Cumbria County Council

NEW WINDERMERE FERRY

PHASE 1 – FEASIBILITY STUDY REPORT

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EXECUTIVE SUMMARY

Background

a) This report summarises the study carried out into the feasibility and options for a new car ferry for the Lake Windermere crossing. The study was carried out by Vectis Marine Design for Cumbria County Council between July and November 2021 and forms the first phase of the project to replace the current ferry *Mallard*.

b) Mallard entered service in 1990 and there are increasing concerns about her age, suitability for ongoing service and reliability and it is required to replace her with a modern and environmentally friendly electrically powered ferry. The conversion and modernisation of the current ferry has been considered but ruled out as not cost-effective.

c) Consideration has also been given to replacing the current ferry either with two smaller cable or free-running ferries, or with a single larger free-running ferry, and while offering some advantages these options have been ruled out due to increased capital and operating costs and the project has focussed on a single new cable ferry.

d) The key requirements for the new ferry have been identified including increased car capacity and the access space between them, improved facilities for the passengers and crew, and improved emergency evacuation arrangements, as well as addressing the reliability and operational issues of the current ferry. A service life of at least 30 years is specified for the new ferry.

Ferry Construction and Inspection

e) A key consideration of the project is the fact that there are no shipyard facilities on Lake Windermere and the new ferry will have to be constructed elsewhere and assembled at the lake side. To minimise the lake side work, a fully or partially modular ferry design offers benefits as the ferry can be completed to a large degree in a shipyard before dismantling for delivery to Windermere and re-assembly.

f) A related issue is the Maritime and Coastguard Agency (MCA) requirement for the 5-yearly out of water inspection of the ferry's hull. To provide increased capacity, the new ferry will be larger than Mallard and too big for the biggest slipway on the lake and an alternative cost-effective solution with minimal downtime of the ferry is required. A modular or semi-modular ferry design could also provide a solution to this requirement.

g) It is recognised that the correct priority weighting must be achieved between the one-off assembly and launch of the new ferry, the 5-yearly out of water inspections (hence six in a 30-year service life), and the routine operation of the ferry for up to 15 hours a day, 365 days per year, for 30 years or more. The design, efficiency and operating costs of the new ferry should not be compromised by either the delivery constraints or out of water inspection requirements.

Issues with the Current Ferry

h) The current ferry experiences accelerated wear of the two drive cables such that they require replacing every 12 months or less. The cause is linked to aspects of Mallard's design. One issue is the inability to operate the two cable drive wheels independently from each other which prevents any correction of the ferry's alignment with the cables or with the slipways, and this leads to wear of the cable against the guide wheels as well as affecting the ferry's ability to operate in stronger winds. In addition, the single drive wheel on each side of the ferry has poor geometry to support the cable and results in the cable rubbing against itself. These issues will be addressed in the design of the new ferry.

i) The operation of the current ferry is limited by southerly and especially northerly winds above a fresh breeze, by restricted visibility due to fog or mist, and by high lake water levels.

j) The wind speed limit is due to the wind pushing the ferry either north or south of her "normal" track and this restricts alignment of the ferry and ramp with the slipway thereby preventing loading and unloading. Northerly winds are worse because of the orientation of the two slipways and the tension in the drive cables is also a factor. As the current ferry cannot operate the two drive wheels independently there is no means of correcting the ferry's alignment to the cables or to the slipway. The new ferry will be larger and hence have greater windage than Mallard, but it will have independent operation of each drive wheel so will be able to adjust her alignment to the slipways. The issue of cable tension will be addressed in the next phase of the project.

k) The current ferry is not fitted with radar and so is totally reliant on visual lookout. This restricts the ferry's ability to operate in conditions of low visibility due to mist or fog. A project is underway to install radar onto Mallard to test its effectiveness prior to the new ferry being procured.

