'Applying the learning'

The Geraldton Port dredging project 2002-03

Paper to the Freight and Logistics Council of WA and Ports WA - 1st of December 2009

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Abstract:

This paper describes the key outcomes and lessons learnt from a major capital dredging project in Western Australia. The paper summarises the key characteristics, issues that arose during the project and their management, as well as the applied research post-project to improve the science for proponents and regulatory authorities moving forward.

The Port of Geraldton is located some 400 kilometres north of Perth on the mid-west coast of Western Australia. The Port lies in the shelter of Point Moore and is situated at the southern end of Champion Bay. The Port is managed by the Geraldton Port Authority (GPA) lead by a Board of Directors and Chief Executive Officer. In 2002-03 the Geraldton Port Authority undertook a Port Enhancement Project involving the dredging, and sea disposal, of some 5Mm^3 of pre-dominantly limestone rock to deepen and widen the harbour basin and navigational channel from 9.4m to 12.1m and from 80m to 200m, respectively. The dredging project was expected to run for 10 months. Key environmental issues were:

- Turbidity from dredging operations impacting on seagrass health in Champion Bay;
- Sedimentation from dredging operations smothering seagrasses in Champion Bay;
- Duration of dredging exacerbating the above issues; and
- Dredging and berth construction activities impacting on humpback and southern right whale migration and disturbance of the residing Australian Sea Lion.

The project was the subject of a Public Environmental Review (PER) and approved by the Minister for the Environment in 2002. The PER predicted impacts to seagrasses through smothering and light limitation although the extent and duration of impacts were not comprehensively defined largely because inadequate geotechnical assumptions compromised the plume model. In March 2003, some 5 months after the commencement of dredging, the size and intensity of the turbid plume exceeded predictions. Seagrass monitoring had also confirmed impacts to seagrasses at the southern end of Champion Bay. It was also determined that the dredging project would take 3 months longer than predicted and when coupled with the plume characteristics and seagrass impacts the environmental regulating authorities implemented additional conditions including the need to suspend dredging if water quality criteria exceeded newly prescribed criteria.

The project concluded in early November 2003. The impacts to seagrasses varied with some areas being significantly affected whilst other areas showed little impact. It was apparent that the knowledge of the resilience of mid-west coast seagrasses to light limitation, and their subsequent recovery potential, was less than ideal. In order to address some of the knowledge gaps, the GPA commissioned a three-year, two-part seagrass research project. Those finding are now complete and proponents and regulating authorities can apply the learning.

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Acronyms:

AQIS	Australian Quarantine Inspection Service
CSD	Cutter Suction Dredge
DEC	Department of Environment and Conservation
DMP	Dredge Management Plan
DPMAG	Dredge Plume Management Advisory Group
ECU	Edith Cowan University
EMP	Environmental Management Plan
EPA	Environmental Protection Authority
FWA	Fisheries Western Australia
GPA	Geraldton Port Authority
IMS	Introduced Marine Species
JDN	Jan De Nul
LDV	Leonardo Da Vinci
MBACI	Multiple Before After Control Impact
PD	Port Datum
PER	Public Environmental Review
PSD	Particle Size Distribution
SRFME	Strategic Research Fund for the Marine Environment
TSS	Total Suspended Solids
GEMS	Global Environmental Modelling System

Introduction:

In 2001, and at a draft of 9.4m, the Port of Geraldton was one of the shallowest southern Ports in the world. This created significant limitations including ships often requiring partial loading at Geraldton before sailing to another WA port to complete loading. The two-port loading requirements imposed direct costs to mid-west grain farmers, only, of around $2 per tonne. Without corrective action, the long term viability of Geraldton Port was tenuous.

The GPA developed a feasible business case to deepen the Port and in 2001 released a PER for the proposed Geraldton Port Enhancement Project. A major component of the project was the dredging of some 5Mm^3 of predominantly limestone material from the harbour basin and navigational shipping channel. The harbour basin would be deepened from -9.3m Port Datum (PD) to -12.3m PD, with berth pockets to -13.1m CD. The main shipping channel would be deepened from -9.0m CD to -12.5m CD at the harbour basin end and -14.2 CD at the seaward end.

