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Technical Note

Project Number:	J15028.00	Project Name:	Esperance Jetties Condition Assessments
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Client:	Shire of Esperance – Mr. Alun Hughes		
Subject:	Esperance Tanker Jetty - Feasibility of preventing potential collapse of the Tanker Jetty superstructure		

Introduction

The Heritage Council has recommended to the Shire that the jetty structure is made safe, without removal of material to minimise the risk of uncontrolled failure.

The purpose of this document is to provide an opinion on the feasibility of preventing potential further collapse of the Tanker Jetty superstructure as a result of its worsening condition as noted in a number of previously supplied condition reports [1,2,3] to the Shire of Esperance which detailed numerous significant defects to a number of critical component types. These included failed piles, half caps, corbels, external stringers and braces. Part of the driver for such a determination to include “make safe” is that collapse brings with it public risk and port and recreational navigation hazard risks from uncontrolled debris. The other is to maintain the historic fabric of the jetty.

Prior to the first issue of this report in late 2017, Pile Group 66 failed and permission under the Conservation Order was sought and received to remove materials from this bent to manage consequences of their escape into navigable waters and to the structure itself. It is understood that removal was carried out in late March 2017. Subsequently, Pile Group 67 failed in April 2018 and the deck structure is coming apart as a result of the failed condition of all connections within the deck superstructure.

In my capacity as an experienced Maritime Engineer of over 25 years experience and advisor to the Shire, I have over a number of years assisted with condition assessment and management of this aging and now rapidly deteriorating timber structure and as such have a detailed knowledge of the structure, its condition, loading and deterioration rate. It was on this basis as a Professional Engineer with significant experience particularly in the design of

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A	Issued for Client Review	B.Saunders	Shire of Esperance	21/09/2017	1 Elec.
0	Issued for Client Use	B.Saunders	Shire of Esperance	22/09/2017	1 Elec.
1	Updated for condition with costs	B.Saunders	Shire of Esperance	02/05/2018	1 Elec.
2	Updated for stakeholder comments	B.Saunders	Shire of Esperance	03/05/2018	1 Elec.

timber marine structures, that I advised the Shire to close the structure as a result of its worsening condition and risk assessments in 2016.

I will review the feasibility of the above in 2 parts:

a) *the condition of the structure which would question the value in maintaining the existing material, and*
b) *works to enable it to be made safe and risks in doing so*

The Tanker Jetty Condition

Background

The Esperance Tanker Jetty is situated approximately 2km north of Esperance Port extends from the beach in an easterly/south-easterly direction. The original 875m long timber structure made up of a Jetty Section and a Wharf Section was constructed in 1934 and after deterioration and failures in the 1980's was separated into an "island" portion of the original wharf which continued to deteriorate to the extent that it was demolished by the Port in 2015, and a 630m Jetty Section. The remaining Jetty Section was refurbished in 1991/2 replacing the piles and topped with concrete to cover the failing deck timbers to facilitate pedestrian access. Only the outer (North and South) piles were replaced during the refurbishment. After recent collapses, the remaining section of the Tanker Jetty is approximately 512m long. The jetty was originally constructed of pile frames at 4.5m spacing made up of 3 piles. During the 1991/2 refurbishment, replacement piles, for a 2 pile frame, have been constructed outside, to the north and south, of the original piles in each bent. The pile frame substructure (pier) consists of the piles and half caps which support the deck superstructure. The piles, of each pile frame, are connected by 2 half caps, which are seated into and bolted to both sides of the pile tops. The pile frames support the deck superstructure on the half caps. The superstructure is comprised of the main longitudinal stringers, deck planks and the concrete deck. The main longitudinal stringers are supported on bearing corbels over the half caps at each pile frame. The 5 longitudinal stringers support deck planks, arranged transversely, which are topped with concrete pavement. The substructure pile frames are a critical load path for the dead and pedestrian live loading. The piles are also subject to wave loading and have continued to deteriorate with failures, including 'necking', at the seafloor and at sea level. In addition the connections of the half caps at the top of some of the piles have also suffered several failures, including crushing.

