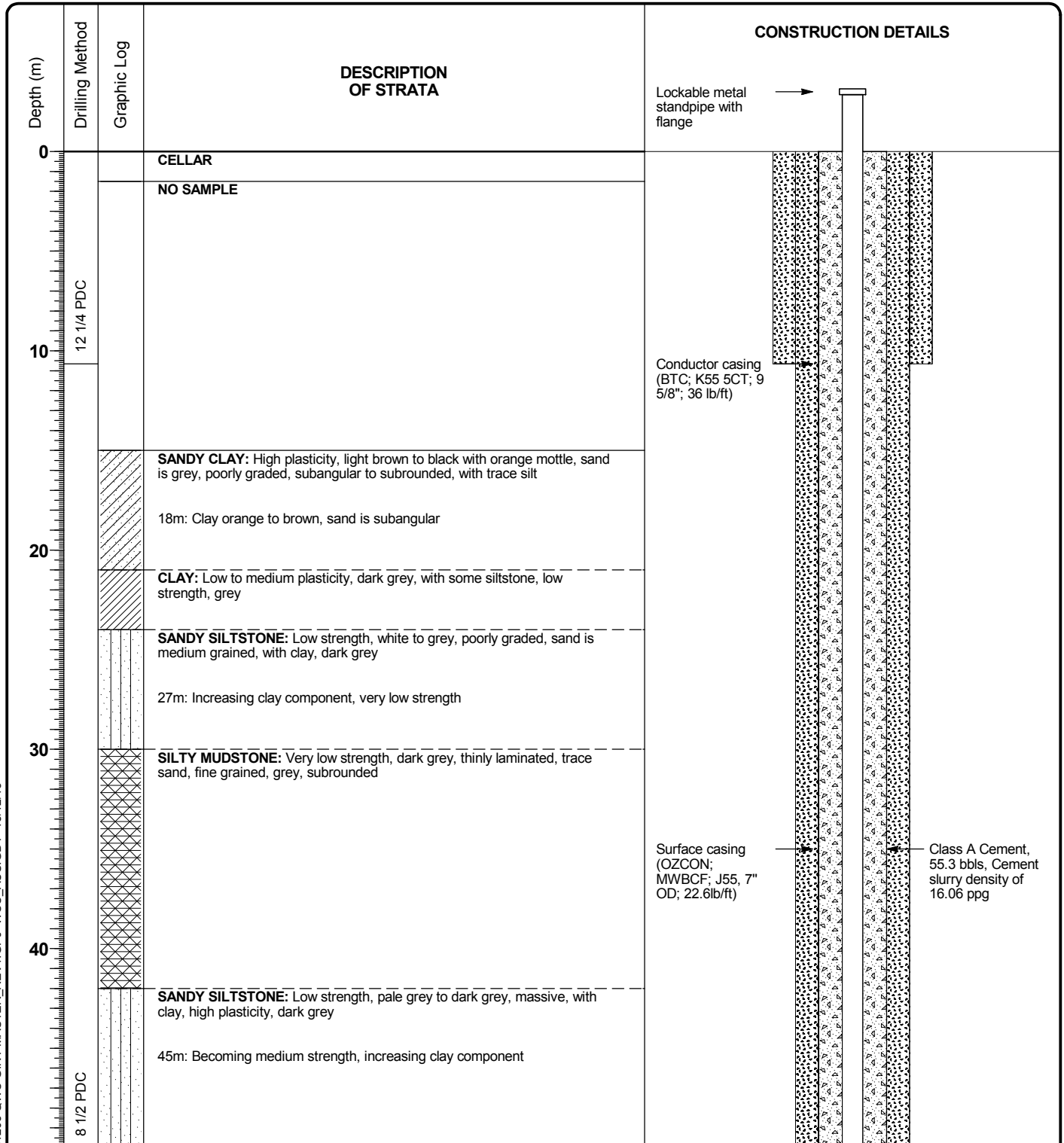
Long: 149.054605

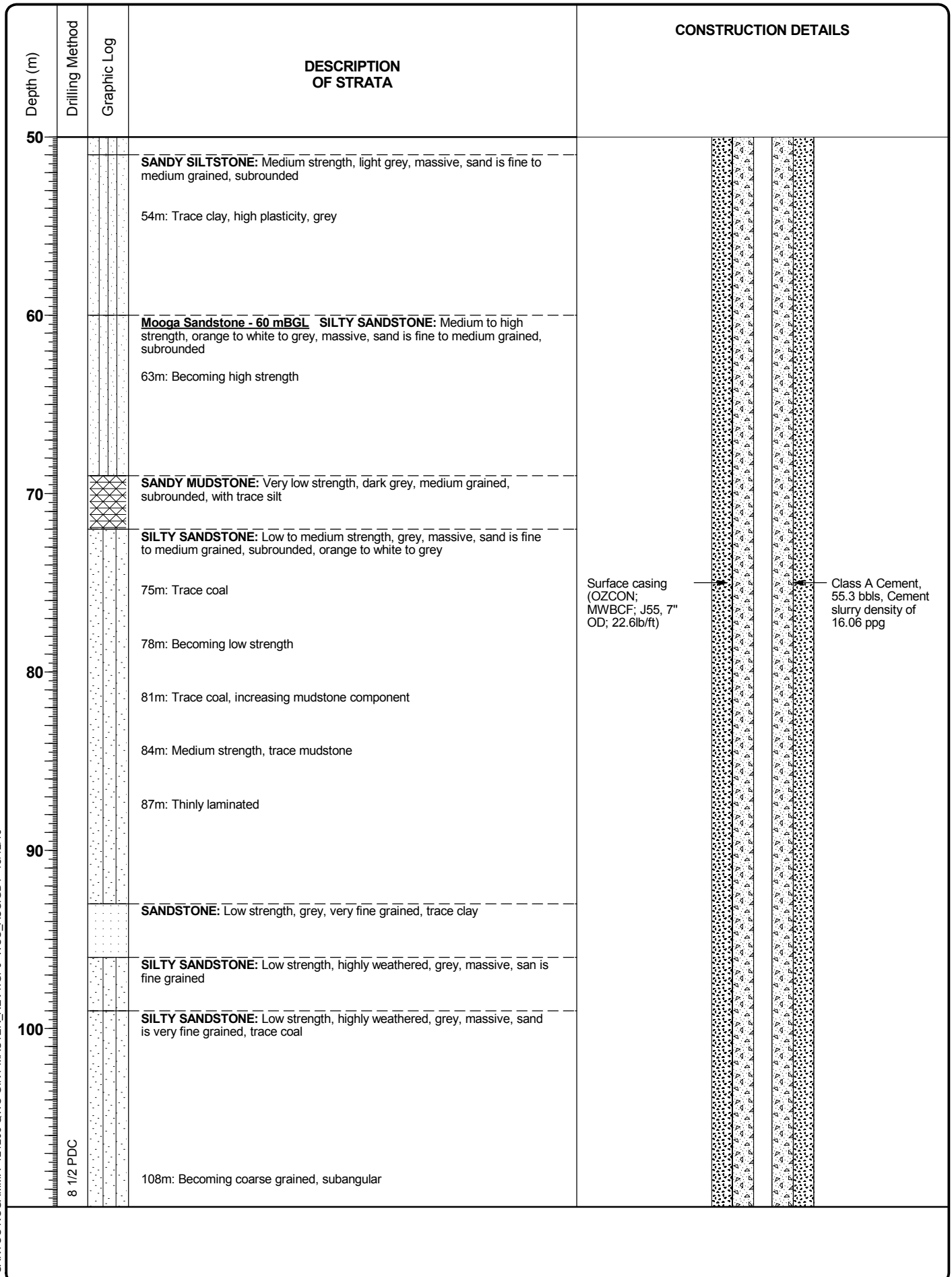
Drill Fluid: **MUD (refer to mud programme)**

Date Finished: **2-2-13**

Permit No: **GDEQGW12-76**

SANTOS NOGAMMA 121203 QWC GINT MASTER_REV1.GPJ WCC_AUS_GDT 18/12/13





Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
110			SILTY SANDSTONE: Medium strength, grey, massive, sand is very fine grained 117m: High strength, grey, massive, very fine grained, with some quartz	
120			SANDSTONE: High strength, fresh, grey, massive, fine to medium grained, quartzose SANDSTONE: Medium strength, grey, very fine grained, trace silt	
130				
140			SILTY SANDSTONE: Low to medium strength, grey, sand is very fine grained, trace siltstone, medium strength, large chips INTERBEDDED SILTSTONE AND MUDSTONE: Very low strength, moderately weathered, light grey to white, massive INTERBEDDED SANDSTONE AND SILTSTONE: Sandstone is low strength, grey, very fine grained, siltstone is medium strength, dark grey, massive SANDSTONE: Medium strength, grey, massive, very fine grained, medium grained, trace quartz SILTY SANDSTONE: Low strength, highly weathered, grey, very fine grained	Surface casing (OZCON; MWBCF; J55, 7" OD; 22.6lb/ft) Class A Cement, 55.3 bbls, Cement slurry density of 16.06 ppg
150			INTERBEDDED SILTSTONE AND MUDSTONE: Siltstone is low strength, dark grey, massive, mudstone is low strength, highly weathered, dark grey, massive INTERBEDDED SILTSTONE AND SANDSTONE: Sandstone is medium strength, light grey, siltstone is low strength, dark grey, massive, trace coal SILTSTONE: Low to medium strength, moderately weathered, grey to light grey, massive, trace clay	
160			SILTSTONE: Low to medium strength, moderately weathered, grey, with coal, trace quartz Orallo Formation - 169 mBGL SANDSTONE: Medium strength, fresh, light grey, medium grained, subangular, trace coal 168m: White to grey, subangular to subrounded, quartzose	

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
170			171m: Trace coal		
			SANDY SILTSTONE: Low strength, highly weathered, light to dark grey, sand is fine to medium grained, white to grey, subrounded		
180			177m: White to orange-grey, medium to coarse grained, subrounded to subangular, trace coal		
			SANDSTONE: Medium to high strength, white to dark grey, medium to coarse grained, trace silt, light grey, trace organic matter, trace coal		
			SILTY SANDSTONE: Low to medium strength, white to dark grey, fine to medium grained, silt is light to dark grey, trace organic matter, trace coal		
190			SILTSTONE: Medium strength, fresh, light grey to dark grey, thinly laminated, trace sand, poorly graded, white to grey, trace organic fragments (25mm)		
			195m: Medium to high strength (35mm)		
			198m: Trace coal		
200			INTERBEDDED MUDSTONE AND SILTSTONE: Very low strength, light grey, massive, trace organic matter		
			SILTSTONE: High strength, fresh, dark grey, laminated, trace sand, white to grey, moderately graded, fine to medium grained, trace mudstone, trace coal		
			INTERBEDDED SANDSTONE AND SILTSTONE: Low strength, white to grey, massive		
210			210m: Brown to dark brown, trace mudstone, very low strength, light grey to dark grey		
			SANDSTONE: Very low strength, light grey to dark grey, fine to medium grained, trace mudstone, low strength, light grey, trace coal		
220			219m: Trace siltstone, medium strength, dark brown to grey, thinly laminated		
			222m: Trace coal, fragments up to 7mm		
			SANDY SILTSTONE: Low strength, grey to dark grey, sand is white to grey, moderately graded, fine to medium grained, trace coal		

Surface casing
(OZCON;
MWBCF; J55, 7"
OD; 22.6lb/ft)

Class A Cement,
55.3 bbls, Cement
slurry density of
16.06 ppg

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
230			231m: Trace mudstone, very low strength, white	
			SANDSTONE: Low to very low strength, grey to white, trace silt, trace coal	
240			SILTY SANDSTONE: Low strength, light grey to dark grey, massive, fine to medium grained, trace mudstone, trace coal	
			SANDSTONE: Medium strength, white to grey, fine to coarse grained, trace silt, trace coal	
250			SILTY SANDSTONE: Low to medium strength, grey to dark grey, fine to coarse grained, silt is dark grey, trace coal	
			INTERBEDDED SANDSTONE AND SILTSTONE: Sandstone is Low strength, light grey, fine to coarse grained, siltstone is medium strength, dark grey, finely laminated, trace coal	
260			SILTY SANDSTONE: Low to medium strength, grey to dark grey, fine to coarse grained, silt is dark grey, trace coal	
			INTERBEDDED SILTSTONE AND SANDSTONE: Low strength, light grey, fine to coarse grained, siltstone is medium strength, dark grey, finely laminated, trace coal	
			SILTY SANDSTONE: Very low strength, light grey to grey, fine to medium grained, silt is dark grey, trace coal	
270			SANDSTONE: Medium strength, highly weathered, white to light grey, medium to coarse grained, subrounded, trace mudstone, low strength, light grey, trace coal	
			279m: Low to medium strength, trace siltstone, medium strength, dark grey	
280			282m: Grey to light grey, medium grained, trace silt, trace coal	

Surface casing
(OZCON;
MWBCF; J55, 7"
OD; 22.6lb/ft)

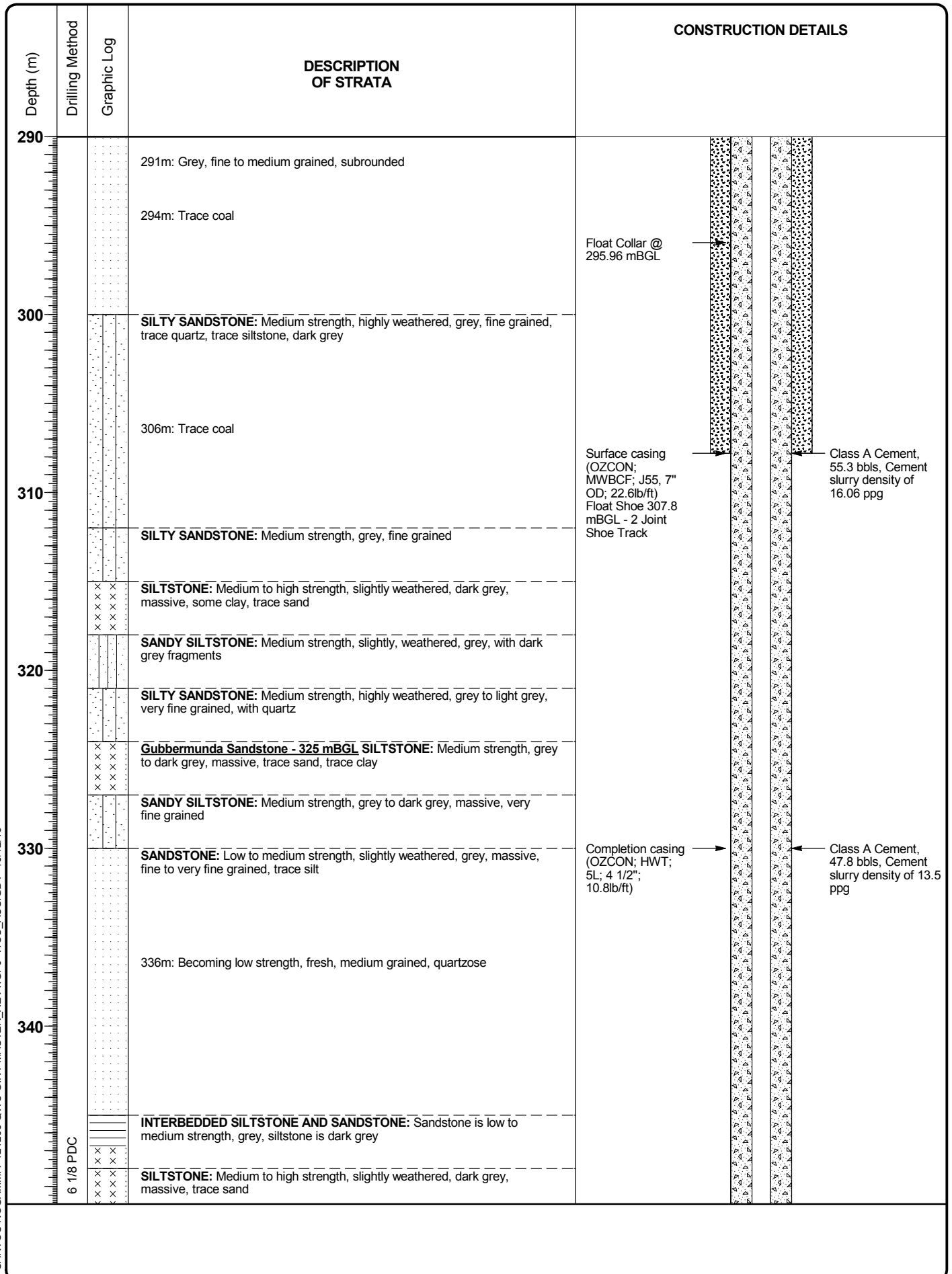
Class A Cement,
55.3 bbls, Cement
slurry density of
16.06 ppg

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
350				
			SANDSTONE: Low strength, highly weathered, grey, very fine grained, trace coal 357m: Fine to medium grained, trace siltstone, medium strength, dark grey, massive 363m: Trace mudstone, very low strength, medium grey	
360				
			SANDY SILTSTONE: Low to medium strength, light grey with dark grey fragments up to 20mm, sand is white to light grey, fine to medium grained, subrounded to rounded, quartzose, trace mudstone, dark grey	
370			SILTY SANDSTONE: Low strength, light to dark grey, medium to coarse grained, subrounded, trace siltstone, low strength, dark grey, trace coal 372m: Becoming medium strength	
			SANDY SILTSTONE: Medium to high strength, light to dark grey, thinly laminated, sand is subrounded to rounded, white to grey, well graded, trace mudstone, low strength, white 378m: Trace mudstone, trace coal 381m: Becoming fine to medium grained	
380				
			SANDSTONE: Low to medium strength, light grey to dark grey, fine to medium grained, trace silt 387m: Trace siltstone, medium strength, dark grey, finely laminated, with coal	
390			Westbourne Formation - 390 mBGL SILTSTONE: Low to medium strength, moderately weathered, dark grey, thinly laminated, trace sand, fine to medium grained, poorly graded, subrounded, trace mudstone, low strength, grey to white 393m: Trace mudstone 396m: Becoming medium strength, light grey to dark grey 399m: Becoming low strength, grey to brown	
400			SILTY MUDSTONE: Medium strength, brown to dark grey, very thinly laminated, silt is dark grey, trace sand, grey INTERBEDDED SILTSTONE AND MUDSTONE: Mudstone is medium strength, brown to dark grey, very thinly laminated, siltstone is medium to high strength, dark grey, thinly laminated	Completion casing (OZCON; HWT; 5L: 4 1/2"; 10.8lb/ft) Class A Cement, 47.8 bbls, Cement slurry density of 13.5 ppg
	6 1/8 PDC			

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
410			411m: Becoming low strength, grey to brown		
			SILTSTONE: Low strength, fresh, dark grey, thinly laminated, trace mudstone, extremely low strength, light grey to white		
			Weald Sandstone - 417 mBGL SILTY SANDSTONE: Low to medium strength, light grey, fine to medium grained, silt is dark grey		
420			SANDY SILTSTONE: Low to medium strength, medium to dark grey, sand is medium grained, light grey, poorly graded		
			423m: Trace coal		
			SILTY SANDSTONE: Low to medium strength, light grey, fine to medium grained, silt dark grey (10mm), trace coal		
430			Springbok Sandstone - 432 mBGL SANDSTONE: Medium strength, fresh, light grey, massive, fine to medium grained, quartzose		
			435m: Trace silt		
440			444m: Medium to high strength		
			SILTSTONE: Low to medium strength, dark grey, massive, trace clay		
450			450m: Trace coal (10mm)		
			SILTY SANDSTONE: Low strength, highly weathered, light to medium grey, fine to medium grained, subrounded, silt dark grey, trace coal		
460			SILTSTONE: Low to medium strength, highly weathered, medium to dark grey, thinly laminated, trace sand, light grey, subangular, trace mudstone, light to medium grey		
			465m: Trace coal		
			SILTY SANDSTONE: Medium strength, light grey, fine to medium grained, subrounded, silt is light grey, trace coal (13mm)		

Completion casing (OZCON; HWT; 5L; 4 1/2"; 10.8lb/ft)

Class A Cement, 47.8 bbls, Cement slurry density of 13.5 ppg

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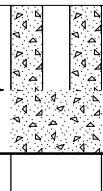
Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
470			SANDSTONE: Medium to high strength, light to medium grey, fine grained, subrounded to subangular, trace silt 474m: Trace coal		
480			INTERBEDDED SILTSTONE AND SANDSTONE: Sandstone is medium to high strength, light grey, subrounded to rounded, very fine to fine grained, siltstone is low strength, dark grey SANDSTONE: Medium to high strength, medium grey, fine to medium grained, subrounded, trace mudstone, medium strength, brown, thinly laminated SILTSTONE: Medium strength, dark grey to black, massive, with clay, trace coal		
490			MUDSTONE: Very low strength, highly weathered, dark grey to black, massive SANDSTONE: Very low strength, highly weathered, light grey, massive, very fine grained		
500			501m: Trace clay	Completion casing (OZCON; HWT; 5L: 4 1/2"; 10.8lb/ft)	Class A Cement, 47.8 bbls, Cement slurry density of 13.5 ppg
510			SILTSTONE: Low strength, highly weathered, dark brown to dark grey, thinly laminated, trace sandstone, very low strength, pale grey, fine to medium grained SILTY SANDSTONE: Medium strength, light grey, fine to medium grained, subangular, silt is light grey SANDSTONE: Low to medium strength, light to medium grey, fine to medium grained, trace silt, dark grey, with coal 519m: Trace coal (<1mm)		
520			SILTSTONE: Low strength, highly weathered, pale grey, trace sand, light to medium grey to black, subrounded to subangular 525m: Grey to brown, trace sandstone, light grey, fine grained 528m: Becoming medium strength, trace mudstone, very low strength, medium brown, trace coal	Float Collar @ 520.7 mBGL	

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No.: **42626910**

Document
ID: **130307_BBNGWS02_DRILLLOG_FINAL_REV1**

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
530			SANDY SILTSTONE: Very low strength, light grey, sand is grey, fine grained, trace coal SANDSTONE: Low to medium strength, highly weathered, medium grey, fine to coarse grained, subrounded to subangular, with quartz, trace coal	Rat Hole from 533.2 mBGL to 535.6 mBGL 
540			<u>EOH - 535.6 mBGL - Target Depth Reached 02/02/2013</u>	
550				
560				
570				
580				

ARMGWG13 (INTERIM)

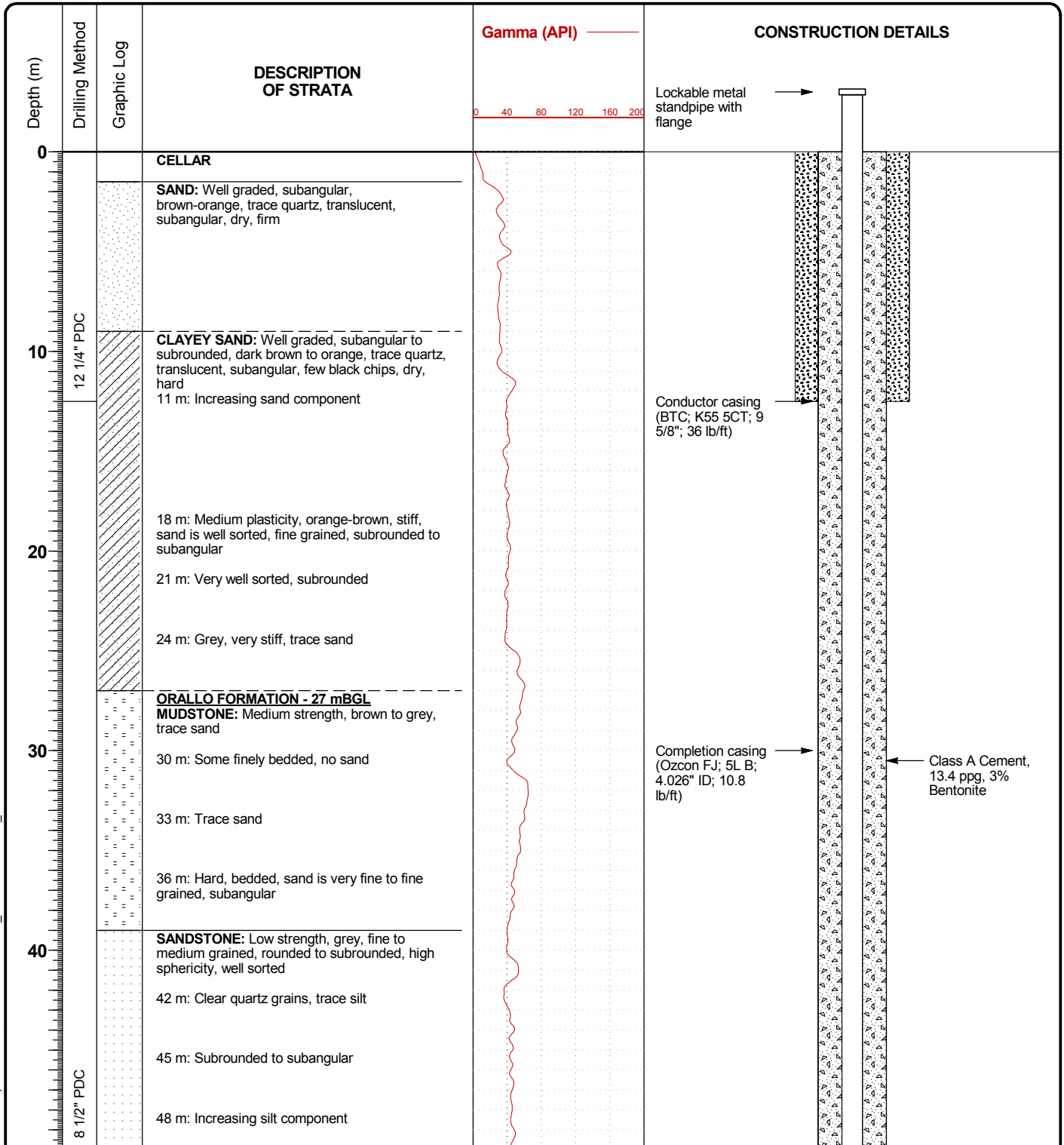
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Phone: (07) 3243 2199Project Name: **Roma Deep Drilling
Campaign 1**Client: **Santos Ltd**

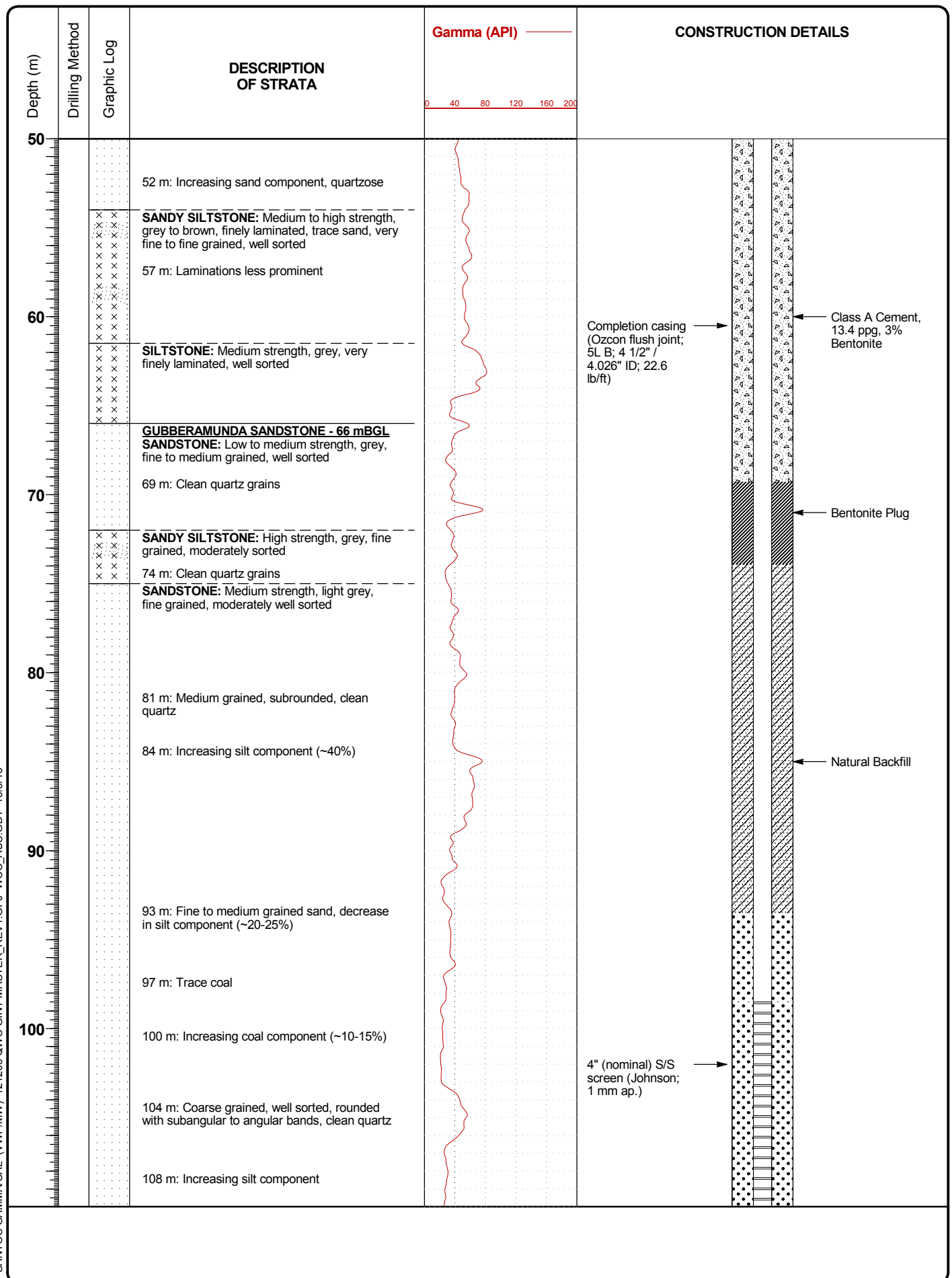
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130315_ARMGWG13_DRILLOG_INTERIM_REV1

Drilling Contractor: **Spaulding Drillers**Project No.: **42626910**Location: **Roma**Logged By: **RF**
Checked By: **MR**
Date Started: **18-11-12**
Date Finished: **26-11-12**Bore Dia.: **177.8 mm**
Total Depth: **113.5 m**
Casing I.D.: **102.3 mm**Casing RL: **387.92 mAHD**
Coordinates: **Lat: -26.387106**
Long: 149.125620
Permit No: **GDEQGW12-07**Drill Type: **Mud Rotary**
Drill Model: **Foremost 24 HD**
Drill Fluid: **MUD (Bentonite & PAC)**

SANTOS GAMMA/CAL (VWP/MMW) 121203 QWC GINT MASTER_REV1.GPJ WCC_AUS.GDT 15/3/13





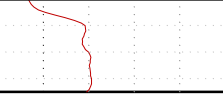
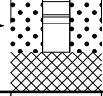
ARMGWG13 (INTERIM)

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Project No.: **42626910**

Document ID: **130315_ARMGWG13_DRILLOG_INTERIM_REV1**

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	Gamma (API)	CONSTRUCTION DETAILS
				0 40 80 120 160 200	
110	8 1/2" PDC		WESTBOURNE FORMATION - 111.5 mBGL SILTY SANDSTONE: Very high strength, grey to blue, finely laminated, trace coal, trace quartz		Zero slot sump → 
120			EOH 113.5 mBGL - Target Depth Reached 26/11/12		
130					
140					
150					
160					

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Project Name: **Roma Deep Drilling Campaign 1**

Client: **Santos Ltd**

Document ID:

