APPENDIX II

AIR PHOTOGRAPH BLOW UPS,

(See map box accompanying this report).
HISTORY AND IMPACTS OF

SAND & GRAVEL

EXTRACTION FROM

THE HUNTER RIVER

AT OAKHAMPTON N.S.W.

BY: Alasdair Webb
Geologist
March 1989
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INTRODUCTION

This report outlines the property details, the current quarrying operations and the history of quarrying at Oakhampton. Specific reference to the effects of quarrying upon the Hunter River has been made with the aim of providing a qualitative groundwork for ongoing river studies and for the renewal of the quarrying lease issued by the Public Works Department (P.W.D.). It is anticipated that the operation at Oakhampton will cease in approximately 12 to 24 months time as reserves will then be depleted.

Air photograph interpretation has provided much information on the history of quarrying and its effect upon the river. Surveys of the P.W.D. cross-sections 1-10 have been carried out at 3 monthly intervals since May 1988 (a P.W.D. lease approval requirement) by Scott, Crisp & Cashmere, Surveyors of Maitland. Bathymetric maps have also been prepared by the surveyors at 6 monthly intervals. Two sets of earlier cross-sections compiled in 1982 and 1986 have also been included for comparison. A comparison chart showing all of the cross-sections to date is presented in this report.

Personal communication with two quarry employees provided much of the historical details of where and when certain quarrying activities took place. The employees are: Mr. Don Sargent, the Quarry Manager, who has worked at Oakhampton since 1969, and Mr. Barry Atkins, a life long resident of the riverfront property, part of which now belongs to BMG, and a long term employee of the quarry.

LOCATION

BMG's Oakhampton river gravel quarry is located on the Hunter River, approximately 5 km north of Maitland, see Figure 1.

PROPERTY DETAILS

The quarrying operations are located upon land originally owned by three different farmers. Surrounding land on both sides of the river is referred to by the name of the owners who held the land during early quarrying operations. Some of the blocks of land have been sold and subdivided but are still referred to under the name of the previous owner. Identification of the land in this manner is useful as the history of quarrying operations is written with reference to the local landowners' properties. See Figure 2 for location and names of properties. The river upstream of the Bone and Comerford boundary is administered by the Department of Water Resources (Catchment Management Branch) and downstream by the Public Works Department.

The Quarry Properties

1. BMG Property: DP 248331 Part Portion 225, Lots 1, 2, 3 & 5. This property, originally owned by Logan was sold to Frost Developments Pty. Ltd. in 1962 and later to BMG. Currently no extraction is carried out on this property. It is used to locate the main screening and classifying plant, to stockpile the quarry
2. products, to locate the office, amenities block and weighbridge. The size of the property also helps to keep the quarrying operations remote from the surrounding houses.

2. BMG Property: DP 217718, Part Portion 225, Lots 1 & 3. Originally part of a larger block owned by Atkins, Lots 1 & 3 on the riverbank were bought by Frost Developments Pty. Ltd. and later by BMG. The property has been worked in the past but is currently used to gain access to the extraction area in the river. Future extraction from this area is planned and will be described later in this report.


Ward's property was originally part of a larger block leased to Gore Brothers for the extraction of sand and gravel from the high bank in the 1960's. In 1969 it was leased to BMG for a 12 year period with subsequent renewals until the 31st December 1991.

At present, Ward's lease is the main area for extraction of sand and gravel from the river channel and its southern banks. The primary screening plant is located at the northern end of Ward's lease, close to the extraction site.
Figure 1 - Oakhampton River Gravel Quarry Location Map
Figure 2
LOCATION OF PROPERTIES AND P.W.D. CROSS-SECTIONS
3.

REGIONAL GEOLOGY

The Hunter Valley/Hunter Region can be split into several main subdivisions:-

1. The southern side of the Hunter Valley is formed of Triassic age sandstones and conglomerates, commonly occurring as prominent cliff lines.

2. Per/ian age sedimentary rocks form the outcrops along the Hunter Valley from Newcastle to the north of Scone and also extend into the Goulburn Valley.

3. Carboniferous to Devonian age sediments and lavas make up the more rugged country in the north-east of the region.

The Hunter River flows in an easterly direction along a valley that follows the Hunter Thrust Fault. This fault forms the boundary between the Permian sedimentary rocks of the Sydney Basin to the south and the predominantly Carboniferous volcanic rocks of the New England area to the north.

Deposits of sand and gravel can be found associated with the Hunter River from Muswellbrook to the coast. Upstream from Maitland, washed river sand and gravel are produced at several locations along the Hunter River. Downstream from Maitland the proportion of silt increases and the gravel clast size is predominantly less than 30mm in size and the proportion of sand is high. River gravels in this area require very little to no crushing. Further upstream around Singleton the gravels are generally 70-80mm in size. The gravels are mostly well rounded and smooth and are thus unsuitable for use as road aggregate. However, the rounded gravels are suitable for use in decorative landscaping and especially for use in the production of concrete. Downstream of Maitland ancient coarse river gravels exist at depth. They were deposited during the last Pleistocene glaciation when sea level was much lower and the coast was near the continental margin.

Through the Quaternary period, the Hunter River has given rise to a broad floodplain composed primarily of gravel, sand and silt. The percentage of each of these sediment types varies greatly above and below the confluence of the Hunter River with the Goulburn River at Denman. Above this junction the river is known as the "upper Hunter River", and below it it is termed the "lower Hunter River".