The design depths were established to enable vessel with a draft of 11.5m to use the facility at zero tide. The harbour end of the shipping channel was also widened from 90m to 200m to accommodate the reduced manoeuvrability from fully-laden Panamax class vessels.

The proposal involved dredged material being placed in >20m deep water offshore from Point Moore to form three artificial reefs in an area that had, through consultation with local fishermen, been of low fishing importance. The proposed disposal sites had no substantive habitat present and the benthos was dominated by coarse sands.

The rock density and swell climate were the principle constraints influencing the timing and methodology of dredging. In order to undertake the dredging task safely and efficiently in the prevailing seas-state conditions, a self-propelled cutter suction dredge (CSD) was employed whose global availability and number were extremely limited. The proposed methodology specified in the PER involved the CSD having to regularly move locations based on the swell climate. The dredging methodology involved the CSD cutting swaths of rock through the profile to be subsequently removed by a trailer hopper dredge. The project was expected to take 10 months.

The PER was approved by the Minister for Environment in July 2002 under Ministerial Statement 600.

Environmental Impact Predictions:

The turbidity plume was modelled by Global Environmental Modelling Systems (GEMS). The model was based on laboratory scrape tests of the Geraldton limestone and quantitative particle size distribution (PSD) and total suspended sediment (TSS) data from a small dredging project underway at Esperance is Western Australia. The meaningfulness of this data applied to the plume model assumptions was ultimately inadequate. Based on the tests it was assumed that 2.5% of the total material dredge at Geraldton would be less than 100 microns (fines) and of these fines some 73% would be less than 40 microns. Based on the PSD results and historical wind, wave and current data, the hydrodynamic model predicted a dense but relatively localised plume.

Based on the model outputs the PER predicted several key environmental aspects:

- impacts of turbidity and sedimentation on seagrasses within Champion Bay - seagrass impacts were expected to be most severe around the channel where anticipated seagrass smothering due to high sedimentation may occur whilst seagrass in other areas of the Bay were expected to show reduced vigour and productivity due to the turbidity plume causing a reduced light climate in the water column ;
- it was predicted the project would result in the direct loss of 7ha of reef, sand and seagrass habitat in Champion Bay;
- it was predicted the sedimentation and light impacts from dredging would result

in the loss of 23ha of habitat adjacent to the channel;

- the small coral community near the entrance to the harbour was expected to be lost due to its close proximity to the channel and dredging operations;
- it was expected that there would be water discolouration in and around the Project area;
- potential impacts of reduced water quality on rock lobster fishing and live holding facilities;
- potential impacts from dredging and post construction activities on a small group of male Australian Sea Lions (*Neophoca cinerea*) which haul out on nearby breakwaters; and
- potential impacts of dredging on migrating Humpback (*Megaptera novaeangliae*) and Southern Right (*Eubalaena australis*) whales.

As part of the overall Project Environmental Management Plan (EMP) a Dredge Management Plan (DMP) was prepared. The DMP proposed 'Alert' and 'Action' water quality criteria based on scientific information available at the time and through extensive stakeholder consultation including environmental regulatory authorities.

The DMP, and overall EMP, were approved in 2002.

Change to Methodology:

Following Ministerial Approval the GPA awarded the dredging contract to international contractor Jan De Nul (JDN). However JDN did not wish to perform the dredging in the same methodology as described in the PER instead offering to use a large cutter suction dredge '*Leonardo Da Vinci*' (LDV) feeding material to two self propelled trailer hopper barges '*Pinta*' and '*Nina*'.

This change to methodology meant a cyclic, surface overflow from the barges - an issue that was not predicted and appreciated by all parties concerned until operation.

Dredge Arrival:

The dredge LDV and barges '*Pinta*' and '*Nina*' arrived in Geraldton in October 2002. The CSD and barges had been inspected for biofouling by officers prior to its sailing for Geraldton as contract conditions required all hulls to be free from biofouling.