l) When lake water levels exceed approximately 1.3m the current ferry cannot operate as at this height the ferry's ramp does not land onto the inclined part of the slipway, however the length and down angle of the ramp prevents it from landing on the brow of the slipway. The lake level has exceeded 1.3m on approximately 22 occasions in the last 8 years. A detailed survey of the slipways will enable the geometry and operation of the ramps on the new ferry to be designed to maximise the range of water levels over which the ferry can operate.

m) The approach roads to the two slipways are at heights of approximately 1.8m and 1.9m and it may be possible for the new ferry with improved ramp design to operate at lake levels up to around 1.6m. The water level has exceeded 1.6m on five occasions in the last 8 years. If it is required to operate the ferry at water levels higher than this, then the height of the slipway approach roads will need to be increased and the slipways modified.

n) Mallard was designed in the 1980s to carry 15 cars. Since then, car sizes have increased leading to the ferry typically carrying 10 to 15 cars and despite this, space between the cars is very limited leading to restricted access for emergency evacuation.

Concept Design of the New Ferry

o) The concept arrangement of the new ferry has been developed to provide increased car capacity and improved facilities for the passengers and crew. A study of modern car sizes and two modern small ferries led to the sizing of the vehicle deck to accommodate 21 large modern cars in 3 lanes with greatly increased space between each lane.

p) The deckhouse on the south side provides a passenger saloon, accessible WC, crew rest room and kiosk. Visibility of the ramps from the wheelhouse is achieved by locating the wheelhouse on a bridge over the car deck as has been adopted for other modern chain/cable ferries. The image below shows the concept design of the new ferry.

q) The additional car capacity and onboard facilities result in the new ferry being around 30% longer and 30% wider than Mallard. The compatibility of the existing slipways, drive cables, their spacing and diameter, with the new larger ferry will be addressed in the next phase of the project.

Electric Propulsion

r) Cable ferries require less power and have a more efficient propulsion system than an equivalent free running ferry and operating at slow speed means they require relatively little power for propulsion. The propulsion, ramp and services loads have been estimated for the new ferry, for summer and winter, to obtain the electrical power required per crossing cycle and hence per day. Using these power requirements alternative electrical propulsion system options have been developed and assessed.

s) Three options for the electric propulsion system have been considered:
   a. **Battery powered** electric motor propulsion - where all the power for propulsion and services is provided by an onboard battery bank that is charged overnight only or overnight and while unloading/loading at the east slipway.
   b. **Grid-connected** electric motor propulsion – where the ferry is permanently connected to the grid at the east slipway via a power cable that is reeled in and out as the ferry crosses the lake.
   c. **Shore mounted winches** – where the un-powered pontoon ferry is pulled across the lake by electric winches mounted on both or just one slipway.

t) **Battery powered** electric propulsion technology for ferries is now well proven with many examples of similar sized and larger free-running ferries in service for up to 6 years. Operating experience from these ferries indicates their safety, reliability, reduced operating and maintenance costs, and low noise and vibration.

u) As with modern electric cars, Lithium-Ion batteries are used for ferries as they have the highest power density (kWh/kg) of the current battery technologies, although they are heavy and expensive and require replacement every 10 years or so. There are also demanding installation requirements to maintain battery capability and safety in ships. For all these reasons it is desirable to minimise the installed battery capacity.

v) To achieve this, in addition to charging overnight when out of service most ferries receive a “fast charge” each time they dock to unload/load. For the new ferry the required battery capacity has been determined for overnight charging only and with a fast charge at the Ferry Nab (east) slipway.

w) If the new ferry was only charged overnight a battery capacity of 1,300 kWh is required with a weight of nearly 8 tonnes and a cost approaching £600,000 (2022). If she receives a 3-minute 200 kW fast charge each time she stops at the east slipway then the required battery capacity reduces to around 650 kWh, 4.0 tonnes and £280,000 (2022).

x) The low power requirements of the new ferry means that a fast charge could be delivered from a standard electric vehicle charger which is manually plugged in to the ferry by a crew member.