Drilling Contractor: **Spaulding Drillers**

Project No.: **42626910**

Location: **Roma**

130315_ARMGWH01_DRILLOG_INTERIM_REV1

Logged By: **DGP, RP, PO, SH**

Bore Dia.: **177.8 mm**

Casing RL: **382.54 mAHD**

Drill Type: **Mud Rotary**

Checked By: **MR**

Total Depth: **700.6 m**

Coordinates: **Lat: -26.387256**

Drill Model: **Foremost 24 HD**

Date Started: **12-12-12**

Casing I.D.: **102.3 mm**

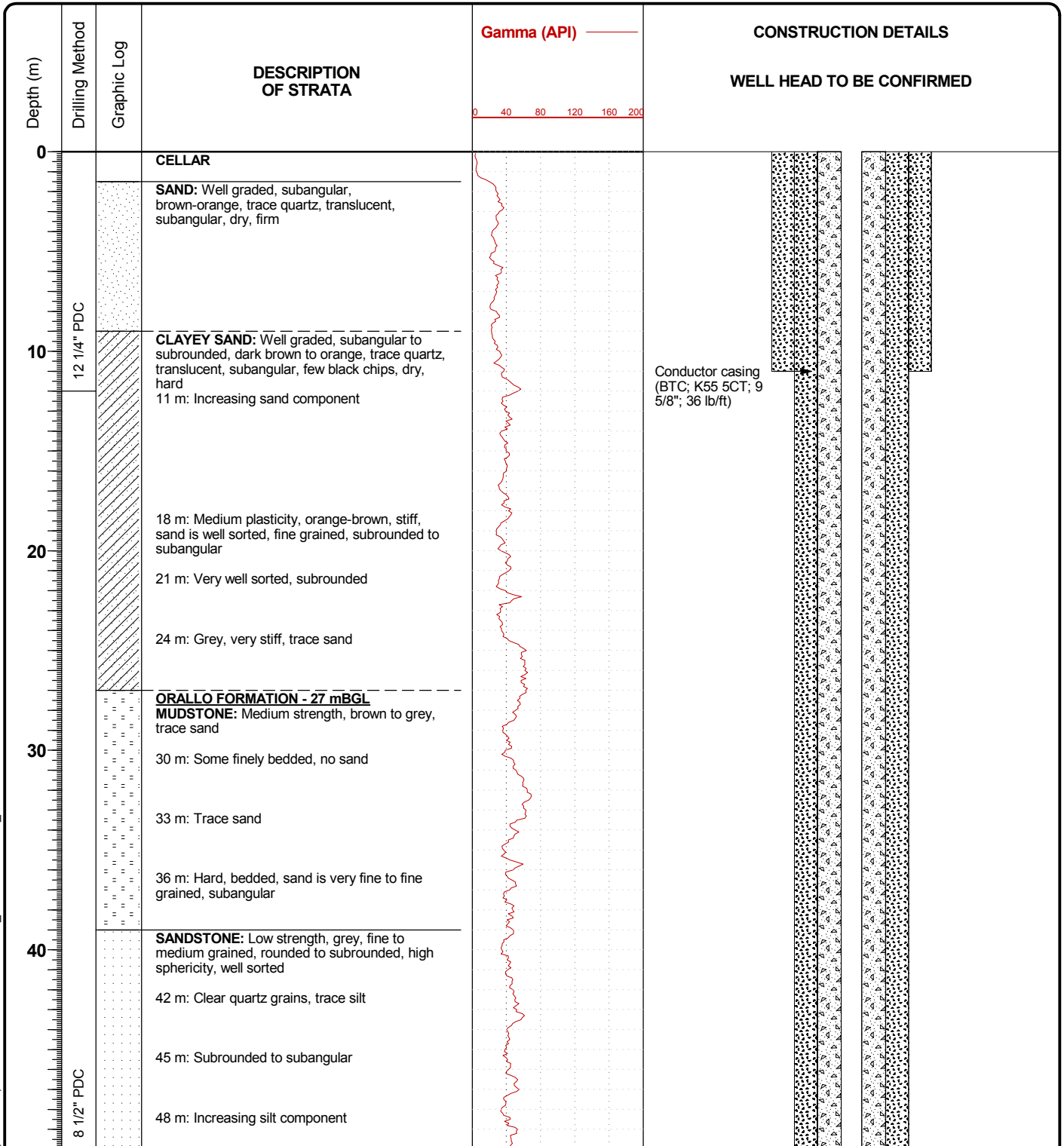
Long: 149.125871

Drill Fluid: **MUD (refer to mud program)**

Date Finished: **11-1-13**

Permit No: **GDEQGW12-07**

SANTOS GAMMA/CAL (VWP/MMW) 121203 QWC GINT MASTER_REV1.GPJ WCC_AUS.GDT 15/3/13



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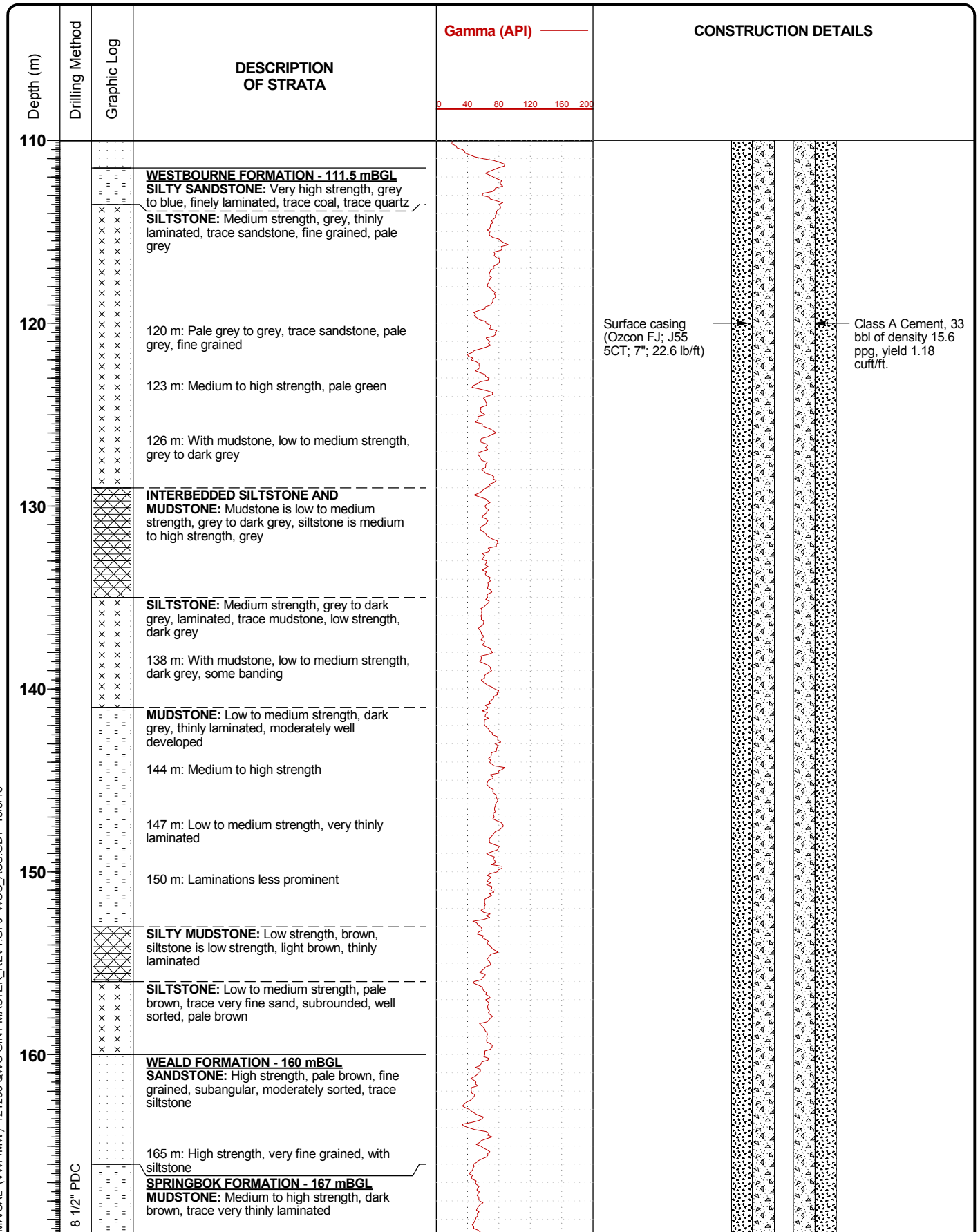
ARMGWH01 (INTERIM)

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ID: 130315_ARMGWH01_DRILLOG_INTERIM_REV1



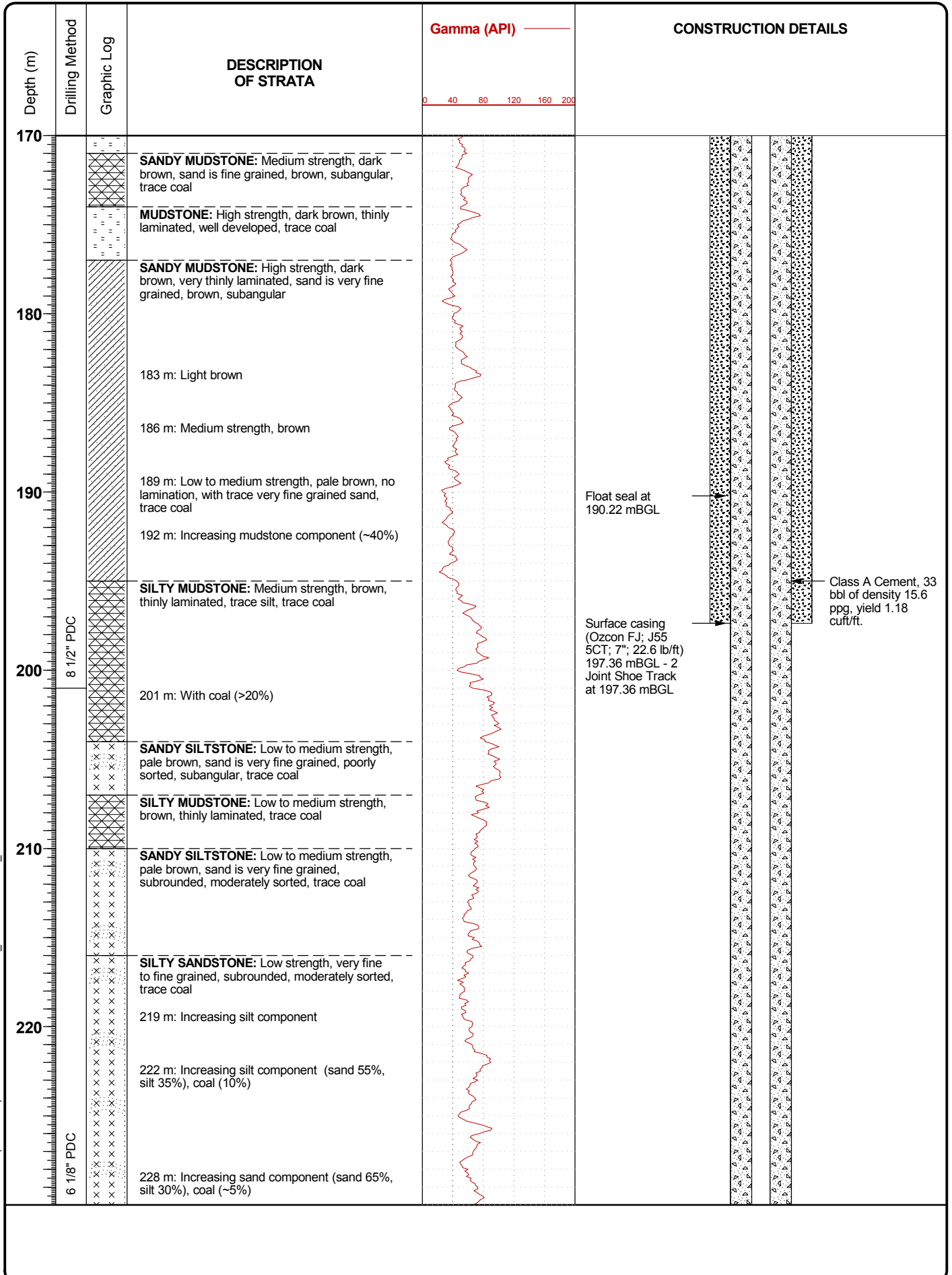
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No.: 42626910

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ID: 130315_ARMGWH01_DRILLOG_INTERIM_REV1

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ARMGWH01 (INTERIM)

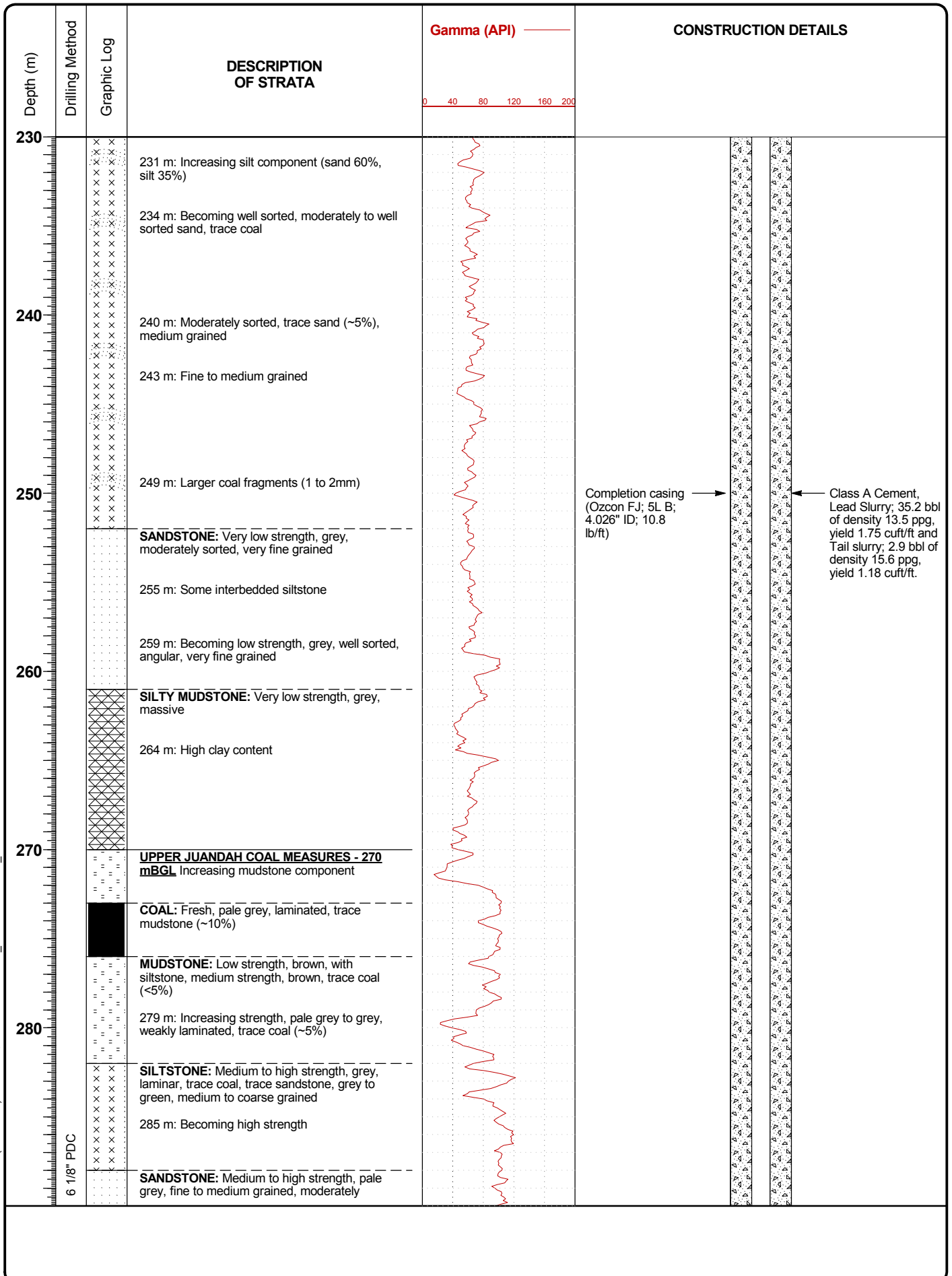
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No.: 42626910

Document
ID: 130315_ARMGWH01_DRILLOG_INTERIM_REV1

SANTOS GAMMA/CAL (VWP/MMW) 121203 QWC GINT MASTER_REV1.GPJ WCC_AUS.GDT 15/3/13

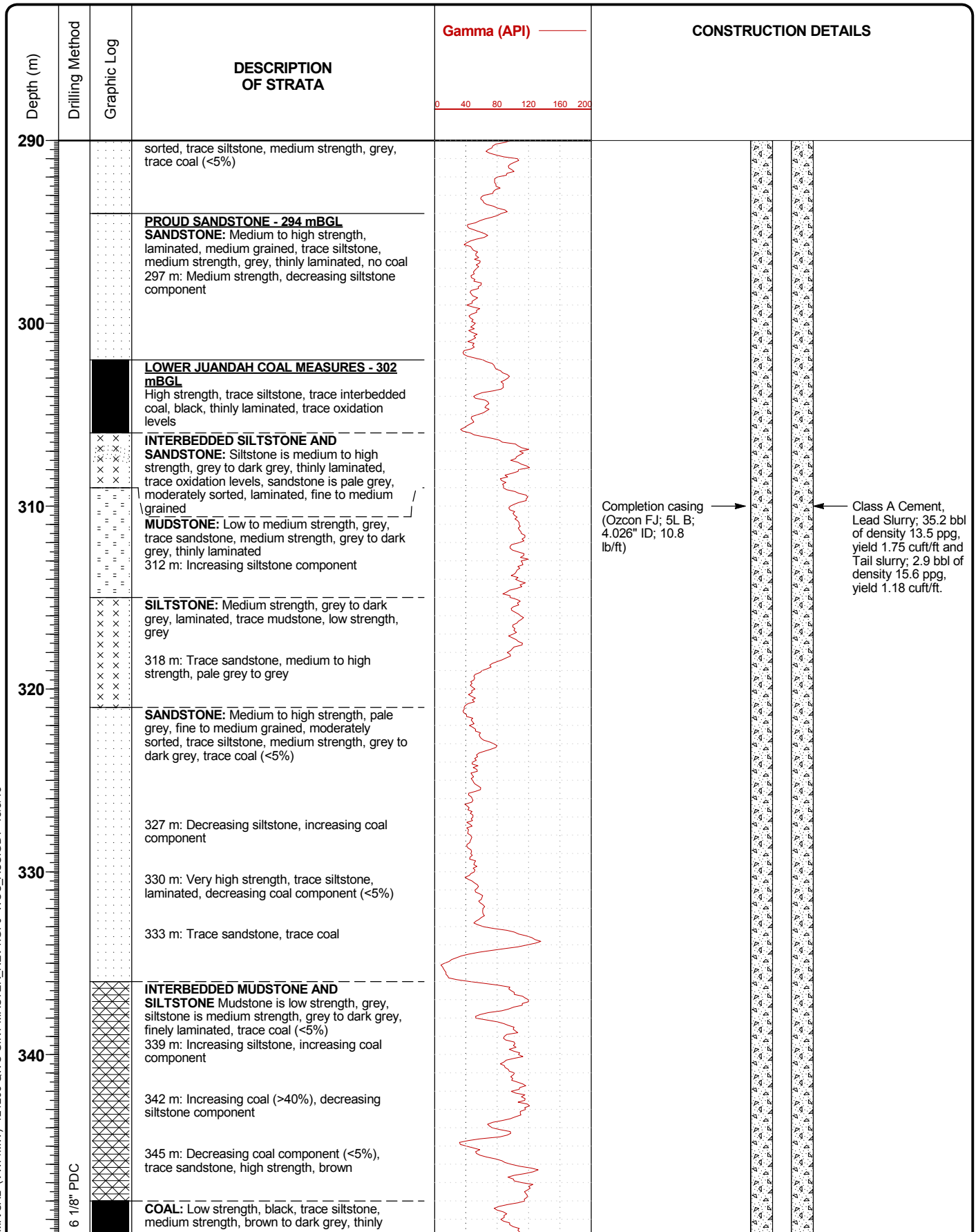


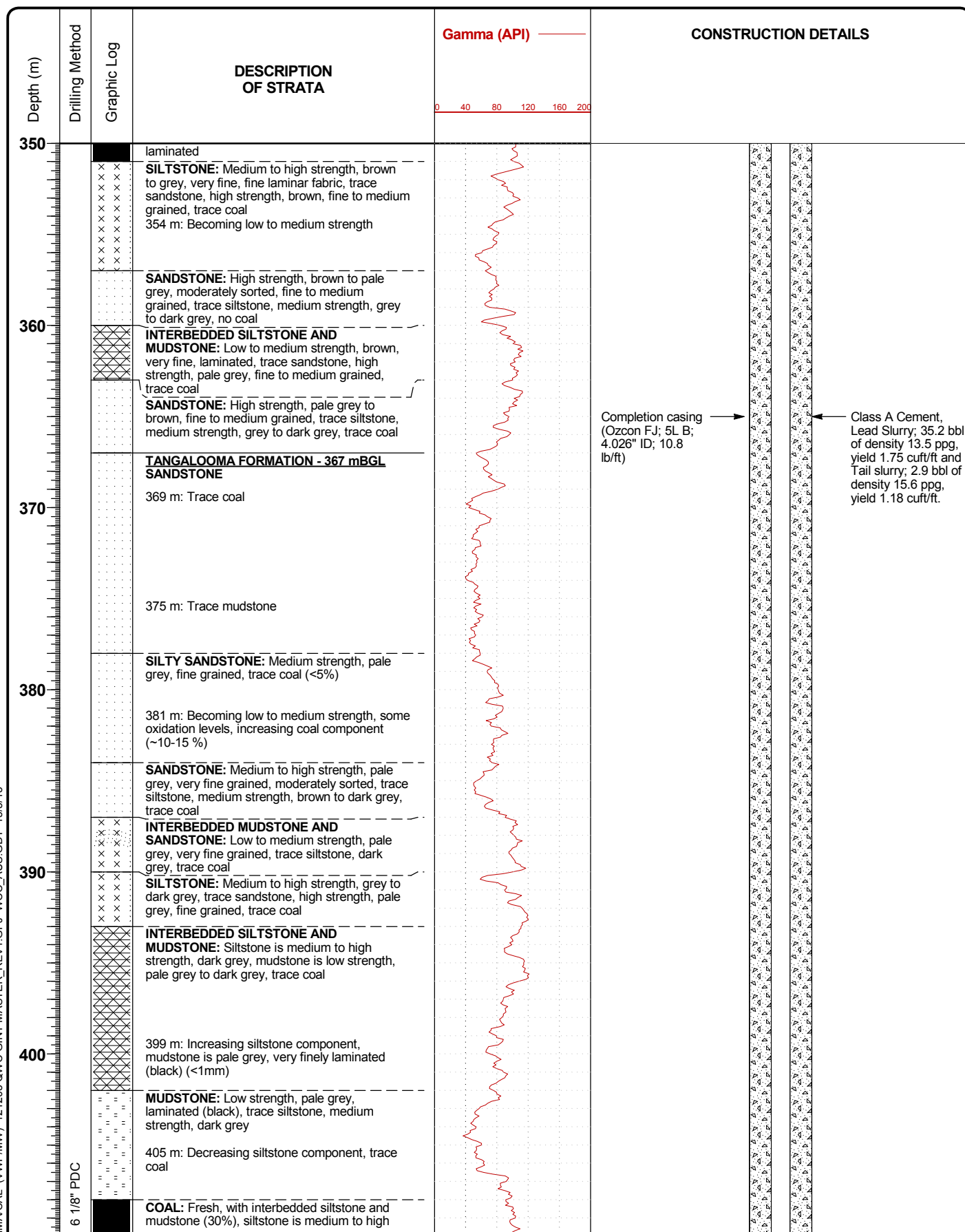
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ID: 130315_ARMGWH01_DRILLOG_INTERIM_REV1





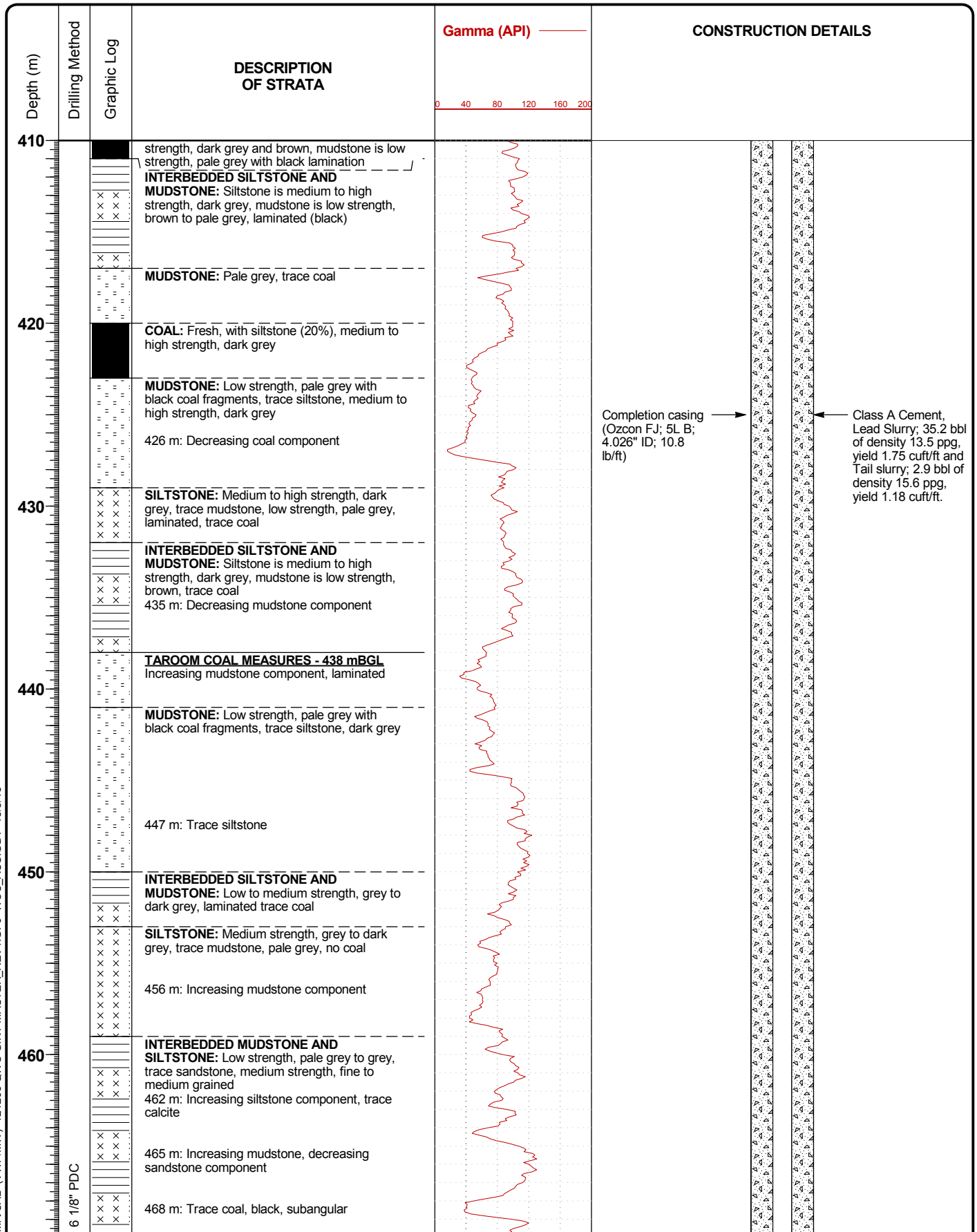
ARMGWH01 (INTERIM)

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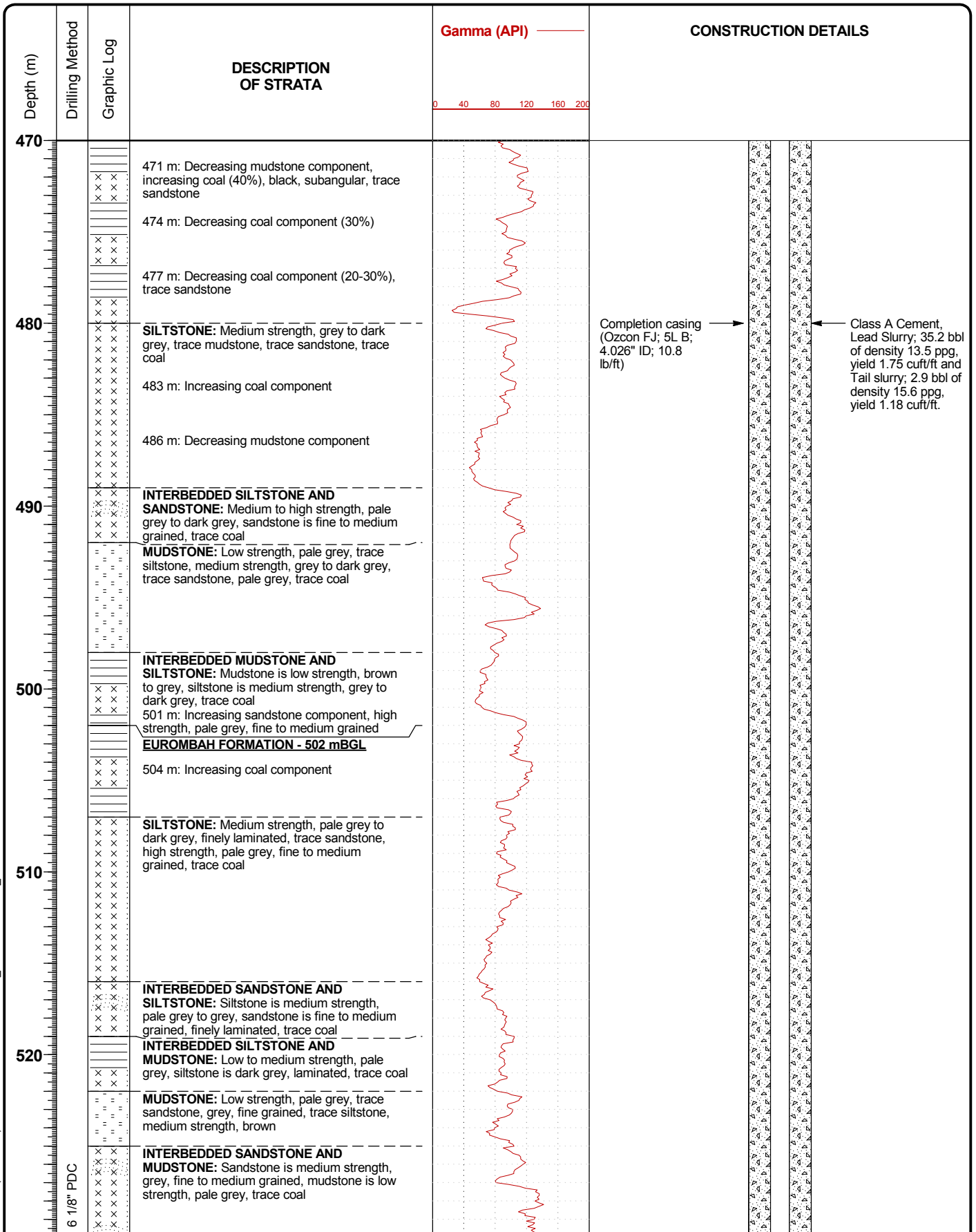
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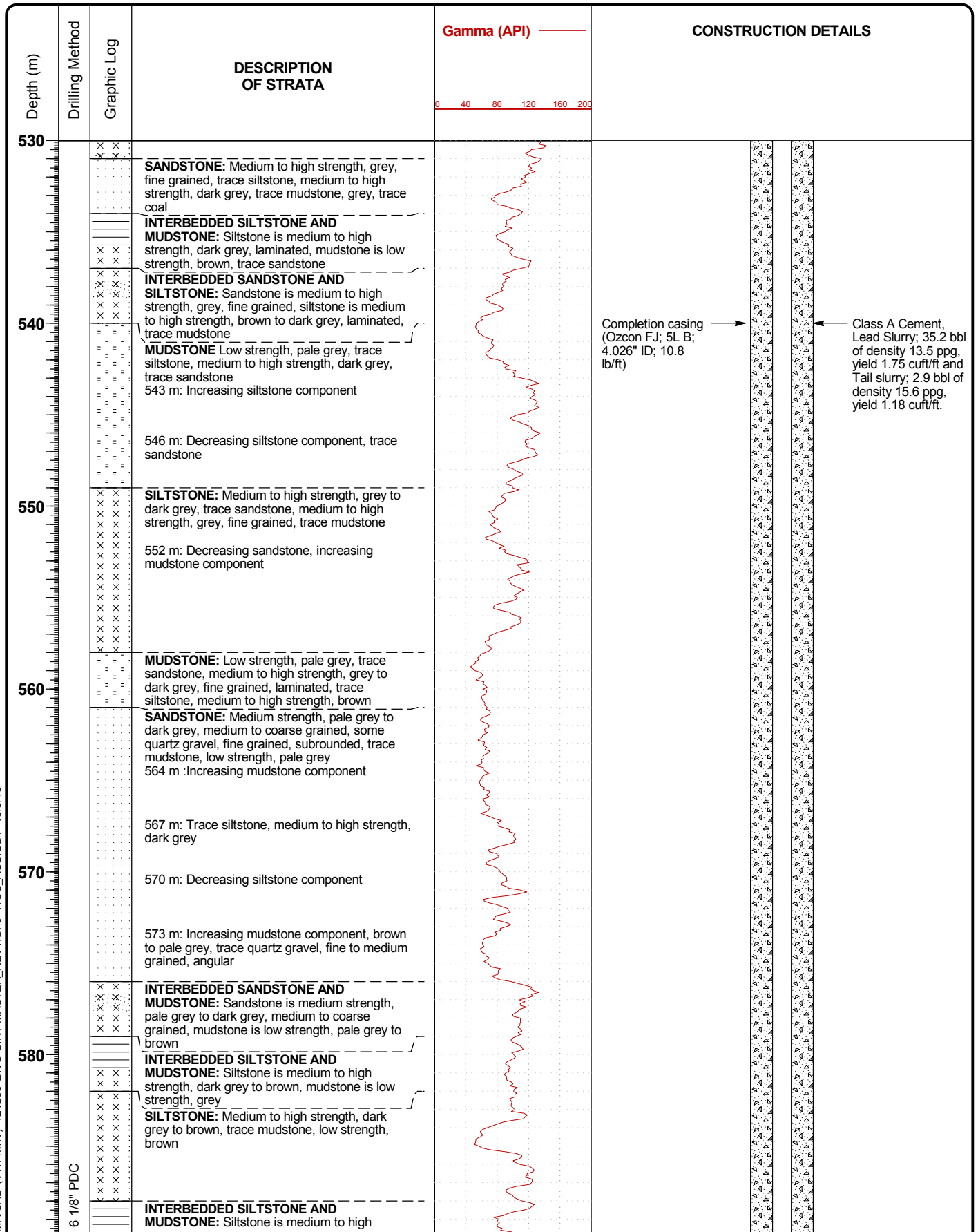
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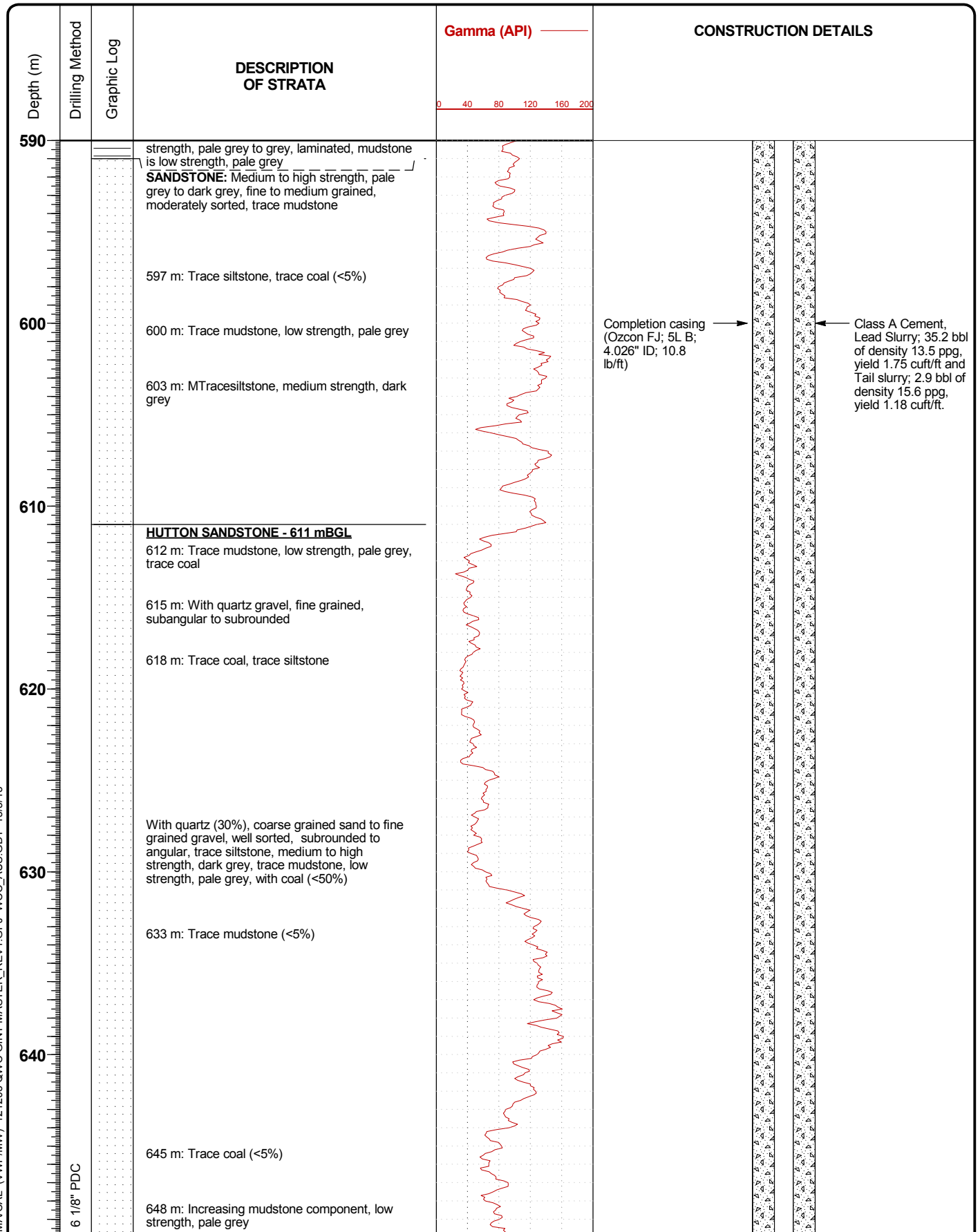
ARMGWH01 (INTERIM)