Upon arrival in Geraldton LDV was inspected by Australian Quarantine Inspection Service (AQIS) officers. The ladder section and sea chests of LDV was found to contain extensive biofouling including several live non-indigenous marine specimens. GPA were concerned by the risk of an Introduced Marine Species (IMS) introduction and immediately isolated the LDV and notified government authorities including Fisheries WA (FWA), AQIS and the Department of Environment and Conservation (DEC).

GPA convened meeting of representative from AQIS, FWA, DEC and the WA Museum. The parties resolved to determine the extent of biofouling. It was also resolved to weld plates on all ladder penetrations and dose the internal portions with concentrated detergent. The lethal dose and exposure was determined through the use of sacrificial live Gastropods (*Thais orbita* and *Turbo intercostalis*) caught locally. Once all local Gastropods had died a further 12 hours was applied to ensure all IMS were dead (Wells & Mulligan, 2009).

Large underwater drapes were hung to the outside of LDV before fouled external structures were water blasted and scraped (i.e. in-water cleaning). Dislodged material fell to the seafloor and was subsequently removed by a small Perth-based dredger that had been working in the Geraldton harbour and placed in an enclosed land-based reclamation area.

A subsequent Incident Management Committee re-convened and resolved that the risk of IMS introduction had been reduced to acceptable levels and ongoing monitoring would be required to validate this.

The dredging was ready to commence.

Dredging Phase:

Dredging started in late October 2002. The EMP was implemented and the project initially proceeded as predicted in the PER and DMP. The dredge moved often and the plume was relatively localised and quickly dispersed out of Champion Bay by strong prevailing southerly winds and surface currents.

It was in March 2003, some 5 months after the commencement of dredging, that the size and intensity of the plume significantly increased such that the plume extended up the coast some 70km in a 1-2km wide strip, far exceeding predictions (see image this page). The plume was visible in satellite imagery especially during subsequent high swell conditions where fine material was resuspended exacerbating an already large turbid plume.

On occasions during calm periods a layer, or strata, of turbid water was suspended in the water column to within 2-3m of the seafloor. This layer limited light to the seafloor and the seagrasses exhibited strong signs of decreased health (e.g. leaf loss) (see figure page 6).

A review of the sediment and geotechnical characteristics inputted into the model assumptions was conducted and found that **the dredge was producing about 50% (2% predicted, 4% actual) more fines (<100 microns) than originally assumed, and of these fines particles where heavily skewed towards the very fine particle size fraction (i.e. 96% of the actual fines were in the very fine (<40 microns) fraction).** It was also found that LDV was producing some 1,800 tonnes of fines per day (t/day) instead of the 1,200 t/day predicted in the model.

The GEMS plume model was re-run based on the *actual*, rather than predicted, particle size distribution and daily fines tonnages. Once the correct sediment and geotechnical characteristics were inputted into the model the outputs displayed good agreement with the actual plume and varied significantly from that of the initial outputs.

The DMP 'Action' level was regularly exceeded, requiring formation of the Dredge Plume Management Advisor Group (DPMAG) consisting of DEC, JDN, local rock lobster fishermen and the GPA. The DPMAG reviewed the project progress, water quality results, all recent seagrass monitoring results and any other factors relevant at the time and resolved to continue dredging to ensure project conclusion prior to the pending rock lobster season opening of November 15th.

Because the project was now expected to extend a few months beyond the initially predicted 10 months an extension to the Commonwealth sea dumping permit was required.

URS had undertaken further seagrass surveys and had advised that the Bay would not experience ongoing, long-term, turbidity after the dredging had ceased and that there would be no long-term loss of seagrass habitat in excess of the 30ha predicted in the PER.