y) Because of the low power requirements, the possibility exists to extend the battery life beyond 10-years by installing larger batteries when the ferry is new, and to reduce battery costs by using pre-used batteries, possibly from a larger ferry, again by installing more capacity than would be required with new batteries. When it does come to replacing the batteries, the cost of batteries is expected be less in the future, and new battery technology with higher power density may then be available.

z) In summary, the Windermere ferry is well suited to battery operated electric propulsion and there are several possibilities to minimise the costs. However, a battery-operated ferry will inevitably be more expensive to build and operate than one that is permanently connected to the grid and hence needs only a very small battery pack as an emergency supply.

aa) **Grid connection** of the ferry means that a large battery bank is not required on the ferry with the attendant environmental impact, weight, installation, initial and replacement cost. The technology is proven; the Swedish Highways Agency has seven grid-connected ferries in service, albeit all for shorter crossings than Windermere, and another four in procurement.

bb) A hydrographic survey has confirmed that there are no hazards on the lakebed, so the technical challenges of the longer crossing are the cable size to transmit the power over the longer distance and the associated size of cable reel. A small onboard battery bank would provide power to return to the slipway in the event of a grid power cut or cable failure. Power cable replacement is expected every 12 to 24 months but the trade-off is the reduced capital cost and simplification of the ferry. Further work is required to confirm grid-connection as a low-risk solution for the Windermere ferry, including further liaison with the Swedish Highways Agency.

cc) **Winches mounted on the shore** would greatly simplify the design, construction, cost, and lead time of the new ferry as it would become an un-powered pontoon ferry with no propulsion machinery of its own. The ferry is pulled by electric winches installed on one or both slipways, which appears to be a straightforward and low risk solution. However, the technical challenge and risk comes from the control and synchronisation of the winches to ensure that the required cable tension is maintained in both the pulling in and paying out winches, and to maintain a constant pulling speed while the winch drums empty and fill.

dd) To reduce these challenges a cable car type of arrangement has been proposed with two continuous cables, winches, and cable tensioners on each side of one slipway, however significant control and synchronisation challenges would still apply.

ee) A more significant issue is that the winch cables will be dragged across the lakebed up to 92 times a day for 7 days/week, which will inevitably reduce their life, probably to an unacceptable level. The extent of the infrastructure works at each slipway to install the winches will also counteract savings in the cost of the new ferry. Noise from the winches operating on the slipway is also likely to be unacceptable. For all these reasons, the propulsion option of shore mounted winches was not considered further.

ff) In summary, electric propulsion powered either by an onboard battery pack or by connection to the grid are both technically feasible options. The crossing distance poses some challenges for the grid connected option, but the benefits are reduced ferry complexity, operating and ongoing costs compared with the battery powered solution.

<u>Power Supply to the New ferry</u>

gg) Electricity NorthWest Limited (ENWL) are installing a new power supply to the east slipway for the new ferry. Communication with ENWL indicates that the (low) power requirements of the new ferry are unlikely to be an issue, however this is to be confirmed.

<u>Out of Water Inspection</u>

hh) Discussions have commenced with the MCA on the potential to extend the out of water inspection from 5 to 7 or more years. It is considered that this can be justified because the vessel operates in fresh water in benign conditions and the out of water survey could be supported by a regime of intermediate in-water inspections. Regardless of the outcome of those discussions there will always remain the necessity to lift the ferry for inspection, and potentially for repairs, so a solution is needed.

ii) The new ferry is expected to be too large for the privately-owned slipway used by Mallard, and four potential alternatives for removing the new ferry from the water have been identified. These are lifting the entire ferry ashore with heavy-lift cranes, lifting sections of a modular ferry ashore by crane, slipping the ferry up one of the ferry slipways, and lifting the ferry on a road transportable dry dock. None of these is a straightforward or low-cost solution and all need further development to determine the feasible and most cost-effective solution.