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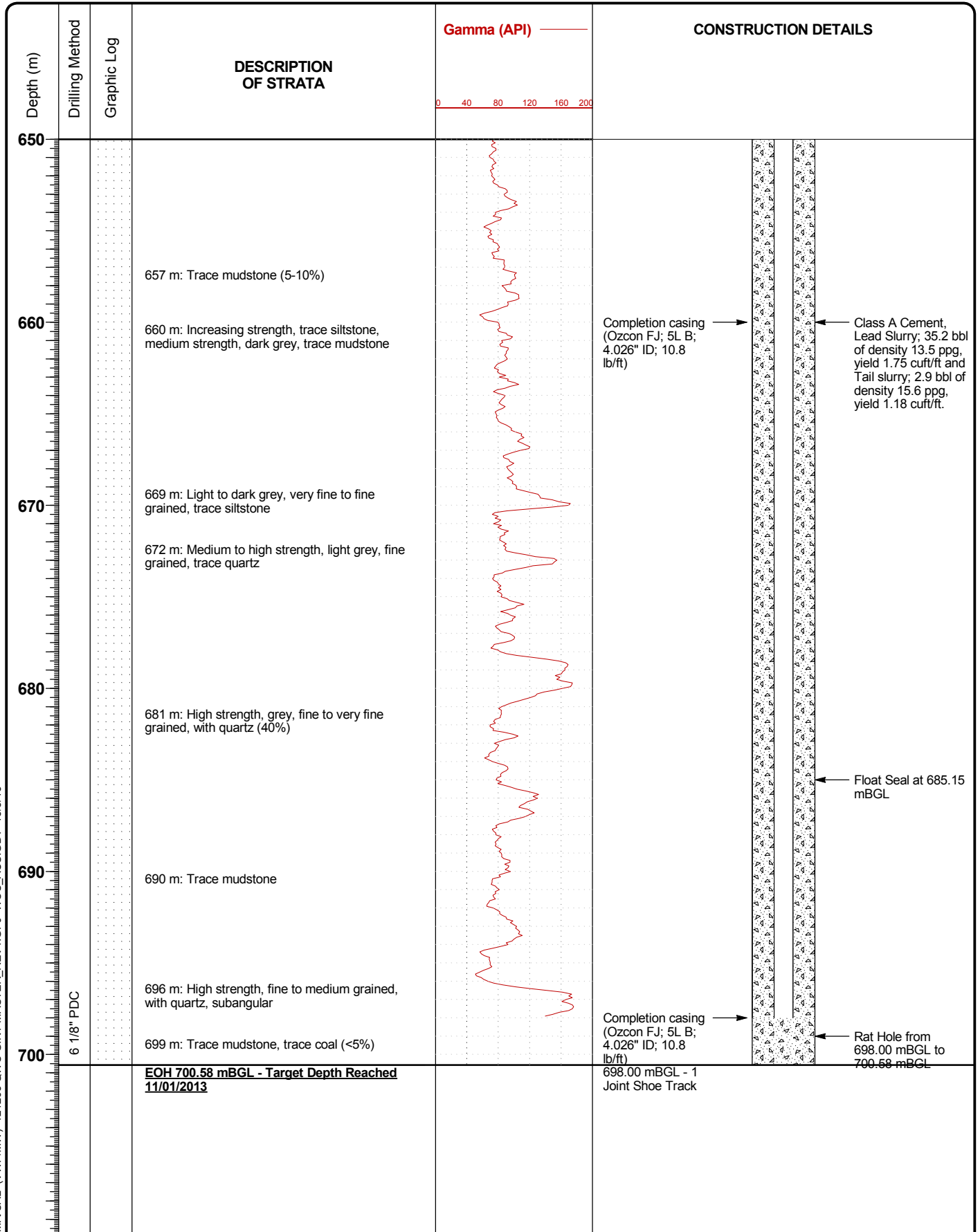


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ID: **130315_ARMGWH01_DRILLOG_INTERIM_REV1**



ARMGWS01 (INTERIM)

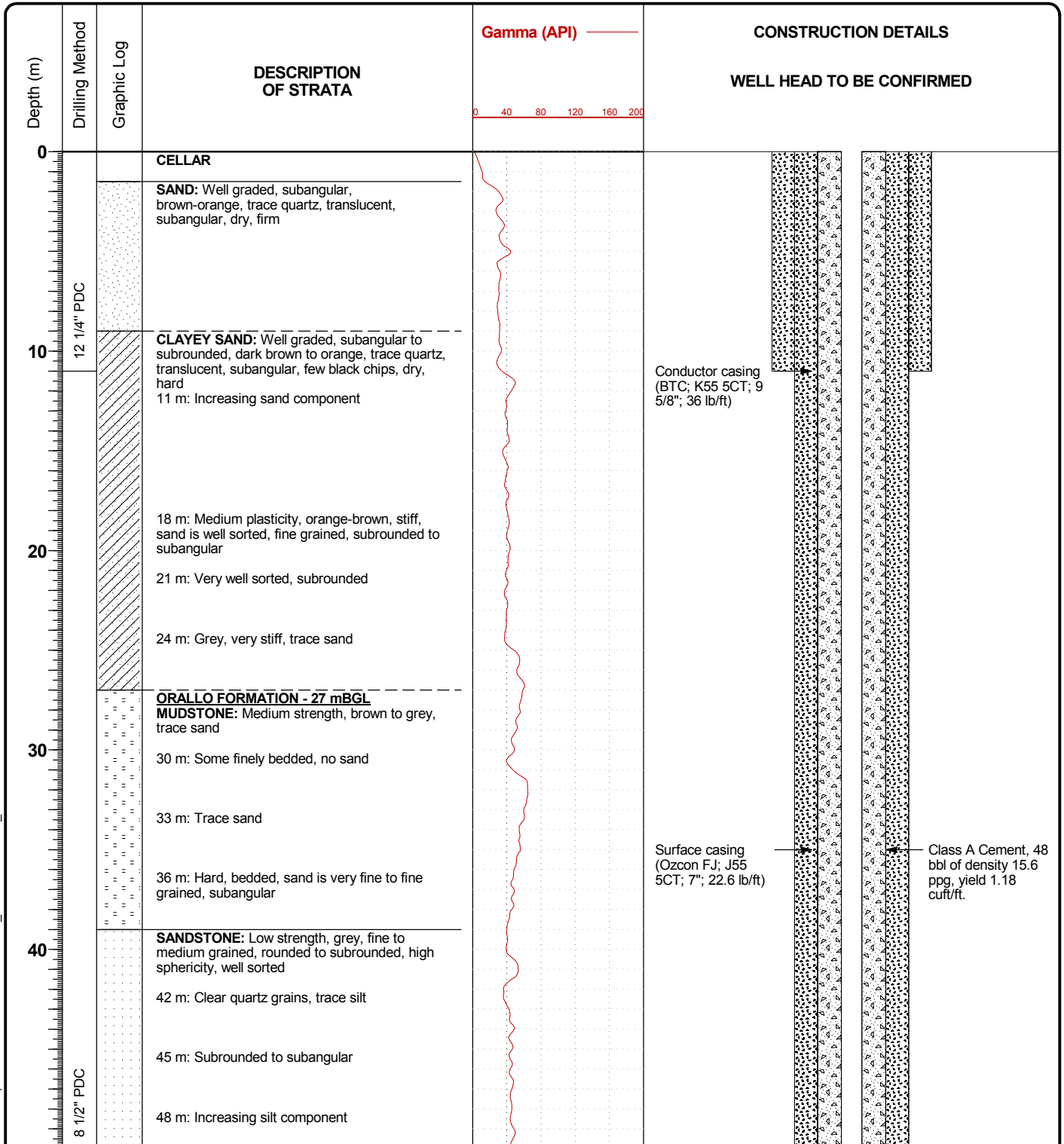
URS Australia Pty. Ltd.
Level 17, 240 Queen St, Brisbane QLD 4000Phone: (07) 3243 2111
Phone: (07) 3243 2199Project Name: **Roma Deep Drilling
Campaign 1**Client: **Santos Ltd**

Document ID:

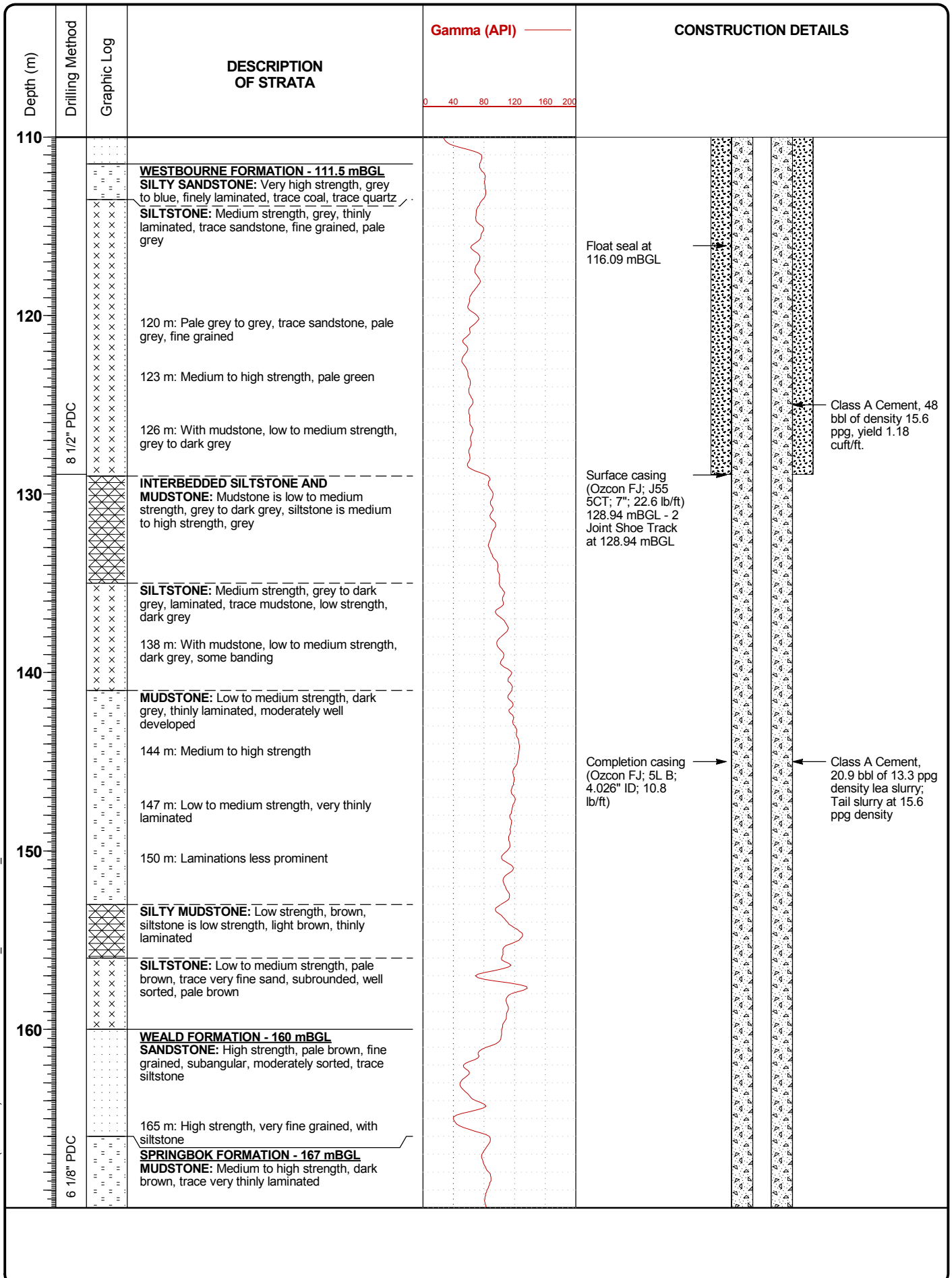
130315_ARMGWS01_DRILLOG_INTERIM_REV1

Drilling Contractor: **Spaulding Drillers**Project No.: **42626910**Location: **Roma**Logged By: **PO, RF, DP**Bore Dia.: **177.8 mm**Casing RL: **371.11 mAHD**Drill Type: **Mud Rotary**Checked By: **MR**Total Depth: **271.7 m**Coordinates: **Lat: -26.387181**Drill Model: **Foremost 24 HD**Date Started: **26-11-12**Casing I.D.: **102.3 mm****Long: 149.125746**Drill Fluid: **MUD (refer to mud program)**Date Finished: **12-12-12**Permit No: **GDEQGW12-07**

SANTOS GAMMA/CAL (VWP/MMW) 121203 QWC GINT MASTER_REV1.GPJ WCC_AUS.GDT 15/3/13



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ARMGWS01 (INTERIM)

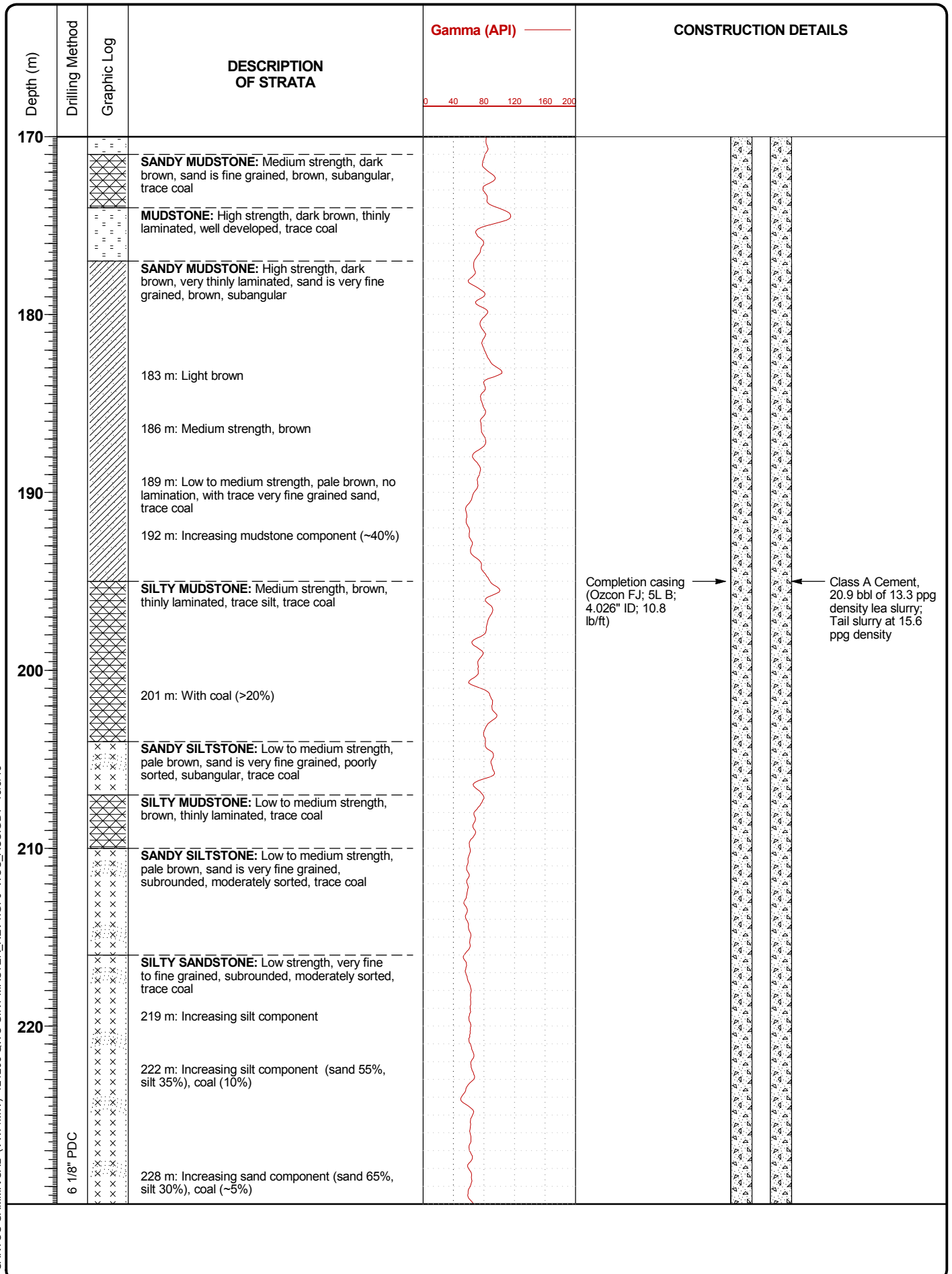
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No.: 42626910

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ID: 130315_ARMGWS01_DRILLOG_INTERIM_REV1

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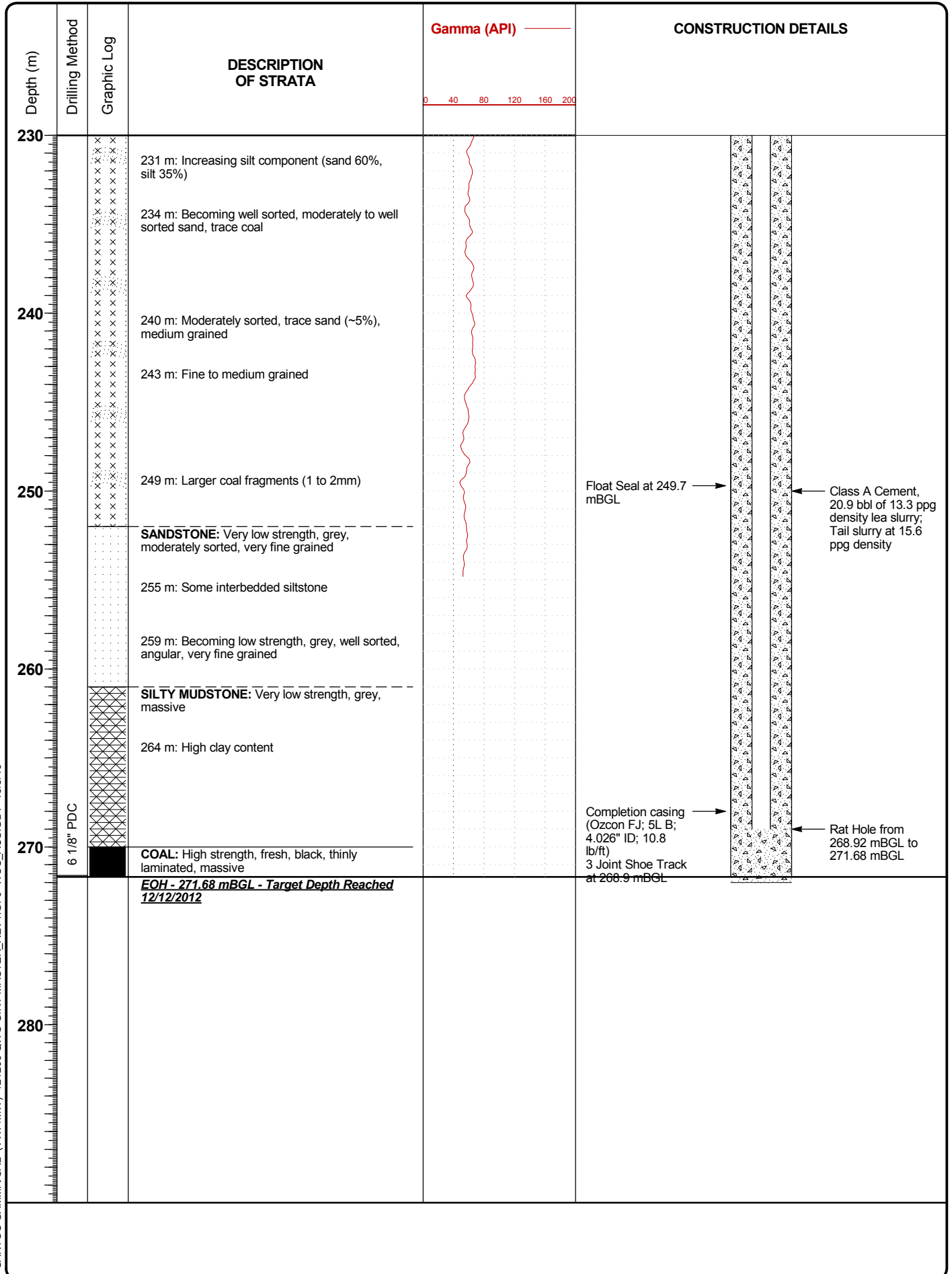


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Project Name: **Santos Deep Drilling Programme**

Client: **Santos Ltd**

Document ID:

Drilling Contractor: **Spaulding Drillers**

Project No.: **42626910**

Location: **Roma**

130310_CRLGWS03_DRILLLOG_FINAL_REV1

Logged By: **RF, SC, TF, DGP**

Bore Dia.: **177.8 mm**

Casing RL: **324.54 mAHD**

Drill Type: **Mud Rotary**

Checked By: **MR**

Total Depth: **565.7 m**

Coordinates: **Lat: -26.583025**

Drill Model: **Foremost 24 HD**

Date Started: **25-2-13**

Casing I.D.: **102.3 mm**

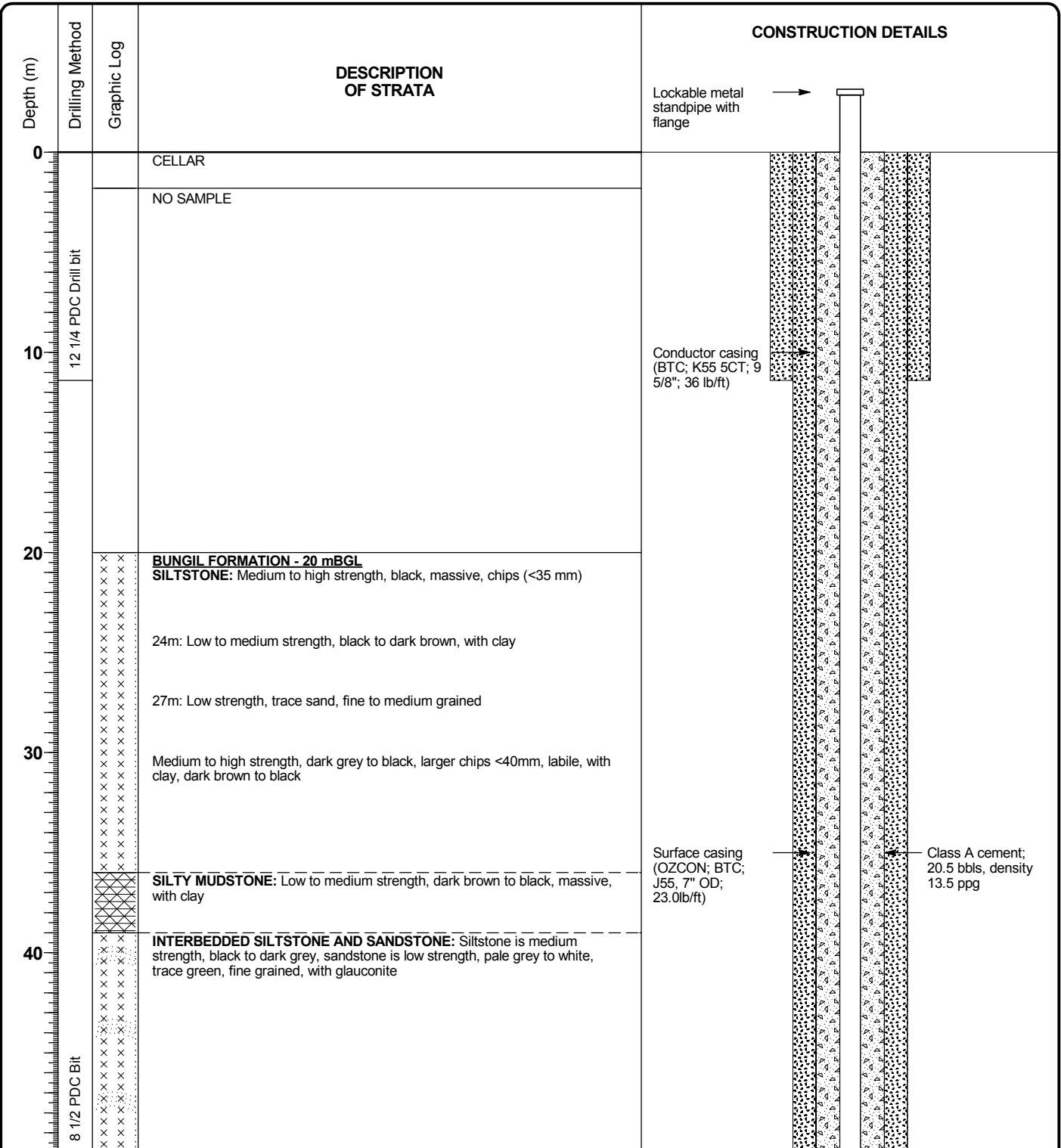
Long: 148.851223

Drill Fluid: **MUD (refer to mud programme)**

Date Finished: **5-3-13**

Permit No: **GDR12-75**

SANTOS NOGAMMA 121203 QWC GINT MASTER_REV1.GPJ WCC_AUS_GDT 18/12/13



Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
50			51m: Siltstone low to medium strength, sandstone fine to medium grained, no glauconite		
			57m: With quartz		
60			63m: Sandstone white to dark grey, siltstone very thinly laminated, well developed		
			SILTY MUDSTONE: Low strength, black, with silty sandstone, trace quartz		
70			INTERBEDDED SANDSTONE AND SILTSTONE: Sandstone is low strength, pale grey to brown, fine to medium grained, trace glauconite, weathered, siltstone is low strength, grey to brown		
			75m: Siltstone low to very low strength	Surface casing (OZCON; BTC; J55, 7" OD; 23.0lb/ft)	Class A cement; 20.5 bbls, density 13.5 ppg
80			81m: Sandstone fine grained, siltstone low strength		
			84m: Trace mudstone, low strength, black		
90			90: Siltstone low to medium strength, dark grey to black, trace quartz		
			93m: Sand very fine to fine grained		
			96m: Siltstone very low strength, chips <1mm		
100			99m: Sandstone medium strength, grey to white		
			105m: Siltstone medium strength, pale grey to dark grey, massive		
			108m: Siltstone low to very low strength, light brown		

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
110			INTERBEDDED SILTSTONE AND MUDSTONE: Siltstone is low strength, pale grey to brown, massive, mudstone is medium to high strength, dark brown, massive, chips (~35mm)	
120			120m: Mudstone high strength, trace very thin laminations, poorly developed 123m: Siltstone medium strength	
130			132m: Siltstone trace thin laminations, poorly to well developed	
140			141m: Siltstone massive, with coal, black, vitreous, small chips (<1mm) SANDSTONE: Medium strength, grey, very fine grained, subangular, quartzose	Surface casing (OZCON; BTC; J55, 7" OD; 23.0lb/ft) Class A cement; 20.5 bbls, density 13.5 ppg
150			INTERBEDDED SILTSTONE AND MUDSTONE: Siltstone is medium to high strength, pale grey, very thinly laminated, well developed, mudstone is high strength, dark brown, thinly laminated, poorly to well developed	
160			MOOGA SANDSTONE - 155 mBGL INTERBEDDED SILTSTONE AND SANDSTONE: Siltstone medium strength, pale to dark grey, massive, sandstone low to medium strength, grey, very fine to fine grained 159m: Trace coal, black, vitreous 162m: No coal SILTSTONE: Medium to high strength, grey, thinly laminated, poorly to well developed, with sand, fine grained, subangular, coarse quartz, clean	

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ID: **130310_CRLGWS03_DRILLLOG_FINAL_REV1**

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
170			174m: Medium strength, no coarse quartz		
180			180m: Trace fine grained sand, subrounded		
			186m: Thinly laminated, well developed		
190			191m: Very high strength, red to brown, massive, with iron		
			LITHIC SANDSTONE: Very high strength, pale grey to yellow, matrix based, few grains		
			SILTY SANDSTONE: Medium to high strength, pale grey to grey, fine grained, subrounded, trace lithic sandstone (~15%), chips (~1mm)	Surface casing (OZCON; BTC; J55, 7" OD; 23.0lb/ft)	Class A cement; 20.5 bbls, density 13.5 ppg
200			198m: Trace lithic sandstone (<10%)		
			SANDY SILTSTONE: High strength, grey to dark grey, thinly laminated, well developed, very fine grained sand, subangular to subrounded		
			204m: Trace coal (~5%), black, vitreous		
210			213m: With coal (~20%)		
			216m: No coal		
			219m: Lignified matter (~30%)		
220			ORALLO FORMATION - 220 mBGL SILTSTONE: Medium strength, pale grey, trace thin laminations, poorly developed, trace lignified matter (~15%), trace sand (~10%)		
			High strength, trace mudstone, brown to black, thinly laminated, poorly developed		
			228m: Trace sand (~5%)		

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
230			231m: Medium strength	
			234m: Trace sand (~10%)	
240			SILTY SANDSTONE: Medium strength, grey to dark grey, massive, fine grained, subangular, siltstone low strength, grey, trace coal (~10%)	
			246m: Low strength, pale grey, fine to medium grained	
250			SILTSTONE: Low strength, dark brown, massive	
			252m: Medium to high strength, grey to brown	
			255m: Low to medium strength, trace mudstone, dark grey	
260			INTERBEDDED SANDSTONE AND SILTSTONE: Sandstone low strength, pale grey to white, fine to medium grained, subangular, quartzose, siltstone high strength, dark grey, large chips (<40mm)	
			264m: Trace coal	
270			270m: Siltstone high strength	
			279m: Sandstone fine grained, with quartz	
280			282m: Siltstone low strength, dark brown, trace mudstone	
			SILTSTONE: Low to medium strength, dark brown, massive, with sand, pale grey, fine to medium grained	

Surface casing
(OZCON; BTC;
J55, 7" OD;
23.0lb/ft)

Class A cement;
20.5 bbls, density
13.5 ppg

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Project
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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
290				
			SANDSTONE: Low strength, grey, fine to medium grained, with coal, chips (<2mm)	
300				
			INTERBEDDED SANDSTONE AND SILTSTONE: Sandstone is low strength, grey, fine to medium grained, with coal, low strength chips (<2mm), siltstone is medium strength, dark grey, massive, trace mudstone, black 306m: Siltstone low to medium strength, with sand, very fine grained	
310				
			SANDY SILTSTONE: Low strength, dark grey, fine grained, massive	
			SILTY SANDSTONE: Low strength, pale grey, fine grained, massive	
320	8 1/2 PDC Bit		321m: Medium strength, dark grey, fine to medium grained	Surface casing (OZCON; BTC; J55, 7" OD; 23.0lb/ft) Surface shoe @ 322.93 mBGL Class A cement; 20.5 bbls, density 13.5 ppg
330			SANDY SILTSTONE: Very low strength, light to medium grey, sand (~30%), light to dark grey, fine grained, subrounded	Completion casing (OZCON; HWT; 5L; 4 1/2"; 10.8lb/ft) Class A cement; 48.9bbls, density 13.5ppg
340			SILTY SANDSTONE: Low strength, light grey to black, fine to medium grained, subrounded to subangular, silt (~40%), medium to dark grey, trace mudstone (<5%), dark grey SANDY SILTSTONE: Low to medium strength, light to medium grey, sand (~30%), light to dark grey, fine grained, subrounded	

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Project
No.: 42626910

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ID: 130310_CRLGWS03_DRILLLOG_FINAL_REV1

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
350			SILTY SANDSTONE: Medium strength, light to medium grey, fine to medium grained, subangular, siltstone (~35%), light grey with dark brown to grey chips 354m: Decrease in siltstone (~30%), no chips	
360			SILTSTONE: Low to medium strength, medium brown to grey, thinly laminated, with sandstone (~20%), low strength, light grey to black, fine grained, subangular	
370			GUBBERAMUNDA SANDSTONE - 363 mBGL SANDSTONE: Low to medium strength, light grey, fine to medium grained, subrounded, trace silt (~10%), medium grey 369m: Trace siltstone (~5%), dark grey, chips (<10mm), silt (~15%) light grey 372m: Increase in silt (~30%) 375m: Trace coal (<1%), with quartz	
380			SILTY SANDSTONE: Very low strength, light grey, fine grained, subrounded, with quartz, silt (~40%), light grey, trace coal (<1%)	
390	6 1/8 PDC Bit		SANDSTONE: Medium to high strength, light grey, fine to medium grained, subangular to angular, quartzose, with silt (~10%), light grey 396m: Trace coal (~5%) 399m: Sandstone subrounded to rounded 402m: Poorly graded, subangular to subrounded, no coal	Completion casing (OZCON; HWT; 5L; 4 1/2"; 10.8lb/ft)
400			SANDY MUDSTONE: Low strength, medium grey, sand (~30%) white to dark grey, poorly graded, subangular, with quartz WESTBOURNE FORMATION - 407 mBGL SILTY MUDSTONE: Medium grey mottled dark grey, silt (~30%) light to medium grey	Class A cement; 48.9bbls, density 13.5ppg

