Essential Readings in Light Metals: Alumina and Bauxite.
Edited by Don Donaldson and Benny E. Raahauge.

DEVELOPMENTS IN THE DISPOSAL OF RESIDUE FROM THE ALUMINA REFINING INDUSTRY

D J COOLING

Residue Supervisor
Alcoa of Australia Limited
Pinjarra Refinery, Western Australia

The disposal of residue forms an integral part of the alumina refining process. The refining of Western Australia bauxite, which is low grade ore by world standards, results in 2 dry tonnes of residue for every 1 tonne of alumina produced. The disposal of this residue contributes a significant proportion of the overall cost of producing alumina. The residue is also highly alkaline, and, if not contained in sealed impoundment areas, can impact on the local environment. It has been these two considerations, the cost of disposal and the potential impact of disposal on the environment, which have been the main driving forces behind changes to the way residue is stored. This paper traces the various residue disposal techniques adopted by Alcoa of Australia Limited from containment in large settling ponds, to splitting the coarse and fine fractions for separate disposal, to the storage of the fine mud fraction in base drained ponds, to the more recent pre-thickening of the fine mud fraction for disposal in solar drying ponds. The reasons for change and the problems encountered are reviewed, and possible future developments are discussed.

INTRODUCTION

Alcoa of Australia Limited currently produces 5.0 million tonnes of alumina annually at its Western Australian refineries located at Kwinana, Pinjarra and Wagerup. All these refineries utilize bauxite mined in the Darling Range; ore which by world standards is low grade. For every tonne of alumina produced, approximately 2 tonnes (dry weight) of residues are produced.

Waste disposal from mineral processing industries poses some major environmental problems. In the Western Australian alumina industry this is particularly so for a number of reasons - the volume of waste produced, the location of the refining operation near to population centres and adjacent to some of the state's most productive land, and the potential adverse impact of the caustic waste components on groundwater.

Waste disposal also adds significantly to the cost of producing alumina. Economic problems associated with disposal operations include the high capital cost of constructing sealed impoundment ponds, the value of residual caustic tied up with the slurry, and the cost of rehabilitating a relatively hostile environment after disposal is complete.

Alcoa of Australia Limited has recently adopted a number of alternative disposal strategies aimed at lessening both the environmental and economic impacts of residue disposal on its alumina refining operations.

CONVENTIONAL DISPOSAL

Refining of alumina commenced at Kwinana in 1963 and at Pinjarra in 1972. Single disposal areas were constructed at each site to contain the total residue produced. The refineries and disposal sites were located on the relatively flat coastal plain at the base of the Darling Scarp (see Figure 1). It was therefore necessary to construct the disposal areas as elevated ponds with the surrounding embankments formed from material excavated from the base of the ponds and material borrowed from adjacent land. The ponds were sealed by incorporating a layer of natural clay into the base and a core or blanket of natural clay into the walls. The ponds varied in area from 10Ha to 120Ha and have been approximately 20m deep. Figure 2 shows the type of construction adopted at the Kwinana and Pinjarra refineries.

The disposal areas were operated by dumping the total residue as a dilute slurry from peripheral discharge systems. The coarser sand fraction would settle close to the discharge points while the finer material would be carried further out into the pond and settle more slowly. The liquor used to carry the residue to the pond would be decanted from the surface and returned to the process.

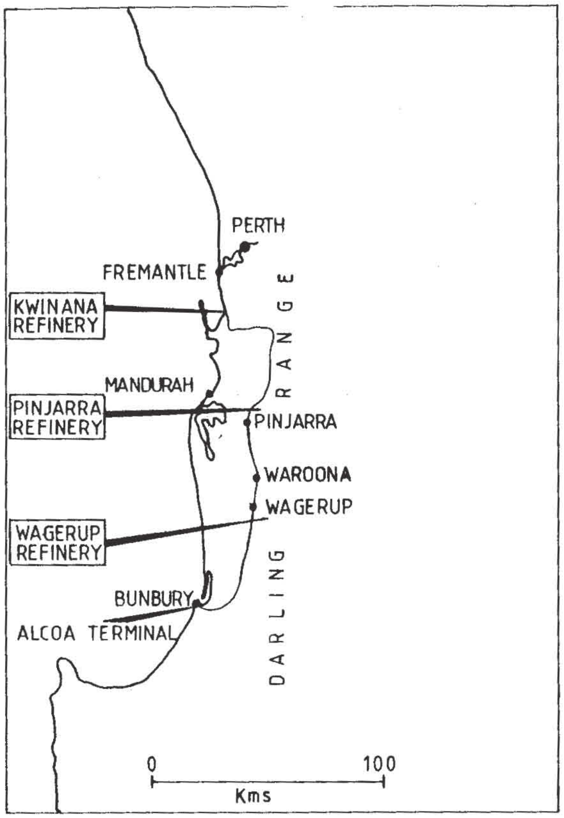

Figure 1: Location of Alcoa of Australia Alumina Refineries in the South West of Western Australia