<u>Project Costs and Finance Options</u>

jj) Based on the concept design produced for the new ferry, a preliminary RFP for the design, construction, delivery, and commissioning of the new ferry has been prepared and issued to five shipyards who have all provided budgetary proposals and costings. These costings supported by other budgetary prices and estimates have formed the basis for the estimated initial and ongoing costs for each option.

kk) Based on the initial proposals received it is expected that a new battery-operated ferry will cost in the region of £5.2 million and a grid-connected ferry in the region of £4.8 million. Including infrastructure and associated costs the total project cost is estimated to be in the range £6.5 to £6.8 million. This does not include any allowance for slipway strengthening work to enable the slipping of the ferry if this proves to be feasible and if strengthening is required.

ll) The major difference in through-life maintenance costs is the replacement of the batteries or replacement of the grid connection power cable. At 2022 prices these are expected to be in the region of £560k and £360k respectively over the 30-year service life of the new ferry.

mm) Based on indicative project durations from the three shipyards the programme from contract to commissioning of the new ferry is expected to be 18 to 20 months.

nn) Several options exist for the financing of the new ferry, from outright cash purchase in accordance with the agreed stage payment schedule, to the lease of the ferry from a ship owner. The options are presented within this report.

Conclusions

oo) This study has confirmed the feasibility of a new electric ferry for the Lake Windermere service that meets the requirements identified for the new ferry, that addresses the operational and reliability issues of the current ferry, and that considers the constraints associated with the delivery and out of water inspection of the new ferry.

pp) The following is proposed as offering the best solution for the new Windermere ferry.

a. A catamaran or monohull ferry of semi-modular construction designed for complete construction, fitting out and (partial) testing in the shipyard before dismantling for delivery to the lake side for rapid re-assembly, launch, installation, and commissioning.
b. The electric propulsion system may be powered by either an onboard battery bank with the associated charging regime, or by permanent connection to the grid by a power cable. Grid-connection offers the lowest initial and ongoing cost and environmental impact but is a greater technical challenge and needs further development and de-risking.
c. There are several potential solutions for removing the new ferry from the water for inspection and repair but there is no straightforward or low-cost solution, and this aspect also requires further development in the next phase of the project.
d. Communication with the MCA with the aim of achieving agreement to an out of water inspection every 7+ years is to be concluded.

CONTENTS

1. INTRODUCTION

In July 2021, Cumbria County Council (CCC) commissioned Vectis Marine Design to provide consultancy support to the Windermere Ferry and to carry out a study into the feasibility and options for a new ferry. The Council had previously decided that the existing diesel-powered ferry *Mallard* should be replaced by an electrically powered ferry either by converting Mallard or by a new ferry.

Vectis Marine Design is marine consultancy established in 2008 specialising in the naval architecture, engineering, and design of specialist vessels and small craft. Vectis provides technical support to small ferries including the Strangford Lough and Rathlin Island ferries operated by the Northern Ireland Department for Infrastructure, and to the Caledonian MacBrayne (CalMac) fleet that services the Scottish western islands. Vectis also provides electric propulsion feasibility studies and solutions for ferries and small craft.

The scope of the study is defined in Ref. A and was carried out between July and November 2021.

Unless credited otherwise, all photographs were taken by Vectis Marine Design.

2. REFERENCES

This report refers to the following documents.