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
410	6 1/8 PDC Bit		MUDDY SILTSTONE: Low strength, medium grey, trace sand (~10%), white to grey, medium grained, subangular		
			417m: Siltstone chips (~5%), medium strength, brown, sand medium to coarse grained		
420			420m: Decrease in sand (<1%), siltstone chips dark brown to grey, thinly laminated		
			SILTSTONE: Low to medium strength, medium brown to grey, chips (<2mm), trace mudstone (~10%), white		
430			SILTY MUDSTONE: Very low strength, medium grey, thinly laminated, silt light to dark grey		
			438m: Highly weathered, light grey to grey, massive, with siltstone (~20%),		
440			441m: Trace siltstone (~15%)		
			MUDSTONE: Very low strength, moderately weathered, light grey, thinly laminated, poorly developed		
450			SILTY MUDSTONE: Very low strength, highly weathered, light grey to grey, massive		
			SANDY SILTSTONE: Low strength, slightly weathered, dark grey to light grey, thinly laminated, minor sand, very fine grained		
460			SILTY MUDSTONE: Very low strength, highly weathered, dark grey, massive		
			SANDY SILTSTONE: Very low strength, highly weathered, light grey, massive, very fine grained		
			SILTY SANDSTONE: Very low strength, highly weathered, light grey, massive, very fine grained, with silt (~30%)		

Completion casing
(OZCON; HWT;
5L; 4 1/2";
10.8lb/ft)

Class A cement;
48.9bbls, density
13.5ppg

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Phone: (07) 3243 2199

Project
No.: **42626910**

Document
ID: **130310_CRLGWS03_DRILLLOG_FINAL_REV1**

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
470			471m: With silt (~20%)		
			474m: Trace coal (~5%)		
480			SANDY SILTSTONE: Very low strength, highly weathered, dark grey, massive, trace sand, very fine grained		
			WEALD SANDSTONE - 482 mBGL SANDSTONE: Very low strength, highly weathered, grey, massive, very fine grained		
490					
			SPRINGBOK SANDSTONE - 486 mBGL SILTSTONE: Very low strength, highly weathered, dark grey to grey, massive, with sandstone (~10%)		
500			INTERBEDDED SILTSTONE AND SANDSTONE: Siltstone low strength, highly weathered, black, sandstone very low strength, highly weathered, grey, very fine grained		
			SILTY SANDSTONE: Low strength, moderately weathered, massive, grey, very fine grained, with silt (~20%)	Completion casing (OZCON; HWT; 5L: 4 1/2"; 10.8lb/ft)	Class A cement; 48.9bbls, density 13.5ppg
			SANDSTONE: Low strength, slightly weathered, grey, massive, very fine grained, trace coal (~5%)		
510					
			516m: With coal (~15%)		
520			522M: Very low strength, brown, massive		
			525m: Grey, well sorted		
			528m: Trace coal (~5%)		

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
530			537m: Fine grained, larger sandstone fragments (>1mm)	
540			SILTY SANDSTONE: Very low to low strength, medium grey, fine grained, subangular, silt (~40%) light to dark grey, chips ? 3mm 543m: Trace siltstone chips (~5%), dark grey to black (<2mm) 546m: Siltstone chips (~10%), dark grey to black (<10mm) 549m: Sandstone fine to medium grained, trace coal (<5%), siltstone ~30%	Completion casing (OZCON; HWT; 5L: 4 1/2"; 10.8lb/ft) → Class A cement; 48.9bbls, density 13.5ppg →
550			SANDSTONE: Low strength, light grey, fine to medium grained, subrounded, with silt (~30%), light grey SANDY SILTSTONE: Low to medium strength, dark grey, thinly laminated, sand (~30%) light to dark grey, medium grained, subrounded to subangular, trace mudstone (<5%), white, soft	Float Collar @ 550.57 mBGL →
560	6 1/8 PDC Bit		SILTY SANDSTONE: Low strength, light grey, fine grained, subrounded to angular, silt (~40%), light grey 563: Trace coal (<5%), trace siltstone (<5%), medium strength, dark brown to grey, thinly laminated	Rat Hole from 563.72 mBGL to 565.72 mBGL →
			END OF HOLE @ 565.72m BGL	
570				
580				

MHTGWP01 (INTERIM)

URS Australia Pty. Ltd.
Level 17, 240 Queen St, Brisbane QLD 4000Phone: (07) 3243 2111
Phone: (07) 3243 2199Project Name: **Santos Deep Drilling Programme**Client: **Santos Ltd**

Document ID:

Drilling Contractor: **Spaulding Drillers**Project No.: **42626910**Location: **Fairview**

130609_MHTGWP01_DRILLLOG_INTERIM_REV1

Logged By: **SC, RF**Bore Dia.: **177.8 mm**Casing RL: **mAHD**Drill Type: **Mud Rotary**Checked By: **MR**Total Depth: **443.1 m**Coordinates: **Lat: -25.824574**Drill Model: **Foremost 24 HD**Date Started: **9-6-13**Casing I.D.: **102.3 mm****Long: 148.791424**Drill Fluid: **K2SO4 (refer to mud program)**Date Finished: **23-6-13**Permit No: **GDFVN13-010**

Depth (m)

Drilling Method

Graphic Log

DESCRIPTION
OF STRATA

CONSTRUCTION DETAILS

0

12 1/4" PDC Drill bit

Cellar

No Sample

10

20

WALLOON COAL MEASURES (0.0 - 96.0 mBGL)**SANDSTONE:** Very low strength, some oxidation weathering, yellow-brown to grey, fine grained, some siltstone, grey**SILTY SANDSTONE:** Low to medium strength, grey to brown, with white quartz inclusions, fine to medium grained, few clay**SILTSTONE:** Low strength, dark grey, few sand, fine grained, trace coal flecks

Low to medium strength, few coal flecks, few clay

30

SILTY SANDSTONE: Low to medium strength, grey to white, fine to medium grained, ~20% quartz, some feldspar, subangular**INTERBEDDED SILTY SANDSTONE - SILTSTONE:** Silty sandstone is low to medium strength, grey to white, fine to medium grained, ~20% quartz, some feldspar, subangular, siltstone is low strength, brown to black, laminated

Siltstone is medium strength, grey to black

40

SANDSTONE: Low to medium strength, white to grey, fine to medium grained, ~50% quartz, medium grained, some siltstone flecks

Fine grained

INTERBEDDED SANDSTONE - SANDY SILTSTONE: Sandstone is low to medium strength, white to grey, fine to medium grained, ~50% quartz, medium grained, sandy siltstone is, low strength, dark grey, fine grained, trace coal, black, non-vitreousConductor casing
(BTC; K55 5CT; 9
5/8"; 36 lb/ft)Completion casing
(OZCON; HWT;
5LB; 4 1/2";
10.8lb/ft)Class A cement;
18.2bbbls, 14.2ppg,
yield of 2.26ft/sk

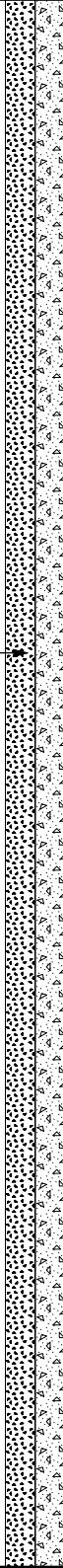
MHTGWP01 (INTERIM)

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Project
No.: 42626910

Document
ID: 130609_MHTGWP01_DRILLLOG_INTERIM_REV1

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
50	8 1/2" PDC Bit		Low strength, medium grained	 	
			INTERBEDDED SANDSTONE - SILTSTONE: Sandstone is low to medium strength, white to grey, fine to medium grained, ~50% quartz, medium grained, siltstone is low to medium strength, black and grey laminae, trace sand, fine grained		
			SILTY SANDSTONE: Low to medium strength, grey-green, fine grained, ~35% quartz, poorly sorted		
60			INTERBEDDED SILTY SANDSTONE - SILTSTONE: Silty sandstone is low to medium strength, grey-green, fine grained, ~35% quartz, poorly sorted, siltstone is low to medium strength, alternating grey and black laminae, few sand, fine grained		
			INTERBEDDED SANDSTONE AND SANDY SILTSTONE: Sandstone is low strength, grey, fine to medium grained, sandy siltstone is medium strength, grey to black, fine grained		
			SANDY SILTSTONE: Low to medium strength, grey to black, fine grained, ~20% quartz, few coal flecks, black, non-vitreous		
			SILTSTONE: Low to medium strength, dark grey to black, laminated, few sand, fine grained, ~30% quartz		
70			Fine to medium grained		
			SILTY SANDSTONE: Low strength, pale grey, fine to medium grained, subangular to subrounded, ~30% quartz, trace mudstone, medium strength, dark brown, trace fine laminations		
			MUDSTONE: Medium strength, dark brown, fine laminations, trace sand, fine grained, subrounded		
80			Trace sand (~10-15%)		
			Dark brown to black, no sand		
			SILTY MUDSTONE: Low to medium strength, dark brown, trace fine laminations, pale grey		
			Increased siltstone content ~40%		
90			MUDSTONE: Medium strength, dark brown, fine laminations, trace sand, very fine to fine grained, subangular to subrounded, 25% quartz		
			SILTY SANDSTONE: Very low to low strength, pale grey, fine grained, subrounded, 20% quartz		
			HUTTON SANDSTONE (96.0 to 210.0 mBGL) SILTY SANDSTONE: Low to medium strength, ~25% quartz, trace mudstone (5-10%), medium strength, brown, massive		
100			No mudstone		
			Increased silt content (~40%)		
			SANDY SILTSTONE: Low strength, pale grey, massive, fine grained,		

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Project
No.: **42626910**

Document
ID: **130609_MHTGWP01_DRILLLOG_INTERIM_REV1**

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
110			subrounded, 10% quartz Pale to dark grey Trace lignified matter (10%), low strength, brown	
120			SILTY SANDSTONE: Low strength, pale grey, fine grained, subangular to subrounded	
			SANDSTONE: High strength, pale grey to pale yellow, medium grained, subangular to subrounded, lithic, trace siltstone, low strength, grey	
130			SILTY SANDSTONE: Very low to low strength, pale grey, fine grained, subrounded Trace mudstone (5%), medium strength, dark brown, finely laminated Medium to coarse grained, 30% quartz, 10 -15% mudstone No mudstone Fine to medium grained Pale grey to grey	Completion casing (OZCON; HWT; 5LB; 4 1/2"; 10.8lb/ft) Class A cement; 18.2bbbls, 14.2ppg, yield of 2.26ft/sk
140			Medium strength, grey to dark grey, 15% quartz High strength Dark grey	
150			Coarse grained, 25% quartz, trace coal (10%), black, non-vitreous No coal, pale grey Dark grey, siltstone is medium strength	
160			Pale grey, 15% quartz, coarse grained	

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
170			20% quartz, coarse grained, subrounded, clean	
180			Increased silt content (35-40%)	
			Trace coal flecks (5%)	
190			SILTSTONE: Low strength, black to dark grey, trace sand, very fine grained	
			Fine grained, 30% quartz, some coal, black, vitreous to subvitreous	
			Dark grey, fine to medium grained, few coal	
			Few sand, fine grained, trace coal	
200			INTERBEDDED SILTY SANDSTONE - SILTSTONE: Silty sandstone is low strength, grey, fine grained, subangular to subrounded, ~40% quartz, siltstone is low strength, dark grey	Completion casing (OZCON; HWT; 5LB; 4 1/2"; 10.8lb/ft)
			SANDSTONE: Low strength, grey, fine to coarse grained, some silt, quartzose, subangular to subrounded, trace coal	
			Few quartz, coarse grained, subrounded	
210			SILTSTONE: Low to medium strength, dark grey, few sand, fine grained, ~10% quartz, trace coal, black, subvitreous	
			EVERGREEN FORMATION (210.0 - 345.0 mBGL)	
			SILTSTONE: Medium strength, dark grey to black, some sand, fine grained, few coal	
			Dark grey, few sand, fine grained	
220			INTERBEDDED SILTY SANDSTONE - SILTSTONE: Silty sandstone is low strength, dark grey to black, fine grained, siltstone is low strength, grey to green	
			Increased siltstone content, black, few coal, subvitreous	
			SILTSTONE: Low to medium strength, dark grey, trace sand, fine grained, few coal, black, vitreous to subvitreous	
			Medium to high strength, dark grey to black, no sand, trace coal	
			Low strength, thinly laminated	Class A cement; 18.2bbbls, 14.2ppg, yield of 2.26ft/sk

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Project
No.: 42626910

Document
ID: 130609_MHTGWP01_DRILLLOG_INTERIM_REV1

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
230			Few coal, black, subvitreous, trace oxidation weathering Low to medium strength Medium to high strength, grey, trace sand, fine grained, trace mudstone, low to medium strength, black High strength, moderately hard, dark grey, some sand, very fine grained	
240			INTERBEDDED SILTSTONE - SANDY SILTSTONE: Siltstone is high strength, dark grey, sandy siltstone is low strength, pale grey, fine grained, few coal flecks SILTSTONE: Medium strength, brown to black, trace coal Very high strength, dark grey to black, no sand, few mudstone Medium to high strength, black, some mudstone, some coal, black-brown, vitreous	
250			SANDSTONE: Very low strength, grey to white, translucent, medium to coarse grained, quartzose, some siltstone, black ~80% quartz, very coarse grained, subrounded to subangular, few coal flecks, black, subvitreous	Completion casing (OZCON; HWT; 5LB; 4 1/2"; 10.8lb/ft)
260			INTERBEDDED SANDSTONE - SANDY SILTSTONE: Sandstone is very low strength, grey to white, very coarse grained, sandy siltstone is low strength, moderately hard, dark grey to black SILTSTONE: Medium strength, dark grey black, some mudstone, some coal, black, subvitreous	Class A cement; 18.2bbbls, 14.2ppg, yield of 2.26ft/sk
270			SILTY SANDSTONE: Low strength, pale grey to black, medium to fine grained, quartzose, trace coal, trace siltstone SANDY SILTSTONE: Low to medium strength, pale grey to dark grey, fine grained, trace coal, trace quartz Fine to medium grained, some quartz, subangular Low strength, dark grey, few sand, fine grained	
280			INTERBEDDED SILTSTONE - SILTY SANDSTONE: Siltstone is low to medium strength, grey, finely laminated, and silty sandstone is low strength, pale grey to black, medium to fine grained, quartzose Trace coal, black, subvitreous SILTSTONE: Medium strength, dark grey to black, trace sand, fine grained, trace coal, black, subvitreous Dark grey	

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ID: 130609_MHTGWP01_DRILLLOG_INTERIM_REV1

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
290					
			MUDSTONE: Medium strength, dark brown, massive, trace sand, very fine grained, trace coal, black		
			SILTSTONE: Low to medium strength, pale grey, trace quartz (~10-15%), fine to medium grained, trace coal, black, dull lustre		
300			SILTSTONE: Low to medium strength, grey to brown, trace sand, fine grained, trace coal, black, dull lustre		
			Pale grey, coal is subvitreous		
			Increased sand content (~25%), fine grained, subrounded, clean quartz, no coal		
310			Sand (>30%), fine to medium grained		
			SILTY SANDSTONE: Medium strength, grey, fine to medium grained, subrounded, 30% quartz, trace coal, black, vitreous		
			SANDY SILTSTONE: Low to medium strength, pale grey to grey, fine to medium grained, subrounded, ~20% quartz, rounded		
320			MUDSTONE: Low to medium strength, dark brown, medium grained, trace fine laminations, few quartz, medium grained		
			Decrease in quartz (~5%)		
			SILTSTONE: Low to medium strength, pale grey		
			Grey, few sand, fine to medium grained, subrounded, 15% quartz, few mudstone, as above		
330			SILTSTONE: Medium to high strength, dark grey, massive, trace fine laminations, ~10% quartz, coarse grained		
			INTERBEDDED SILTSTONE - SANDSTONE: Siltstone is medium to high strength, dark grey, massive, trace fine laminations, sandstone is medium to high strength, pale grey, fine grained, subangular		
			Increased sand content		
340			SILTY SANDSTONE: Medium strength, pale grey, medium grained, subangular to subrounded, ~15% quartz		
			INTERBEDDED SILTY SANDSTONE - SILTSTONE: Silty sandstone is medium strength, pale grey, medium grained, subangular to subrounded, ~15% quartz, siltstone is medium strength, black, few coal, black, vitreous		
			PRECIPICE SANDSTONE (345.0 TO 438.5 mBGL)		
			SILTY SANDSTONE: Medium strength, pale grey, medium grained, subangular to subrounded, ~15% quartz, few siltstone, low to medium strength, dark grey		
			SANDSTONE: Low strength, grey-white, coarse grained, few siltstone, as		

Completion casing
(OZCON; HWT;
5LB; 4 1/2";
10.8lb/ft)

Class A cement;
18.2bbbls, 14.2ppg,
yield of 2.26ft/sk

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Document
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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
350			above Medium grained, few coal, low strength, black, subvitreous	
			SILTSTONE: Low strength, grey to dark grey, few sand, fine grained, trace coal	Completion casing (OZCON; HWT; 5LB; 4 1/2"; 10.8lb/ft)
360			SANDY SILTSTONE: Low strength, pale grey to dark grey, fine to medium grained, ~30% quartz, no coal Medium grained, some coal	
			SILTSTONE: Low strength, pale grey to dark grey, few sand, fine grained, trace coal	
370			INTERBEDDED SANDSTONE - SILTSTONE: Sandstone is low strength, grey-white, translucent, few quartz, siltstone is low strength, pale grey to dark grey, few sand, fine grained, trace coal Sandstone is medium to coarse grained, subrounded, siltstone is low strength, black Siltstone has few sand, medium grained Fine to medium grained	
380			INTERBEDDED SANDSTONE - SANDY SILTSTONE: Sandstone is low strength, grey-white, translucent, medium to coarse grained, subrounded, sandy siltstone is low strength, grey, fine grained, ~80% quartz, trace coal Few siltstone Coarse grained, subrounded, trace silt Medium to coarse grained, subangular to subrounded, few feldspar	393.0 mBGL - Top of perforation interval Rat hole; 7.79m (390.14-397.93mBGL)
390			INTERBEDDED SANDSTONE - SILTSTONE: Sandstone is medium to coarse grained, subangular to subrounded, few feldspar, siltstone is low to medium strength, dark grey Fewer sand, subrounded Medium to coarse grained, white to grey, translucent, quartzose, subrounded to subangular, few siltstone, low strength, black Siltstone is medium strength, dark grey, poorly sorted, quartz is angular to subrounded Fine to medium grained, 80% quartz, subangular to subrounded, increased siltstone Siltstone is pale to dark grey, clean quartz	399.0 mBGL - Bottom of perforation interval
400				

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
410			Siltstone is dark grey		
			SILTSTONE: Low to medium strength, dark grey, trace fine laminations, ~5% quartz, trace sandstone, pale grey	Completion casing (OZCON; HWT; 5LB; 4 1/2"; 10.8lb/ft)	Class A cement; 18.2bbls, 14.2ppg, yield of 2.26ft/sk
420			>85% quartz, translucent, medium to coarse grained, angular to subrounded, clean, trace siltstone, as above	Bentonite Seal (2m)	
			SILTSTONE: Medium strength, dark grey, trace very fine laminations, ~60% quartz, translucent, fine to coarse grained, poorly sorted, trace sandstone, as above	Filter sand; 1m	Gravel Pack: 2-4mm gravel (421.2 - 441.3 mBGL)
430			Medium to coarse grained, ~80% quartz, translucent to white		
			~50% quartz, angular to subrounded		
			~85% quartz, medium to very coarse grained, trace coal, low strength, black, dull lustre		
440			MOOLAYEMBER FORMATION (438.5 - EOH) SILTSTONE: Medium strength, dark grey, trace thin laminations, trace quartz, fine to medium grained, subrounded Low to medium strength, dark grey to black, no quartz		Johnson Stainless Steel 1mm Aperture Screen (426.2 - 438.2 mBGL)
			END OF HOLE: 443.0 mBGL		
450					
460					

FVGWP01 (FINAL)

URS Australia Pty. Ltd.
Level 17, 240 Queen St, Brisbane QLD 4000

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Project Name: **Roma Deep Drilling
Programme
Campaign 2**

Client: **Santos Ltd**

Document ID:

Drilling Contractor: **Spaulding Drillers**

Project No.: **42626910**

Location: **Fairview**

130701_FVGWP01_DRILLLOG_INTERIM_REV1

Logged By: **DGP**
Checked By: **MR**
Date Started: **1-7-13**
Date Finished: **2-7-13**

Bore Dia.: **177.8 mm**
Total Depth: **93.7 m**
Casing I.D.: **102.3 mm**

Casing RL: **mAHD**
Coordinates: **Lat: -25.622395**
Long: 148.961733
Permit No: **GDFVN13-008**

Drill Type: **Mud Rotary**
Drill Model: **Foremost 24 HD**
Drill Fluid: **MUD (refer to mud program)**

SANTOS NOGAMMA 121203 QWC GINT MASTER_REV1.GPJ WCC_AUS.GDT 10/7/13

CONSTRUCTION DETAILS

Depth (m)

Drilling Method

Graphic Log

DESCRIPTION
OF STRATA

0

22" PDC Drill Bit

Cellar

No sample

10

EVERGREEN FORMATION (0 - 52 mBGL) SANDSTONE: Low to medium strength, ~50% highly weathered, ~50% fresh, pale brown-red to pale grey, fine grained, massive, quartzose

12m: Medium strength, fresh, pale grey to grey

20

INTERBEDDED SANDSTONE AND SILTSTONE: Sandstone is medium strength, fresh, grey, fine grained, massive, siltstone is medium strength, fresh, black, thinly laminated, poorly developed

SILTSTONE: Very low strength, highly weathered, dark grey, massive, some sand, fine grained

INTERBEDDED SANDSTONE AND SILTSTONE: Sandstone is medium strength, grey, fine grained, massive, siltstone is medium strength, black, massive

SANDSTONE: Medium strength, moderately weathered, grey to red-brown, fine grained, massive, subrounded, poorly sorted

27m: Low to medium strength, extensive oxidation weathering, fine to very fine grained

30

INTERBEDDED SANDSTONE AND SILTSTONE: Siltstone is medium strength, black, massive

SANDSTONE: Medium strength, moderately weathered, red-brown to grey, fine grained, massive

36m: Medium grained, some orange mottling

39m: Becoming dark brown

40

42m: Low strength, dark red, fine to medium grained, massive, well sorted

45m: Becoming pale red

INTERBEDDED SANDSTONE AND SILTSTONE: Sandstone is low strength, slightly weathered, grey, fine grained, massive, siltstone is low

Conductor casing
(BTC; K55 5CT; 9
5/8"; 36 lb/ft)

Completion casing
(OZCON; HWT;
5LB; 4 1/2";
10.8lb/ft)

Class A Cement: 9.1
bbls, 13.5 ppg, 3 %
bentonite slurry

Bentonite Seal
(48.2-51.8 mBGL)

[illegible]

URS Australia Pty. Ltd.
Level 17, 240 Queen St, Brisbane QLD 4000Phone: (07) 3243 2111
Phone: (07) 3243 2199Project Name: **Roma Deep Drilling
Campaign 1**Client: **Santos Ltd**

Document ID:

Drilling Contractor: **Spaulding Drillers**Project No.: **42626910**Location: **Roma**

130611_WBLGWH03_DRILLLOG_INTERIM_REV1

Logged By: **RF, SC**Bore Dia.: **177.8 mm**Casing RL: **mAHD**Drill Type: **Mud Rotary**Checked By: **MR**Total Depth: **442.1 m**Coordinates: **Lat: -26.787376**Drill Model: **Foremost 24 HD**Date Started: **26-3-13**Casing I.D.: **102.3 mm****Long: 149.201182**Drill Fluid: **K2SO4 (refer to mud program)**Date Finished: **19-4-13**Permit No: **GDR12-077**

Depth (m)

Drilling Method

Graphic Log

DESCRIPTION
OF STRATA

CONSTRUCTION DETAILS

WELL ABANDONED

CELLAR

NO SAMPLE

12 1/4" PDC Drill bit

8 1/2" PDC Bit

WALLUMBILLA FORMATION (0-184mBGL)

CLAY: Medium to high plasticity, uniform, yellow orange, trace grey silt,
tightly packed, stiff**SILT:** Medium plasticity, dark grey, trace yellow orange uniform clay, tightly
packed, stiff

27m: Decrease in clay (<5%)

SILTSTONE: Medium strength, fresh, grey, massive, trace subrounded
quartz

34m: Becoming low to medium strength

37m: Medium strength, grey to dark grey

43m: Trace thin lamination, well developed, no quartz

49m: Becoming low to medium strength

Conductor casing
(BTC; K55 5CT; 9
5/8"; 36 lb/ft)Surface casing
(5CT; J55, 7",
23.0lb/ft)Perforation Zone
4: 47mBGL -
50mBGL For full
details refer toClass A cement: 3%
bentonite slurry,
410L of water, and
13sks cement,
14.1ppgClass A cement;
Pumped 64.6bbl @
6bpm, 260psi,
density of 13.5ppg

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
50				well construction record
				Bridge Plug @ 56mBGL →
60			64m: Medium to high strength, trace very fine quartz, subangular	
			70m: Grey to dark brown, trace mudstone	
70			73m: Very fine to fine grained quartz	
				Surface casing (5CT; J55, 7", 23.0lb/ft) →
				Class A cement; Pumped 64.6bbl @ 6bpm, 260psi, density of 13.5ppg ←
80			82m: Grey, no mudstone, very fine grained quartz	
			88m: No quartz	
90			91m: Becoming high strength	
			97m: Medium strength	
100			103m: Light grey, trace fine grained sand, subangular	
			109m: Dark grey, massive	

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
110					
120					
130			133m: Increased sand content (~15%)		
140			INTERBEDDED SILTSTONE - SANDSTONE: Siltstone is medium strength, grey, massive, sandstone is medium strength, light grey, fine grained, subrounded		
150			145m: Grey to brown, sandstone is fine to medium grained		
160			151m: Fine grained		
			154m: Fine to medium grained		
			157m: Increase in sandstone (~40%)		
			SANDSTONE: Medium strength, light grey, fine grained, subangular, clean quartz (~5-10%), trace siltstone, medium strength, light grey		
			163m: Trace fine black minerals		

8 1/2" PDC Bit

Perforation Zone
3: 129.6mBGL - 131.6mBGL For full details refer to well construction record

Surface casing
(5CT; J55, 7", 23.0lb/ft)

Class A cement;
Pumped 64.6bbl @ 6bpm, 260psi, density of 13.5ppg

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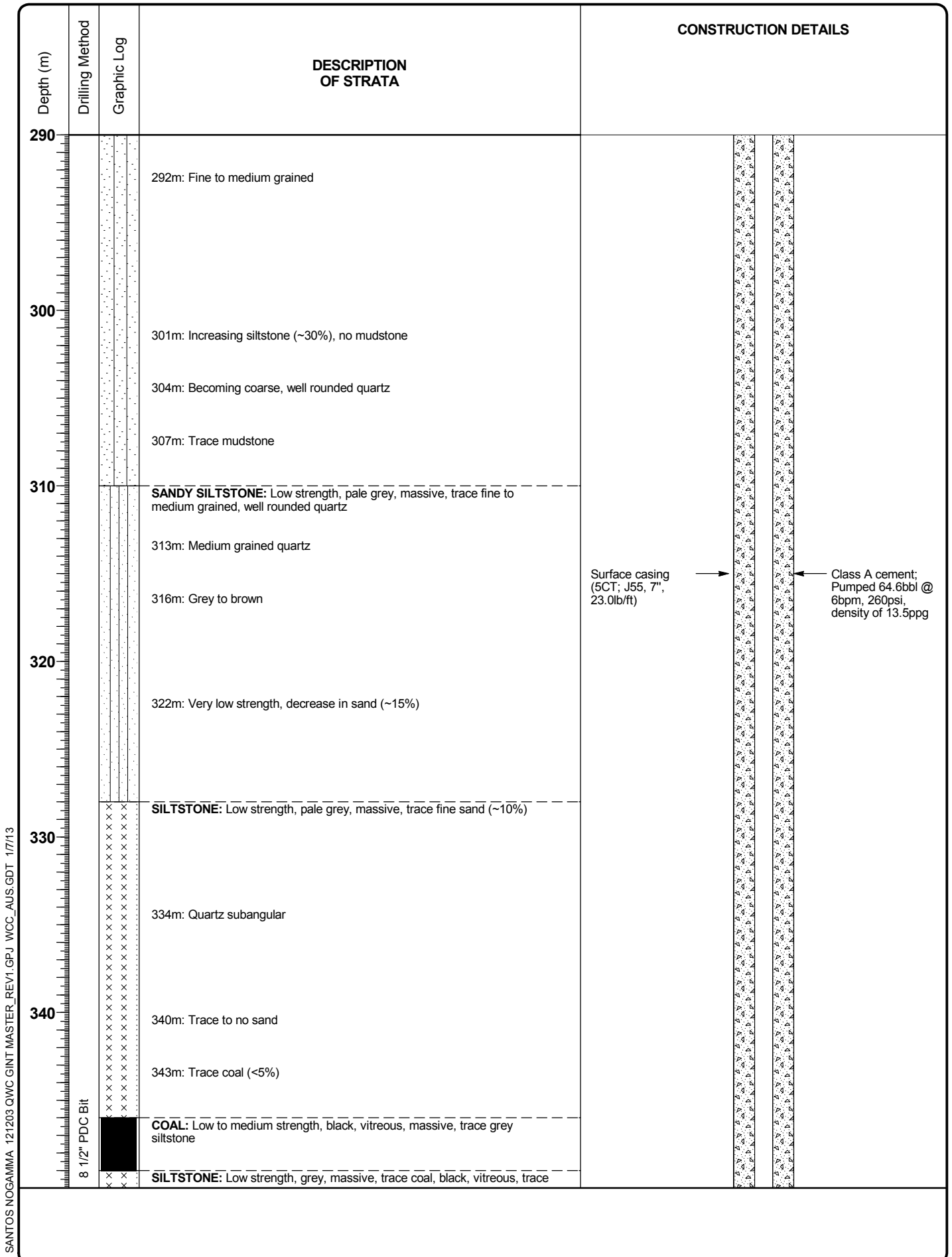
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No.: **42626910**

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ID: **130611_WBLGWH03_DRILLLOG_INTERIM_REV1**

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
170			175m: Becoming dark grey	Perforation Zone 2: 171mBGL - 173mBGL For full details refer to well construction record
180				
190			BUNGIL FORMATION (184-271mBGL) INTERBEDDED SANDSTONE - MUDSTONE: Sandstone is medium strength, grey, fine grained, subrounded, mudstone is low strength, carbonaceous sand 187m: Trace very fine siltstone	
200			193m: Sandstone, very fine	Surface casing (5CT; J55, 7", 23.0lb/ft)
210			202m: Increasing sandstone	Class A cement; Pumped 64.6bbl @ 6bpm, 260psi, density of 13.5ppg
220			SANDSTONE: Medium strength, grey, fine to medium grained, clean, subrounded, sorted quartz grains MUDSTONE: Medium strength, grey to dark grey, trace siltstone	
	8 1/2" PDC Bit		INTERBEDDED MUDSTONE - SILTSTONE: Mudstone is medium strength, grey to dark grey, siltstone is medium strength, dark grey, fine to very fine quartz grains	

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
230				
240				
250			247m: Siltstone, light to dark grey	
			SANDSTONE: Medium strength, light to dark grey, medium to coarse grained, subangular quartz, trace siltstone, grey	Perforation Zone 1: 248mBGL - 250mBGL For full details refer to well construction record
260			SANDY SILTSTONE: Medium strength, grey, massive, trace fine grained sand	Surface casing (5CT; J55, 7", 23.0lb/ft)
			262m: Trace brown mudstone	Class A cement; Pumped 64.6bbl @ 6bpm, 260psi, density of 13.5ppg
			SILTY SANDSTONE: Low to medium strength, dark grey, fine to medium grained, subangular, trace grey siltstone, trace grey to brown mudstone	
270			268m: Trace lignified matter, low strength, dark brown	
			MOOGA SANDSTONE (271-403mBGL)	
			SANDY SILTSTONE: Low strength, grey, massive, trace fine grained sand and trace brown mudstone	
			274m: Decreasing sand (<10%)	
			277m: Increasing sand (~15-20%)	
280			280m: Sand fine to medium grained	
			283m: Sand fine grained	
			SILTY SANDSTONE: Low strength, grey, fine grained, subangular to subrounded, trace light grey silt, trace grey to brown mudstone	
			289m: Coarse quartz grains, subangular, trace lithic sandstone	