The resultant deposits consisted of the fine grained material which had settled and consolidated to an average of 55% solids by weight (72% liquor by volume) surrounded by the coarser grained material. The material in the ponds is saturated, creating a perched water table in the pond.

The base of the pond is subjected to a hydrostatic head equivalent to the depth of the perched water table. This will promote seepage of the contained liquor through the base seal. Low levels of caustic have been detected in the groundwater below the Kwinana ponds, however the overall seepage rate is considerably less than the rate predicted during original design. A series of bores has been installed external to the ponds to recover this seepage. Though no contamination of the underlying groundwater has been detected at Pinjarra, the first signs of seepage have been measured in the surface layers of material immediately below the dykes, and seepage into groundwater aquifers may be seen at some stage in the future.

Rehabilitation of several small Kwinana ponds is well advanced. The surfaces of the ponds have been reclaimed and commercial crops ranging from lucerne to vegetables have been established. Recovery of liquor from these ponds has been possible by slow pumping of a sand layer which was installed immediately above the clay seal during construction. Rehabilitation of one of the Pinjarra ponds is underway. Reclamation of the surface has been in progress for the past 5 years, but is not yet complete. Progress has been slow due to the very low strengths of the fine grained material. Measured shear strengths vary from 20kPa at the base of the deposit to 1kPa at the surface. Recovery of the caustic liquor from the deposit has not been attempted due mainly to problems associated with pumping from a fine grained material having a permeability of around 10^{-6} cm/sec. The long term reality is that the deposit containing alkaline liquor may remain for many years.

Although operation of conventional ponds is simple and inexpensive, the ponds have the potential to impact on the surrounding groundwater. Also substantial modification of the deposits beyond superficial surface treatments will be difficult and expensive. It was this realisation some eight years ago which