The 2010 BG&E Esperance Tanker Jetty Structural Assessment [4] for which BMT provided wave estimates and loadings stated "The missing and poor condition of pier bracing elements in conjunction with poor ironwork and half cap connectivity means that the jetty resistance to lateral loads arising from wind and wave action is reduced, and the stability of the jetty may be jeopardised during storm events." This is believed to be at relatively low return periods and this is likely to be even lower in its current condition. Since that time, BMT has worked with the Shire to monitor the condition of the structure to maintain access and recommended a series of repairs. However, due to the scale of the structure and its state of deterioration only de-rated pedestrian access was allowed for until such time as intervention

was required. The scale of the refurbishment task with the failure of all piles meant that at some stage the structure would be deemed as at the end of its serviceable life and could no longer be economically maintained. As a result of inspections in late 2015, it was recommended that the structure was closed as significant portions of the remaining structure were at immediate risk of partial collapse. Partial failures and more recently collapses have been monitored since that time by the Shire. Every maritime structure has a recognised life due to the severe degradation by the marine environment. This is particularly so with organic material structures such as timber. Past that life it is generally recognised that the only economically viable alternative is replacement and that would be in newer more durable materials to be economically viable to maintain. For example, large portions of the Busselton Jetty have been significantly rebuilt with steel and concrete elements.

The structure is well beyond its expected design and service lives and was in fact so when handed over for the Shire to maintain.

Condition Guidelines

Australian Standards [5] quote "Generally timber would not be used as the principal structural medium for a facility with a design life of greater than 25 years …" and the reason for this is generally maintenance of the assembly of individual members can be prohibitive. With component service lives such as marine exposed piles with as little as 5-10yrs but longer if protected with treatments and decking as low as 10 years but can be up to 25 years if maintained, such timber structures need to be thought of as "living structures" needing constant care and maintenance. Deterioration mechanisms are listed as:

- mechanical degradation (wear), rot, biological including marine organism attack
- moisture exposure and ingress induced fixing corrosion and rot which must be carefully designed against and maintained
- lack of maintenance of old structures from
  - lack of economic activity to fund a commitment to regular inspection and maintenance and ongoing replacement of components as the rot and fail
  - loss of timber working skills
  - lack of availability of sufficient sized timber supplies
  - difficulty in accessing and maintaining bolted connections particularly difficulty of mobilising in the marine environment

Condition Timeline

It is instructive to remind ourselves of the timeline and put this in the context of asset design life, expected service life, current condition and management.

Table 1: Jetty Timeline [6] – an engineering infrastructure asset perspective

Date	Description	Comment
1934	Jetty constructed	
1970	Port ceased operations – end of economic use	Jetty 35y old and past its expected design life for timber which could be inferred as 25 years from guidelines and considered end of Service Life
1976	PWD wants to demolish, agreement of reportedly $20,000 per year over 10 years arrived at	This would be a reasonable move to extend the Service Life for de-rated recreational use with only minor maintenance. It did not envisage major refurbishments which are more akin to large portions of the replacement cost.
1986 ǂ	End of PWD tenure and agreement – some public activity brings some further money for now much needed repairs	Period of minor repairs including piles at a reduced loading lowering intervention level with ongoing deterioration and collapse failures in mid 1980's
1992	WA Govt passes to Shire with $150,000	Funding for pile replacement in major upgrade – deck topped in lieu of replacing all deck boards – ie not a full refurbishment.
2010/11	Condition triggers condition inspections and warns of limited life	Jetty condition now below a reduced intervention level and way beyond life extension. Some works to extend use are continued with close monitoring.
2013 - 2016	Condition monitoring in 2016 closes jetty Port demolishes Island section	Loss of function of all elements evident and safety concerns govern. Demolition recommended some 47 years after initially required. Only replacement of ALL elements (ie complete rebuild) will address the current condition.

ǂ DoT advise (email 3 May 2018 Kim Davis) understanding that the PWD tenure relating to the jetty ended in **1968** by virtue of Section 20 of the then Esperance Port Authority Act 1968, notwithstanding the Government subsequently utilised PWD as the vehicle/agency to provide ongoing financial assistance towards maintenance of jetty for recreational purposes following the cessation of active commercial use by the Port Authority.

Some observations relating to engineering condition:

- It is now **47 years since the Jetty was scheduled for demolition**.
- The only major replacement of components has been of piles around or before 1992 some **25 years ago** and so they have reached end of life (note durability expectations of 10 years above).
- **The deck structure**, already in poor condition when concrete topped in 1992, is now 83 years old and **has had its life extended from a failed condition by some 25 years**.
- Funding amounts in the history are not major and in essence only targeted life extension at a much reduced level of service and intervention level in the realistic

expectation that eventually the structure would have to be demolished as originally proposed by the State in 1976.