Commercial Western Rock Lobster (*Panulirus cygnus*) catches had remained very strong both during the dredging period and in subsequent years. Likewise local puerulus (Western Rock Lobster larval life cycle stage)

Figure: An large plume in Champion Bay emanating from Leonardo Da Vinci (visible top left) settlement counts had remained consistent with other areas along the WA coast.

However, on the 2nd of September 2003, the DEC issued a Section 73 under the EPA Act, 1986 stating that in its opinion the turbidity generated during the dredging was greater than that assessed by the Minister. The Section 73 imposed new water quality criteria and 'Action' levels. The Section 73 also amended the DMP 'Action' response to require dredging cessation until water quality had improved to below 'Action' levels.

Although on a number of occasions monitoring had exceeded 'Alert' levels the Action level was never subsequently exceeded and dredging concluded on the 9th of November 2003.

It took many weeks for water quality to markedly improve and even subsequent to this time, large swell events would cause the re-suspension of some fines and the return of turbid conditions. Ongoing turbidity was exacerbated by beach renourishment works by the City of Geraldton using terrigenous (land based) fill sourced from the Southern Transport Corridor works.

Figure: The seagrass *Posidonia sinuosa* exhibiting leaf necrosis following prolonged light

The Learning:

Whilst there are varying spectral views on what transpired from the Geraldton project and the resultant outcomes, it is broadly agreed that the project highlighted areas for significant improvement on multiple fronts from both, proponents and regulators. It was the project we 'had to have' to encourage improved approaches from both sides. As is often the case after any contentious issue, the regulatory response appears to have over-corrected in relation to dredging in that the impact predictions being prescribed through the regulatory approvals pathway are so conservative that they appear to be of limited value as an informative tool. This paper attempts to highlight the lessons learnt from Geraldton in order to facilitate a more meaningful and pragmatic approach to the key aspects and approaches to impact predictions.

The GPA committed to two research projects to better understand seagrasses, their responses and sensitivities to light limitation and any subsequent recovery trends. The research focused on the dominant seagrasses of WA's mid-west. The first project, lead by CSIRO, was a 3-year study into the recovery of the seagrasses in Geraldton following dredging. The second project was a collaborative study lead by GPA, CSIRO's Strategic Research Fund for the Marine Environment (SRFME) and Edith Cowan University to commission a large seagrass shading experiment in Jurien Bay. These are each discussed in more detail below.

Research Project #1: Geraldton Recovery

In the three years from 2005 to 2007 GPA commissioned CSIRO Marine and Atmospheric Research to monitor the recovery of the dominant seagrasses in the Geraldton area and reference sites in Greenough, Port Denison and Jurien.

In 2005 CSIRO's survey found that the plume had extended 70 kilometres north and seagrass impacts were limited to areas within the 0-5km range. The severity of the impacts found within this limited 0-5km range were, similarly, limited to occasional relict seagrass rhizomes nestled amongst healthy seagrasses. The exception to this predominance of largely, healthy seagrass was limited to near-field sites or hotspots close to the dredging and beach re-nourishment zones where dredge-related impacts remained detectable. However, these sites largely lay within the original predicted impact loss areas. All other areas were relatively healthy and compared well with far-field reference sites and other sites within Western Australia. In the hot-spot areas, the CSIRO concluded that seagrass recovery had begun, as there was an increase in leaves per cluster, associated with an increase in shoot density and other health characteristics, which is a typical sign of seagrass recovery (CSIRO 2005).

In 2006, there was a further increase in health characteristics at areas within 0-2 km of the Port for *Amphibolis antarctica* and *Posidonia sinuosa* (CSIRO 2006). Shoot density measures for *A. griffithii* decreased at areas within 2-5 km of the Port, and yet increased at 5-10 km compared to 10+ km from the Port (CSIRO 2006). This suggested that any affected seagrass within 2-5 km had already recovered from dredging impacts and was undergoing a natural decline due to temporal variation.

Results from 2007 showed that the trend in seagrass health over the post dredging period continued to be positive, showing increases in many of the health characteristics around the Port, hot-spot areas and given that seagrass characteristics vary naturally it could be concluded that seagrasses had recovered (CSIRO 2007). However, it is important to note that applying pragmatic, quantitative reference baseline data in future projects is advisable in order to validate the predictions over time post-implementation.