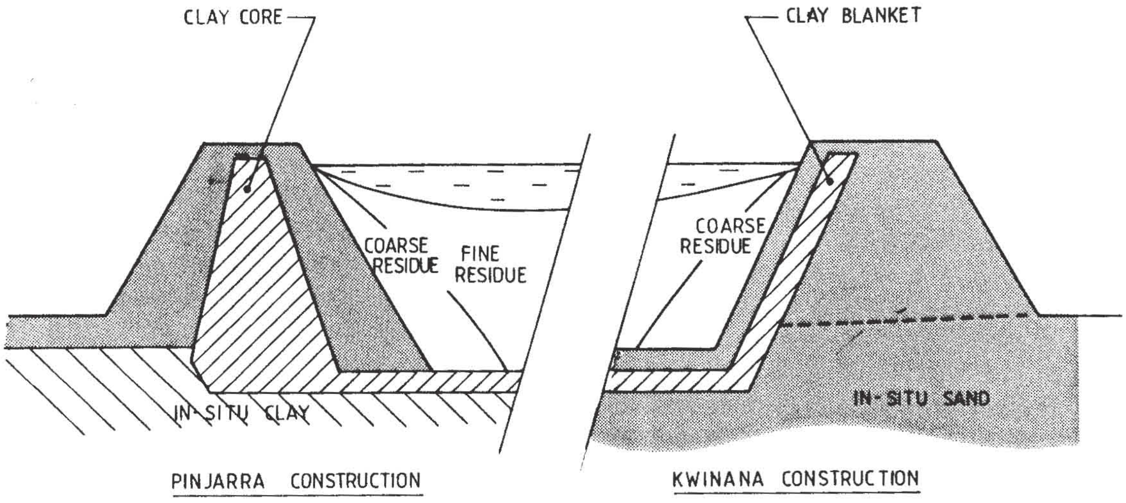

Figure 2: Conventional Disposal Pond

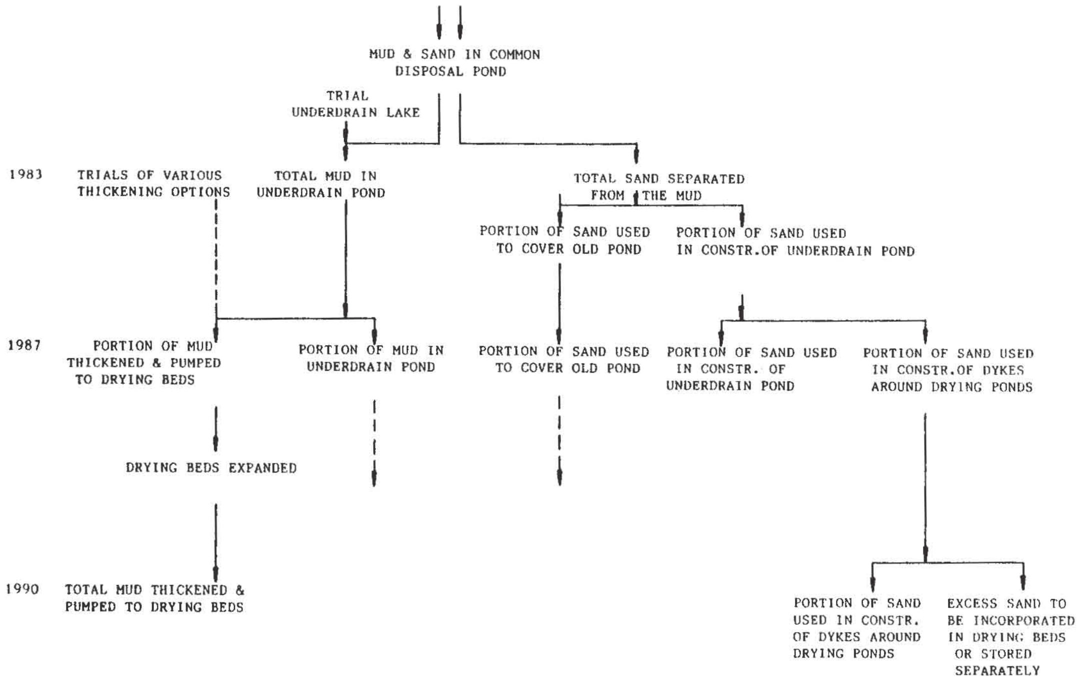

Figure 3: Developments in Residue Disposal

prompted Alcoa of Australia Limited to investigate a number of alternative disposal techniques. Figure 3 traces the changes to residue disposal which have taken place at the Pinjarra refinery site since 1980. The following text discusses these changes, and the advantages and shortcomings of each.

BASE DRAINED DEPOSITS

In 1980 a trial base-drained pond was constructed to evaluate the concept of base drainage on the fine fraction of the Pinjarra residue. The pond was identical to the conventional pond except that a 1m deep sand layer was installed above the base clay seal. A network of perforated pipes was installed in the sand layer, and this drained to a common sump.

The base drained pond offered a number of advantages over the conventional pond. Pumping of the sump maintained a low hydraulic head on the base seal removing the potential for seepage. Base drainage also improved consolidation of the fine grained material. Monitoring of the deposit in the trial pond (1) showed an improvement in the density from the 55% solids by weight achieved in the conventional pond to 60% solids by weight (68% liquor by volume). This improved density increased the strength of the fine grained material providing a more stable deposit which in turn aided surface reclamation. Long term rehabilitation will also be enhanced by a deposit which will eventually release all the alkaline liquor to the underdrain layer.

The base-drained ponds are more expensive to construct and require more attention during operation than the conventional ponds. However the long term advantages of a more stable deposit which is continually draining outweigh the short term costs. All ponds constructed by Alcoa of Australia Limited since 1983 have incorporated a base drainage layer.

SEPARATION OF THE COARSE AND FINE GRAINED RESIDUE

The first full sized disposal pond to include a base drainage layer was constructed at Pinjarra during the summer of 1982/1983. It was decided to utilise the coarse fraction of the residue in the construction of the underdrain layer. A number of tests had previously been carried out on the coarse fraction which showed it to be suitable as a drainage medium with a permeability of $9x10^{-3}$ cm/sec (2). To provide an adequate supply of residue sand a separation plant was constructed. It consisted of 4 cyclones and 4 wash towers. The primary separation was completed in the cyclones, secondary separation and washing being completed in counter flow wash towers. The typical particle size distributions shown in Figure 5 were achieved by the plant. Approximately 50% of the total residue can be characterised as sand.