SANTOS NOGAMMA 121203 QWC GINT MASTER_REV1.GPJ WCC_AUS.GDT 17/13

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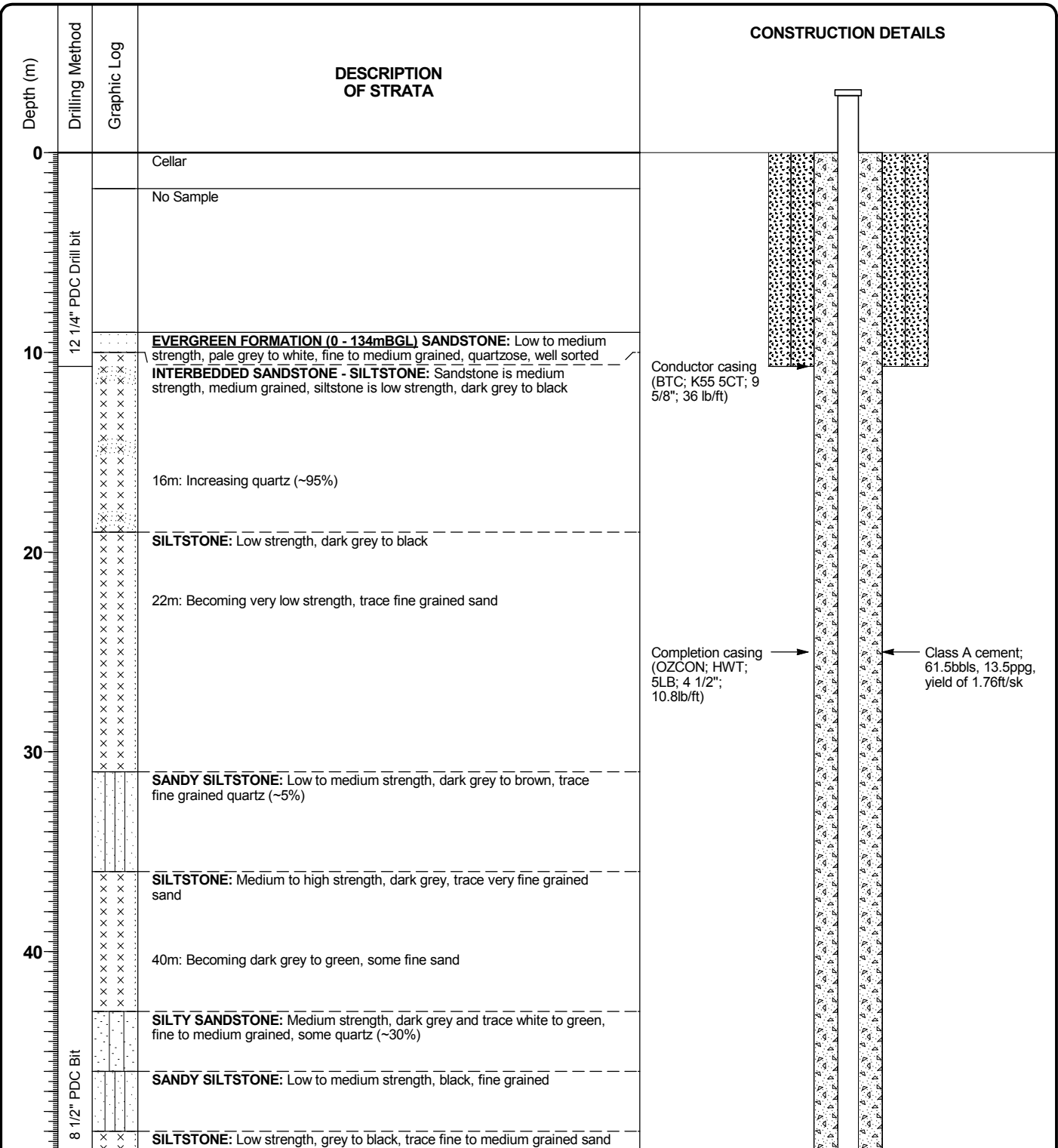
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No.: **42626910**

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
410				
			INTERBEDDED SANDSTONE - MUDSTONE: Sandstone is medium strength, grey, fine to medium grained, subrounded, uniform, mudstone is medium strength, grey, trace black coal	
			COAL: Medium strength, black, vitreous	
420			INTERBEDDED SANDSTONE - MUDSTONE: Sandstone is medium strength, grey, fine to medium grained, subrounded, uniform, mudstone is medium strength, grey, trace black coal	
			424m: Sandstone medium to high strength	
430				
			MUDSTONE: Medium strength, grey, trace silt	
440	8 1/2" PDC Bit		439m: Trace sandstone	Surface casing (5CT; J55, 7", 23.0lb/ft) →
			END OF HOLE: 442.07mBGL	← Class A cement; Pumped 64.6bbl @ 6bpm, 260psi, density of 13.5ppg
450				
460				

URS Australia Pty. Ltd. Level 17, 240 Queen St, Brisbane QLD 4000		Phone: (07) 3243 2111 Phone: (07) 3243 2199	Project Name: Santos Deep Drilling Programme	Client: Santos Ltd	Document ID: 130530_EVGGWC01_DRILLLOG_FINAL_REV1
Drilling Contractor: Spaulding Drillers			Project No.: 42626910	Location: Fairview	
Logged By: SC, DGP		Bore Dia.: mm	Casing RL: mAHD	Drill Type: Mud Rotary	
Checked By: MR		Total Depth: 400.0 m	Coordinates: Lat: -26.531212	Drill Model: Foremost 24 HD	
Date Started: 18-5-13		Casing I.D.: 102.3 mm	Long: 148.769362	Drill Fluid: K2SO4 (refer to mud program)	
Date Finished: 26-5-13			Permit No: GDFVN13-009		



Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
50					
			SANDY SILTSTONE: Low to medium strength, grey to black, fine to medium grained quartz (~30%), moderately sorted		
			SILTSTONE: Low to medium strength, grey to black, trace fine grained sand		
			SANDY SILTSTONE: Medium strength, black, sand fine grained (~20%)		
60					
			SILTSTONE: Low to medium strength, grey, some fine to medium grained sand (~25%), interbedded with mudstone		
			SANDY SILTSTONE: Medium strength, dark grey to black, fine grained		
70					
			SILTY SANDSTONE: Medium strength, pale grey to black, fine grained, trace quartz (~15%), trace mudstone, laminated		
			SANDY SILTSTONE: Medium strength, dark grey, trace quartz (~10%)		
			76m: Some medium strength, black mudstone interbedded		
80					
			SANDSTONE: Low to medium strength, grey to dark grey, fine to medium grained, some quartz (~35%), some silt interbedded		
			SANDY SILTSTONE: Medium strength, dark grey		
			SILTSTONE: Low strength, dark grey to black, some fine grained sand		
			88m: Interbedded medium strength, black, laminated mudstone		
90					
			SANDY SILTSTONE: Medium strength, dark grey to black, fine grained, laminated, some quartz (~25%)		
			96m: Low to medium strength		
			SILTSTONE: Low to medium strength, dark grey to black, trace fine grained sand		
100					
			SILTSTONE: Low strength, grey to black, trace fine grained sand, trace coal		
			SILTY SANDSTONE: Low to medium strength, dark grey to black, fine to coarse grained, poorly sorted, some quartz (~30%), trace coal		
			109m: Some interbedded medium strength, black siltstone		

Completion casing
(OZCON; HWT;
5LB; 4 1/2";
10.8lb/ft)

Class A cement;
61.5bbbls, 13.5ppg,
yield of 1.76ft/sk

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Project
No.: **42626910**

Document
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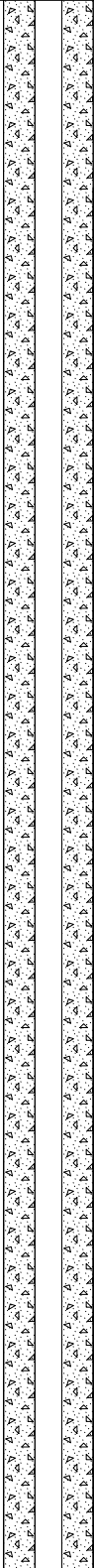
Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
110			112m: Some low strength, black mudstone, trace coal		
120			SANDSTONE: Low strength, grey to white, fine to medium grained, quartzose, interbedded with low to medium strength, black, very fine grained siltstone		
			SILTY SANDSTONE: Low to medium strength, grey to white, fine grained, some siltstone		
			127m: Low to medium strength, dark grey to green, trace fine sand		
130			SILTSTONE: Medium strength, grey, trace fine grained sand		
			SILTSTONE: Low strength, dark grey, interbedded with some low strength, pale grey, fine to medium grained sand PRECIPICE SANDSTONE (134mBGL - 168mBGL)		
			SANDSTONE: Low strength, grey to white, medium to coarse grained, quartzose, subangular to subrounded, some siltstone	Completion casing (OZCON; HWT; 5LB; 4 1/2"; 10.8lb/ft)	Class A cement; 61.5bbls, 13.5ppg, yield of 1.76ft/sk
140					
			148m: Becoming medium grained		
150			151m: Becoming medium to coarse grained, some siltstone, trace coal		
160			160m: Becoming coarse grained, quartzose (~90% quartz), subrounded		
			163m: Becoming very coarse grained, trace siltstone		
			166m: Becoming medium to coarse grained, some low strength, dark siltstone		
			MOOLAYEMBER FORMATION (169mBGL - 288mBGL) SANDY		

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
170			SLITSTONE: Low strength, black to dark grey, fine grained sand, trace quartz, trace coal	 Completion casing (OZCON; HWT; 5LB; 4 1/2"; 10.8lb/ft) Class A cement; 61.5bbbls, 13.5ppg, yield of 1.76ft/sk	
			SANDY SILTSTONE: Very low strength, grey to dark grey, medium to coarse grained quartz sand (~40%)		
180			180m: Some coal, black, very low strength		
			SANDY SILTSTONE: Low strength, white to dark grey, medium to coarse grained, poorly sorted, some quartz (~35%)		
190			SILTY SANDSTONE: Low strength, white to black, medium to coarse grained, some quartz (~30%)		
			SANDY SILTSTONE: Low strength, dark grey, fine to medium grained, trace quartz, trace low strength brown to black coal		
200			SILTSTONE: Low to medium strength, grey to dark grey, trace fine grained sand, trace quartz		
			202m: Some low to medium strength, dark brown to black mudstone		
			SANDY SILTSTONE: Low strength, dark grey, fine grained, trace quartz, poorly sorted		
210			SILTSTONE: Low strength, dark grey to black, trace fine grained sand, trace quartz		
220			223m: Becoming very low strength, some quartz (~20%)		
			226m: Trace low strength mudstone		
			229m: Trace fine grained sand		

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
230			232m: Becoming low to medium strength, some medium strength mudstone, trace coal 235m: Thinly laminated siltstone, some mudstone (~30%), trace quartz (~5%) 238m: Some light grey mudstone (~30%), trace coal (~2%)	
240			SANDSTONE: Medium strength, grey to dark grey, medium to coarse grained, massive	
250			SANDSTONE: Medium to high strength, fresh, grey to dark grey, medium to coarse grained, massive, trace low strength, dark grey siltstone (~10%)	
			INTERBEDDED SANDSTONE - SILTSTONE: Sandstone is high strength, fresh, grey, medium grained, massive, siltstone is medium to high strength, dark grey to black	
260			SILTSTONE: Medium strength, fresh, dark grey to black, massive 262m: Some fine sandstone	
			SANDSTONE: High strength, dark grey, fine to medium grained, massive, some siltstone 268m: Trace siltstone, some quartz	
270			SILTSTONE: High strength, black, massive, trace sandstone	
			INTERBEDDED SANDSTONE - SILTSTONE: Sandstone is high strength, grey to dark grey, fine to medium grained, siltstone is medium strength, black, massive	
280			SANDSTONE: High strength, light grey to dark grey, fine to medium grained, massive	
			SANDSTONE: High strength, moderately weathered, dark grey to grey, fine to medium grained, massive CLEMATIS SANDSTONE (288mBGL - 397mBGL) 289m: Becoming low strength, quartz grains interbedded within white to grey	Completion casing (OZCON; HWT; 5LB; 4 1/2"; 10.8lb/ft) Class A cement; 61.5bbls, 13.5ppg, yield of 1.76ft/sk

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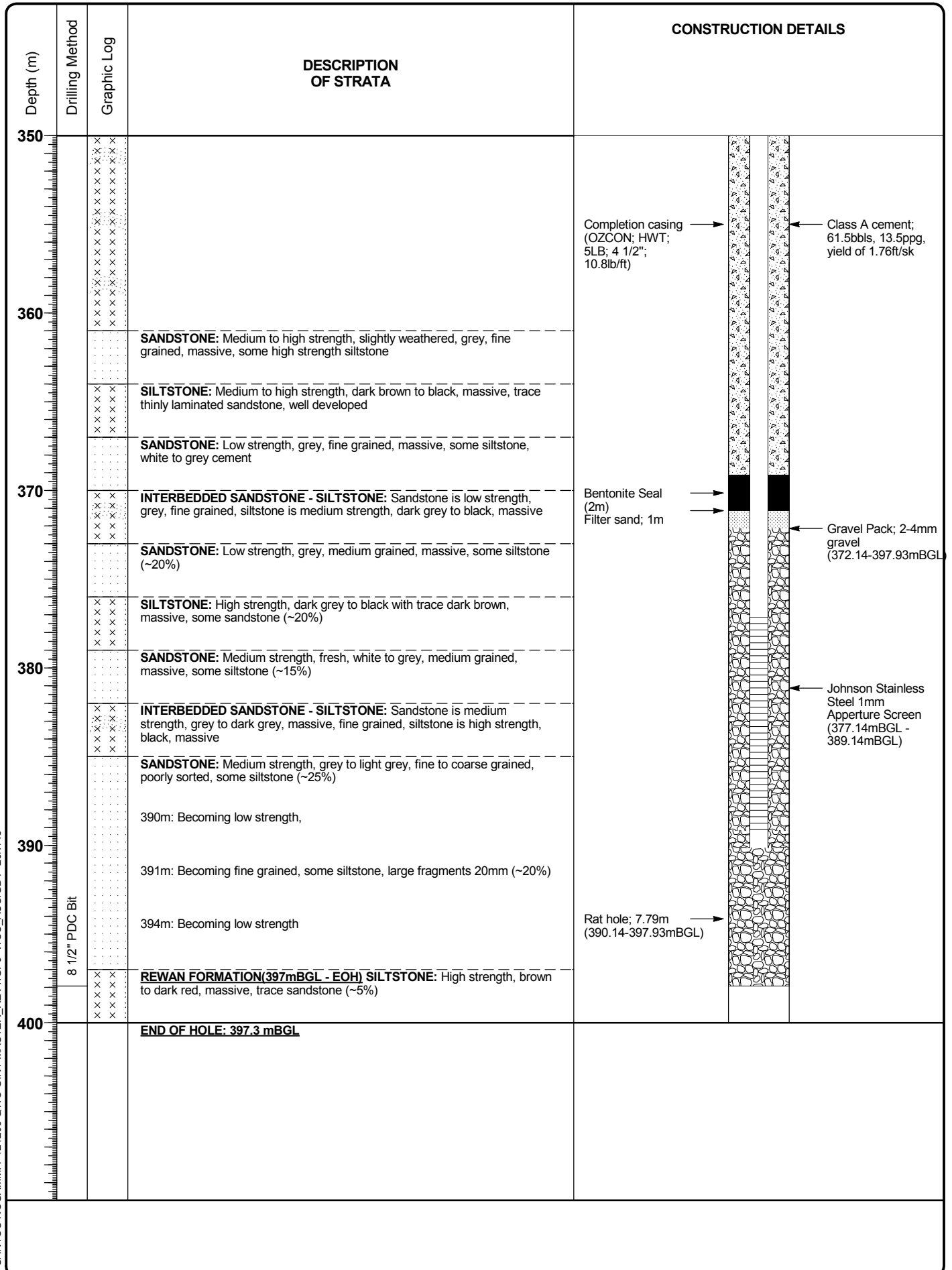
Project
No.: 42626910

Document
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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
290			matrix	
300			INTERBEDDED SANDSTONE - SILTSTONE: Sandstone is low strength, highly weathered, grey, fine grained, massive, siltstone is medium strength, dark grey, massive	
310			SANDY SILTSTONE: Medium strength, medium to high strength, black, massive, with fine grained white sand (~30%)	
320			SILTSTONE: Medium strength, black, massive, trace grey, fine grained sandstone	
			INTERBEDDED SANDSTONE - SILTSTONE: Sandstone is low to medium strength, slightly weathered, grey, medium grained, massive, siltstone is medium strength, black, massive	
			SANDSTONE: Low to medium strength, dark grey, massive, poorly sorted, fine to coarse grained, subrounded quartz	
330			SILTSTONE: Low strength, fresh, black, thinly laminated, poorly developed	
			SANDSTONE: Low to medium strength, dark grey, massive, poorly sorted, fine to coarse grained	
340			SILTSTONE: High strength, fresh, black, massive, trace sandstone	
			INTERBEDDED SANDSTONE - SILTSTONE: Sandstone is very low strength, fresh, light grey, fine to medium grained, white to grey cement, well sorted, siltstone is high strength, black, massive	

Completion casing
(OZCON; HWT;
5LB; 4 1/2";
10.8lb/ft)

Class A cement;
61.5bbls, 13.5ppg,
yield of 1.76ft/sk



KNAGWH01 (INTERIM)URS Australia Pty. Ltd.
Level 17, 240 Queen St, Brisbane QLD 4000Phone: (07) 3243 2111
Phone: (07) 3243 2199Project Name: **Santos Deep Drilling Programme**Client: **Santos Ltd**

Document ID:

130919_KNAGWH01_DRILLLOG_INTERIM_REV1

Drilling Contractor: **Spaulding Drillers**Project No.: **42626910**Location: **Roma**Logged By: **KM, SC**Bore Dia.: **177.8 mm**Casing RL: **mAHD**Drill Type: **Mud Rotary**Checked By: **TB**Total Depth: **420.0 m**Coordinates: **Lat:**Drill Model: **Foremost 24 HD**Date Started: **18-9-13**Casing I.D.: **102.3 mm****Long:**Drill Fluid: **K2SO4 (refer to mud programme)**Date Finished: **30-9-13**

Permit No:

Depth (m)

Drilling Method

Graphic Log

DESCRIPTION OF STRATA**CONSTRUCTION DETAILS**Lockable metal
standpipe with
flangeConductor casing
(BTC K55; 7", 33.7
kg/m)Completion casing
(ECPS; HWT;
5LB; 4 1/2"; 16.1
kg/m)CBM Cement - total
slurry 46.0 bbl,
density 13.50 ppg

CELLAR

JUANDAH COAL MEASURES (0 - 36 mBGL)
INTERBEDDED SANDSTONE AND MUDSTONE: Sandstone is low strength, grey with black flecks, medium grained, angular, mudstone is medium strength, light brown, massive**SANDSTONE:** Very low strength, highly weathered, grey with black flecks, massive, medium to fine grained, poorly sorted, angular

18 m: Medium strength, moderately weathered, medium grained, well sorted

COAL: High strength, black, massive**MUDSTONE:** Very low strength, highly weathered, brown, massive**TANGALOOMA SANDSTONE (36 - 57 mBGL)**
SANDSTONE: Extremely low strength, highly weathered, grey, laminated, poorly developed, fine grained, with mudstone (~30%)

45 m: With coal, black

48 m: Very low strength, massive, well sorted

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
50			51 m: Increasing strength	
			INTERBEDDED SANDSTONE AND SILTSTONE: Sandstone is low strength, grey, fine grained, siltstone is medium strength, fresh, dark grey, massive	
			TAROOM COAL MEASURES (57 - 140 mBGL)	
			INTERBEDDED MUDSTONE AND SILTSTONE: Mudstone is very low strength, brown, siltstone is medium strength, dark grey, massive	
60			60 m: Siltstone low strength, mudstone extremely low to very low strength, light grey	
			66 m: With interbedded coal, medium strength, black, vitreous	
70			72 m: Mudstone is extremely low strength, no coal	
			75 m: Increase in mudstone	
80			MUDSTONE: Extremely low strength, light grey, trace siltstone, dark grey	
90			90 m: Trace coal, black, vitreous	
			93 m: Mudstone light to medium grey, siltstone low to medium strength, medium to dark grey	
100			INTERBEDDED MUDSTONE AND SILTSTONE: Mudstone is extremely low strength, light grey, siltstone is low to medium strength, medium to dark grey, trace sandstone, medium strength, light grey, fine grained	
			SILTSTONE: Medium strength, medium grey with black rootlets, with mudstone (~20%), extremely low strength, white to very light grey	
			MUDSTONE: Extremely low strength, light grey with black flecks, trace siltstone, low strength, grey	

Completion casing
(ECPS; HWT;
5LB; 4 1/2"; 16.1
kg/m)

CBM Cement - total
slurry 46.0 bbl,
density 13.50 ppg

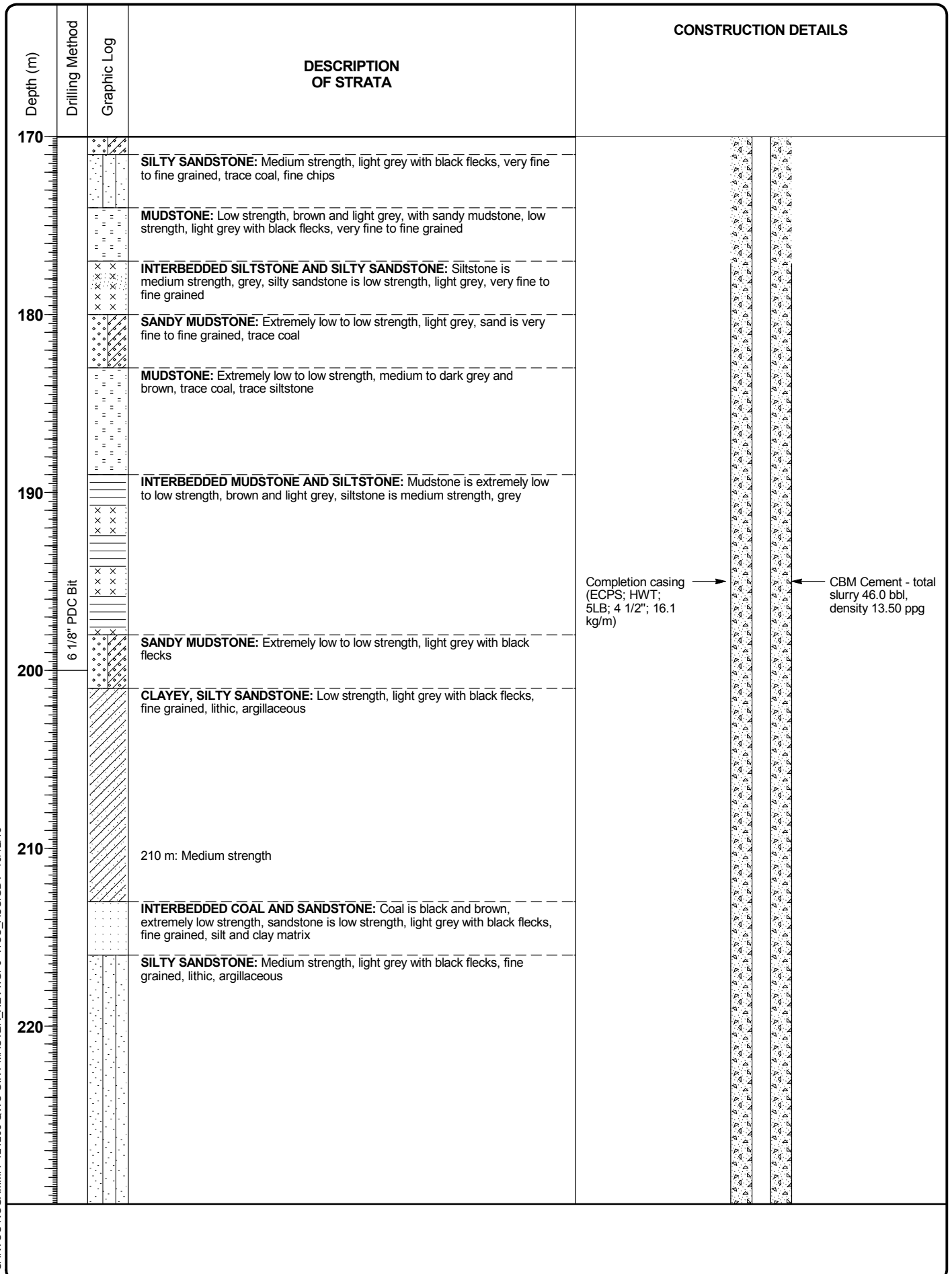
Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
110	6 1/8" PDC Bit		INTERBEDDED MUDSTONE AND SILTSTONE: Mudstone is extremely low strength, light grey with black flecks, siltstone is medium to low strength, medium grey, trace coal, extremely low strength, black	
			INTERBEDDED MUDSTONE, SANDSTONE AND SILTSTONE: Mudstone is extremely low strength, light grey, sandstone is extremely low strength, light grey with black flecks, lithic, siltstone is medium strength, medium grey	
			INTERBEDDED MUDSTONE AND SILTSTONE: Mudstone is extremely low strength, light grey, siltstone is medium strength, medium grey, trace coal, black, vitreous	
120				
			INTERBEDDED MUDSTONE AND SANDSTONE: Mudstone is extremely low to low strength, light grey, sandstone is light grey with black specks, fine to very fine grained, lithic	
			SILTY SANDSTONE: Low to medium strength, light grey with black flecks, very fine to fine grained, argillaceous, with mudstone (~20%), extremely low strength, light grey	
130				
			INTERBEDDED MUDSTONE AND SILTSTONE: Mudstone is low strength, light grey, siltstone is medium strength, medium grey, trace coal (~10%), black, vitreous 138 m: No coal	
140			EUROMBAH FORMATION (140 - 330 mBGL) 141 m: Siltstone dark to medium grey	
			SILTY SANDSTONE: Low to medium strength, light grey with black flecks, very fine to fine grained, lithic, argillaceous	
150	6 1/8" PDC Bit		SANDY MUDSTONE: Low strength, light grey with black flecks, very fine to fine grained	Completion casing (ECPS; HWT; 5LB; 4 1/2"; 16.1 kg/m) → CBM Cement - total slurry 46.0 bbl, density 13.50 ppg
			INTERBEDDED MUDSTONE AND SILTSTONE: Mudstone is low strength, light grey, with sand, siltstone is medium strength, dark grey, trace white clay	
			MUDSTONE: Low strength, brown and light grey, with sandy mudstone, low strength, light grey with black flecks, very fine to fine grained	
			SANDY MUDSTONE: Low strength, light grey with black flecks, very fine to fine grained	
160	6 1/8" PDC Bit			

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
230	6 1/8" PDC Bit		237 m: Trace silt, brown to red		
240			SANDY MUDSTONE: Low strength, light grey with black flecks, trace coal (10%), extremely low strength, black and dark brown		
			INTERBEDDED MUDSTONE AND SILTSTONE: Mudstone is extremely low to low strength, light grey, siltstone is medium strength, medium grey, trace coal, black and brown		
250					
			MUDSTONE: Extremely low strength, light and dark grey, thinly laminated		
			255 m: With siltstone (~20%), medium strength, dark grey	Completion casing (ECPS; HWT; 5LB; 4 1/2"; 16.1 kg/m)	CBM Cement - total slurry 46.0 bbl, density 13.50 ppg
260			INTERBEDDED MUDSTONE AND SILTSTONE: Mudstone is extremely low to low strength, brown and light grey, thinly laminated, siltstone is medium strength, dark grey		
			267 m: Trace siltstone (~5%), medium strength, dark grey		
270			INTERBEDDED SANDSTONE AND SILTSTONE: Sandstone is low strength, slightly weathered, grey, massive, fine grained, well sorted, siltstone is low strength, dark grey, fresh, massive		
			SANDSTONE: Very low strength, highly weathered, grey, massive, fine grained, well sorted		
			INTERBEDDED MUDSTONE AND SANDSTONE: Sandstone is very low strength, highly weathered, grey, massive, fine grained, well sorted, mudstone is very low strength, brown, massive		
280			SANDSTONE: Low strength, grey, massive, fine grained, white matrix, with mudstone (~25%)		
			285 m: Trace siltstone, medium to high strength, brown		
			288 m: Extremely low strength, thinly laminated, poorly developed		

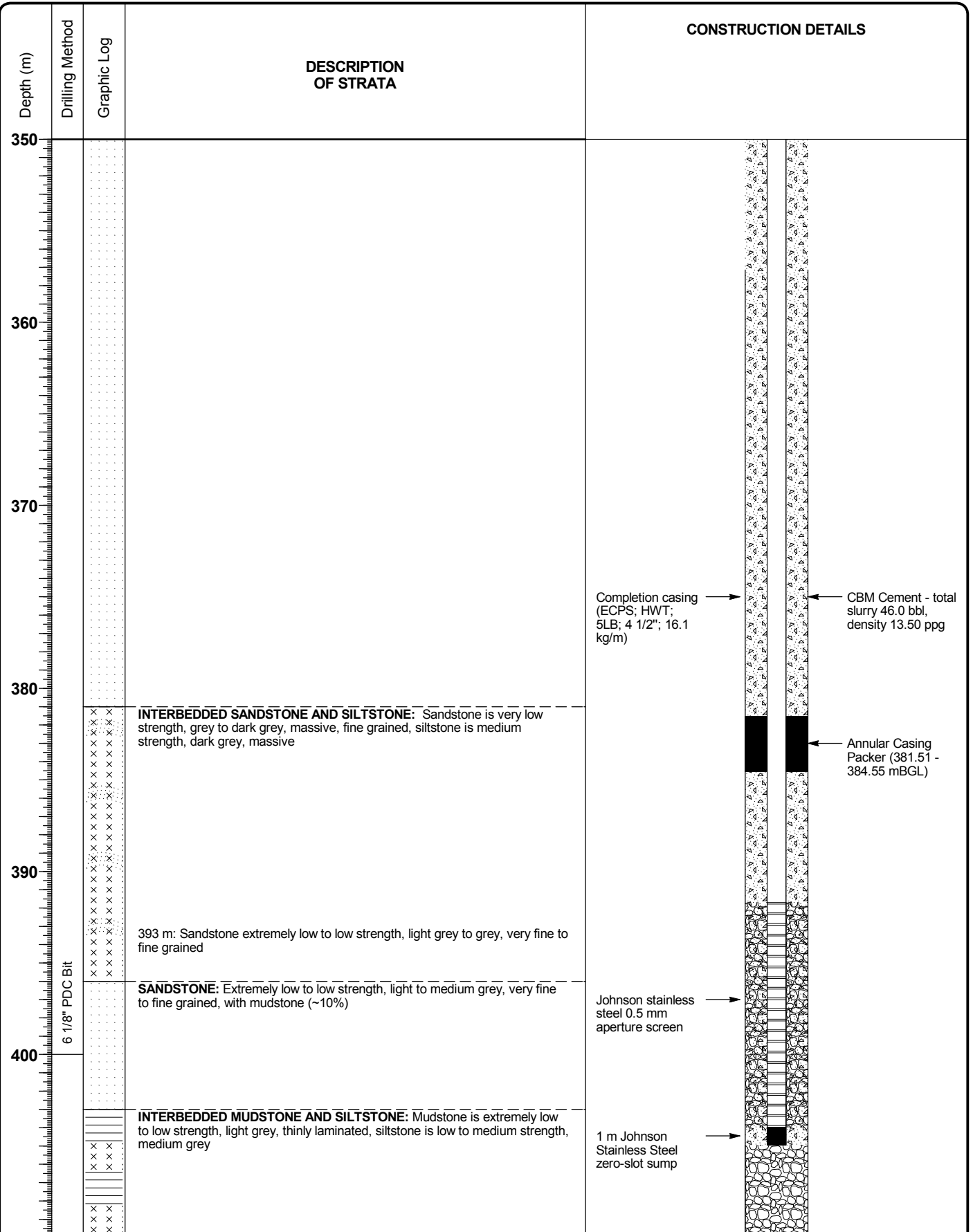
SANTOS NOGAMMA 121203 QWC GINT MASTER_REV1.GPJ WCC_AUS_GDT 16/12/13

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No.: **42626910**

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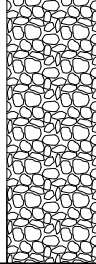


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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
410			MUDSTONE: Extremely low to low strength, light grey, very fine to fine grained sand, trace sand INTERBEDDED MUDSTONE AND SILTSTONE: Mudstone is extremely low to low strength, light grey, thinly laminated, siltstone is low to medium strength, medium grey MUDSTONE: Extremely low to low strength, light grey, very fine to fine grained sand, trace sand	
420			END OF HOLE: 420.0 mBGL	
430				
440				
450				
460				

YEBGWC01 (INTERIM)

URS Australia Pty. Ltd.
Level 17, 240 Queen St, Brisbane QLD 4000Phone: (07) 3243 2111
Phone: (07) 3243 2199Project Name: **Santos Deep Drilling Programme**Client: **Santos Ltd**

Document ID:

Drilling Contractor: **Spaulding Drillers**Project No.: **42626910**Location: **Roma**

130916_YEBGWC01_DRILLLOG_INTERIM_REV1

Logged By: **DGP, CP**Bore Dia.: **177.8 mm**Casing RL: **mAHD**Drill Type: **Mud Rotary**Checked By: **TF**Total Depth: **522.0 m**Coordinates: **Lat:**Drill Model: **Foremost 24 HD**Date Started: **12-8-13**Casing I.D.: **102.3 mm****Long:**Drill Fluid: **K2SO4 (refer to mud programme)**Date Finished: **17-8-13**Permit No: **GDFVS13-007**

Depth (m)

Drilling Method

Graphic Log

DESCRIPTION
OF STRATA

CONSTRUCTION DETAILS

Lockable metal
standpipe with
flange

22" PDC bit

CELLAR

NO SAMPLE

NO SAMPLE

NO SAMPLE

EVERGREEN FORMATION (0 - 56 mBGL)
SILTSTONE: Low strength, dark grey to black, massive**INTERBEDDED SILTSTONE - SANDSTONE:** Sandstone is low strength, slightly weathered, grey, massive, fine grained, siltstone is low strength, black, massive**SANDSTONE:** Low strength, light grey, fine to medium grained

24 m: Light grey with black flecks

27 m: Fine to coarse grained

36 m: With siltstone, dark grey, orange and black

39 m: Low to medium strength with quartz, orange, coarse grained

Conductor casing
(BTC; K55 5CT; 9
5/8"; 53.6 kg/m)Surface casing
(BTC; J55 5CT;
7", 33.7 kg/m)Class A cement;
Pumped 33.7 bbl,
density of 11.0 ppg

8 1/2" PDC bit

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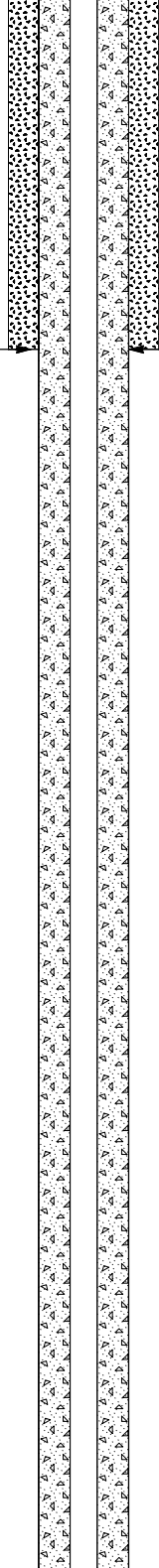
Project
No.: **42626910**

Document
ID: **130916_YEBGWC01_DRILLLOG_INTERIM_REV1**

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
50			SILTSTONE: Low strength, medium to dark grey, with sandstone		
			PRECIPICE SANDSTONE (56 - 96 mBGL) INTERBEDDED SILTSTONE - SANDSTONE: Siltstone is low strength, dark grey, sandstone is light grey, coarse grained, well graded		
60			SANDSTONE: Light grey, coarse grained, quartzose, trace coal 63 m: Subangular to subrounded, poorly graded, with some black siltstone 66 m: Light grey and white		
70					
			79 m: Sandstone orange, medium to coarse grained, with siltstone, dark grey, angular		
80			INTERBEDDED SILTSTONE - SANDSTONE: Sandstone is light grey and white, some orange, medium to coarse grained, subangular to subrounded quartz, poorly graded, siltstone is low strength, dark grey		
			SANDSTONE: Light grey, medium to coarse grained, subangular to subrounded, with some black siltstone chips (~0.2 to 0.5mm) 91 m: Light grey, red and orange 94 m: Coarse grained		
90			MOOLAYEMBER FORMATION (96 - 281 mBGL) INTERBEDDED SILTSTONE - SANDSTONE: Siltstone is low strength, medium grey, sandstone is light grey, fine grained 97 m: Medium to light grey, fine to coarse grained		
100					
			SILTSTONE: Low strength, medium grey, with sand, fine grained		
			INTERBEDDED SILTSTONE - SANDSTONE: Siltstone is medium grey,		