Research Project #2: Jurien Seagrass Shading Experiment

GPA and SRFME commissioned Edith Cowan University (ECU) to lead the Jurien Seagrass Shading Experiment. The shading experiment involved the suspension of shade cloth on a PVC frame 1m above a mono-specific *Amphibolis griffithii* seagrass meadow. The *Intensity* (Control, Moderate and High), *Timing* (Post-summer, Post-winter) and *Duration* (3,6 and 9 months) of shading was manipulated and the deterioration of the seagrasses monitored against approximately 30 physiological and morphological characteristics. The intensity, timing and duration were determined to represent typical dredging durations.

The project aimed to determine early-warning indicators of seagrass stress, the tolerances of the seagrasses to shading and the ability for the seagrasses to subsequently recover. The project was designed by Masters student Michael Mulligan and Professor Paul Lavery based on recent similar work by former ECU students Catherine Collier and Paul Mackey.

The experiment gained significant interest both within Australia and oversees. Worldwide there had been few experiments of this type and scale previously undertaken.

The experiment determined *Amphibolis griffithii* has an initial physiological response to light reduction including, but not limited to, a significant alteration to rhizome sugars and leaf nutrient concentrations. If the physiological alternations are not enough to maintain a cost-neutral carbon balance because the amount of available light continues to decrease, or the period of light reduction is prolonged, then the plant engages some morphological adjustments including, but again not limited to, a reduction in leaves and leaf growth and, if required, subsequent loss of whole leaf clusters.

These physiological and morphological adjustments are made to reduce the plants respiratory demand and minimise self-shading in order to reach a neutral carbon balance. If this balance is not achieved, and the shading continues, the plants will eventually die.

The interaction of the timing of shading was an important element in understanding the plants response. Post-summer shading (i.e. over autumn and winter where total ambient light is naturally lower) meant the number of hours available above H_{SAT} was reduced, by up to 50%, when compared with Post-winter shading (i.e. over spring and summer where total ambient light is naturally higher). The result was a more rapid response in the Post-summer treatments with the response exacerbated by higher water temperatures during the Post-summer period than the Post-winter period causing a greater respiratory demand and therein H_{SAT} requirement.

The shading experiment also confirmed that seagrasses do recover but the period over which the recovery takes place can vary depending on the duration, timing and intensity of the shading episode.

So what did we learn?

Lesson 1: Baseline monitoring

It's impossible to predict impacts when you have little to compare it against. Whilst URS did conduct some baseline seagrass monitoring in hindsight it lacked a quantitative approach, it was low on replicates, it lacked a suitable suite of monitoring variables, and it lacked sufficient spatial coverage. We know that naturally seagrasses characteristics vary from year to year and season to season quite significantly