	REFERENCE
A	Windermere Ferry Professional Services Framework 3 – Scope, Cumbria County Council
B	https://cumbria.gov.uk/roads-transport/highways-pavements/windermereferry.asp
C	Code of Practice for the construction, machinery, equipment, stability and operation of Chain/wire ferries acting as a Floating Bridge, carrying passengers and vehicles, Revision 01/18, Maritime and Coastguard Agency
D	https://www.windermere-lakecruises.co.uk/about-us/new-for-2020-mv-swift-a-timeline-of-our-new-vessels-construction
E	Damen Presentation on Modular Constructions
F	Windermere Ferry Users | Facebook
G	https://www.navionics.com/gbr/charts/
H	Wire Rope Handbook, Usha Martin Limited
I	https://en.wikipedia.org/wiki/Cable_ferry
J	https://www.automobiledimension.com/
K	Replacement Floating Bridge, Technical Specification Rev 0, BCTQ
L	Isle of Wight Council, General Arrangement, Issue D, 3/5/17, Mainstay Marine Solutions
M	https://riverlevels.uk/lake-windermere-windermere-far-sawrey
N	https://www.fba.org.uk/FBA/Public/Ferry-Cam/Ferry-Cam-Windermere-Car-Ferry-From-the-West-Side-of-the-Lake.aspx
O	https://twitter.com/windermereferry?ref_src=twsrc%5Egoogle%7Ctwcamp%5Eserp%7Ctwgr%5Eauthor
P	Ellen ferry presentation https://www.youtube.com/watch?v=7NpKv6U59Ro
Q	Design, construction & commissioning of a new electric cable ferry for Lake Winderemere, Request for Preliminary Proposal, Vectis Marine Design, 20/9/21

References

3. OVERVIEW OF THE SERVICE

3.1 The Windermere Ferry Service

The Windermere Ferry operates between Ferry Nab, Bowness on Windermere on the east side of Lake Windermere, and Ferry House, Far Sawrey on the west side. The ferry connects the B5285 on each side of the lake and provides a key service to the local communities and economy.

The ferry operates 7 days/week for 365 days/year and in the Summer the ferry operates for approximately 15 hours a day and crosses the lake 92 times. In 2019 the ferry transported approximately 100,000 vehicles and 450,000 passengers across the lake (Ref. A).

The ferry departs every 10 minutes from alternate slipways (Ref. B). It takes approximately 6 minutes to cross the lake and approximately 4 minutes unloading/loading. The length of the crossing is approximately 500m.

3.2 The Current Ferry "Mallard"

The current Windermere ferry is the *Mallard* which entered service in 1990. Mallard is of steel construction and has an overall length of approximately 40m with a capacity of up to 15 cars and 140 passengers and crew.

The ferry is a cable ferry, which in a similar manner to a chain ferry, pulls herself across the lake along a pair of steel wire cables fixed between the two slipways. The ferry is powered by a diesel engine that drives the cable pulley wheels on each side of the vessel. Mallard is illustrated in the figures below.

The current Windermere Ferry "Mallard"

Mallard approaching the Ferry Nab (east) slipway, the two drive cables can be seen

Increasing concerns about the age, suitability for ongoing service and reliability of the Mallard have resulted in Cumbria County Council, who own and operate the ferry, to commission a project to provide a modern and environmentally friendly electrically powered solution. Such a solution could potentially be provided either by conversion and modernisation of the existing ferry, or alternatively by the introduction of a completely new ferry.

4. REQUIREMENTS FOR THE NEW FERRY

4.1 General Requirements

The key requirements for the new ferry were identified by Cumbria County Council and are shown in Annex A and summarised as follows:

- An electric propulsion system
- A propulsion system with a high degree of safety, reliability and redundancy
- Increased drive cable service life
- Means of improving the alignment of the ferry with the slipway
- Improved visibility from wheelhouse, especially of ramps
- Vehicle capacity increased to 18 or ideally 21 cars with adequate space between them
- 140 passengers and crew
- Improved passenger facilities (kiosk, Wi-Fi, information screens)
- Improved crew facilities (mess room, office)
- Accessible WC for crew and passenger use
- Improved emergency evacuation routes
- Increased ability to operate in low visibility, high winds, and high lake water levels

- A service life of at least 30 years
- Compliance with the MCA Code of Practice for … chain/wire ferries (Ref. C)
- A solution to the requirement for a 5-yearly out of water survey of the ferry hull

4.2 Certification Requirements

The UK Maritime and Coastguard Agency (MCA) specify the operation, inspection, and maintenance regime for passenger vessels in the UK. For cable and chain ferries the MCA's requirements are contained within the *Code of Practice for the construction, machinery, equipment, stability, and operation of Chain/Wire ferries acting as a Floating Bridge, carrying passengers and vehicles* (Ref. C). This Code of Practice specifies requirements for existing chain/cable ferries and more onerous requirements for new vessels.