- **ALL components now require replacement** – ie there is no historical fabric that is of a condition that would form any purpose other than decorative in a new engineered structure

The following figure relating condition, maintenance and intervention over time is instructive to inform non-technical people of the impact of infrastructure assets that deteriorate over time.

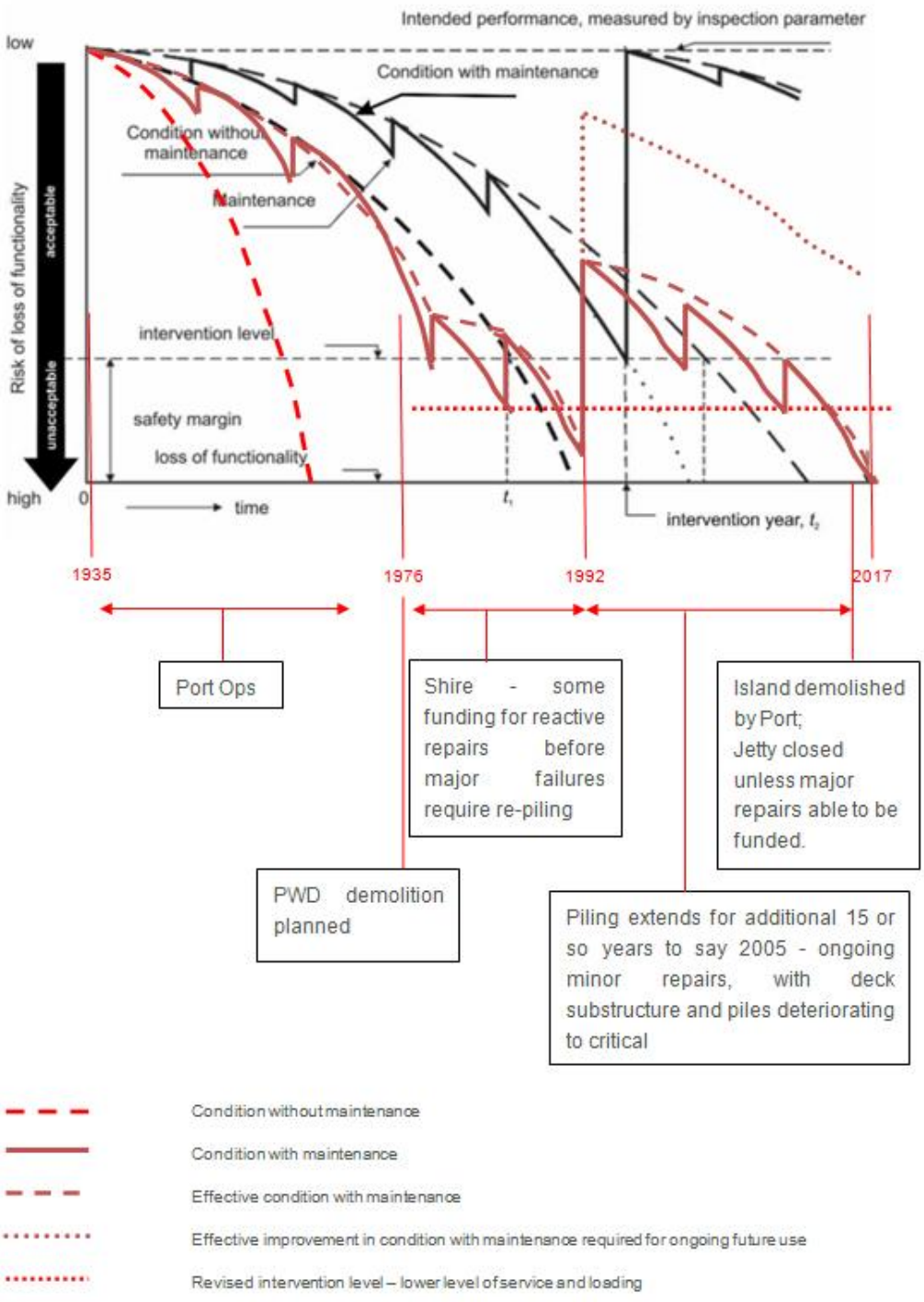

Figure 1 How we got here - Tanker Jetty Condition (Ageing of a structure – (sources CIRIA C674 & The Rock Manual [8])

The chart shows the concepts of a variation in loss of functionality with time with a range of strategies and highlights the impact of various interventions. Even with good durability design and construction, a structure may be assumed to approach some limiting criteria based on functionality, capacity, failure mode and often safety. The strategy employed must ensure that management actions are optimised over its defined life and economic decisions can be framed around its later performance with regard to rehabilitation or replacement [8].