Along with the difference in particle size of the detritus there is a compositional difference reflecting the differing geology of the regions supplying the river with sediment. The upper Hunter River and its tributaries drain the Carboniferous New England volcanic terrain to the north and northeast, giving rise to cherts, jaspers, reddish siliceous and acid volcanic clasts along with minor basic clasts. The gravel to sand ratio is approximately 2:1 (MacRae 1988).

Where the Hunter River meets the Goulburn River at Denman and at its confluence with Wollombi Brook, it is supplied large quantities of quartzose sand detritus along with lesser amounts of chert and ironstone pebbles mainly derived from the weathering and erosion of Triassic sandstones to the west and south. The presence of petrified wood and agate clasts indicates that gravels are also sourced from Permian rocks of the Hunter Valley. The gravel to sand ratio is 1:3 (this includes the gravel contribution from the upper Hunter River), (MacRae 1988).
These sequence interbedded units may consist of:

- Fine flood sand
- Mud lenses
- Permian gravel
- New England gravel
- Mud
4.

Above Denman the upper Hunter River currently has a gravel bed, whereas the lower Hunter River currently has a sand bed. Both stretches of the river are classified as bedload streams.

Downstream of Denman a large amount of fine sand overlies and is intermixed with older gravel and coarse sand (remnants of a higher flow regime). This fine material has been deposited in recent times due to widespread erosion of unstable sandy soil slopes in the catchment area of the lower Hunter River. The clearing of land for agricultural purposes has caused devastating erosion of land in the Hunter Valley. Large amounts of fine to medium grained quartz sand and silt were deposited in the river by the major floods of 1949 and 1955. Smaller floods since then have deposited huge quantities of sand and silt into the bed of the Hunter River. This fine to medium sand is a recent addition to the river bed, in places filling up the low flow channel and spreading out on the banks during floods.

The addition of fine to medium grained flood sand to the river bed has contaminated the established gravel extraction sites that work the older gravel and coarse sand deposits. This blanket of flood sand has reduced the gravel bedload recovery rate from as high as 50% to as low as 10% at Oakhampton (Brownlow 1980). However, at Oakhampton, I tend to think that the current recovery rate of coarse sand and gravel is presently zero. The current dredge pond is partly infilled with fine to medium grained flood sand after a flood and this must be removed by the dredge prior to continued extraction of virgin coarse sand and gravel.

The Oakhampton deposit is very variable in nature. The general sequence from the top passes through fine flood sand, mud lenses/horizons, Permian gravel and finally New England gravel. Each horizon may have interbedded mud and fine sand and the Permian gravel is sometimes absent. The New England gravel overlies mud, is grey in colour and often oxidises to red when exposed to the air. The deposit at Oakhampton appears to become finer downstream.

The flood sand is of limited use to the quarry operator. It is too fine and too poorly graded for use in concrete. It can be used as filling sand, as a filter medium or blended into concrete sand to provide correct gradings.

The quantity of the fine flood sand is so great that it continues to accumulate in the low flow channel and is not flushed out by floods. The old channel fill gravels that are the principal source of material at Oakhampton are being progressively buried. Very large floods would now be required to clear the river of this fine flood sand and to re-mobilise the older gravels and coarse sand into the migrating bedload.

If the fine sand was flushed from the river system in such a flood it would be deposited in Newcastle Harbour. The completion of Glenbawn Dam in 1958 saw the beginning of smaller and more controlled flood activity in the river. In addition, it is 100% efficient at restricting the addition of gravel to the river system below the dam.

The fact that the low flow channel is full of fine sand causes the river to meander within it at times of very low flow and increases the possibility of bank breaching flooding.
EXTRACTION AND PRODUCTION METHODS

Currently a cutter-suction dredge is used to win sand and gravel from the river bed. Extraction takes place from a depth of approximately 6m to a depth of 10-14m. Some 4-6m of fine flood sand covers the older channel fill gravel and coarse sand deposit. This fine sand must be removed before the target gravel is encountered. The base of the gravel has not been found by the dredge and the depth of dredging is limited by the depth that the dredge can reach. Therefore, the current P.W.D. depth restriction of -6.33m AHD and a 1 in 6 batter is impracticable as at this depth the economic gravel/sand zone is only just encountered.

Sand and gravel (-100mm) are pumped from the dredge to the primary screening plant on Ward’s lease. (See Figure 2 for plant location). This plant rejects +25mm oversize and primary fines. The +25mm fraction is used as general fill in the quarry area. The sand and gravel are dewatered and travel via conveyor to the surge pile and main plant on BMG property. Here screening and washing take place and the raw feed is separated into five main size fractions; 20mm, 14mm, 10mm and 7mm gravels and sand. Waste water from the plant and classifier are pumped to a series of settling ponds which intercept the remaining fines and prohibit their return to the river channel.

In the past a dragline was used to win the raw feed from both the river bed and banks. At times both dredge and dragline were used together. A cutter suction dredge gives rise to some turbidity but not as much as a dragline produces. The history of quarrying operations is presented in a later section of this report.

QUARRY PRODUCTS

High quality river gravels and construction sand are produced at Oakhampton for sale on the local market.