Surface casing
(BTC; J55 5CT;
7", 33.7 kg/m)

Class A cement;
Pumped 33.7 bbl,
density of 11.0 ppg

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
110	8 1/2" PDC bit		sandstone is low strength, fine to medium grained	 Completion casing (OZCON; HWT; 5LB; 4 1/2"; 16.1 kg/m) Class A cement; Pumped 42.1 bbl, 13.5ppg
			SILTSTONE: Low strength, medium grey, with sandstone, fine grained	
120			INTERBEDDED SILTSTONE - SANDSTONE: Siltstone is dark grey, sandstone is white with black flecks, fine grained, quartzose	
130	6 1/8" PDC bit		SANDSTONE: White to light grey with black flecks, fine grained	
140			INTERBEDDED SILTSTONE - SANDSTONE: Siltstone is dark grey, sandstone is white with black flecks, fine grained	
150			143 m: Increase in siltstone	
160			161 m: Siltstone low strength, medium grey	
			164 m: Siltstone dark to medium grey, sandstone light grey to white with black flecks	
			167 m: Siltstone medium to light grey, sandstone medium strength, light grey	

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Project
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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
170			173 m: Siltstone medium grey	
180				
190			SILTSTONE: Low strength, medium grey	
200			INTERBEDDED SILTSTONE - SANDSTONE: Siltstone is low strength, medium grey to dark grey, sandstone is fine grained, light grey with black flecks, thinly bedded	
210				Completion casing (OZCON; HWT; 5LB; 4 1/2"; 16.1 kg/m) →
220				← Class A cement; Pumped 42.1 bbl, 13.5ppg

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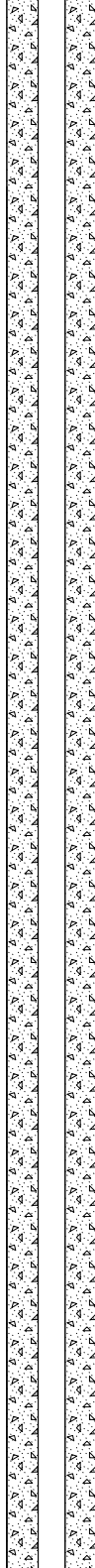
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No.: **42626910**

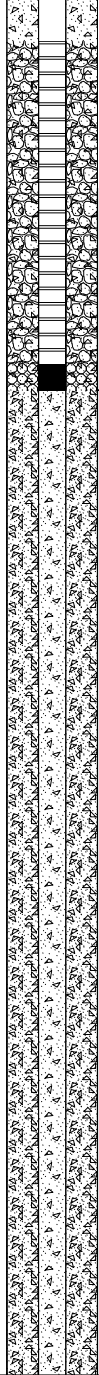
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ID: **130916_YEBGWC01_DRILLLOG_INTERIM_REV1**

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
230					
240					
250			SANDSTONE: Light grey with black flecks, fine grained, quartzose	Completion casing (OZCON; HWT; 5LB; 4 1/2"; 16.1 kg/m)	Class A cement; Pumped 42.1 bbl, 13.5ppg
			INTERBEDDED SILTSTONE - SANDSTONE: Sandstone is light grey and white with black flecks, fine grained, siltstone is dark grey		
260					
			INTERBEDDED SILTSTONE - MUDSTONE: Dark and medium grey		
270					
280					
			CLEMATIS SANDSTONE (281 - 518 mBGL)		

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
290			290 m: With mudstone, brown and grey		
300					
310			INTERBEDDED SILTSTONE - SANDSTONE: Siltstone is very low strength, black, massive, sandstone is low strength, highly weathered, grey, very fine grained, massive with white cement		
320			SILTSTONE: Very low strength, black, massive		
330			INTERBEDDED SILTSTONE - SANDSTONE: Siltstone is low strength, black, massive, sandstone is low strength, grey, massive, fine grained	Completion casing (OZCON; HWT; 5LB; 4 1/2"; 16.1 kg/m)	Class A cement; Pumped 42.1 bbl, 13.5ppg
			SANDSTONE: Low to medium strength, grey, massive, fine grained, with siltstone (~30%)		
			INTERBEDDED SILTSTONE - SANDSTONE: Siltstone is low strength, black, massive, sandstone is low strength, grey, massive, fine grained		
			SANDSTONE: Low strength, slightly weathered, grey, fine grained, massive, well sorted, white cement		
340			INTERBEDDED SILTSTONE - SANDSTONE: Sandstone is low strength, grey, massive, fine grained, siltstone is low strength, black, massive		
			SILTSTONE: Siltstone is low strength, black, massive, trace sandstone		
			SANDSTONE: Low strength, grey to light grey, massive, fine to medium grained, with siltstone		

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
350			350 m: No siltstone	 Completion casing (OZCON; HWT; 5LB; 4 1/2"; 16.1 kg/m) Class A cement; Pumped 42.1 bbl, 13.5ppg	
360			359 m: Sandstone medium grained 362 m: Sandstone fine grained		
370			INTERBEDDED SILTSTONE - SANDSTONE: Sandstone is low strength, grey and dark grey, massive, fine grained, siltstone is low strength, black		
380			SANDSTONE: Low strength, dark grey, massive, trace siltstone (~10%) 380 m: Trace coal (~5%) 383 m: No coal		
390			SILTSTONE: Low strength, dark grey, massive, trace sandstone (~10%)		
			SANDSTONE: Medium strength, grey to pale grey, massive, fine to medium grained, well sorted, rounded to subrounded 392 m: Sandstone fine grained		
400			SILTSTONE: Low to medium strength, black to dark grey, trace sand		
			INTERBEDDED SILTSTONE - SANDSTONE: Siltstone is low to medium strength, black to dark grey, sandstone is low to medium strength, light grey, fine to medium grained, massive, subrounded		
			SILTSTONE: Medium strength, dark grey to black, massive		
			SANDSTONE: Low strength, highly weathered, grey to pale grey, massive, very fine grained, well sorted, with siltstone		

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
410	6 1/8" PDC bit		410 m: Becoming dark grey	Completion casing (OZCON; HWT; 5LB; 4 1/2"; 16.1 kg/m)	Class A cement; Pumped 42.1 bbl, 13.5ppg
			413 m: Thinly laminated		
420			419 m: Medium strength, grey to dark grey, thinly laminated, fine grained, rounded, grey cement		
			422 m: Becoming coarse grained		
430			SILTSTONE: Medium strength, dark grey		
440			SANDSTONE: Light grey, medium to coarse grained, quartzose, subrounded, with siltstone, dark grey and black		
			SILTSTONE: Medium strength, dark and medium grey		
450			SANDSTONE: Pale grey, massive, medium to coarse grained, subrounded, with siltstone chips, black		
			INTERBEDDED SILTSTONE - SANDSTONE: Siltstone is dark grey and black, sandstone is medium grained, with mudstone, low strength, light grey		
460			SILTSTONE: Dark grey, fine grained, with mudstone, low strength, light grey		
			INTERBEDDED SILTSTONE - MUDSTONE - SANDSTONE: Siltstone is black, sandstone is light grey and white, medium to coarse grained, mudstone is very low strength, light grey		
			INTERBEDDED SILTSTONE - MUDSTONE: Siltstone is dark grey, mudstone is light grey with some white, fine grained sandstone		

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
470			470 m: With sandstone, very fine grained, cemented	 Johnson stainless steel screen, 1 mm aperture screens Johnson stainless steel, zero-slot sump Rat hole from 484.77 to 522.02 mBGL
			INTERBEDDED SILTSTONE - SANDSTONE: Sandstone is medium to fine grained, cemented, siltstone is dark grey	
			SANDSTONE: Light grey to white, medium grained, subangular to subrounded, poorly graded, with siltstone chips (0.5-1 mm), black and dark grey	
480			SILTY SANDSTONE: Light grey to white and dark grey, fine to medium grained sand in a light grey, silty matrix	
			485 m: Increase in siltstone	
			SILTSTONE: Low strength, dark grey to black, massive	
490			491 m: Becoming medium strength	
			INTERBEDDED SILTSTONE - MUDSTONE: Siltstone is low strength, dark grey to black, massive, mudstone is very low strength, pale grey, thinly laminated	
500			MUDSTONE: Very low strength, pale grey, massive, trace siltstone	
510			INTERBEDDED SILTSTONE - SANDSTONE: Sandstone is medium strength, pale grey to grey, fine grained, well sorted, siltstone is medium strength, dark grey, massive	
			CLEMATIS SANDSTONE (518 mBGL - TD). INTERBEDDED SILTSTONE - MUDSTONE: Siltstone is medium strength, dark grey, massive, mudstone is low strength, red-brown, massive	
520	6 1/8" PDC bit		END OF HOLE: 522.02 mBGL	

KNAGWH01 (INTERIM)URS Australia Pty. Ltd.
Level 17, 240 Queen St, Brisbane QLD 4000Phone: (07) 3243 2111
Phone: (07) 3243 2199Project Name: **Santos Deep Drilling Programme**Client: **Santos Ltd**

Document ID:

130919_KNAGWH01_DRILLLOG_INTERIM_REV1

Drilling Contractor: **Spaulding Drillers**Project No.: **42626910**Location: **Roma**Logged By: **KM, SC**Bore Dia.: **177.8 mm**Casing RL: **mAHD**Drill Type: **Mud Rotary**Checked By: **TB**Total Depth: **420.0 m**Coordinates: **Lat:**Drill Model: **Foremost 24 HD**Date Started: **18-9-13**Casing I.D.: **102.3 mm****Long:**Drill Fluid: **K2SO4 (refer to mud programme)**Date Finished: **30-9-13**

Permit No:

Depth (m)

Drilling Method

Graphic Log

DESCRIPTION OF STRATA**CONSTRUCTION DETAILS**Lockable metal
standpipe with
flangeConductor casing
(BTC K55; 7", 33.7
kg/m)Completion casing
(ECPS; HWT;
5LB; 4 1/2"; 16.1
kg/m)CBM Cement - total
slurry 46.0 bbl,
density 13.50 ppg

CELLAR

JUANDAH COAL MEASURES (0 - 36 mBGL)
INTERBEDDED SANDSTONE AND MUDSTONE: Sandstone is low strength, grey with black flecks, medium grained, angular, mudstone is medium strength, light brown, massive**SANDSTONE:** Very low strength, highly weathered, grey with black flecks, massive, medium to fine grained, poorly sorted, angular

18 m: Medium strength, moderately weathered, medium grained, well sorted

COAL: High strength, black, massive**MUDSTONE:** Very low strength, highly weathered, brown, massive**TANGALOOMA SANDSTONE (36 - 57 mBGL)**
SANDSTONE: Extremely low strength, highly weathered, grey, laminated, poorly developed, fine grained, with mudstone (~30%)

45 m: With coal, black

48 m: Very low strength, massive, well sorted

8 1/2" PDC Bit

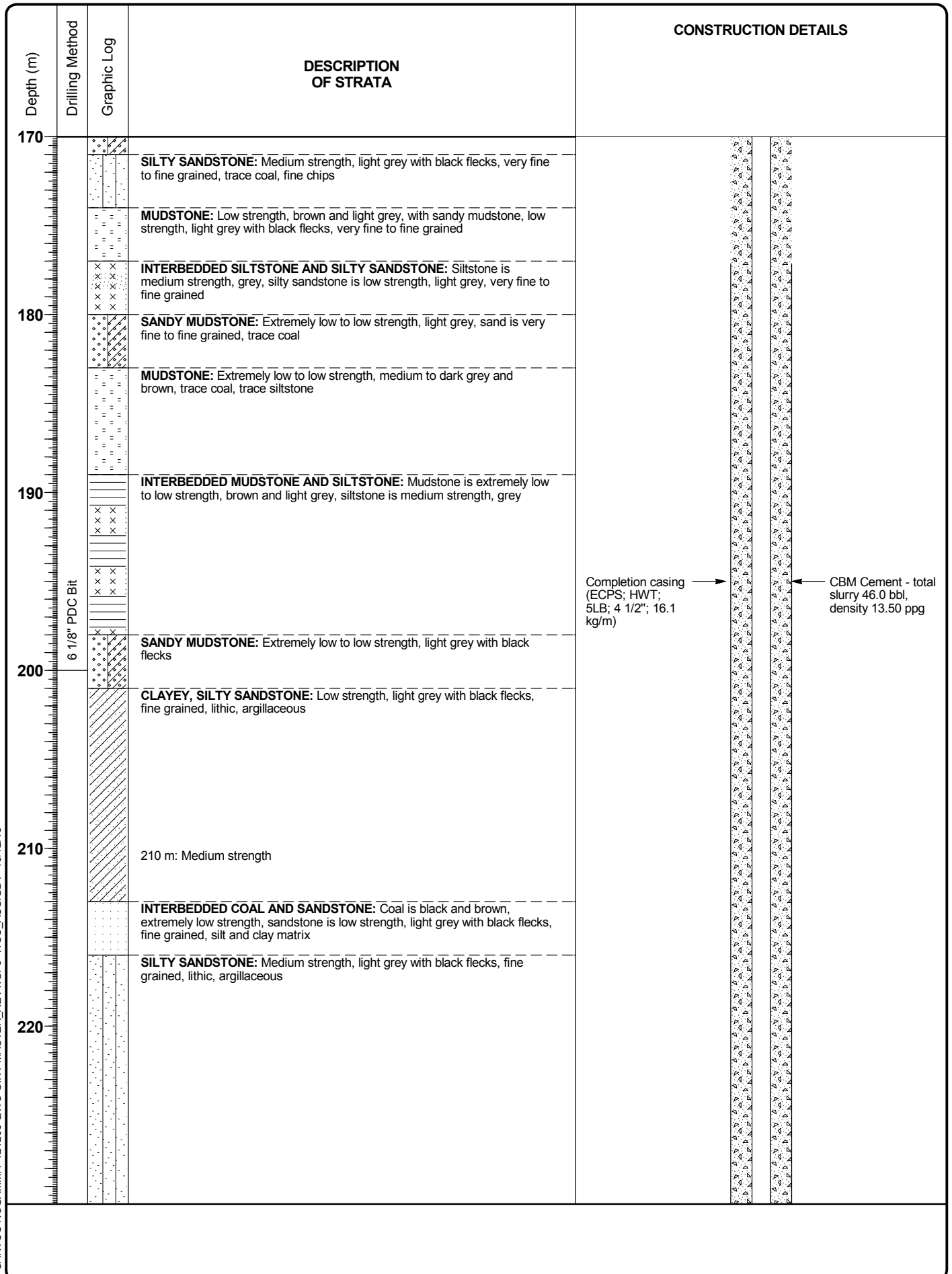
6 1/8" PDC Bit

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
50			51 m: Increasing strength	
			INTERBEDDED SANDSTONE AND SILTSTONE: Sandstone is low strength, grey, fine grained, siltstone is medium strength, fresh, dark grey, massive	
			TAROOM COAL MEASURES (57 - 140 mBGL)	
			INTERBEDDED MUDSTONE AND SILTSTONE: Mudstone is very low strength, brown, siltstone is medium strength, dark grey, massive	
60			60 m: Siltstone low strength, mudstone extremely low to very low strength, light grey	
			66 m: With interbedded coal, medium strength, black, vitreous	
70			72 m: Mudstone is extremely low strength, no coal	
			75 m: Increase in mudstone	
80			MUDSTONE: Extremely low strength, light grey, trace siltstone, dark grey	
90			90 m: Trace coal, black, vitreous	
			93 m: Mudstone light to medium grey, siltstone low to medium strength, medium to dark grey	
100			INTERBEDDED MUDSTONE AND SILTSTONE: Mudstone is extremely low strength, light grey, siltstone is low to medium strength, medium to dark grey, trace sandstone, medium strength, light grey, fine grained	
			SILTSTONE: Medium strength, medium grey with black rootlets, with mudstone (~20%), extremely low strength, white to very light grey	
			MUDSTONE: Extremely low strength, light grey with black flecks, trace siltstone, low strength, grey	

Completion casing
(ECPS; HWT;
5LB; 4 1/2"; 16.1
kg/m)

CBM Cement - total
slurry 46.0 bbl,
density 13.50 ppg

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
110			INTERBEDDED MUDSTONE AND SILTSTONE: Mudstone is extremely low strength, light grey with black flecks, siltstone is medium to low strength, medium grey, trace coal, extremely low strength, black INTERBEDDED MUDSTONE, SANDSTONE AND SILTSTONE: Mudstone is extremely low strength, light grey, sandstone is extremely low strength, light grey with black flecks, lithic, siltstone is medium strength, medium grey INTERBEDDED MUDSTONE AND SILTSTONE: Mudstone is extremely low strength, light grey, siltstone is medium strength, medium grey, trace coal, black, vitreous	
120			INTERBEDDED MUDSTONE AND SANDSTONE: Mudstone is extremely low to low strength, light grey, sandstone is light grey with black specks, fine to very fine grained, lithic SILTY SANDSTONE: Low to medium strength, light grey with black flecks, very fine to fine grained, argillaceous, with mudstone (~20%), extremely low strength, light grey	
130			INTERBEDDED MUDSTONE AND SILTSTONE: Mudstone is low strength, light grey, siltstone is medium strength, medium grey, trace coal (~10%), black, vitreous 138 m: No coal	Completion casing (ECPS; HWT; 5LB; 4 1/2"; 16.1 kg/m)
140			EUROMBAH FORMATION (140 - 330 mBGL) 141 m: Siltstone dark to medium grey	CBM Cement - total slurry 46.0 bbl, density 13.50 ppg
150	6 1/8" PDC Bit		SILTY SANDSTONE: Low to medium strength, light grey with black flecks, very fine to fine grained, lithic, argillaceous SANDY MUDSTONE: Low strength, light grey with black flecks, very fine to fine grained INTERBEDDED MUDSTONE AND SILTSTONE: Mudstone is low strength, light grey, with sand, siltstone is medium strength, dark grey, trace white clay	
160			MUDSTONE: Low strength, brown and light grey, with sandy mudstone, low strength, light grey with black flecks, very fine to fine grained SANDY MUDSTONE: Low strength, light grey with black flecks, very fine to fine grained	

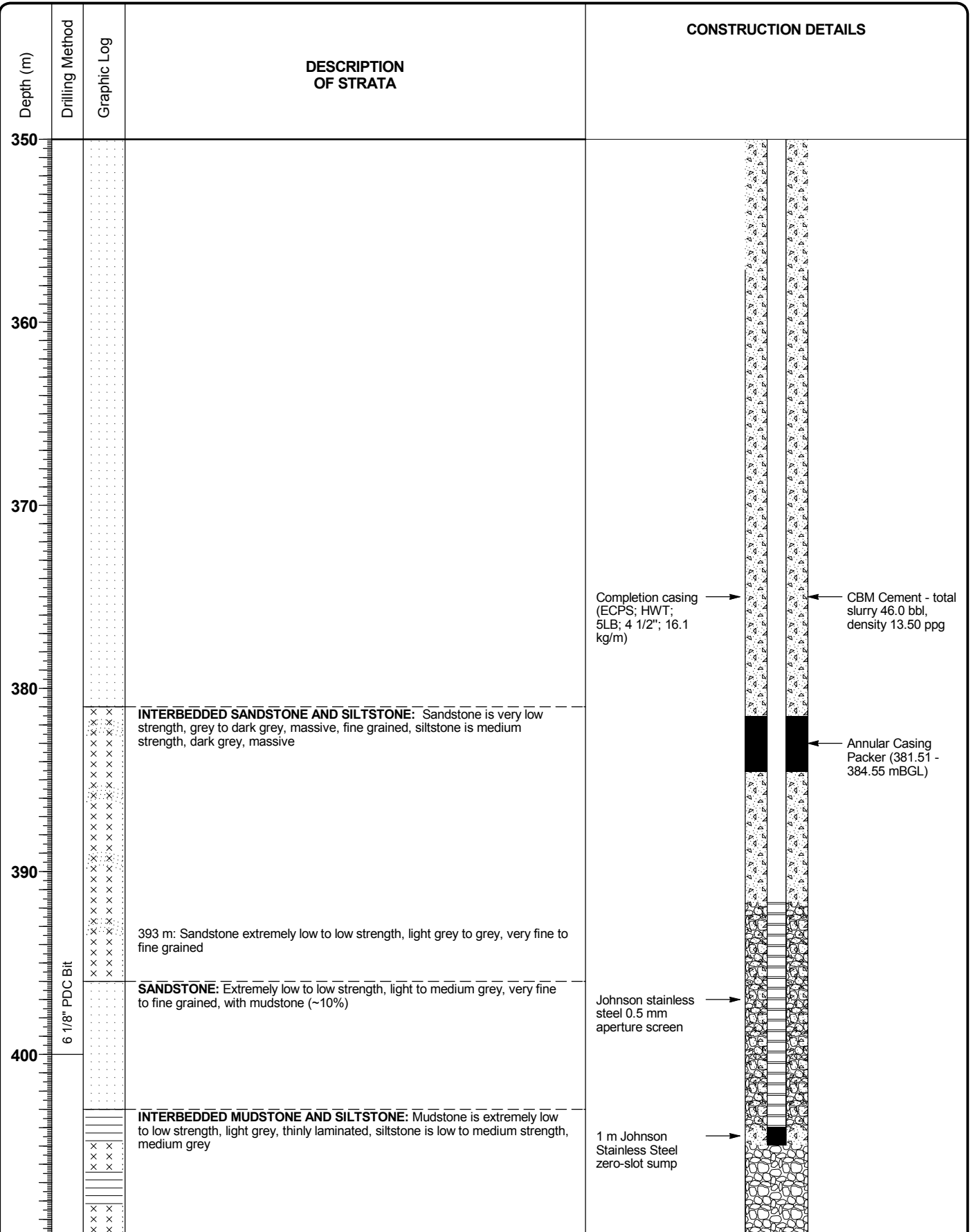


Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
230			237 m: Trace silt, brown to red	
240			SANDY MUDSTONE: Low strength, light grey with black flecks, trace coal (10%), extremely low strength, black and dark brown	
			INTERBEDDED MUDSTONE AND SILTSTONE: Mudstone is extremely low to low strength, light grey, siltstone is medium strength, medium grey, trace coal, black and brown	
250	6 1/8" PDC Bit		MUDSTONE: Extremely low strength, light and dark grey, thinly laminated	
			255 m: With siltstone (~20%), medium strength, dark grey	
260			INTERBEDDED MUDSTONE AND SILTSTONE: Mudstone is extremely low to low strength, brown and light grey, thinly laminated, siltstone is medium strength, dark grey	
			267 m: Trace siltstone (~5%), medium strength, dark grey	
270			INTERBEDDED SANDSTONE AND SILTSTONE: Sandstone is low strength, slightly weathered, grey, massive, fine grained, well sorted, siltstone is low strength, dark grey, fresh, massive	
			SANDSTONE: Very low strength, highly weathered, grey, massive, fine grained, well sorted	
			INTERBEDDED MUDSTONE AND SANDSTONE: Sandstone is very low strength, highly weathered, grey, massive, fine grained, well sorted, mudstone is very low strength, brown, massive	
280			SANDSTONE: Low strength, grey, massive, fine grained, white matrix, with mudstone (~25%)	
			285 m: Trace siltstone, medium to high strength, brown	
			288 m: Extremely low strength, thinly laminated, poorly developed	

Completion casing
(ECPS; HWT;
5LB; 4 1/2"; 16.1
kg/m)

CBM Cement - total
slurry 46.0 bbl,
density 13.50 ppg

SANTOS NOGAMMA 121203 QWC GINT MASTER_REV1.GPJ WCC_AUS_GDT 16/12/13

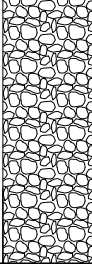


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Project
No.: **42626910**

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
410			MUDSTONE: Extremely low to low strength, light grey, very fine to fine grained sand, trace sand INTERBEDDED MUDSTONE AND SILTSTONE: Mudstone is extremely low to low strength, light grey, thinly laminated, siltstone is low to medium strength, medium grey MUDSTONE: Extremely low to low strength, light grey, very fine to fine grained sand, trace sand	
420			END OF HOLE: 420.0 mBGL	
430				
440				
450				
460				

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Phone: (07) 3243 2199Project Name: **Santos Deep
Drilling Programme**Client: **Santos Ltd**

Document ID:

131012_OBGGWS01_DRILLLOG_INTERIM_REV1

Drilling Contractor: **Spaulding Drillers**Project No.: **42626910**Location: **Roma**Logged By: **DGP, CH, TF**Bore Dia.: **177.8 mm**Casing RL: **mAHD**Drill Type: **Mud Rotary**Checked By: **TB**Total Depth: **720.2 m**Coordinates: **Lat:**Drill Model: **Foremost 24 HD**Date Started: **11-10-13**Casing I.D.: **102.3 mm****Long:**Drill Fluid: **K2SO4 (refer to mud programme)**Date Finished: **21-10-13**Permit No: **GDR13-115**

Depth (m)

Drilling Method

Graphic Log

DESCRIPTION
OF STRATA

CONSTRUCTION DETAILS

0

12 1/4" PDC Drill bit

NO SAMPLE

Conductor casing
(BTC; K55 5CT; 9
5/8"; 36 lb/ft)

10

20

30

40

8 1/2" PDC Bit

BUNGIL FORMATION (0-199 mBGL)**SILTSTONE:** Extremely low strength, moderately weathered, black,
massive, trace fine sand

39 m: Low strength

42 m: Low to medium strength, moderately weathered, black, massive

INTERBEDDED SILTSTONE - MUDSTONE: Siltstone is low strength, black,
mudstone is low strength, brown and dark grey, laminated, poorly developedSurface casing
(5CT; J55, 7",
23.0lb/ft)Class A cement;
Pumped 39.3 bbl,
density of 13.5ppg

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Project
No.: **42626910**

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ID: **131012_OBGGWS01_DRILLLOG_INTERIM_REV1**

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
50			INTERBEDDED SILTSTONE - SANDSTONE: Siltstone is low strength, black, massive, sandstone is low strength, grey, massive, laminated, well developed, fine grained, well sorted		
			SANDSTONE: Low strength, moderately weathered, grey, fine grained, well sorted		
60			INTERBEDDED SILTSTONE - SANDSTONE: Siltstone is low strength, black, massive, sandstone is low strength, moderately weathered, grey, fine grained, well sorted		
70			SILTSTONE: Low strength, black, massive, with sandstone 72 m: Trace sandstone 75 m: Siltstone black, massive	Surface casing (5CT; J55, 7", 23.0lb/ft)	Class A cement; Pumped 39.3 bbl, density of 13.5ppg
80			INTERBEDDED SANDSTONE - SILTSTONE: Sandstone is low strength, grey, massive, fine grained, siltstone is low strength, black, massive SILTSTONE: Low strength, black, massive, trace sandstone 84 m: With sandstone (~20%)		
90			SANDSTONE: Low strength, grey to dark grey, massive, fine grained 90 m: With siltstone (~20%)		
100			SILTSTONE: Low strength, grey, black, massive, trace sandstone SANDSTONE: Low strength, grey to dark grey, massive, fine grained, clay matrix 105 m: Trace siltstone		

SANTOS NOGAMMA 121203 QWC GINT MASTER_REV1.GPJ WCC_AUS_GDT 14/11/13

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
170				
180			180 m: With some organic matter (~20%) (coal / rootlets) 183 m: Laminated, poorly developed	
190			INTERBEDDED SANDSTONE - MUDSTONE: Sandstone is low strength, moderately weathered, grey, massive, fine grained, white to pale grey matrix, mudstone is very low strength, brown, massive MUDSTONE: Very low strength, brown, massive INTERBEDDED MUDSTONE - SILTSTONE: Mudstone is very low strength, brown, massive, siltstone is medium strength, black, massive INTERBEDDED SILTSTONE - MUDSTONE - SANDSTONE: Sandstone is low strength, dark grey, massive, fine grained, siltstone is medium strength, fresh, black, massive, mudstone is very low strength, brown, massive MOOGA SANDSTONE (199-218 mBGL) SANDSTONE: Low strength, dark grey, massive, fine grained	Surface casing (5CT; J55, 7", 23.0lb/ft) Class A cement; Pumped 39.3 bbl, density of 13.5ppg
200				
210			213 m: Grey, well sorted	
220			ORALLO FORMATION (218-371 mBGL) INTERBEDDED SILTSTONE - MUDSTONE: Siltstone is medium strength, black to dark brown, massive, mudstone is very low strength, brown, massive	

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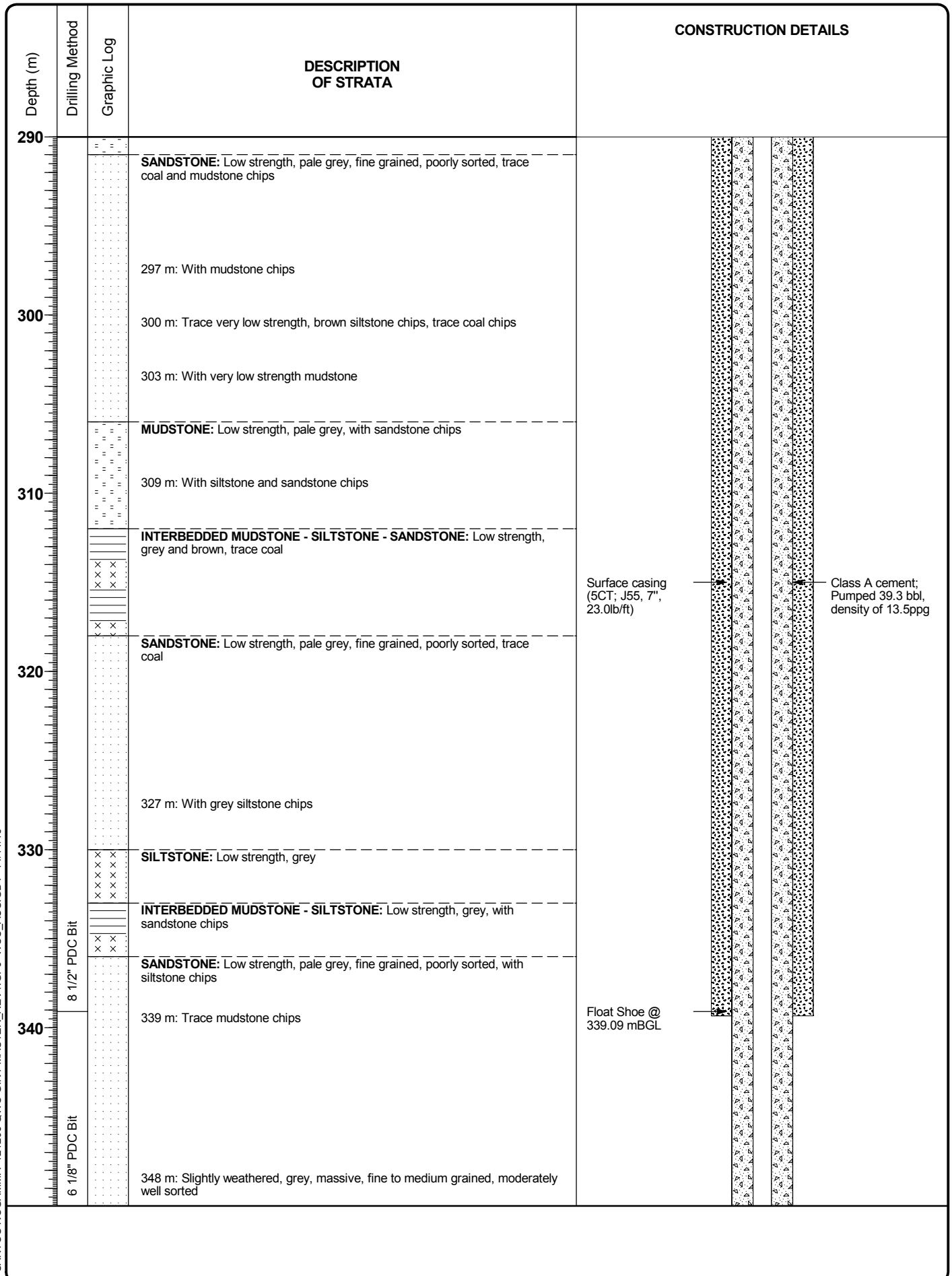
Project
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Document
ID: **131012_OBGGWS01_DRILLLOG_INTERIM_REV1**

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
230			INTERBEDDED SANDSTONE - BRECCIA	
			SANDSTONE: Low strength, grey, laminated, poorly developed, fine grained, well sorted	
240			COAL and MUDSTONE	
			INTERBEDDED MUDSTONE-SILTSTONE: Mudstone is very low strength, brown and dark brown, massive, siltstone is medium to high strength, black, massive	
250			SANDSTONE: Low strength, grey, laminated, poorly developed, fine grained, well sorted	
			258 m: Poorly sorted	
260			273 m: Low to medium strength, trace coal	
270			INTERBEDDED SILTSTONE - MUDSTONE: Low strength, grey, with coal chips	
			279m: Trace coal chips	
280			MUDSTONE: Low to medium strength, pale grey and grey, with coal chips	
			285m: Trace fine grained sandstone chips, trace coal chips	

Surface casing
(5CT; J55, 7",
23.0lb/ft)

Class A cement;
Pumped 39.3 bbl,
density of 13.5ppg



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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
350			357 m: Fine grained, well sorted		
360					
			MUDSTONE: Very low strength, highly weathered, brown, massive, with fine grained sand (~20%)		
370			INTERBEDDED SILTSTONE - MUDSTONE: Siltstone is medium strength, black, massive, mudstone is very low strength, highly weathered, brown, massive		
			GUBBERAMUNDA SANDSTONE (371-481 mBGL)		
			375 m: Trace medium strength siltstone		
			SANDSTONE: Low strength, moderately weathered, grey, massive, fine grained		
380			381 m: Slightly weathered, fine to medium grained, poorly sorted		
			384 m: Trace siltstone		
			387 m: Medium grained		
390			390 m: Thinly laminated, fine grained, well sorted		
			396 m: Trace coal (~5%) and organic matter		
400			399 m: Fine to medium grained		
			402 m: Fine grained		