The condition axis can also be thought of in terms of cost, the lower the structure is over time on this axis the larger portion of its replacement value will be required to bring it back up to the deterioration curve one expects with ongoing maintenance. The following element condition issues exist for the structure:

Piles

Stabilisation of the essentially failed piles (and this should be clearly communicated that every pile on this structure is failed under a structural capacity definition mainly due to reduction of section from marine damage) would require almost as much effort as re-piling every bent as was done in the last full pile replacement in . Therefore such work equates to substructure replacement in effort and cost and indeed temporary propping would almost require the same effort and cost as every bent would require support to give any assurance of stabilising all of the deck structure.

Crossheads

Despite the effort to stabilise the substructure support piles, there remains the difficulty that the Crossheads between the piles which support the deck are failing and no longer fit for use and are collapsing under deck self weight as the pile fixings tear out. Connection to the propping posts or new piles would essentially require replacement of this support element for the deck in some form or spliced and bolted connection be installed to each crosshead. There remains significant difficulty and danger in installing such repairs due to the fragility of the structure and I believe any work may have significant challenges in meeting Safety in Design risk assessments which would also be difficult and costly to implement. Again the cost would be a large proportion of any refurbishment of the substructure.

Deck

The timber deck elements – primarily corbels, stringers and deck planks are all structurally failed due to rot.

- Deck planks have been topped with a concrete topping as they were severely weathered and splintered and the fixings are all failed. The deck relies on gravity for fixity.
- Stringers are all suffering dry rot in the centre and no longer have the material soundness to in most cases fix to as part of repairs. Based on demolition section members, the deck cannot be relied on to even span between the existing bents

unless major deck repairs are also carried out. No fixing of deck planks would be possible.

- Corbels are collapsing under deck self weight.
- All fixings are now failed with severe fixing corrosion or dry rot and this has contributed to the recent collapses.

Structure stabilisation and "making safe"

As a result it may be expected that any temporary stabilisation solution would likely have the following outcomes:

- Prevention of further collapse could not be guaranteed (or signed off) without significant design and site works.
- The stabilised deck would still be at risk of damage and failure from the severe metocean conditions and susceptible to substructure wave loading failure and deck uplift and collapse in relatively low return period storm events as noted in 2010 BG&E Esperance Tanker Jetty Structural Assessment which can occur in any year going forward.
- Require significant marine mobilisation and operational cost due to the time it would take to stabilise the structure.
- Require significant expense which is expected to be more than the anticipated demolition cost and a significant portion of any refurbishment or replacement cost.
- Such works have significant safety in design challenges.
- Remove significant budget from that required to retain a structure at the site going forward.
- Resulting limited design life for the works with unknown effects from the further deterioration of the structure exacerbating this.
- Relatively high cost would be questionable value for money and provide low ranking in any project option assessment.

Should collapse occur, a number of adverse outcomes would be realised as previously noted [3] :

- Additional expense would be incurred to ensure appropriate clearance of the site with diving requirements. This may include a requirement to clean up plastic barrier and concrete deck overlay materials.
- It is likely that some elements would be released into navigational waters and certainly deck planks, stringers and other dry timbers would become a hazard to navigation. It is uncertain that dry upper sections of piles would also not be buoyant and become a hazard floating at or just below the surface. In water sections have been known to sink to the seabed.
- Timber piles would likely be collapsed with the deck and would not be available for heritage purposes as freestanding representative elements of the past structure.

- Collapsed materials may promote further damage to the adjacent remaining jetty fabric.
- Construction (Safety in Design) risk is increased with clearance of materials.

In response to a desire to inform regarding the costs to carry out feasible pile bent replacement and support for the deck, a concept screening level costing of a possible option to make the structure safe without removing material was carried out. The following method was proposed for temporary support of the deck superstructure:

Steel piles could be driven adjacent to the existing timber piles with temporary steel brackets fitted to connect with good timber of the existing half caps or replacement half caps be provided as required for temporary support of the deck in its existing condition. No work is possible to improve the condition of the deck due to safety concerns. Any replacement steel half cap cross beams would need to be fed underneath the jetty which may require additional plant costs and mobilisation negating reductions proposed in the mobilisation costs for limited scope works.