Aggregate

Four coarse aggregate products are produced –

1. 20mm river gravel ) For use in landscaping, decorative and exposed aggregate. This material accounts for about 10% of aggregate sales.
2. 14mm river gravel )
3. 10mm river gravel )
4. 7mm river gravel for use in concrete. This material accounts for about 90% of aggregate sales.

Crushing of the gravels does not take place.

Sand

Coarse and fine sand are blended to produce a product with constant gradings for use in concrete. The non-uniform nature of the deposit sometimes yields too much fine sand (-600 micron) which is stockpiled for later use. If there is not enough fine sand in the dredged material, fine flood sand is excavated from the point bar beaches. 90% of the sand is sold for use in concrete and the remaining 10% is sold as filling sand.
Current yearly production is around 200 000 tonnes worth between half a million and one million dollars. Production figures from the Department of Mineral Resources indicate that from 1973 to the present the BMG river gravel quarry at Oakhampton has been the greatest producer of construction sand in the Upper Hunter Valley (with the exception of the three financial years 77/78, 79/80 and 81/82). See Table 1. Since the financial year 82/83 the Oakhampton Quarry has been the largest producer of sand and gravel in the area and shows a general trend towards an increasing market share. In 1987 production equalled 211096 tonnes with sales of 190493 tonnes. In the first six months of 1988 production equalled 88258 tonnes with sales of 100197 tonnes.
### Table 1 - Major sand producers in the Upper Hunter Valley (from McRae 1988)

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**TOTAL** | 253 859 | 367 809 | 681 960 | 599 504 | 445 988 | 294 950 | 403 226 | 417 545 | 3 464 841 |

**Source:** Statistical Section, Department of Mineral Resources

Letters indicate: 1:25 000 topographic sheet; A: Aberdeen; MU: Muswellbrook; D: Denman; J: Jerry Plains; DCL: Doyles Creek; S: Singleton; G: Greta; H: Helensville.

* Estimated.
The history of the quarry operation is presented briefly here along with some comment on its effect upon the river. Reference has been made to a series of aerial-photographs obtained from the N.S.W. Department of Lands. The photographs span a time period from 1958 to 1986. Where an aerial photograph exists for a certain year, the subheading "(P)" will be used next to the date. Copies of the photographs accompany this report.

Several points regarding the early history of the Hunter River were documented in 1967 by W.J. Hynes, Quarry Superintendent for Frost Developments Pty. Ltd., the original operators at Oakhampton (the records were found in BMI company archives). Hynes states that, "the Hunter River was navigable to Singleton and occasionally to Muswellbrook in the early 1800's. The river was tidal to Maitland in 1844 where further tidal influence was prevented by rapids (Maitland Falls). The stream bed depth has become gradually shallower over the period until tidal effects have receded from Maitland to Morpeth (11.2 km)."

According to Barry Atkins of BMG, prior to the 1955 flood, the Hunter River flowed about 25m south of its present channel on the Oakhampton bend. The outer bank was badly eroded during the early 1950's as the river migrated northwards. After a big flood the outer bank would fall in - often waking the locals at night. Constant flooding eroded the soil away from large trees on the river bank and the 1955 flood took all of the trees. The river was 200m wide at Oakhampton in this flood and water flowed over the specially constructed flood level bank and damaged the rail viaduct. The concave bank underwent severe undercutting and erosion during the 1955 flood and the river at the Oakhampton bend migrated approximately 25m northwards. Presently a mud remnant of the old concave bank can be seen in the river at average water level on the existing convex bank where the river is narrowest. Lateral accretion of fine flood sand on the point bar has almost completely covered this remnant. This remnant has also been encountered by dredging operations in the embayment in the bank on Ward's lease. Prior to the northward lateral migration of the river caused by the 1955 flood, the creek at the base of Comerfords Hill (Comerfords Creek in Figure 2) entered the river near the railway bridge. It now enters the river opposite the primary gravel plant. (see Figure 2).

1958 (P): Prior to quarrying operations, large bodies of sand were present within the river channel in the form of point-bar, channel island and channel fill deposits. There were very few to no trees along the river banks in the Oakhampton area due to their removal by the 1955 flood. A large willow tree can be seen on the 1958 photograph close to the river's edge on O'Keefe's property. It is still there today.

Quarrying operations began in the early 1960's with the extraction of material from the BMG property by the then owner, Frost Developments Pty. Ltd. Extraction was restricted to land based sand and gravel upon the gravel terrace. Material was not removed from the river. Gravel terrace deposits of sand and gravel were also extracted from Ward's property by Gore, the previous owner of Ward's property, at about the same time. I am unsure of the date that Gore sold to Ward.
By 1965 BMG had purchased the land at Oakhampton from Frost Developments. The 1965 photograph shows a dragline pond operating on the point bar and this pond was completely land locked. The pond was located in the lateral bar deposits on the river land. The working face of the pond had reached a point opposite the boundary between Bone's and Comerford's property. This pond was located on the mid bar facies of the flood sand point bar. The river was at a very low level at the time the photograph was taken and it can be clearly seen that the river is choked with sand. The photograph also shows some small scale extraction occurring on the high bank of Ward's property (by Gore) and two small dragline ponds in the river within Ward's property. These ponds were on the convex bank just downstream of the main landlocked dragline pond and had slightly altered the course of the river. The river tended to flow through the ponds changing from the outside of the bend to the inside and depositing a sand bar at the mouth of Comerfords Creek. Prograding crescent shaped chute bars in the distal facies of the point bar indicated that the river system was unaffected by these two small dragline holes. Just downstream of the mouth of Comerfords Creek it appears that some erosion of the concave bank had occurred and the bedrock outcrop of Comerfords Hill can be seen.