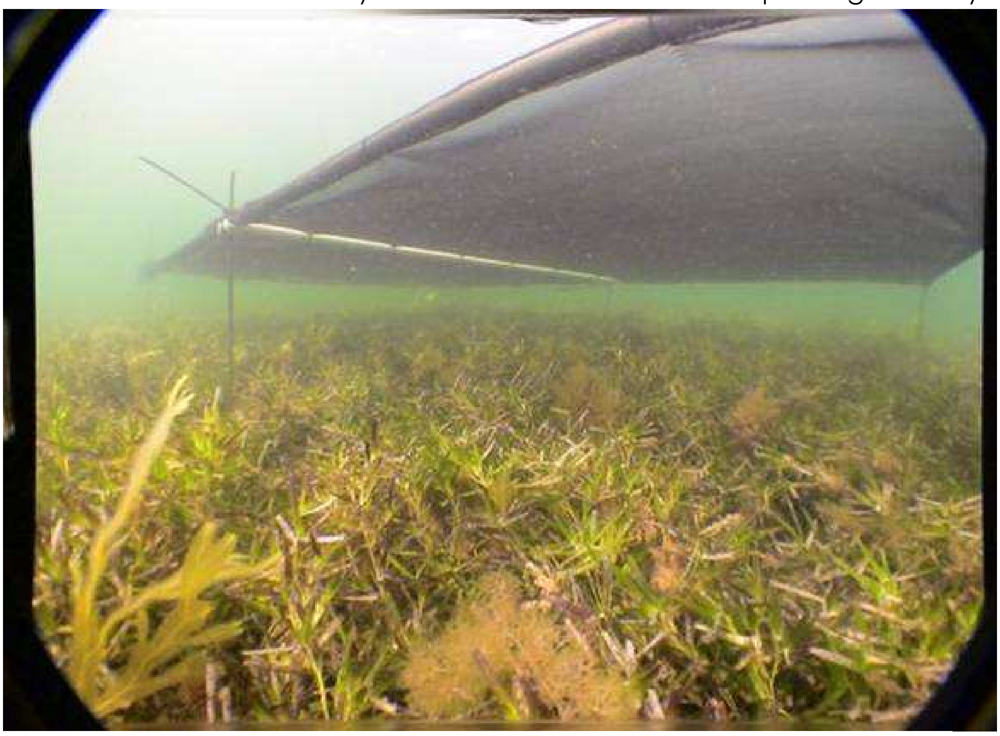

Figure: Shade cloth suspended an *Amphibolis griffithii* meadow. The collaborative seagrass shading experiment in Jurien Bay emphasising the need for baseline monitoring program that captures this variation.

Contemporary projects of today such as the Oakajee Port project have applied this knowledge and conducted rigorous baseline monitoring encompassing significant natural variation. The ideal monitoring program should be designed on a Multiple Before After Control Impact (MBACI) approach.

Further to baseline seagrass monitoring, It is also important to understand the natural variation in other aspects such as the natural temporal and spatial variability in water quality (TSS, light attenuation, etc). This baseline information is particularly important when assessing the relative contribution of dredging activity and turbidity plumes amongst ambient conditions.

Lesson 2: Model inputs and validation

The hydrodynamic model and plume dispersion models are only as effective as the inputs provided. It is therefore essential that reliable geotechnical and coastal process data is applied. Adequately characterising the sediments and geotechnical data is fundamental to obtaining meaningful outputs from the hydrodynamic model. The importance of a thorough assessment of these engineering and physical factors is vital.

Lesson 3: Impact Predictions and Monitoring

The research by GPA, CSIRO & ECU answered many of the 'unknowns' about seagrass impacts and recovery potential. But like most research it generated further valid questions that could be explored.

It is highly questionable that State Government ports, chartered with the primary role of trade facilitation, should have to answer increasingly complex ecological questions at the cutting edge of science relating to ecosystem function. If the scientific community is only just scratching the surface of these highly complex and often inter-related processes then what hope is there for a port authority.

It is true that the great work by GPA, CSIRO & ECU can now provide more reliable impact predictions and monitoring indicators that will enable reliable early indicators of stress in *Amphibolis griffithii,* and perhaps some other large perennial WA seagrasses, but it does not answer ecosystem function.

Proponents should look to apply the learning's of seagrass impact and subsequent recovery potential in their submissions. Proponents should also monitor reliable early warning indicators to allow for timely management responses in an appropriately triggered and actioned, staged management framework in a risk-based outcome focussed manner.

Conclusion:

The Geraldton dredging project highlighted areas for significant improvement on multiple fronts from both proponents and regulators. The project highlighted the need for rigorous geotechnical investigation to provide the most reliable inputs into the plume and hydrodynamic model. The project also emphasised the need for a comprehensive quantitative MBACI approach to baseline monitoring so that natural variation can be defined and any potential impacts can be conclusively quantified.

The lessons learnt highlights the need for a meaningful and pragmatic approach to the key aspects and approaches to future capital dredging.

Figure: An Australian Sea Lion basking on a Geraldton Port breakwater