The current ferry Mallard is certified by the MCA in accordance with this Code of Practice for operation with up to 140 persons onboard (including crew) in Category C waters, defined as "*tidal rivers and estuaries and large deep lakes and lochs where the significant wave height could not be expected to exceed 1.2 metres at any time*".

The new ferry will also be required to be certified under the MCA Code of Practice for this operational area and numbers of persons.

4.3 Out of Water Survey

One of the requirements of the MCA Code of Practice (Ref. C) is for an out of water survey of the ferry every 5 years. This requires the ferry to be slipped or lifted out of the water every 5 years so that the underwater hull can be inspected by an MCA surveyor.

There are only limited shipyard facilities on Lake Windermere for a vessel the size of the ferry and to comply with the MCA requirement the current ferry Mallard is slipped every 5 years using the Windermere Lake Cruises facility at Lakeside. To reduce the weight and length of Mallard to within the capacity of the slipway the two ramps must first be removed before the ferry is towed to the slipway. This out of water survey was last undertaken for Mallard in 2019 at a cost of £250,000 not including lost revenue (Ref. A) and requires the ferry to be out of service for up to 3 weeks.

To avoid these costs and downtime for the new ferry an alternative and cost-effective solution to the 5-yearly out of water survey is required.

4.4 Delivery of a New ferry

The land-locked nature of Lake Windermere and the limited shipyard facilities on the lake also impact the feasibility of the convert and modernisation of the current ferry, and on the introduction of a new ferry. The project by Windermere Lake Cruises to launch the new 34m cruise vessel *Swift* onto the lake in 2020 (Ref. D) demonstrates the feasibility of assembling a vessel on the lake side from fabricated sections delivered by road from the shipyard and launching her by heavy-lift cranes, as shown below.


Assembly, fitting out and launch of the MV Swift at Lakeside in 2019 (Ref. D)

The introduction of a new ferry for Lake Windermere will necessarily require a similar process as that applied to the Swift, while recognising that the new ferry will be significantly larger (longer and wider) and heavier than Swift. Due to the size of the new ferry, the car park on the north side of the Lakeside railway station and aquarium is probably the only lake side location suitable for the assembly and launching of the new ferry. The Swift was launched from this location but assembled in the car park on the south side of the aquarium. Once launched the ferry can be towed up the lake by another vessel.

The largest units that can be delivered to the lake side by road transport are approximately 18m long by 4m wide by 4m high and the new ferry will have to be delivered in sections that are within this size. There are several options for this; either to design the new ferry so it is constructed in units that are permanently joined at the lake side by welding them together or select a modular ferry design that is assembled from individual three-dimensional modules that are bolted together, or a combination of the two. In the case of a fully or partially modular design, the vessel can be dis-assembled when required for maintenance, repair, or inspection ashore. An example of a fully modular vessel design is shown below. This is for a workboat, but the standard modules may also be configured into other vessel types.

An example of a fully modular vessel design with modules that bolt together (Ref. E)

The key advantage of a modular design is that the vessel can be fabricated, assembled, fitted out and tested at the shipyard before it is dis-assembled for delivery to the lake. This greatly reduces the assembly and finishing time at the lake in working conditions that are inevitably less than ideal. As an illustration, the cruise vessel Swift was not of this type of modular design and the complete process from delivery of the first steel units to Lakeside to the commissioning of the vessel took around 15 months. With a modular design this duration may be reduced to a few weeks with resultant cost savings.