As in the 1958 photograph, the 1965 photograph indicated very few trees along the river banks and no trees in the vicinity of the Oakhampton site. From drilling records it appears that the concave bank was known to contain good deposits of gravel in 1965, however, only the convex bank was being worked.

By 1967 the large landlocked dragline pond on the BMG property had been extended upstream with the working face opposite the Bone/Campbell boundary. The pond was completely landlocked and no degradation of the river or its banks was taking place due to the presence of this pond.

The extremely low water level at this time and the abundant sand infilling the river was causing the water to flow as a braided stream within its own banks. The water was effectively seeking an increase in the gradient of the stream by braiding. The braids are together less efficient (because of greater surface area) than the original stream and therefore where division takes place, steepening of the gradient of the distributaries may occur. However, there was so little water in the river in this photograph, the river was not involved in erosional processes.

Several small dragline ponds had been dug in the river in the same vicinity as the holes in 1965, (in Ward's lease just upstream of the mouth of Comerfords Creek). These holes had influenced the flow of the river and the water had changed its course slightly (whilst remaining within the confines of the river banks), flowing through some of the small dragline ponds.

Again, in 1967 there was no sign of tree growth on the river banks in the vicinity of the Oakhampton site. The concave bank was well grassed and appeared to be stable.

By this time the dragline pond on BMG property had progressed further upstream. The working face was roughly opposite the middle of Campbell's riverfrontage.
The 1969 photograph shows that the river level was very low. In some places the water had ceased to flow over the sand river bed and was soaking through the sand. The dragline pond was essentially landlocked, however, the water would occasionally flow over the top of the sand spit enclosing the pond.

The large BMG dragline pond was constantly backfilled with flood sand brought down by each successive "fresh". It should be noted that all dragline holes, both in and near the river had never been backfilled by the quarry operators. Flood sand had backfilled the holes. The pond was abandoned as the working face began to encounter more fine sand than gravel and it was decided (prior to March 1967) to cross the river and work a gravel terrace deposit upon Middlebrook's property. A dragline pond was established on the western side of the Middlebrook property. A causeway was constructed across the river from BMG land to O'Keefe's property in order to give access to Middlebrook's land. Material draglined from Middlebrook's was trucked back across the river to the BMG plant.

Extraction also took place from two dragline ponds in the river channel at the bend in the centre of O'Keefe's river frontage. These ponds were worked by a dragline standing on the northern bank of the river. The dragline sat on a sand spit between the ponds. The ponds worked the gravel and coarse sand channel-fill deposit. These holes must have been started around 1968-1969 as they are not to be seen in the 1967 photograph. Material from this site was also transported by truck across the river causeway to the BMG plant. A small delta formed on the downstream side of the causeway due to the reduction in the velocity of the river water as it crossed the raised causeway.

Continued small scale extraction by dragline was also evident at the northern end of Ward's lease, both on the bank and in the river channel. This pposting was done by the dragline prior to moving to Middlebrook's. The river level was very low in the photograph and the bed was so full of flood sand that these holes were having no detrimental erosional effect upon the bed or banks. When the water levels were slightly higher (ie. at average level), the flow would be influenced away from the concave bank by the dragline holes close to the convex bank. A firm high sand bank (lateral bar) had been deposited at the mouth of Comerfords Creek due to the change in the course of the river caused by the small dragline holes.

Both up and down stream of the extractive areas the river was choked with sand at this time.

The river-side vegetation in early 1969 was also very sparse and there were no large trees on the banks in the vicinity of the extraction areas.

Don Sargent, the current quarry manager, started at Oakhampton in 1969.

September 1969 (P): In this photograph the water level was again very low and the river was flowing as braided channels upon the sand infilling the river channel. Just to the north of the BMG plant it appears that the river had stopped flowing and was soaking into the sand. This was probably due to the fact that the causeway installed by BMG to give access to the O'Keefe and Middlebrook properties was altering the grade of the river and reducing the velocity of the flow. This reduction in velocity led to the deposition of sand on the downstream side of the causeway to bring the grade back into equilibrium. Combined with this, the poothing
of the river by dragline at the northern end of Ward's lease caused a change in direction of the low level river and a reduction in the velocity of the water. Therefore, sand was deposited in this area effectively raising the base level of the river. When the river was at very low levels such as in this photograph, the water did not have enough energy or the level required to flow over the higher sand deposit but soaked in and flowed through the unconsolidated sand.

At the time of this photograph, the old landlocked dragline pond on BMG property was standing idle and may have been used as a siltation pond.

The main workings were located primarily on Middlebrook's property and in the two large dragline holes in the river on O'Keefe's riverfrontage. The holes in the river probably had not been used much since the photograph was taken in March 1969. The potholes on the bank and in the river on Ward's lease also do not appear to have been worked since 1968-69.

The photograph shows very little vegetation upon the river banks (especially the convex bank) both upstream and downstream of the extraction sites.