Completion casing
(HWT; 5LB; 4
1/2"; 10.8lb/ft)

Class A cement;
Pumped 42.1 bbl,
density of 13.5ppg

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
410					
			417 m: Medium grained		
420					
			426 m: Grey to pale grey		
430					
			432 m: Moderately weathered, dark grey to grey, well sorted, clay matrix		
			MUDSTONE: Extremely low strength, dark grey to dark brown, massive	Completion casing (HWT; 5LB; 4 1/2"; 10.8lb/ft)	Class A cement; Pumped 109.6 bbl @ 3.8bpm, 320psi, density of 13.5ppg
			SANDSTONE: Low strength, grey, massive, fine grained, well sorted		
440					
			INTERBEDDED SANDSTONE - MUDSTONE: Sandstone is low strength, grey to dark grey, massive, fine grained, mudstone is low strength, brown, massive		
450					
			SANDSTONE: Low strength, grey, massive, fine grained, well sorted		
			456 m: Trace coal	Completion casing (HWT; 5LB; 4 1/2"; 10.8lb/ft)	Class A cement; Pumped 42.1 bbl, density of 13.5ppg
460					
			459 m: High strength, fresh, medium grained, quartzite		
			468 m: Low strength, fine grained		

SANTOS NOGAMMA 121203 QWC GINT MASTER_REV1.GPJ WCC_AUS_GDT 14/11/13

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
530			MUDSTONE: Very low strength, brown to dark brown, massive, with sandstone INTERBEDDED MUDSTONE - SILTSTONE: Mudstone is very low strength, brown to dark brown, massive, siltstone is medium strength, black, massive	
540			MUDSTONE: Low strength, dark grey, trace siltstone and sandstone SILTSTONE: Low strength, dark grey, with low strength, pale grey, siltstone chips 549 m: Dark grey and grey 552 m: Trace siltstone and sandstone	
550				
560			561 m: With low strength siltstone and sandstone chips 564 m: With sandstone chips	
570			WEALD SANDSTONE (570-574 mBGL) SANDSTONE: Very low strength, pale grey, medium to coarse grained, trace shale and siltstone" SPRINGBOK SANDSTONE (574 mBGL-EQH)	
580			SILTSTONE: Very low strength, pale grey, with fine grained sandstone chips	Completion casing (HWT; 5LB; 4 1/2"; 10.8lb/ft) Class A cement; Pumped 42.1 bbl, density of 13.5ppg

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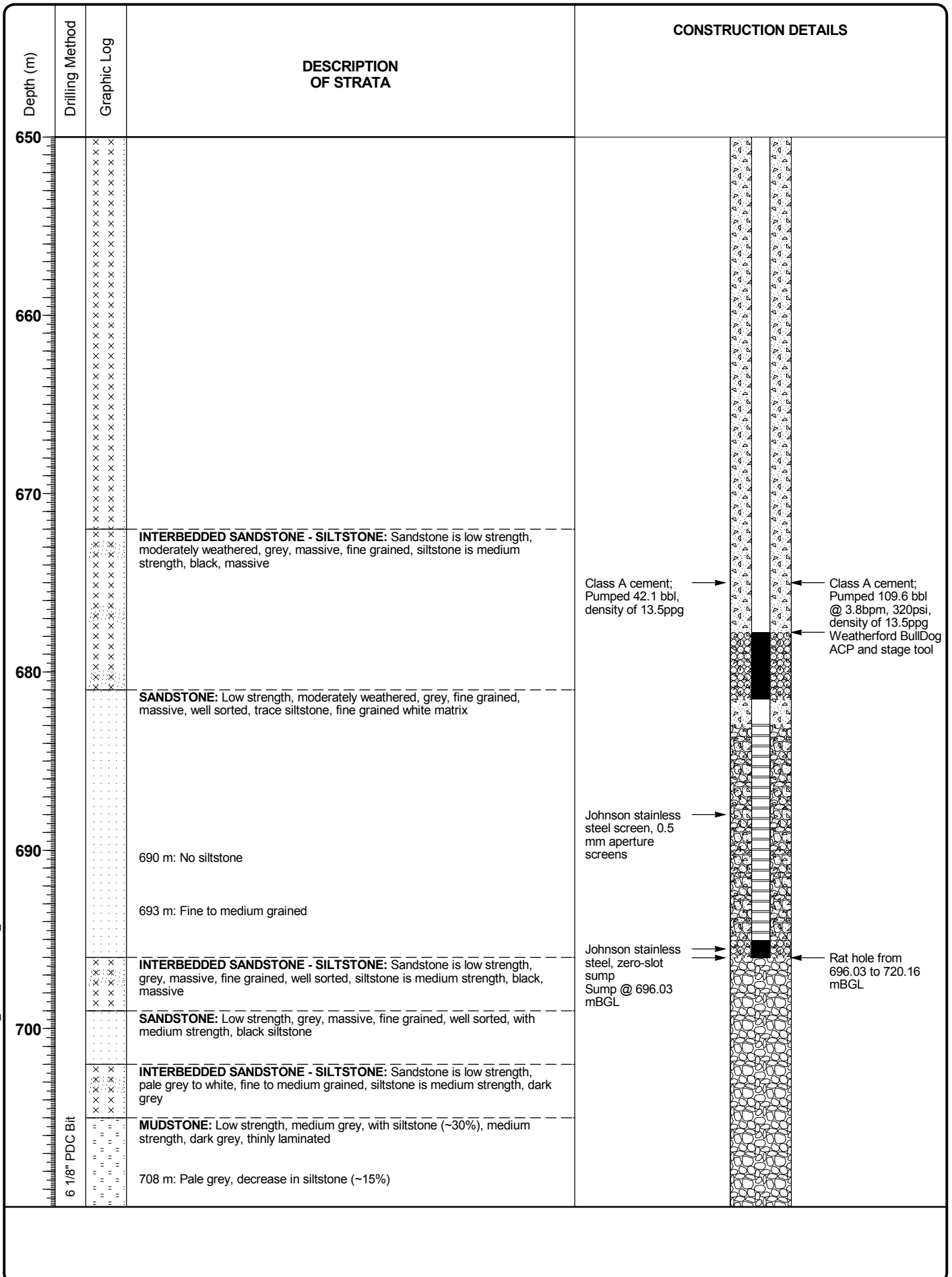
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No.: **42626910**

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ID: **131012_OBGGWS01_DRILLLOG_INTERIM_REV1**

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
590			591 m: With fine grained sandstone chips, trace coal		
			597 m: Grey		
600			600 m: Low strength, dark grey, with sandstone chips		
			MUDSTONE: Very low strength, pale grey, with siltstone chips		
610			SILTSTONE: Very low strength, pale grey, with shale and sandstone chips		
			MUDSTONE: Very low strength, pale grey, with shale and siltstone chips		
620			SILTSTONE: Low strength, grey, with shale fragments		
630			INTERBEDDED SILTSTONE - MUDSTONE: Siltstone is low strength, black, massive, mudstone is very low strength, grey and brown, massive		
			INTERBEDDED SANDSTONE - SILTSTONE: Sandstone is low strength, grey, massive, fine grained, siltstone is low strength, black, massive		
640			SANDSTONE: Low strength, grey, massive, fine grained, with siltstone		
			SILTSTONE: Low strength, black, massive with mudstone		

Completion casing
(HWT; 5LB; 4
1/2"; 10.8lb/ft)

Class A cement;
Pumped 42.1 bbl,
density of 13.5ppg



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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
710	6 1/8" PDC Bit		SILTY SANDSTONE: Low to medium strength, white to grey, fine to medium grained, siltstone (~35%) medium strength, brown to dark grey, trace (~5%) coal SANDSTONE: Medium strength, white, brown and black, massive, fine to medium grained, poorly sorted with low to medium strength, brown, thinly laminated siltstone (~10%), trace coal (~5%) 720 m: Increase in siltstone (~25%)	
720			END OF HOLE: 720.16 mBGL	
730				
740				
750				
760				

BEVGWS01 (INTERIM)

URS Australia Pty. Ltd.
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Phone: (07) 3243 2111
Phone: (07) 3243 2199

Project Name: **Santos Deep Drilling Programme**

Client: **Santos Ltd**

Document ID:

Drilling Contractor: **Spaulding Drillers**

Project No.: **42626910**

Location: **Roma**

131022_BEVGWS01_DRILLLOG_INTERIM_REV1

Logged By: **DGP, CH**

Bore Dia.: **117.8 mm**

Casing RL: **mAHD**

Drill Type: **Mud Rotary**

Checked By:

Total Depth: **403.5 m**

Coordinates: **Lat: -26.437490**

Drill Model: **Foremost 24 HD**

Date Started: **4-10-13**

Casing I.D.: **102.3 mm**

Long: 148.921190

Drill Fluid: **K2SO4 (refer to mud programme)**

Date Finished: **5-10-13**

Permit No: **GDR13-111**

Depth (m)

Drilling Method

Graphic Log

DESCRIPTION
OF STRATA

CONSTRUCTION DETAILS

Lockable metal
standpipe with
flange

Surface casing
(BTC; J55 5CT;
7", 33.7 kg/m)

Completion casing
(ECPS; HWT;
5LB; 4 1/2"; 16.1
kg/m)

CBM Cement;
Pumped 43.7 bbl,
density of 13.50 ppg

Cellar
NO SAMPLE

MOOGA SANDSTONE (0 - 82 mBGL)
CLAY: high plasticity, brown to orange, high moisture content, dense

MUDSTONE: Very low strength, highly weathered, dark grey, massive

SILTSTONE: Extremely low strength, grey massive

SANDSTONE: Low strength, highly weathered, grey, massive, fine grained,
with some very low strength siltstone

MUDSTONE: Very low strength, highly weathered, grey, massive with some
sandstone

SANDSTONE: Low strength, highly weathered, grey, massive, fine grained

8 1/2" PDC Bit

6 1/8" PDC Bit

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
50				
60			INTERBEDDED SILTSTONE - SANDSTONE: Sandstone is very low strength, grey, fine grained, siltstone is low strength, dark grey, massive SILTSTONE: Low strength, dark grey, massive SANDSTONE: Low strength, light grey, massive, fine grained 75m: Becoming fine to medium grained, poorly sorted SANDSTONE: Low strength, light grey, massive, fine to medium grained, fine white matrix throughout, trace coal ORALLO SANDSTONE (82 - 221 mBGL) INTERBEDDED SANDSTONE - SILTSTONE: Sandstone is low strength, light grey, massive, fine to medium grained, siltstone is low strength, dark grey, massive, high quartz content SILTSTONE: Low strength, dark grey, massive SANDSTONE: Low strength, dark grey, massive, high quartz content 93m: Trace coal throughout 99m: Becoming medium grained 102m: Becoming very low strength INTERBEDDED SILTSTONE - SANDSTONE: Sandstone is low strength, grey, fine to medium grained, poorly sorted, siltstone is low strength, dark grey, massive SANDSTONE: Sandstone is low strength, grey, fine to medium grained, poorly sorted	Completion casing (ECPS; HWT; 5LB; 4 1/2"; 16.1 kg/m) CBM Cement; Pumped 43.7 bbl, density of 13.50 ppg
70				
80				
90				
100				
	6 1/8" PDC Bit			

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
110			SILTSTONE: Low to medium strength, fresh, dark grey to brown, massive	
120			SANDSTONE: Low strength, light grey, massive, fine to medium grained, with some coal throughout	
130			126m: Becoming dark grey, massive fine grained 129m: With some low strength, brown mudstone	
140			SANDSTONE: Low strength, light grey, massive, trace mudstone 135m: No mudstone	
150			SILTSTONE: Low strength, dark grey, massive	
160			SANDSTONE: Low strength, light grey, fine grained, well sorted 153m: Becoming fine to medium grained, poorly sorted 156m: Becoming fine to medium grained	

Completion casing
(ECPS; HWT;
5LB; 4 1/2"; 16.1
kg/m)

CBM Cement;
Pumped 43.7 bbl,
density of 13.50 ppg

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Document
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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
170			SILTSTONE: Low strength, grey, trace sandstone	
180			MUDSTONE: Low strength, grey, trace siltstone and sandstone	
			183m: With some sandstone and siltstone	
			SANDSTONE: Low strength, grey, fine grained, with some siltstone throughout	
190			SILTSTONE: Low strength, grey, with some sandstone	
200				
210				
			SANDSTONE: Low strength, grey, fine grained, poorly sorted,	
220			SILTSTONE: Low strength, grey, with some fine sandstone	
			GUBBERAMUNDA SANDSTONE (221 - 250 mBGL) SANDSTONE: Low strength, light grey, medium grained, well sorted, clay matrix	
	6 1/8" PDC Bit			Completion casing (ECPS; HWT; 5LB; 4 1/2"; 16.1 kg/m) CBM Cement; Pumped 43.7 bbl, density of 13.50 ppg

SANTOS NOGAMMA 121203 QWC GINT MASTER_REV1.GPJ WCC_AUS_GDT 16/12/13

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
290					
			MUDSTONE: Low strength, dark grey, massive		
300			SILTSTONE: Low strength, dark grey		
310			312m: Becoming low to medium strength		
320				Completion casing (ECPS; HWT; 5LB; 4 1/2"; 16.1 kg/m)	CBM Cement; Pumped 43.7 bbl, density of 13.50 ppg
330			WEALD SANDSTONE (330 - 337 mBGL) SANDSTONE: Low strength, light grey, fine grained, poorly sorted		
340			SPRINGBOK SANDSTONE (337 - EOH) SANDSTONE: Low strength, light grey, fine grained		
			SANDSTONE: Low to medium strength, grey		

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
350	6 1/8" PDC Bit		INTERBEDDED SILSTONE - SANDSTONE: Sandstone is low to medium strength, grey, siltstone is low strength, dark grey	
356m: Minor coal fragments				
360				
370			SANDSTONE: Low strength, grey	
380			381m: Trace coal	Anular Casing Packer, (372.43 - 343.51 mBGL)
390			390m: Trace coal	Johnson Stainless Steel 0.5 mm Aperture Screen
400				1 m Johnson Stainless Steel Zero Sump
			<u>End Of Hole - 403.5 mBGL (05-10-13)</u>	

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ID: **131029_OBGGWG01_DRILLLOG_REV1**

Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
50			51 m: Dark grey	
60				
70			69 m: With (<10%) fine grained sandstone	
80			SANDSTONE: Very low strength, grey, fine grained, with mudstone	Completion casing (HWT; 5LB, 4 1/2", 10.8 lb/ft)
			MUDSTONE: Very low strength, dark grey	Class A cement; Pumped 52.5 bbl, density of 13.5ppg
90			INTERBEDDED MUDSTONE - SANDSTONE: Sandstone is very low strength, grey, fine grained, mudstone is very low strength, dark grey	
			MUDSTONE: Very low strength, dark grey	
100			SANDSTONE: Very low strength, grey, fine grained	
			INTERBEDDED MUDSTONE - SANDSTONE: Sandstone is very low strength, grey, fine grained, mudstone is very low strength, dark grey	

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
110				
120			SANDSTONE: Very low strength, grey, fine grained with siltstone and mudstone MUDSTONE: Very low strength, dark grey 126 m: Trace sandstone 138 m: Trace sandstone SANDSTONE: Very low strength, grey, fine grained, trace mudstone 159 m: With mudstone	Completion casing (HWT; 5LB, 4 1/2", 10.8 lb/ft) Class A cement; Pumped 52.5 bbl, density of 13.5ppg
130				
140				
150				
160				

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
170				
180				
190			MUDSTONE: Very low strength, dark grey, with fine grained sandstone	
200			MOOGA SANDSTONE (199-218 mBGL) SANDSTONE: Very low strength, grey, fine to coarse grained	
			INTERBEDDED MUDSTONE - SANDSTONE: Mudstone is very low strength, dark grey, sandstone is very low strength, grey, fine grained.	
210			SANDSTONE: Very low strength, grey, fine grained	
			213 m: Fine to coarse grained, trace mudstone	
220			ORALLO FORMATION (218-371 mBGL)	
			225 m: Fine grained, poorly sorted	

Completion casing
(HWT; 5LB, 4
1/2", 10.8 lb/ft)

Class A cement;
Pumped 52.5 bbl,
density of 13.5ppg

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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS	
230					
			237 m : Very low to low strength, with mudstone and siltstone		
240					
			249 m: Trace coal		
250					
260					
270					
			273 m: With mudstone and trace coal		
280					

Completion casing
(HWT; 5LB, 4
1/2", 10.8 lb/ft)

Class A cement;
Pumped 52.5 bbl,
density of 13.5ppg

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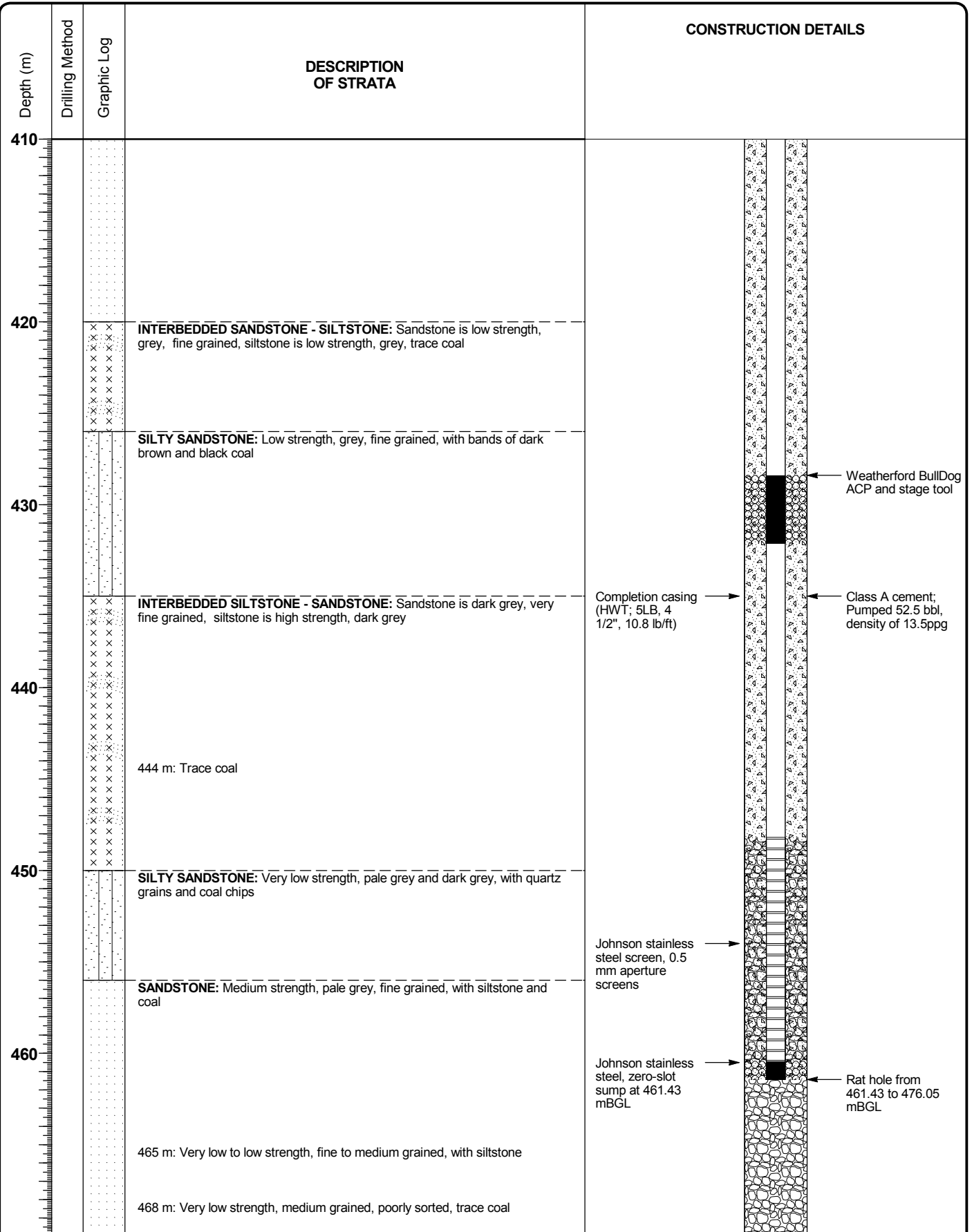
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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
350				
			INTERBEDDED MUDSTONE - SANDSTONE: Sandstone is low strength, grey, fine to coarse grained, mudstone is medium to high strength, dark grey	
360			SANDSTONE: Low strength, brown to grey, fine grained	
			INTERBEDDED MUDSTONE - SANDSTONE: Sandstone is low strength, brown-grey, fine grained, mudstone is medium strength, dark grey	
370			369 m: Trace coal	
			GUBBERAMUNDA SANDSTONE (371-481 mBGL) 378 m: Sandstone coarse grained	
380			SANDSTONE: Low strength, grey, fine grained, with coal fragments	
390				
400			399 m: Trace coal	

Completion casing
(HWT; 5LB, 4
1/2", 10.8 lb/ft)

Class A cement;
Pumped 52.5 bbl,
density of 13.5ppg

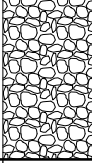


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Depth (m)	Drilling Method	Graphic Log	DESCRIPTION OF STRATA	CONSTRUCTION DETAILS
470	6 1/8" PDC Bit		SILTY SANDSTONE: Low strength, dark grey to pale brown, coarse grained, poorly sorted, with siltstone 474 m: Pale grey, fine to medium grained, trace coal	
480			End of HOLE: 476.05 mBGL	
490				
500				
510				
520				

Appendix F

Implementation Plan for UWIR Water Monitoring Program



Table F.1 Implementation Plan for UWIR Water Monitoring Program

UWIR Requirement									Monitoring Unit					Location							Completion Date					Monitoring Frequency				
UWIR Site number	OGIA Monitoring point ID (New Referencing)	OGIA Responsible Tenure Holder	UWIR Latitude	UWIR Longitude	UWIR Target Unit	UWIR Water Pressure frequency	UWIR Water Quality frequency	UWIR required by	UWIR Existing Reference	Tenure Holder Proposed monitoring point name	Tenure Holder Proposed Monitoring Unit Same as WMS (Y/N)	If Tenure Holder Proposed Monitoring Unit not same as WMS: Alternate unit	If Tenure Holder Proposed Monitoring Unit not same as WMS: Reason for change	OGIA endorsement for proposed monitoring unit (Y/N)	Proposed Latitude	Proposed Longitude	Location Materiality Same as WMS (Y/N)	If Location not same as WMS: Distance between proposed location and UWIR location (km)	Distance between various monitoring points at the same site (De-nesting)	If Location not same as WMS: Reason for a proposed change in location from the UWIR	OGIA endorsement for proposed location (Y/N)	Planned monitoring start quarter	Planned monitoring start year	Planned monitoring start date meets WMS requirement? Y/N	If planned monitoring start date does not meet WMS requirement: Reason for delay	OGIA endorsement for proposed monitoring commencement (Y/N)	Planned monitoring frequency	Planned monitoring frequency meets WMS requirement Y/N	If planned monitoring frequency does not meet WMS requirement: Reason for change	OGIA endorsement for proposed monitoring frequency (Y/N)
52	268	Santos	-26.7922	148.7417	Gubberamunda Sandstone	fortnightly		2012	Hollyrood 5	Hollyrood 5	Yes		Not applicable	Yes	-26.7922	148.7417	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
52	269	Santos	-26.7922	148.7417	Lower Juandah Coal Measures	fortnightly		2012	Hollyrood 5	Hollyrood 5	Yes		Not applicable	Yes	-26.7922	148.7417	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
52	270	Santos	-26.7922	148.7417	Taroom Coal Measures	fortnightly		2012	Hollyrood 5	Hollyrood 5	Yes		Not applicable	Yes	-26.7922	148.7417	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
54	274	Santos	-26.7718	149.206	Gubberamunda Sandstone	fortnightly		2016		Wallabella, WBLGWG06	Yes		Not applicable	Yes	-26.782535	149.19687	No	1.5	1-5 km	Make use of existing infrastructure/Landholder issues/Site access issues	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
54	275	Santos	-26.7718	149.206	Gubberamunda Sandstone		fortnightly/annual	2016		Wallabella, WBLGWG06	Yes		Not applicable	Yes	-26.782535	149.19687	No	1.5	1-5 km	Make use of existing infrastructure/Landholder issues/Site access issues	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Quarterly sampling for both WQ1 & WQ2.	No	Propose more efficient sampling regime	Yes
54	276	Santos	-26.7718	149.206	Springbok Sandstone	fortnightly		2016		Wallabella	Yes		Not applicable	Yes	-26.78753	149.20122	No	1.8	1-5 km	To enhance monitoring program	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
54	277	Santos	-26.7718	149.206	coal seam of the Upper Juandah Coal Measures	fortnightly		2016		Wallabella	Yes		Not applicable	Yes	-26.78753	149.20122	No	1.8	1-5 km	To enhance monitoring program	Yes	Q4	2016	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
54	278	Santos	-26.7718	149.206	coal seam of the Lower Juandah Coal Measures	fortnightly		2016		Wallabella	Yes		Not applicable	Yes	-26.78753	149.20122	No	1.8	1-5 km	To enhance monitoring program	Yes	Q4	2016	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
54	279	Santos	-26.7718	149.206	coal seam of the Taroom Coal Measures	fortnightly		2016		Wallabella	Yes		Not applicable	Yes	-26.78753	149.20122	No	1.8	1-5 km	To enhance monitoring program	Yes	Q4	2016	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
54	280	Santos	-26.7718	149.206	Hutton Sandstone	fortnightly		2016		Wallabella	Yes		Not applicable	Yes	-26.787544	149.20122	No	1.8	1-5 km	To enhance monitoring program	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
58	298	Santos	-26.6833	148.9923	Mooga Sandstone	fortnightly		2012	Coonardoo 2	Coonardoo 2	Yes		Not applicable	Yes	-26.6833	148.9923	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
58	299	Santos	-26.6833	148.9923	Gubberamunda Sandstone	fortnightly		2012	Coonardoo 2	Coonardoo 2	Yes		Not applicable	Yes	-26.6833	148.9923	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
58	300	Santos	-26.6833	148.9923	Upper Juandah Coal Measures	fortnightly		2012	Coonardoo 2	Coonardoo 2	Yes		Not applicable	Yes	-26.6833	148.9923	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
58	301	Santos	-26.6833	148.9923	Lower Juandah Coal Measures	fortnightly		2012	Coonardoo 2	Coonardoo 2	Yes		Not applicable	Yes	-26.6833	148.9923	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
58	302	Santos	-26.6833	148.9923	Taroom Coal Measures	fortnightly		2012	Coonardoo 2	Coonardoo 2	Yes		Not applicable	Yes	-26.6833	148.9923	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
60	307	Santos	-26.6737	148.8464	Upper Juandah Coal Measures	fortnightly		2012	Richmond 25	Richmond 25 (RIC25)	Yes		Not applicable	Yes	-26.67370	148.84640	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
60	308	Santos	-26.6737	148.8464	Lower Juandah Coal Measures	fortnightly		2012	Richmond 25	Richmond 25 (RIC25)	Yes		Not applicable	Yes	-26.67370	148.84640	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
60	309	Santos	-26.6737	148.8464	Taroom Coal Measures	fortnightly		2013	Richmond 25	Richmond 25 (RIC25)	Yes		Not applicable	Yes	-26.67370	148.84640	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
64	324	Santos	-26.6366	149.1119	Gubberamunda Sandstone	fortnightly		2012	Latemore South 2	Latemore South 2	Yes		Not applicable	Yes	-26.6366	149.1119	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
64	325	Santos	-26.6366	149.1119	Springbok Sandstone	fortnightly		2012	Latemore South 2	Latemore South 2	Yes		Not applicable	Yes	-26.6366	149.1119	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
64	326	Santos	-26.6366	149.1119	Lower Juandah Coal Measures	fortnightly		2012	Latemore South 2	Latemore South 2	Yes		Not applicable	Yes	-26.6366	149.1119	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
64	327	Santos	-26.6366	149.1119	Taroom Coal Measures	fortnightly		2012	Latemore South 2	Latemore South 2	Yes		Not applicable	Yes	-26.6366	149.1119	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
65	328	Santos	-26.6033	149.3932	Mooga Sandstone	fortnightly		2012	M02	Boxgrove, BXGGW/M02	Yes		Not applicable	Yes	-26.60333	149.37349	No	2.0	1-5 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
65	329	Santos	-26.6033	149.3932	Mooga Sandstone		fortnightly/annual	2012	M02	Boxgrove, BXGGW/M02	Yes		Not applicable	Yes	-26.60333	149.37349	No	2.0	1-5 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Quarterly sampling for both WQ1 & WQ2.	No	Propose more efficient sampling regime	Yes
65	330	Santos	-26.6033	149.3932	Gubberamunda Sandstone	fortnightly		2012	G04	Boxgrove, BXGGW/G04	Yes		Not applicable	Yes	-26.60349	149.37358	No	2.0	1-5 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
65	331	Santos	-26.6033	149.3932	Gubberamunda Sandstone		fortnightly/annual	2012	G04	Boxgrove, BXGGW/G04	Yes		Not applicable	Yes	-26.60349	149.37358	No	2.0	1-5 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Quarterly sampling for both WQ1 & WQ2.	No	Propose more efficient sampling regime	Yes
65	332	Santos	-26.6033	149.3932	coal seam of the Upper Juandah Coal Measures	fortnightly		2016		Boxgrove	Yes		Not applicable	Yes	-26.60349	149.37358	No	2.0	1-5 km	Not applicable	Yes	Q4	2016	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
66	333	Santos	-26.582468	148.850905	Mooga Sandstone	fortnightly		2012	Damper Creek 4	Carslea, Damper Creek 4a	Yes		Not applicable	Yes	-26.58264	148.85108	Yes	0.026249	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
66	334	Santos	-26.582468	148.850905	Gubberamunda Sandstone	fortnightly		2012	Damper Creek 4	Carslea, Damper Creek 4a	Yes		Not applicable	Yes	-26.58264	148.85108	Yes	0.026249	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
66	335	Santos	-26.582468	148.850905	Springbok Sandstone	fortnightly		2016		Carslea, CRLGW/S01	Yes		Not applicable	Yes	-26.583025	148.851223	Yes	0.060465	0-1 km	Not applicable	Yes	Q2	2014	No	Santos are currently assessing completion options to					