As well as benefiting the construction and delivery process of the new ferry, a modular design may also assist the 5-yearly out of water survey as the individually watertight sections means that the vessel can be partially disassembled in the water and sections lifted ashore by crane for inspection. A partially modular catamaran (two hulls) ferry design would also benefit the construction as each hull could be fully finished, in fore and aft sections, in the shipyard before delivery to the lake side for assembly.

Whether the new ferry is fully or partially modular, a key objective is to minimise the assembly and completion time on the lake side to a few weeks rather than months. It is recognised that the construction and delivery of a new ferry is a one-off process whereas there will be six or more out of water inspections over the 30+ year service life of the new ferry.

The limited shipyard facilities on Windermere have a greater impact on the feasibility of upgrading and modernising the existing ferry as all the work would have to take place either with the vessel afloat or ashore at the lake side, again in less-than-ideal working conditions. The feasibility of converting and modernising the current ferry is addressed below.

4.5 Summary

In summary, in addition to the specific requirements related to the design of the new ferry and its certification requirements, there are also challenges related to the construction and delivery of the new ferry itself and in meeting the MCA's out of water survey requirements. It was these requirements collectively that directed the work to identify and assess the most cost-effective options for the replacement ferry.

However, it was also recognised that the correct priority weighting must be achieved between the one-off assembly and launch of the new ferry, the 5-yearly out of water inspections (hence 6 off in a 30-year service life), and the routine operation of the ferry for up to 15 hours a day, 365 days per year, for 30 years or more. The design and efficiency of the new ferry should not be compromised by either the delivery constraints or out of water inspection requirements.

5. CONVERT AND MODERNISE THE CURRENT FERRY?

5.1 General

To ensure that all opportunities have been explored it is necessary to consider the feasibility of converting and modernising the existing ferry to meet the requirements summarised in the previous section.

The existing ferry has been in service since 1990 so is currently 31 years old. For any vessel and especially a steel vessel that is a good age and many commercially operated ships and vessels would have been replaced before reaching that age. Based only on inspection of the vessel afloat, the steel structure of the existing ferry appears to be in a reasonable condition and no doubt this reflects the fact she operates in fresh water rather than sea water. The current ferry has also been modernised in certain aspects, such as a new engine and controls, re-wiring, and other repairs after her 2018 fire, but fundamentally most aspects of the vessel are original and reflect 1980s standards and design.

Technically it is feasible to refit and modernise a 31-year-old vessel of Mallard's structural condition. But in addition to converting her to electric propulsion it is also required to increase her car capacity and improve the facilities onboard for the crew and passengers, so the extent of any retrofit would be far greater than that required "simply" to convert her to electric propulsion. An increase in her car capacity and onboard facilities could only be accommodated by lengthening and/or widening the vessel and whilst this is technically feasible it is highly unlikely to be cost-effective, especially as there are no suitable shipyard facilities for such work on the lake. In addition, converting the existing ferry to electric propulsion is likely to mean she is out of service for at least 6 months and if other modifications are also included then this is very likely to increase to 12 months. In contrast, a new ferry can be built while the service is maintained by the current ferry with only a short period of downtime as the ferries are changed over.

Annex B contains a table that summarises the advantages and drawbacks of converting and modernising the current ferry compared with a new ferry. It can be seen from this table that there are few advantages and many drawbacks to converting and modernising the current ferry. Fundamentally, after conversion, the existing ferry would be over 33 years old which is elderly by any standard and intuitively it does not make sense to fit a state-of-the-art electric propulsion system into such an old vessel.