Late 1969/Early 1970: Extraction began on the concave bank (Comerford's property) whilst Middlebrook's property was still being worked. Initially Comerford's was worked by dragline. The deposit on Comerford's property is an old channel-fill.

1971 (P): This photograph shows the extraction on Comerford's property well under way with the dragline pond open to the river and forming an embayment. Extraction was also taking place from the river bank immediately up and downstream of the main pit. Initially the extraction pond was landlocked, but it broke through the bank and was open to the river. Access was gained via a causeway built across the river mid-way along the embayment. Figure 4A is a photograph taken in March 1971 by the Department of Water Resources. It shows the extraction area on Comerford's land and the access causeway.

The river level was higher in the aerial photograph than in the two previous aerial photographs. All of the earlier dragline ponds had been infilled with fine to medium flood sand. The extraction pond on Middlebrook's land was infilled with sand in times of flood as the river water rose and flowed across the point bar/terrace depositing fine flood sand. The holes were infilled and no detrimental effects upon the river are apparent from the photograph.

The photograph shows that the causeway to Middlebrook's was submerged and had probably been removed by this stage.

As well as extraction from the concave bank, some erosion of this bank occurred, promoted by the extraction works. Periods of flooding combined with the instability caused by bank extraction gave rise to the erosion of 2m-3m of material from the concave bank. Erosion from this bank just upstream of Comerford's Creek mouth appears to have occurred right up to the crest of the river bank. As the river was cutting outward in this area it was gradually making contact with the rock of Comerford's Hill (Dalwood Group). Outward migration of the meander could not proceed any further once contact with this bedrock had been made. The 1971 photograph shows that the river water was being deflected by the rock of Comerford's Hill back towards the inside of the bend. Eddy
currents acting in the lee of the deflecting rock outcrop gave rise to
a lateral bar composed of fine flood sand on the outside of the bend
just downstream of Comerfords Hill.

Both up and downstream of the extraction site there appears to have
been abundant flood sand in the river.

1971-1972: The first of two dredges was launched in the summer of 1971-72.
It went into the river below the BMG plant site, opposite Bone's property.
It dredged downstream a short distance and then went to Comerford's
extraction area on the concave bank. The dredge worked with the dragline
in the pond on the concave bank and material was won right up to the
boundary of Bone's and Comerford's properties. So close was this
extraction to the boundary that the fence began to fall into the hole.
Sand and gravel was removed to within 30-40m of the sheds on the Comerford's
property and to a depth of 10-12m.

1974-1975 (P): This photograph shows an average water level and abundant
sand in the river both up and down stream of the extraction site.
Extraction from the concave bank at this time was almost complete or had
just reached completion. The entire concave bank had been removed as
shown in the Department of Water Resources photograph, Figure 4B. Bank
collapse caused by dredging too deep too close to the bank was common.
Floods also damaged the exposed concave bank in and around the extraction
area with bank collapse the most damaging. The bank at the mouth of
Comerfords Creek had undergone severe erosion and a large amount of
material was removed by the river water flowing around the outside of
the bend.

During this time when the dredge was operating within Comerford's property,
the dragline worked occasionally in the northern end of Ward's lease
(on the convex bank) for a couple of months. However, it stopped as it
was encountering too much mud (a remnant of the pre 1955 flood concave
bank).

According to Don Sargent, when extraction was complete in Comerford's
property, the bank around the dredge pond was battered down using a dozer.
Further flooding caused the concave bank to fail in this area. Flooding
removed the sand bank just downstream of Comerfords Hill and the river again
flowed down the outside of the bend.

Some small trees can be seen in the photograph on the concave bank between
the extraction area and Comerfords Hill.

Following the extraction of the concave bank the dredge worked the BMG
side of the river in a non systematic pattern. The quarry manager then
organised the dredge to work upstream dredging to the centre thread of
the river and a depth of around 10-12m on the BMG side past Campbell's
property. Campbell would not give permission for the river bed to be
dredged on his side of the river. When the dredge reached O'Keefe's
property it then dredged the full width of the river to a depth of
about 10-12m. However, the deposit became sandy and dredging stopped
opposite the big willow tree close to the bank on O'Keefe's property in
1978. The dredge worked a deep hole into the river bed in this location
to a depth of around 12m. A willow tree growing on the bank actually
fell into the dredge pond as the northern bank collapsed. However,
this deep hole soon infilled with flood sand. The dredge remained in
the area for a while and worked medium to coarse flood sand. The flood sands provided good material (reworked old bank and lateral bar gravels) and one good flood per year could be expected with up to 3 or 4 per year the usual. Towards the end of 1978 the dredge was floated downstream to a point opposite the BMG plant and taken out of the river.

1979 (P): This photograph shows the river with an above average water level and the water was covering much of the sand banks both up and downstream of the extraction site.

Upstream on O'Keefe's property, a scour can be seen on the northern bank in the vicinity of the big willow tree. This scour was due to the erosive action of eddy currents during high floods. The abrupt change in the direction of the river caused an eddy current to be set up on the inside of the bend just downstream of the apex of the bend.

By this time trees were growing at the base of Comerford's extraction area and along the bank between the extraction site and Comerfords Hill. Trees were also becoming established on the east bank both up and downstream of the railway bridge.