UWIR Requirement										Monitoring Unit					Location							Completion Date					Monitoring Frequency			
UWIR Site number	OGIA Monitoring point ID (New Referencing)	OGIA Responsible Tenure Holder	UWIR Latitude	UWIR Longitude	UWIR Target Unit	UWIR Water Pressure frequency	UWIR Water Quality frequency	UWIR required by	UWIR Existing Reference	Tenure Holder Proposed monitoring point name	Tenure Holder Proposed Monitoring Unit Same as WMS (Y/N)	If Tenure Holder Proposed Monitoring Unit not same as WMS: Alternate unit	If Tenure Holder Proposed Monitoring Unit not same as WMS: Reason for change	OGIA endorsement for proposed monitoring unit (Y/N)	Proposed Latitude	Proposed Longitude	Location Materially Same as WMS (Y/N)	If Location not same as WMS: Distance between proposed location and UWIR location (km)	Distance between various monitoring points at the same site (De-nesting)	If Location not same as WMS: Reason for a proposed change in location from the UWIR	OGIA endorsement for proposed location (Y/N)	Planned monitoring start quarter	Planned monitoring start year	Planned monitoring start date meets WMS requirement? Y/N	If planned monitoring start date does not meet WMS requirement: Reason for delay	OGIA endorsement for proposed monitoring commencement (Y/N)	Planned monitoring frequency	Planned monitoring frequency meets WMS requirement Y/N	If planned monitoring frequency does not meet WMS requirement: Reason for change	OGIA endorsement for proposed monitoring frequency (Y/N)
72		QGC (Santos)	-26.523	149.822	Precipice Sandstone	fortnightly	fortnightly/annual	2013	Airfie	Old Bogandilla	N/A	No alternative	>1,500m deep	Yes	N/A	N/A	N/A	0	N/A	Not to be drilled	Yes	N/A	N/A	N/A	N/A	Yes	Not applicable	No	Well not to be drilled (>1,500m deep)	Yes
74	379	Santos	-26.4948	149.3649	Gubberamunda Sandstone	fortnightly		2012	Bendemere 1	Bendemere 1	Yes		Not applicable	Yes	-26.4948	149.3649	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
74	380	Santos	-26.4948	149.3649	Westbourne Formation	fortnightly		2012	Bendemere 1	Bendemere 1	Yes		Not applicable	Yes	-26.4948	149.3649	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
74	381	Santos	-26.4948	149.3649	Springbok Sandstone	fortnightly		2012	Bendemere 1	Bendemere 1	Yes		Not applicable	Yes	-26.4948	149.3649	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
74	382	Santos	-26.4948	149.3649	Upper Juandah Coal Measures	fortnightly		2012	Bendemere 1	Bendemere 1	Yes		Not applicable	Yes	-26.4948	149.3649	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
74	383	Santos	-26.4948	149.3649	Lower Juandah Coal Measures	fortnightly		2012	Bendemere 1	Bendemere 1	Yes		Not applicable	Yes	-26.4948	149.3649	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
74	384	Santos	-26.4948	149.3649	Taroom Coal Measures	fortnightly		2012	Bendemere 1	Bendemere 1	Yes		Not applicable	Yes	-26.4948	149.3649	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
75	385	Santos	-26.465	149.0187	Orallo Formation	fortnightly		2012	The Bend	The Bend (TBD_VWP)	Yes		Not applicable	Yes	-26.46523	149.0144	Yes	0.4	0-1 km	Slight deviation from UWIR location	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
75	386	Santos	-26.465	149.0187	Westbourne Formation	fortnightly		2012	The Bend	The Bend (TBD_VWP)	Yes		Not applicable	Yes	-26.46523	149.0144	Yes	0.4	0-1 km	Slight deviation from UWIR location	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
76	387	Santos	-26.4387	148.904	Springbok Sandstone	fortnightly		2016	Peak Hill	BEVGWS01	Yes		Not applicable	Yes	-26.4392	148.9152	No	1.1	1-5 km	Site access issues	Yes	Q4	2016	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
76	388	Santos	-26.4387	148.904	coal seam of the Upper Juandah Coal Measures	fortnightly		2016	Peak Hill	Beverley	Yes		Not applicable	Yes	-26.4392	148.9152	No	1.1	1-5 km	Site access issues	Yes	Q4	2016	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
76	389	Santos	-26.4387	148.904	coal seam of the Lower Juandah Coal Measures	fortnightly		2016	Peak Hill	Beverley	Yes		Not applicable	Yes	-26.4392	148.9152	No	1.1	1-5 km	Site access issues	Yes	Q4	2016	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
76	390	Santos	-26.4387	148.904	coal seam of the Taroom Coal Measures	fortnightly		2016	Peak Hill	Beverley	Yes		Not applicable	Yes	-26.4392	148.9152	No	1.1	1-5 km	Site access issues	Yes	Q4	2016	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
77	391	Santos	-26.4391	148.8004	Gubberamunda Sandstone	fortnightly		2012	Montana 1	Montana 1 (MTA1)	Yes		Not applicable	Yes	-26.4391	148.8004	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
77	392	Santos	-26.4391	148.8004	Upper Juandah Coal Measures	fortnightly		2012	Montana 1	Montana 1 (MTA1)	Yes		Not applicable	Yes	-26.4391	148.8004	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
77	393	Santos	-26.4391	148.8004	Lower Juandah Coal Measures	fortnightly		2012	Montana 1	Montana 1 (MTA1)	Yes		Not applicable	Yes	-26.4391	148.8004	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
77	394	Santos	-26.4391	148.8004	Taroom Coal Measures	fortnightly		2012	Montana 1	Montana 1 (MTA1)	Yes		Not applicable	Yes	-26.4391	148.8004	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
78	395	Santos	-26.4302	149.3612	Mooga Sandstone		WQ1 - Quarterly; WQ2 - Annual	2012	Santos Bore ID 1137	RGWM15 (Santos Well 1137)	Yes		Not applicable	Yes	-26.4305	149.361	Yes	0.04	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Quarterly sampling for both WQ1 & WQ2.	No	Propose more efficient sampling regime	Yes
78	396	Santos	-26.4302	149.3612	Mooga Sandstone	fortnightly		2012	Santos Bore ID 1137	Ben Bow - BBWVWP	Yes		Not applicable	Yes	-26.4305	149.361	Yes	0.04	0-1 km	Use of existing VWP for Mooga Sandstone at nested site with Ben Bow	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
78	397	Santos	-26.4302	149.3612	Orallo Formation	fortnightly		2012	O01	Ben Bow - BBWGW001	Yes		Not applicable	Yes	-26.43022	149.33883	No	2.2	1-5 km	Utilise existing monitoring infrastructure	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
78	398	Santos	-26.4302	149.3612	Orallo Formation		WQ1 - Quarterly; WQ2 - Annual	2012	O01	Ben Bow - BBWGW001	Yes		Not applicable	Yes	-26.43022	149.33883	No	2.2	1-5 km	Utilise existing monitoring infrastructure	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Quarterly sampling for both WQ1 & WQ2.	No	Propose more efficient sampling regime	Yes
82	418	Santos	-26.3685	149.106	Gubberamunda Sandstone	fortnightly		2013		Armidaale 82 - ARMGWG13	Yes		Not applicable	Yes	-26.38717	149.12559	No	2.9	1-5 km	UWIR proposed site not agreeable to landholder	Yes	Q2	2014	No	Well has been drilled but not scheduled to be completed until Q2 2014 as Santos is currently reviewing completion design options.	No	continuous data logging	Yes	Not applicable	Yes
82	419	Santos	-26.3685	149.106	Springbok Sandstone	fortnightly		2013		Armidaale 82 - ARMGWS01	Yes		Not applicable	Yes	-26.38717	149.12572	No	2.9	1-5 km	UWIR proposed site not agreeable to landholder	Yes	Q2	2014	No	Well has been drilled but not scheduled to be completed until Q2 2014 as Santos is currently reviewing completion design options.	No	continuous data logging	Yes	Not applicable	Yes
82	420	Santos	-26.3685	149.106	Springbok Sandstone		fortnightly/annual	2013		Armidaale 82 - ARMGWS01	Yes		Not applicable	Yes	-26.38717	149.12572	No	2.9	1-5 km	UWIR proposed site not agreeable to landholder	Yes	Q2	2014	No	Well has been drilled but not scheduled to be completed until Q2 2014 as Santos is currently reviewing completion design options.	No	Quarterly sampling for both WQ1 & WQ2.	No	Propose more efficient sampling regime	Yes
82	421	Santos	-26.3685	149.106	coal seam of the Upper Juandah Coal Measures	fortnightly		2013		Armidaale 82 - ARMGWS01	Yes		Not applicable	Yes	-26.38717	149.12572	No	2.9	1-5 km	UWIR proposed site not agreeable to landholder	Yes	Q2	2014	No	Location being investigated; if existing site cannot be used, new wells will be drilled in 2014 and completed by Q4 2014.	No	continuous data logging	Yes	Not applicable	Yes
82	422	Santos	-26.3685	149.106	sandstone or siltstone or mudstone of the Juandah Coal Measures	fortnightly		2013		Armidaale 82 - ARMGWS01	Yes		Not applicable	Yes	-26.38717	149.12572	No	2.9	1-5 km	UWIR proposed site not agreeable to landholder	Yes	Q2	2014	No	Location being investigated; if existing site cannot be used, new wells will be drilled in 2014 and completed by Q4 2014.	No	continuous data logging	Yes	Not applicable	Yes
82	423	Santos	-26.3685	149.106	coal seam of the Lower Juandah Coal Measures	fortnightly		2013		Armidaale 82 - ARMGWS01	Yes		Not applicable	Yes	-26.38717	149.12572	No	2.9	1-5 km	UWIR proposed site not agreeable to landholder	Yes	Q2	2014	No	Location being investigated; if existing site cannot be used, new wells will be drilled in 2014 and completed by Q4 2014.	No	continuous data logging	Yes	Not applicable	Yes
82	424	Santos	-26.3685	149.106	Tangalooma Sandstone	fortnightly		2013		Armidaale 82 - ARMGWS01	Yes		Not applicable	Yes	-26.38717	149.12572	No	2.9	1-5 km	UWIR proposed site not agreeable to landholder	Yes	Q2	2014	No	Location being investigated; if existing site cannot be used, new wells will be drilled in 2014 and completed by Q4 2014.	No	continuous data logging	Yes	Not applicable	Yes
82	425	Santos	-26.3685	149.106	coal seam of the Taroom Coal Measures	fortnightly		2013		Armidaale 82 - ARMGWS01	Yes		Not applicable	Yes	-26.38717	149.12572	No	2.9	1-5 km	UWIR proposed site not agreeable to landholder	Yes	Q2	2014	No	Location being investigated; if existing site cannot be used, new wells will be drilled in 2014 and completed by Q4 2014.	No	continuous data logging	Yes	Not applicable	Yes
82	426	Santos	-26.3685	149.106	lower aquitard of the Walloon Coal Measures	fortnightly		2013		Armidaale 82 - ARMGWS01	Yes		Not applicable	Yes	-26.38717	149.12572	No	2.9	1-5 km	UWIR proposed site not agreeable to landholder	Yes	Q2	2014	No	Location being investigated; if existing site cannot be used, new wells will be drilled in 2014 and completed by Q4 2014.	No	continuous data logging	Yes	Not applicable	Yes
82	427	Santos	-26.3685	149.106	Hutton Sandstone	fortnightly		2013		Armidaale 82 - ARMGWH01	Yes		Not applicable	Yes	-26.38725	149.12587	No	2.9	1-5 km	UWIR proposed site not agreeable to landholder	Yes	Q2	2014	No	Well has been drilled but not scheduled to be completed until Q2 2014 as Santos is currently reviewing completion design options.	No	continuous data logging	Yes	Not applicable	Yes

UWIR Requirement										Monitoring Unit					Location							Completion Date					Monitoring Frequency			
UWIR Site number	OGIA Monitoring point ID (New Referencing)	OGIA Responsible Tenure Holder	UWIR Latitude	UWIR Longitude	UWIR Target Unit	UWIR Water Pressure frequency	UWIR Water Quality frequency	UWIR required by	UWIR Existing Reference	Tenure Holder Proposed monitoring point name	Tenure Holder Proposed Monitoring Unit Same as WMS (Y/N)	If Tenure Holder Proposed Monitoring Unit not same as WMS: Alternate unit	If Tenure Holder Proposed Monitoring Unit not same as WMS: Reason for change	OGIA endorsement for proposed monitoring unit (Y/N)	Proposed Latitude	Proposed Longitude	Location Materially Same as WMS (Y/N)	If Location not same as WMS: Distance between proposed location and UWIR location (km)	Distance between various monitoring points at the same site (De-nesting)	If Location not same as WMS: Reason for a proposed change in location from the UWIR	OGIA endorsement for proposed location (Y/N)	Planned monitoring start quarter	Planned monitoring start year	Planned monitoring start date meets WMS requirement? Y/N	If planned monitoring start date does not meet WMS requirement: Reason for delay	OGIA endorsement for proposed monitoring commencement (Y/N)	Planned monitoring frequency	Planned monitoring frequency meets WMS requirement Y/N	If planned monitoring frequency does not meet WMS requirement: Reason for change	OGIA endorsement for proposed monitoring frequency (Y/N)
82	428	Santos	-26.3685	149.106	Hutton Sandstone		fortnightly/annual	2013		Binbinette, Site 70	Yes		Not applicable	Yes	-26.53315	149.05463	No	17.7 (Site 70)	>10 km	Make use of existing infrastructure	Yes	Q2	2014	Yes	Not applicable	Yes	Quarterly sampling for both WQ1 & WQ2.	No	Propose more efficient sampling regime	Yes
83	429	Santos	-26.3789	148.9636	Mooga Sandstone	fortnightly		2012	M01	BLBGWM01	Yes		Not applicable	Yes	-26.3789	148.9636	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
83	430	Santos	-26.3789	148.9636	Mooga Sandstone		fortnightly/annual	2012	M01	BLBGWM01	Yes		Not applicable	Yes	-26.3789	148.9636	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Quarterly sampling for both WQ1 & WQ2.	No	Propose more efficient sampling regime	Yes
83	431	Santos	-26.3789	148.9636	Gubberamunda Sandstone	fortnightly		2012	G01	BLBGWG01	Yes		Not applicable	Yes	-26.3789	148.9636	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
83	432	Santos	-26.3789	148.9636	Gubberamunda Sandstone		fortnightly/annual	2012	G01	BLBGWG01	Yes		Not applicable	Yes	-26.3789	148.9636	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Quarterly sampling for both WQ1 & WQ2.	No	Propose more efficient sampling regime	Yes
86	446	Santos	-26.3365	148.8381	Gubberamunda Sandstone	fortnightly		2012	Navarra 1	Navarra 1	Yes		Not applicable	Yes	-26.3365	148.8381	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
86	447	Santos	-26.3365	148.8381	Upper Juandah Coal Measures	fortnightly		2013	Navarra 1	Navarra 1	Yes		Not applicable	Yes	-26.3365	148.8381	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
88	456	Santos	-26.2952	148.633	Upper Juandah Coal Measures	fortnightly		2012	Mt Eden 1	Mt. Eden 1 (MED1)	Yes		Not applicable	Yes	-26.2952	148.633	Yes	0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
104	526	Santos	-25.82	149.0314	Hutton Sandstone	fortnightly		2013		Stephenton	Yes		Not applicable	Yes	-25.79965	149.064831	No	4.0	1-5 km	To enhance monitoring program	Yes	Q2	2014	No	Well to be drilled Q1-2014 and scheduled to be completed Q2-2014 as Santos is currently reviewing completion design notions.	Yes	Continuous data logging	Yes	Not applicable	Yes
104	527	Santos	-25.82	149.0314	Precipice Sandstone	fortnightly		2013		Stephenton	Yes		Not applicable	Yes	-25.799633	149.064589	No	4.0	1-5 km	To enhance monitoring program	Yes	Q2	2014	No	Well to be drilled Q1-2014 and scheduled to be completed Q2-2014 as Santos is currently reviewing completion design notions.	Yes	Continuous data logging	Yes	Not applicable	Yes
104	528	Santos	-25.82	149.0314	Bandanna Formation coal seam	fortnightly		2013		FV 188 OBS 2 or FV 188 OBS 3	Yes		Not applicable	Yes	-25.799385	149.064831	No	4.1	1-5 km	Make use of existing infrastructure	Yes	Q2	2014	No	Additional works required before operational	Yes	Continuous data logging	Yes	Not applicable	Yes
106	531	Santos	-25.7863	148.8459	Boxvale Sandstone	fortnightly		2013		OK Station	Yes		Not applicable	Yes	-25.797445	148.863468	No	2.1	1-5 km	To move onto the same well pad as the Bandanna Formation monitoring well	Yes	Q3	2014	No	Well is to be drilled in Q4 2013, but not scheduled to be completed until 2014; Santos is currently assessing the most appropriate completion designs and options.	Yes	Continuous data logging	Yes	Not applicable	Yes
106	532	Santos	-25.7863	148.8459	Precipice Sandstone	fortnightly		2012		OK Station	Yes		Not applicable	Yes	-25.797445	148.863468	No	2.1	1-5 km	Existing Precipice well exists 2.1km from UWIR site; however, on request of OGIA, new Precipice well to be installed on Bandanna well pad.	Yes	Q3	2014	No	Well is to be drilled in Q4 2013, but not scheduled to be completed until 2014; Santos is currently assessing the most appropriate completion designs and options.	Yes	Continuous data logging	Yes	Not applicable	Yes
106	533	Santos	-25.7863	148.8459	Bandanna Formation coal seam	fortnightly		2013		FV 299 OB1	Yes		Not applicable	Yes	-25.797394	148.863461	No	2.1	1-5 km	Make use of existing infrastructure	Yes	Q3	2014	No	Well has been installed, but is awaiting telemetry to be installed. It is anticipated that this will be completed concurrently with the completion of the Precipice and Boxvale wells	Yes	Continuous data logging	Yes	Not applicable	Yes
106	534	Santos	-25.7863	148.8459	Bandanna Formation coal seam		fortnightly/annual	2013		FV205	Yes		Not applicable	Yes	-25.76586	148.89406	No	5.3	5-10 km	Make use of existing infrastructure	Yes	Q4	2013	Yes	Not applicable	Yes	Quarterly sampling for both WQ1 & WQ2.	No	Propose more efficient sampling regime	Yes
108	540	Santos	-25.7538	148.7948	Precipice Sandstone	fortnightly		2012	FV-VW0903	FVWV0903	Yes		Not applicable	Yes	-25.7538	148.7948	Yes	0.0	0-1 km	Not applicable	Yes	N/a	Already monitored	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
109	541	Santos	-25.7347	149.0829	Precipice Sandstone	fortnightly		2012	FV-MW0902	Currently FVMW0902 but will be moved to Bandanna drill pad FV291 OB1	Yes		Not applicable	Yes	-25.73467	149.08276	No	4.3	1-5 km	To enhance monitoring program, moving location to Bandanna pressure well pad	Yes	N/a	Already monitored, however new well to be moved on request of OGIA	NA	Drilling of new well scheduled for Q1 2014, anticipate completion in Q2 2014	Yes	Continuous data logging	Yes	Not applicable	Yes
109	542	Santos	-25.7347	149.0829	Precipice Sandstone		fortnightly/annual	2012	FV-MW0902	Currently FVMW0902 but will be moved to Bandanna drill pad FV291 OB1	Yes		Not applicable	Yes	-25.73467	149.08276	No	4.3	1-5 km	To enhance monitoring program, moving location to Bandanna WQ well pad	Yes	N/a	Already monitored, however new well to be moved on request of OGIA	NA	Drilling of new well scheduled for Q1 2014, anticipate completion in Q2 2015	Yes	Quarterly sampling for both WQ1 & WQ2.	No	Propose more efficient sampling regime	Yes
109	543	Santos	-25.7347	149.0829	Bandanna Formation coal seam	fortnightly		2013		Fairview 291 OB1	Yes		Not applicable	Yes	-25.73497	149.12557	No	4.3	1-5 km	Make use of existing infrastructure	Yes	Q4	2013	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
109	544	Santos	-25.7347	149.0829	Bandanna Formation coal seam		fortnightly/annual	2013		Fairview 275	Yes		Not applicable	Yes	-25.80225	149.08977	No	7.5	5-10 km	Make use of existing infrastructure	Yes	Q4	2013	Yes	Not applicable	Yes	Quarterly sampling for both WQ1 & WQ2.	No	Propose more efficient sampling regime	Yes
110	545	Santos	-25.731	148.981	Precipice Sandstone	fortnightly		2012	FV-MW0903	Currently FVMW0903 but will be moved to Bandanna drill pad FV289 OB1	Yes		Not applicable	Yes	-25.75372	149.04228	No	6.6	5-10 km	To enhance monitoring program, moving location to Bandanna WQ well pad	Yes	N/a	Already monitored, however new well to be moved on request of OGIA	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
110	546	Santos	-25.731	148.981	Precipice Sandstone		fortnightly/annual	2012	FV-MW0903	Currently FVMW0903 but will be moved to Bandanna drill pad FV289 OB1	Yes		Not applicable	Yes	-25.75372	149.04228	No	6.6	5-10 km	To enhance monitoring program, moving location to Bandanna WQ well pad	Yes	N/a	Already monitored, however new well to be moved on request of OGIA	Yes	Not applicable	Yes	Quarterly sampling for both WQ1 & WQ2.	No	Propose more efficient sampling regime	Yes
110	547	Santos	-25.731	148.981	Bandanna Formation coal seam	fortnightly		2013		Fairview 289 OB1	Yes		Not applicable	Yes	-25.75372	149.04228	No	6.6	5-10 km	Make use of existing infrastructure	Yes	Q4	2013	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
110	548	Santos	-25.731	148.981	Bandanna Formation coal seam		fortnightly/annual	2013		Fairview 185	Yes		Not applicable	Yes	-25.72877	148.98667	Yes	0.6	0-1 km	Make use of existing infrastructure	Yes	Q4	2013	Yes	Not applicable	Yes	Quarterly sampling for both WQ1 & WQ2.	No	Propose more efficient sampling regime	Yes
112	550	Santos	-25.5829	149.1042	Clematis Sandstone	fortnightly		2013		Yebna	Yes		Not applicable	Yes	-25.644136	149.164835	No	9.1	5-10 km	Inaccessible area with steep terrain; numerous environmental constraints (ESA)	Yes	Q4	2013	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
112	551	Santos	-25.5829	149.1042	Bandanna Formation coal seam	fortnightly		2013		Yebna North 2	Yes		Not applicable	Yes	-25.65828	149.14106	No	9.1	5-10 km	Inaccessible area with steep terrain; numerous environmental constraints (ESA)	Yes	Q4	2014	No	Workover required to install monitoring gauges	Yes	Continuous data logging	Yes	Not applicable	Yes
113	552	Santos	-25.5014	148.7544	Clematis Sandstone	fortnightly		2013		EVGGWC01	Yes		Not applicable	Yes	-25.531071	148.768321	No	3.7	5-10 km	Site access issues	Yes	Q1	2014	No	Site access issues have delayed drilling and completions to 2014. Secondary Clematis well to be installed on FV412OB1 pad on	Yes	Continuous data logging	Yes	Not applicable	Yes

UWIR Requirement										Monitoring Unit					Location							Completion Date					Monitoring Frequency			
UWIR Site number	OGIA Monitoring point ID (New Referencing)	OGIA Responsible Tenure Holder	UWIR Latitude	UWIR Longitude	UWIR Target Unit	UWIR Water Pressure frequency	UWIR Water Quality frequency	UWIR required by	UWIR Existing Reference	Tenure Holder Proposed monitoring point name	Tenure Holder Proposed Monitoring Unit Same as WMS (Y/N)	If Tenure Holder Proposed Monitoring Unit not same as WMS: Alternate unit	If Tenure Holder Proposed Monitoring Unit not same as WMS: Reason for change	OGIA endorsement for proposed monitoring unit (Y/N)	Proposed Latitude	Proposed Longitude	Location Materiality Same as WMS (Y/N)	If Location not same as WMS: Distance between proposed location and UWIR location (km)	Distance between various monitoring points at the same site (De-nesting)	If Location not same as WMS: Reason for a proposed change in location from the UWIR	OGIA endorsement for proposed location (Y/N)	Planned monitoring start quarter	Planned monitoring start year	Planned monitoring start date meets WMS requirement? Y/N	If planned monitoring start date does not meet WMS requirement: Reason for delay	OGIA endorsement for proposed monitoring commencement (Y/N)	Planned monitoring frequency	Planned monitoring frequency meets WMS requirement Y/N	If planned monitoring frequency does not meet WMS requirement: Reason for change	OGIA endorsement for proposed monitoring frequency (Y/N)
113	553	Santos	-25.5014	148.7544	Bandanna Formation coal seam	fortnightly		2013		FV 412 OB1	Yes		Not applicable	Yes	-25.6076	148.76517	No	11.8	>10 km	Site access issues	Yes	Q4	2013	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
114	554	Santos	-25.41	148.9052	Bandanna Formation coal seam	fortnightly		2013		TBD	Yes		Not applicable	Yes	-25.40384	148.93932	No	3.5	1-5 km	Make use of existing infrastructure	Yes	Q4	2014	No	Well is scheduled to be drilled in 2013, and completed in 2014 as Santos is currently reviewing infrastructure design.	Yes	Continuous data logging	Yes	Not applicable	Yes
115	555	Santos	-25.3492	149.0188	Clematis Sandstone	fortnightly		2013		TBD	Yes		Not applicable	Yes								Q4	2014	No	Access issues have delayed process for establishing site and inclusion in drilling schedule.	Yes	Continuous data logging	Yes	Not applicable	Yes
115	556	Santos	-25.3492	149.0188	Bandanna Formation coal seam	fortnightly		2013		FV 87 OB1	Yes		Not applicable	Yes	-25.55693	148.99767	No	23.1	>10 km	Site access issues and distance from Arcadia..	Yes	Q4	2014	No	Access issues have delayed process for establishing site and inclusion in drilling schedule.	Yes	Continuous data logging	Yes	Not applicable	Yes
116	557	Santos	-25.242	148.9269	Clematis Sandstone	fortnightly		2016		Expedition National Park	Yes		Not applicable	Yes	-25.242	148.9269	Yes	0	0-1 km	Not applicable	Yes	Q4	2016	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
116	558	Santos	-25.242	148.9269	Bandanna Formation coal seam	fortnightly		2016		Expedition National Park	Yes		Not applicable	Yes	-25.242	148.9269	Yes	0	0-1 km	Not applicable	Yes	Q4	2016	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
117	559	Santos	-25.1784	148.8487	Clematis Sandstone	fortnightly		2013		Cattle Creek 4	Yes		Not applicable	Yes	-25.13331	148.9132	No	8.2	5-10 km	Clematis Formation does not exist at this location. Permission gained from OGIA to relocate Clematis well	Yes	Q4	2014	No	Location suitability to be confirmed and drilling scheduled	No	Continuous data logging	Yes	Not applicable	Yes
117	560	Santos	-25.1784	148.8487	Bandanna Formation coal seam	fortnightly		2013		Cattle Creek 4	Yes		Not applicable	Yes	-25.13331	148.9132	No	8.2	5-10 km	Make use of existing infrastructure	Yes	Q4	2014	No		No	Continuous data logging	Yes	Not applicable	Yes
118	561	Santos	-24.9198	149.098	Clematis Sandstone	fortnightly		2012	Santos Bore ID 1368	Santos Bore ID 1333/RN57565	Yes		Not applicable	Yes	-24.8937	149.094	No	2.9	1-5km	Site access issues/make use of existing infrastructure. Santos historically undertakes WQ and WL monitoring at existing nearby well Santos ID 1333 (RN57565) and propose this as alternative site. Geological information indicates this screens Clematis SST.	Yes	Q4	2013	No	A CCA agreement is currently being prepared to instal telemetry upon this site to provide continuous water pressure data.	Yes	Continuous data logging	Yes	Not applicable	Yes
118	562	Santos	-24.9198	149.098	Clematis Sandstone	fortnightly/a nnual		2012	Santos Bore ID 1368	Santos Bore ID 1333/RN57565	Yes		Not applicable	Yes	-24.8937	149.094	No	2.9	1-5km	Site access issues/make use of existing infrastructure. Santos historically undertakes WQ and WL monitoring at existing nearby well Santos ID 1333 (RN57565) and propose this as alternative site. Geological information indicates this screens Clematis SST.	Yes	Q1	2012	Yes	A CCA agreement is currently being prepared to provide water quality data.	Yes	Quarterly sampling for both WQ1 & WQ2.	No	Propose more efficient sampling regime	Yes
119	563	Santos	-24.7348	149.14	Clematis Sandstone	fortnightly		2012	Santos Bore ID 1349	Santos Bore ID 1376/RN57522	Yes		Not applicable	Yes	-24.846	149.098	No	13.0	>10 km	Site access issues/make use of existing infrastructure	Yes	Q4	2013	No	A CCA agreement is currently being prepared to instal telemetry upon this site to provide continuous water pressure data.	Yes	Continuous data logging	Yes	Not applicable	Yes
119	564	Santos	-24.7348	149.14	Clematis Sandstone	fortnightly/a nnual		2012	Santos Bore ID 1349	Santos Bore ID 1376/RN57522	Yes		Not applicable	Yes	-24.846	149.098	No	13.0	>10 km	Site access issues/make use of existing infrastructure	Yes	Q4	2013	No	A CCA agreement is currently being prepared to instal telemetry upon this site to provide water quality data.	Yes	Quarterly sampling for both WQ1 & WQ2.	No	Propose more efficient sampling regime	Yes
120	565	Santos	-25.6843	149.1875	Boxvale Sandstone	fortnightly		2012	RN 58362	Origin Spring Gully MB12-E	Yes		Not applicable	Yes	-25.68422	149.18755	No	0.01	0-1 km	Site access issues	Yes	Q4	2013	No	Discussions between Origin and Santos, and the responsibility of this well, has delayed scheduling. Santos has assumed responsibility of the Boxvale monitoring on request from OGIA	Yes	Continuous data logging	Yes	Not applicable	Yes
120	566	Santos	-25.6843	149.1875	Precipice Sandstone	fortnightly		2013		Origin Spring Gully MB11-P	Yes		Not applicable	Yes	NA	NA	NA	0	NA	NA	NA	NA	NA	NA	Origin to assume responsibility for Precipice monitoring at this location.	Yes	NA	NA	NA	NA
120	567	Santos	-25.6843	149.1875	Bandanna Formation coal seam	fortnightly/a nnual		2013		TBD	Yes		Not applicable	Yes	TBD	TBD	TBD	TBD	TBD	TBD	No	Q4	2013	Yes	Santos to assume responsibility for Bandanna WQ monitoring at this location.	Yes	Quarterly sampling for both WQ1 & WQ2.	No	Propose more efficient sampling regime	Yes
120	568	Santos	-25.6843	149.1875	Bandanna Formation coal seam	fortnightly		2013		Yebna Nth 2	Yes		Not applicable	Yes	-25.65828	149.14106	No	NA	NA	NA	Yes	Q4	2014	No	Discussions between Origin and Santos, and the siting of this well, has delayed scheduling drilling. Origin has been assigned responsibility of the Bandanna water pressure monitoring by OGIA	No	Continuous data logging	Yes	Not applicable	Yes
122	571	Santos	-26.9346	149.6603	Springbok Sandstone	fortnightly		2013		Not provided	Yes		Not applicable	Yes	-26.9346	149.6603	Yes	0	0-1 km	Santos will need to discuss location of well with Arrow. OGIA have endorsed delaying agreement of location to a later date.	Yes	Q1	2016	No	Santos proposes to delay the installation of site 122 until 2016. As compensation, Santos will bring forward drilling Hutton and Precipice wells at site 123 from 2016 to 2013 (2014 completion).	Yes	Continuous data logging	Yes	Not applicable	Yes
122	572	Santos	-26.9346	149.6603	coal seam of the Upper Juandah Coal Measures	fortnightly		2013		Possibly Mongool 1, Rostock 1 or Wilbah 1	Yes		Not applicable	Yes	-26.9346	149.6603	Yes	0	0-1 km		Yes	Q1	2016	No		Yes	Continuous data logging	Yes	Not applicable	Yes
122	573	Santos	-26.9346	149.6603	coal seam of the Lower Juandah Coal Measures	fortnightly		2013		Possibly Mongool 1, Rostock 1 or Wilbah 1	Yes		Not applicable	Yes	-26.9346	149.6603	Yes	0	0-1 km		Yes	Q1	2016	No		Yes	Continuous data logging	Yes	Not applicable	Yes
123	574	Santos	-25.9325	148.6363	Walloon Coal Measures	fortnightly		2016		KNAGWP01	Yes		Not applicable	Yes	-25.92662	148.6359	Yes	0.7	0-1 km		Yes	Q4	2014	No	Well completion date to be brought forward from 2016 to Q4 2014	Yes	Continuous data logging	Yes	Not applicable	Yes

UWIR Requirement										Monitoring Unit					Location							Completion Date					Monitoring Frequency			
UWIR Site number	OGIA Monitoring point ID (New Referencing)	OGIA Responsible Tenure Holder	UWIR Latitude	UWIR Longitude	UWIR Target Unit	UWIR Water Pressure frequency	UWIR Water Quality frequency	UWIR required by	UWIR Existing Reference	Tenure Holder Proposed monitoring point name	Tenure Holder Proposed Monitoring Unit Same as WMS (Y/N)	If Tenure Holder Proposed Monitoring Unit not same as WMS: Alternate unit	If Tenure Holder Proposed Monitoring Unit not same as WMS: Reason for change	OGIA endorsement for proposed monitoring unit (Y/N)	Proposed Latitude	Proposed Longitude	Location Materially Same as WMS (Y/N)	If Location not same as WMS: Distance between proposed location and UWIR location (km)	Distance between various monitoring points at the same site (De-nesting)	If Location not same as WMS: Reason for a proposed change in location from the UWIR	OGIA endorsement for proposed location (Y/N)	Planned monitoring start quarter	Planned monitoring start year	Planned monitoring start date meets WMS requirement? Y/N	If planned monitoring start date does not meet WMS requirement: Reason for delay	OGIA endorsement for proposed monitoring commencement (Y/N)	Planned monitoring frequency	Planned monitoring frequency meets WMS requirement Y/N	If planned monitoring frequency does not meet WMS requirement: Reason for change	OGIA endorsement for proposed monitoring frequency (Y/N)
123	575	Santos	-25.9325	148.6363	Hutton Sandstone	fortnightly		2016		KNAGWH01	Yes		Not applicable	Yes	-25.92663	148.63611	Yes	0.7	0-1 km		Yes	Q2	2014	No	Well completion date to be brought forward from 2016 to Q2 2014	Yes	Continuous data logging	Yes	Not applicable	Yes
123	576	Santos	-25.9325	148.6363	Precipice Sandstone	fortnightly		2016		KNAGWP01	Yes		Not applicable	Yes	-25.92662	148.6359	Yes	0.7	0-1 km		Yes	Q2	2014	No	Well completion date to be brought forward from 2016 to Q2 2014	Yes	Continuous data logging	Yes	Not applicable	Yes
123	577	Santos	-25.9325	148.6363	Bandanna Formation coal seam	fortnightly		2016		KNAGWP01	Yes		Not applicable	Yes	-25.92662	148.6359	Yes	0.7	0-1 km		Yes	Q4	2014	No	Well completion date to be brought forward from 2016 to Q4 2014	Yes	Continuous data logging	Yes	Not applicable	Yes
126	581	Santos	-27.7623	150.2355	Precipice Sandstone	fortnightly		2013		Moonie	Yes		Not applicable	Yes	-27.7623	150.2355	Yes	0	0-1 km		Yes	Q2	2014	No	Well scheduled to be installed in Q2 2014, as per discussions (and agreement) with OGIA	Yes	Continuous data logging	Yes	Not applicable	Yes
127	582	Santos	-25.858	150.0812	Bandanna Formation coal seam	fortnightly		2013		Scotia 34	Yes		Not applicable	Yes	-25.92971	150.02971	No	9.481525	5-10 km	Make use of existing infrastructure	Yes	Q3	2013	Yes	NA	Yes	Continuous data logging	Yes	Not applicable	Yes
129	584	Santos	-25.825	148.7916	Precipice Sandstone	fortnightly		2013		MHTGWP01	Yes		Not applicable	Yes	-25.82457	148.791424	Yes	0.052811	0-1 km	Site access issues	Yes	Q1	2014	No	Site access issues	Yes	Continuous data logging	Yes	Not applicable	Yes
130	585	Santos	-25.6386	148.9103	Precipice Sandstone	fortnightly		2013		FVGWP01	Yes		Not applicable	Yes	-25.622395	148.961733	No	5.485922	5-10 km	Site access issues	Yes	Q4	2013	Yes	Not applicable	Yes	Continuous data logging	Yes	Not applicable	Yes
130	586	Santos	-25.6386	148.9103	Precipice Sandstone		fortnightly/annual	2013		FVGWP01	Yes		Not applicable	Yes	-25.622343	148.96188	No	5.485922	5-10 km	Site access issues	Yes	Q4	2013	Yes	Not applicable	Yes	Quarterly sampling for both WQ1 & WQ2	No	Propose more efficient sampling regime	Yes
130	587	Santos	-25.6386	148.9103	Bandanna Formation coal seam	fortnightly		2013		FV 119 OB1	Yes		Not applicable	Yes	-25.62229	148.962	No	5.500466	5-10 km	Site access issues/Make use of existing infrastructure	Yes	Q2	2014	No	Additional works required before operational	Yes	Continuous data logging	Yes	Not applicable	Yes
130	588	Santos	-25.6386	148.9103	Bandanna Formation coal seam		fortnightly/annual	2013		FV 119 OB1	Yes		Not applicable	Yes	-25.62229	148.962	No	5.500466	5-10 km	Site access issues/Make use of existing infrastructure	Yes	Q2	2014	No	Additional works required before operational	Yes	Quarterly sampling for both WQ1 & WQ2	No	Propose more efficient sampling regime	Yes
139	607	Santos	-25.317	148.6629	Bandanna Formation coal seam	fortnightly		2013		Not provided	Yes		Not applicable	Yes	-25.12521 (Hilltop); -25.53172 (113/FV87)	148.85711 (Hilltop); 148.8353 (113/FV87)	No	26.2 (Hilltop) 36.2 (113/FV87)	0-1 km	Bandanna Formation estimated to be >1,500m deep at this location	Yes	Q4	2016	No	Alternative coal monitoring wells to be monitored until review of UWIR in 2015	Yes	Continuous data logging	Yes	Not applicable	Yes