It should be noted that replacement of the piles does not assist in improving the condition of the deck structures (corbels, stringers and deck planks) this option only acts to replace partially or completely failed pile bents. Removing pile and crosshead triggers to the failure mechanism may reduce near term risk of collapse but in the medium term there is no improvement to the remaining life of the deck structure and ultimate collapse should still be anticipated.

It is anticipated that methods to install piles, half caps, brackets and bolts etc will require detailed and thorough investigation with respect to the safe implementation of these new components in relation to the safety of all operatives undertaking the works on site and also the safety to the heritage structure itself. Risk reviews and Safety in Design assessments in further development of options for the structure are considered to have a significant impact on options screening with likely early discarding of this pathway.

The solution identified to pile outside the line of the structure and support the existing deck on steel corbels or with full steel crossheads therefore has the following characteristics:

- the structure is temporary in nature only but with planning piles could be reused in permanent works but result in a wide deck with increased cost
- there would be no improvement of the current deck levels which are settling significantly in some areas without disturbance and risk of collapse
- extreme care would be required during the work disturbance and risk of collapse and piling operations may be sufficient to do so given its fragile state
- the failed deck is retained with a similar trajectory to failure

The costs of installing replacement piles / pile bents are high for individual replacements due to the high mobilisation costs of the equipment required to undertake such works safely. Based on previous request for contractor pricing on the project mobilisation costs for demolition and replacement works the mobilisation of suitably large floating marine plant required including piling barge and possibly pile transfer barge for example would be in the

order of $1m to $2m. For a limited number of bents, an assumption of a 50% reduction is made.

An approximate cost range is shown below based on costs provided in project request for contractor pricing data.

	Single Pile Bent	50% of Pile Bents	All Pile Bents
Approximate Cost Range	$1.1 – 1.9M	$4.1 – 4.9M	$6.8 – 7.6M

It should be again reiterated that the above costs are firstly screening level, order of magnitude and therefore subject to variance.

Conclusion

On this basis, and without benefit of a full project option selection or cost benefit analyses, it would not generally be considered feasible within the bounds of practical and normal engineering judgement to economically carry out such works and such works would comprise a large portion of the eventual replacement cost for the jetty. Temporary works would essentially be both extensive over the full length of the approximately 512m structure and costly, and still be prone to failure in storms and / or due to the 83 year old deck superstructure's continued decline in condition. More robust stabilisation would in effect be reconstruction retaining some historic fabric such as piles as was done with some lower specification structures in South Australia and of a scale that to the author's knowledge is currently not funded and would cost in the order of tens of millions. Certainly the value for money for the community in the long run would have to be questioned as a large portion of funding some temporary work could be utilised in any refurbishment/replacement.

Recognising that the structure is now considered totally failed and at the end of its functional life requiring each individual component to be replaced, in engineering terms means that it would not be considered feasible to repair or even stabilise the structure economically due to the scale and technical difficulties with such a task. Recent failures at Pile Group 66 and 67 demonstrate the predicted identified collapse mechanism involving the structures failed piles, crossheads, corbels and connections in deck elements. Failure of the reduced sections of jetty piles may induce failure of the crosshead to pile connection resulting in settlement of the deck, crushing of corbels, separation of the stringer connections; or, crushing of elements such as corbels, stringers and failure of the pile to crosshead connection in the rotting ends of the crossheads may induce pile failure; and result in uncontrolled progressive collapse of the deck under deck load alone or exacerbated by storm loadings. Mitigation of the risk of this failure could only be safely and feasibly achieved through removal of the dead load. This would require removal of the deck.

As a result, a "Hold" position as inferred from the Heritage Council advice, is largely unsustainable with unresolved ongoing financial, safety, navigation and reputational risks as well as high levels of community uncertainty.

Reference Documents

1. *Tn-J15028-3 (Rev 0) - Esperance Tanker Jetty - Condition of Jetty Superstructure Components for Re-use, 19/05/2017*
2. *P-J15028-1 Rev0 Tanker Jetty Condition Inspection – Initial Findings 20/11/2016*
3. *Tn-J15028-4 - Esperance Tanker Jetty - Impact of potential collapse of the Tanker Jetty superstructure, 01/08/2017*
4. *BG&E, 2010 - Esperance Tanker Jetty Structural Assessment*
5. *AS4997 Guidelines for the design of maritime Structures*
6. *http://www.esperancetankerjetty.com.au/esperance-tanker-jetty-timeline/*
7. *Esperance Shire Council Minutes 1992*
8. *CIRIA C674 and The Rock Manual*