Due to the continued erosion of the concave bank extraction area on Comerford's property, a rock wall and groynes were constructed around 1978-1979. These can be seen in the 1979 air photograph and in the Water Resources photograph, Figure 4C. The rock wall attempted to reconstruct the original bank shape and to inhibit further erosion. The stone used for the armouring of the bank was obtained from BMG's Raymond Terrace quarry and was placed by truck. An access causeway was built across the river at the upstream end of the extraction embayment and was later removed when the wall was complete.

A new dredge was launched in early 1979 and operated in a landlocked pond on BMG property opposite the rock wall. It was working old gravel terrace material. The dredge worked the deposit downstream to the boundary between Ward's lease and BMG property in the landlocked pond. It then broke out into the river. It was planned to work the dredge within a landlocked pond in a series of slots in a downstream direction for a short distance, within Ward's lease and then turn around and work the interfingering walls in an upstream pattern whilst backfilling behind the dredge. However, this was not possible due to the presence of a mud band in the proposed extraction area. This mud band is possibly the relict mud embankment that was once the concave bank prior to the 1955 flood. The presence of this mud embankment forced the dredge to break out of the landlocked pond and into the river. It worked channel-fill gravels in the river opposite this pond which soon turned into an embayment in the bank that still exists today. The dredge worked in the river in this area until 1984.

March 1984 (P): This aerial photograph shows the dredge in the river just off the embayment in the bank of Ward's lease area. The dredge was sitting here awaiting P.W.D. approval to dredge the river downstream towards the railway bridge. The embayment in Ward's property was dredged to a depth of 10-15m, the outer bank at this location was the exposed rock of Comerfords Hill (Dalwood Group sediments). Siltation ponds were established upon the flood sand point bar on BMG land and were completely landlocked. The siltation ponds were located in the old landlocked dredge pond formed as the dredge progressed downstream on BMG property.
The P.W.D. gave approval to BMG to dredge the river downstream to a point 200m upstream from the railway bridge. This was done in two stages. Firstly the dredge moved downstream sweeping the fine flood sand from the river bed only just providing enough water to keep the dredge buoyant. Secondly, by mid to late 1985 the dredge turned around at a point 200m upstream from the railway bridge. Here it began to dredge coarse sand and gravel from the full width of the river whilst moving in an upstream direction. Dredging must take place whilst moving in an upstream direction as the fine bedload of the river washes over the top of the dredge escarpment. If dredging were to occur in a downstream direction, the fine sand bedload would encounter the steep working face and bury it (especially in times of flood). A booster pump was used to pump the material the extra distance to the plant.

It can be seen that by 1984 the rehabilitation of Comerford's extraction area was working well. The rock groynes trapped flood sediments and the bank was well grassed. Trees were well developed within this area and were also growing on the concave bank between the rehabilitated area and Comerfords Hill.

In the 1984 photograph, the relatively high water level did not expose much sand in the river up and downstream of the operation, apart from the occasional high bar.

The scour in the vicinity of the willow tree on O'Keefe's property had been infilled with flood sand again.

The river banks appear to be in a stable condition in this photograph. The armouring of the concave bank has left the bank in a very stable condition.

1986 (P): This colour photograph shows the dredge sitting in the embayment in the bank on Ward's lease after having worked the full width of the river to a point 200m from the railway bridge. A buffer zone was left between the bridge and the extraction area so as not to have any detrimental effect on the river that may cause damage to the bridge foundations. This buffer zone still exists today. The water level in the river was about average and abundant sand was present in the river upstream and downstream of the extraction site.

From 1986 to the present the dredge has worked in the river concentrating on the lateral bar coarse sand and gravels on the convex bank to a depth of 10-12m. It has worked in an upstream direction from the embayment in Ward's bank toward the old landlocked settling ponds on the point bar. At the end of 1988 the dredge had just made contact with the downstream end of the settling pond. It is now proposed to work the dredge upstream along the thin spit of coarse sand and gravel that landlocked the settling ponds. Once the dredge reaches a point in the river opposite the Bone-Comerford boundary, the deposit will effectively be worked out and operations in the area will cease. This is expected to take a further 12 to 24 months.

Figure 3 illustrates the location of extraction at Oakhampton from the beginning of quarrying operations to the present.
Map showing the location of extraction at Oakhampton from the beginning of quarrying operations to the present.
The extraction of sand and gravel from a river can have damaging effects upon the local environment such as bed aggradation or degradation, erosion of the banks, channel blockage/loss of flow and channel diversion. The type and extent of detrimental effects depend upon the local geomorphology, the size of the operation and the extraction methods used.

Extraction from the convex side of a river bend is preferred as it is generally an area of deposition, whereas the concave bank is an area of erosion. There can be no doubt that the creation of dredge holes in the river bed will interrupt the movement of bed-load sediment. As the stream and its bed-load encounter a large instream dredge pond, the velocity of the stream is checked. The lower Hunter River has a high bed-load during flood, but very little bed-load movement occurs during times of low flow. As the velocity of the current increases, the bed-load carrying capacity increases. Firstly fine sand is picked up and transported downstream. As the velocity increases further, coarser particles such as coarse sand and fine gravels are picked up and transported. During a flood, the deeper open waters of the dredge pond are initially infilled with fine sand and as the current builds coarser particles are deposited in the hole. As the current wanes, the grainsize of the bed-load decreases and finer material is again deposited in the dredge pond. The amount of deposition that will take place is difficult to quantify. Also, the effect that the "sediment poor" stream water will have upon the river bed and banks downstream as it leaves the quiet water of the dredge pond is uncertain. At Oakhampton, from airphoto and bank inspection evidence, it appears that the erosive effects of this possibly "sediment hungry" water, are minimal. It takes considerably more energy to initiate motion in particles upon the river bed and in the banks than it does to keep them moving as bed-load. Therefore, in times of low flow, I consider that the bed-load deficient stream water does not cause appreciable erosion downstream of an in-stream extraction site.