Operation of the separation plant continued beyond the 1983 construction, the sand being used to reclaim the surface of one of the conventional ponds as previously discussed. More recently, the sand has been used in the construction of perimeter dykes surrounding dry disposal areas.

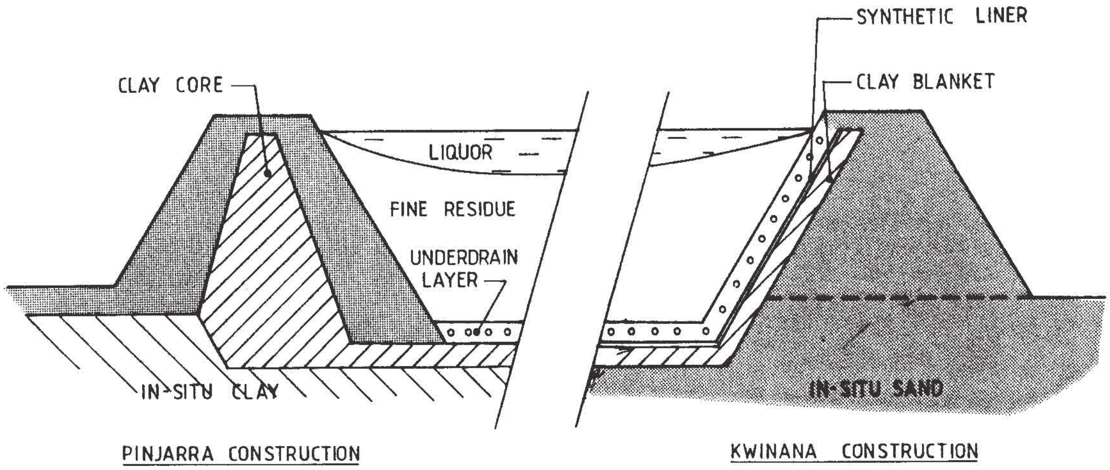

Figure 4: Underdrained Disposal Pond

Separation of the coarse from the fine residue reduced the volume of slurry which needed to be stored in the settling ponds. This extended the life of these ponds thus reducing the capital expenditure programme.

On the negative side, additional manpower was required to run the separation plant, and because a sand slurry was being handled the plant was subjected to high wear and hence high maintenance. Although the capital expenditure programme had been reduced the ongoing operating costs had been increased.

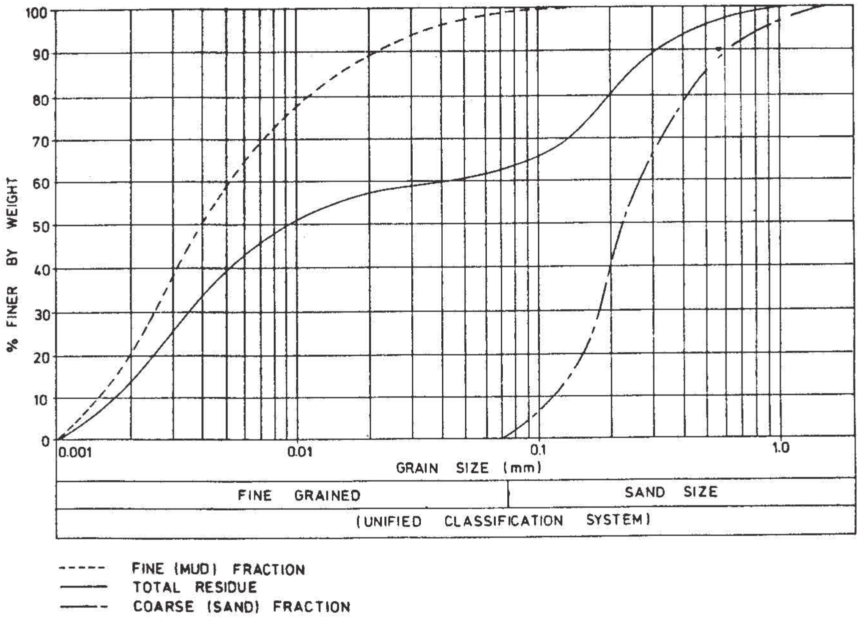

Figure 5: Typical Particle Sizing Data,
Pinjarra Residue

DRY RESIDUE DISPOSAL

Dry residue disposal refers to the compaction of the residue through evaporative moisture loss. In 1983 it was recognised that if dry disposal of the fine grained residue could be achieved it would offer a number of advantages over disposal in wet underdrained ponds.