Examination of P.W.D. cross-sections 1 to 6 in an area directly downstream of the current extraction site shows a stable river bottom with some net deposition occurring between August and November 1988 (cross-sections 5 and 6). Note some extraction occurred on cross-section 6 from the convex bank.

Previous dredge/dragline ponds have infilled with flood sand and do not appear to have created erosive turbulence in the process. Once the flood sand is deposited in a dredge pond, it remains there and is not scoured out by the next flood. It is not a pocket of fine sand forming a nucleus for future erosion, but an area infilled with material the same as elsewhere on the river bed.

Extraction from the main channel can effectively lower the local base level, and may initiate bank and bed scour both upstream and downstream of the dredge pond, until the pond is infilled with material derived from upstream (Sparks 1960) (Erskine et al. 1985). Erosive action will decline as the river returns to an equilibrium profile. Comparison of the cross-sections and bathymetric maps shows the river bed to be stable and not undergoing serious erosion. However, minor sediment redistribution does occur and would occur if dredging did not take place. The railway bridge at the downstream end of Ward's Lease is a permanent fixture and helps to stabilise the local base level. A buffer zone of 200m was left between the bridge and cross-section 1 (the downstream limit of extraction).
also provides a semi-permanent fixture of local base level and was designed
to stop any undermining of the bridge foundations should erosion be initiated
by extraction.

From cross-sections 1 to 4, dredging occurred up to the bank on both sides
and in particular on Ward's lease, causing it to fall in. The bank is
now well grassed and stable. The recent cross-sections 1 to 4 show that the
bank is stable and in some places flood sand has been deposited. The
concave bank in cross-sections 5, 6, 7 and 8 is formed from the rock outcrop
that makes up Comerfords Hill. It is extremely stable and is not likely to
undergo any serious erosion.

The embayment in the river bank on Ward's Lease can be seen to be stable in
cross-sections 5 and 6 and on the Bathymetric Maps. This embayment will be
rehabilitated by backfilling it with quarry oversize in the future.

The current working area is now in the vicinity of cross-sections 8 and 9
and extraction is taking place close to the convex bank. It is not
interfering with the concave bank in any way. Minor bank collapse does
occur on Ward's Lease associated with extraction but has no effect upon the
river. On the concave side of the river a large lateral bar is being
deposited at the mouth of Comerfords Creek. The river is being diverted
away from the outside of the bend and into the dredge pond on the convex
side of the bend. Erosion of the concave bank at the mouth of Comerfords
Creek is due to storm water rapidly flowing out of the creek and into the
Hunter River. Erosion of the concave bank upstream of this creek is due
to flood waters flowing around the outside of the bend and is not caused
by the slumping of the bank into a dredge pond worked too deep and too
close to the concave bank. The dredge pond is not close enough to the
concave bank to cause slumping.

The rock-wall and groynes emplaced upon Bones and Comerfords properties have
performed very well in stabilising the old concave bank extraction area
and have actually improved the river bank in this area (see Water Resources
photographs, Figures 4C and 4D. The rock wall is starting to degrade
caused by exposure to flooding and it may need to be reconditioned with
the addition of more armour stone. This should not be the responsibility
of BMG as quarrying is almost complete and current operations/planned
operations will not interfere with the rock wall. I consider the recent
planting of trees on the rock wall to be a retrograde step, as in times of
flood, the water will rise and tear the trees from the wall and thus initiate
erosion. A tight well grassed surface is preferred.

Erskine et al. (1985) state that in order to prevent river degradation, the rate
of extraction of sand and gravel from the river bed and other temporary
sediment storages in the channel must not be greater than the replenishment
of the same size fractions. This may be the case for the upper Hunter River
where the stream has a gravel bed and a gravel armour layer. However, at
Oakhampton the sand and gravel that is the main target for extraction will
not be replaced under the current environmental conditions. The gravels and
coarse sand are relict deposits of a river with a higher flow regime. As
mentioned previously, the lower Hunter River is choked with fine to medium
flood sand and is constantly being supplied with more. As much as 4m of
sand has been deposited in the bed of the lower Hunter River downstream
of Wollombi Brook since early this century. The floods of the last 30 years
have not been large enough to flush the sand from the system and re-initiate
gravel transport.
Department of Water Resources river gauging stations have been used to calculate the mean annual bed material load yields for a number of locations along the Hunter River (Erskine et al. 1985). Singleton was the nearest location to Oakhampton where measurements were carried out. Here an estimated 720000 tonnes per annum ($d_{50} = 0.3\text{mm}$) is transported at varying rates depending on stream discharge. Data were collected between the years 1954 and 1979 (the error is considered to be as high as 50 to 100%).

Today the upper Hunter River is only moving small amounts of bed material. The restriction of sand and gravel addition and flood size by Glenbawn Dam along with the natural armouring of the bed reduces the ability of the river to move gravel bed material. River training works on the upper Hunter have also reduced bank erosion since 1956 thus reducing another major source of sand and gravel supply to the upper Hunter. However, in the lower Hunter the bed material load transport rate has greatly increased with recent and constant addition of fine to medium flood sand from the Goulburn River, Wollombi Brook and other streams that enter the river from the south. Occasional transport of sand and gravel cannot easily be predicted from the dimensions of in stream dredge ponds. Unsteady sand bed material movement is hard to predict, but it probably occurs in waves.

Erskine et al. (1985) state that in 1985 downstream of the Goulburn River confluence the annual extraction rate of sand and gravel was 500000 tonnes. This is about 70% of the estimated mean annual bed material yield at Singleton. They considered that once allowance had been made for errors, extraction equalled replacement and they concluded that at present, sand and gravel extraction in the lower Hunter was not creating a net deficit in bed material. What they did not appreciate is that the sand and gravel extractors are not interested in the flood sand but want the relict coarse sand and gravel from an older higher flow regime buried below the fine flood sand. In the lower Hunter River the present bed-load gravels are derived principally from the reworking of bank and bar deposits. The old coarse gravels are so deeply buried by flood sand that they are not exposed to flood erosion. The deep dredge holes (10-14m) are dug so as to provide access to the coarse sand and gravel which lies at a depth greater than 4 to 6m below river level. These holes interrupt the flood sand bed-load continuity and cause a short term deficit in sand bed-load downstream of the site. The ponds are mildly re-shaped and infilled with flood sand and soon become stable (as can be seen by comparison of the bathymetric charts and cross-sections). The abundance of the flood sand provides a buffer against channel instability.

Knowledge of the time span that sediments remain in place and in semi permanent bed control features is limited. If the Oakhampton operation was to continue, detailed sediment budgeting studies could be performed and provide information beyond the scope of this report.
FIGURE 4A
COMERFORDS EXTRACTION AREA,
23.3.1971
Extraction by dragline from concave bank at Oakhampton
FIGURE 4B
CONCAVE BANK AFTER EXTRACTION
BY DREDGE & DRAGLINE 9.8.1977
Note dredge operating in river
opposite O'Keefe's, Aberglasslyn
House in distance opposite
Middlebrook's property. Photog-
graph looking west.
FIGURE 4C
CONCAVE BANK AFTER CONSTRUCTION OF ROCK WALL & GROYNES, 23.4.1979
Note flood sand infill accumulating between the groynes. Photograph looking west.
FIGURE 4D
CORMFORDS CONCAVE BANK EXTRATION AREA, 22.10.1987
Rock wall & groynes well grassed and stable. Photograph looking west (upstream).
CONCLUSION

Quarrying of river sand and gravel has taken place at Oakhampton over the last twenty years. In the early stages of the operation, extraction took place from the banks of the Hunter River in landlocked dragline ponds. Later, when a dredge was introduced, material was won from the main channel of the river. The abundance of fine flood sand acted as a buffer against erosion in the early stages of the operation, backfilling the dragline holes and infilling holes created by the dredge.

Degradation of the concave bank occurred when extraction of material from Comerford's property took place. However, the construction of the rock wall and groynes on the concave bank has re-stabilised the bank. Subsequent flooding has infilled the troughs between the groynes and the bank is now well grassed.

Dredging operations along the convex bank of Ward's lease resulted in minor bank collapse. Extraction has ceased in this area and the bank is now well grassed and stable.

Present quarrying operations are having no significant environmental impact upon the Hunter River at Oakhampton. The supply of fine flood sand to the lower Hunter River is roughly equal to the amount of material removed from the river by the sand and gravel miners. Therefore, the replacement of the coarse sand and gravel required by the quarry operators with fine flood sand does not result in a net deficit of material. The dredge ponds when infilled with fine flood sand, do not appear to form nuclei of erosion during times of flood. The bed of the lower Hunter River is covered with an average of 4m of fine flood sand that is generally immobile. Small scale shifting of sand occurs continuously as can be seen on the bathymetric maps and cross-sections prepared for the P.W.D.

Reserves of quality material are limited at Oakhampton. The deposit will be worked from the current working area in the vicinity of cross-sections 7 and 8 upstream to the boundary between Bone's and Comerford's properties (the boundary between P.W.D. and Dept. of Water Resources jurisdiction). Extraction will be limited to the BMG side of the river. Upon reaching this boundary the deposit will be exhausted and extractive operations will cease. This is expected to take a further two years.

Alasdair Webb
Geologist
17.3.89
AW: AM
LIST OF REFERENCES


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APPENDIX I

P.W.D. CROSS-SECTIONS 1 - 10

COMPARISON CHARTS
OAKHAMPTON QUARRY

COMPILATION OF CROSS SECTIONS 1 - 10 (PWD)

SCALE

HORIZONTAL 1: 500

VERTICAL 1: 200

R.L. IN METRES

APRIL - MAY 1982

8TH DECEMBER 1986 WL 1.09m

EARLY MAY 1988 WL 1.36m

22ND JUNE 1988 WL 1.16m

22ND - 30TH AUGUST 1988 WL 1.4m

21ST - 23RD NOVEMBER 1988 WL 1.1m
CROSS SECTION 1
CROSS SECTION 6

PM 7 at 19.2m chainage