A much higher density could be achieved than was already being achieved in the underdrained ponds. Early tests indicated that 70-75% solids by weight were attainable, although practical limitations on the time required to reach these densitites have more recently shown 65% solids by weight (63% liquor by volume) to be an optimum density. Because the deposit is built up layer by layer, the density through the deposit is uniform. This means a uniform strength through the deposit and hence a more stable mass.

Also the capital cost of construction of the impoundment area is reduced. A base seal and underdrain layer are still required but there is no longer the need for large perimeter dykes. A small starter dyke is required, then progressive upstream dykes are installed as the height of the deposit increases. The coarse grained residue can be used in the upstream dykes eliminating the dependence on externally borrowed material. (See Figure 6). Other economic advantages of dry disposal over wet disposal include greater caustic return to the process due to the higher deposit density achieved, and the reduced ongoing capital investment in a 4-6 yearly construction programme.

The major drawback to dry disposal is the large area required to dry the residue from an initial decanted slurry density of approximately 35-40% solids by weight. This can be overcome by pre-thickening the slurry prior to deposition in the drying ponds.

PRE-THICKENING OF THE FINE GRAINED RESIDUE FOR DRY DISPOSAL

Between 1983 and 1985 a number of trial facilities were installed and operated, all aimed at producing a thickened slurry of 50% solids by weight suitable for disposal in drying ponds. These facilities included a high rate thickener, a deep cone thickener, a vacuum drum filter, a centrifuge filter, modified operation of a shallow coned thickener already in use in the refinery, and reclamation of settled mud from an existing pond. While all could achieve the required slurry density they all had their particular shortcomings ranging from low throughput to high operating and maintenance costs. Of all the options considered, thickening in an enlarged version of the convention shallow coned thickener offered the optimum solution.

In 1986 a single vessel measuring 90m in diameter was constructed at Pinjarra. It had a central slurry bed depth of 10m, and a conical floor slope of 6 horizontal to 1 vertical. It had an internal raking system rotated by a peripheral rack and pinion drive. The drive had a torque rating of 13 MNm, the high torque required to overcome the drag forces exerted on the rake.

The thickener was commissioned early in 1987. Initial problems were experienced; average underflow densities of only 45% solids by weight could be achieved. A series of sampling profiles through the mud bed showed the settled mud not to be releasing the liquor. A set of vertical 'pickets' was installed on both the leading and trailing rake arms in an attempt to create vertical drainage channels through the mud bed to enhance compaction. This improved the underflow densities to 47% solids by weight. Further changes to the type of flocculant used, and the method of flocculant addition have given the ability to produce underflow densities of up to 52% solids by weight.

Installation of the thickener and associated equipment was a large capital investment in residue disposal. Also the manning, operating and maintenance costs of the overall disposal of residue was further increased above that required to run a separation plant and wet underdrained pond. However overall projected costs for dry disposal remain marginally less than projected costs for continued wet disposal, and environmental impact is very substantially reduced.

FUTURE DEVELOPMENTS IN RESIDUE DISPOSAL

Residue disposal at Pinjarra is still in a transitional phase between wet and dry disposal. Only half the fine fraction is being processed through the thickener, but this will increase as the drying beds are expanded. By 1990 all the fine fraction will be discharged into drying ponds.

Present difficulties are being experienced in the drying ponds. At 50% solids by weight, the slurry has a high viscosity, making it difficult to spread in relatively thin layers. Also the rate at which the moisture migrates to the surface of each layer and evaporates is slow. Measurements have shown the rate of moisture loss to be only half that which can be achieved from a free liquor surface. Both these factors increase the area required to achieve full dry disposal. These two areas will attract much of the future research and development work as there is the potential to significantly reduce the cost of disposal by improving on present performance.

Construction of perimeter dykes around the drying ponds will consume only 10% of the coarse fraction of the residue. The excess will need to be disposed of separately or incorporated into the dry disposal areas. There are a number of research projects presently underway which will evaluate different methods of combining the coarse fraction with the thickened slurry, and to determine the effect the coarse fraction will have on the drying rate of the slurry.

The development of residue storage practices is evolving in the context of increasing social and environmental standards. The Company's objective continues to be the return of disposal areas to self-sustaining land uses at some time in the future, with a more recent addition of aesthetic considerations.

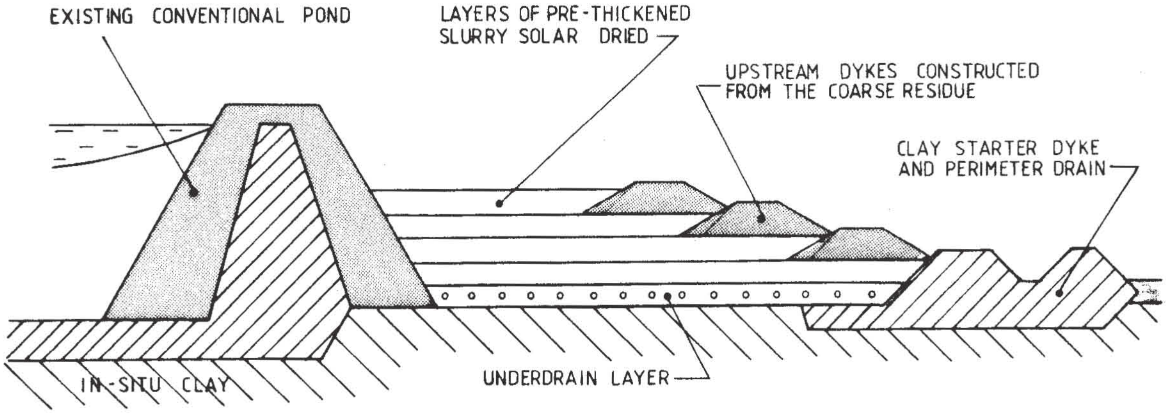

Figure 6: Dry Disposal Pond

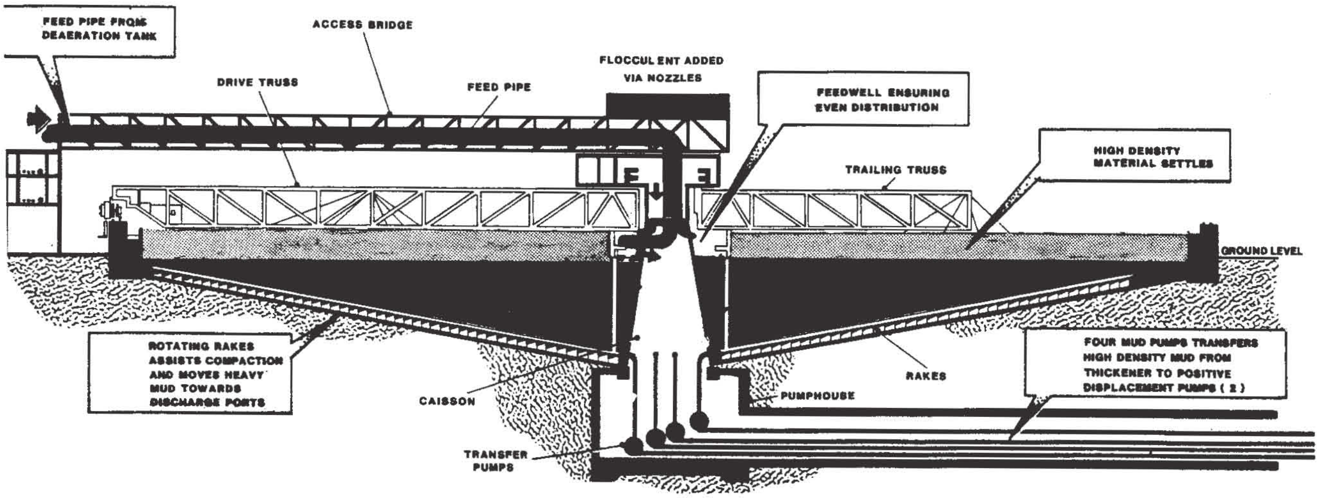

Figure 7: Residue Thickener Constructed at Pinjarra

REFERENCES

1. D.J. Cooling, 'Finite Strain Consolidation of Red Mud Residue from the Alumina Refining Industry' (M.App.Sci. Thesis, Western Australian Institute of Technology, 1985) 22-23.

2. P.M. Colombera, 'Mud Deliquoring - Multiple Drainage' (Alcoa of Australia Limited, Research and Development Progress Report, 1978).