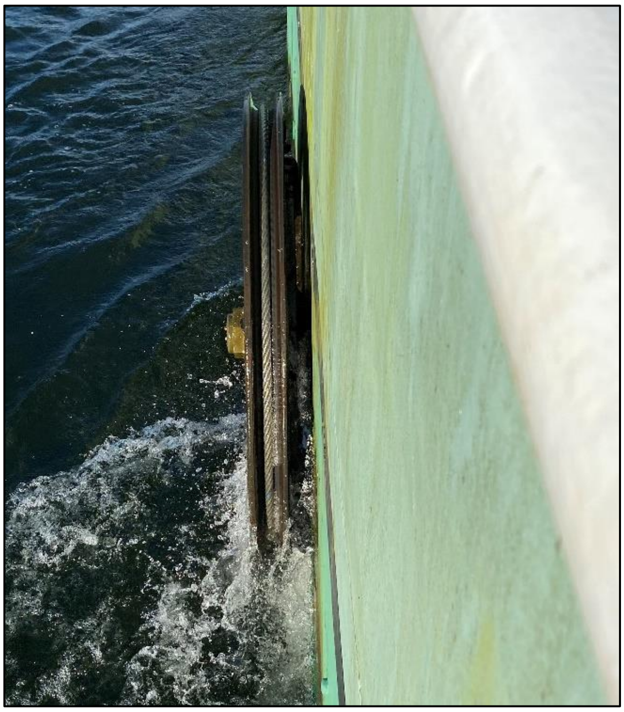
5.2 Summary

In summary, there are numerous and compelling drawbacks and very few benefits in converting and modernising the current ferry and intuitively to do so would be neither cost-effective nor represent good value for money. It was therefore concluded that the focus of the study should be to develop options for a new electric ferry of modern design that will deliver the requirements identified.

6. NEW FERRY OPTIONS

6.1 Cable, Chain, or Free-running Ferry?

The current Windermere ferry is a cable ferry that is propelled by pulling itself along a pair of steel wire cables fixed between the two slipways. Propulsion along the cables is achieved by the cables being wrapped around a large pulley wheel mounted on each side of the vessel that is driven by a diesel engine via a hydraulic motor and pump system. One of Mallard's two drive wheels is shown below. The wire cables wrap around one complete circumference of the drive wheel, overlapping at the bottom as they run to each slipway.



One of Mallard's cable drive wheels

There is one other cable ferry in the UK; the Dartmouth Higher Ferry that crosses the River Dart in Devon. In addition, there are seven chain ferries operating in the UK. Chain ferries operate in a similar way but with chain instead of wire cables.

The Dartmouth Higher Ferry, the only other UK cable ferry

As a propulsion mechanism cable drive is a very efficient means of propelling a ferry. There are no propellers, rudders, or other appendages on the hull to support the propeller shaft(s), all of which create drag. Providing there is no slip between the wire cables and the drive wheels, which does occur periodically but is not continuous, the efficiency of the propulsion mechanism is very high. In contrast, a ferry powered by conventional propellers or similar propulsors will have lower efficiency due to the appendage drag and efficiency of the propulsors which may be only around 60%.

High propulsion efficiency also applies to chain ferries. Chain has the advantages over wire cable of weight and the positive engagement of the chain links within a notched drive wheel. The weight of the chain reduces the transverse movement of the ferry under the influence of wind or tide as it makes its crossing, and the engagement of the chain links within a notched drive wheel reduces the likelihood of slip between the chain and the drive wheel. As is the case with wire cable, the chains wear and stretch and require regular replacement. The major drawback of chain ferries is the noise from the chain which is difficult to avoid or reduce.

Chain/cable ferries are typically employed in locations of strong current flow such as in tidal rivers and harbour entrances. In these locations the chains or cables limit the sideways movement of the ferry by the current and in doing so greatly reduce the power required to counteract the current. It is for this reason that chain/cable ferries generally have propulsive power requirements that are only around 25% of the equivalent size of a free-running ferry.

Tidal flow is not an issue on Lake Windermere, and it is only the wind that pushes the ferry transversely off her track between the slipways, but despite this it is estimated that an equivalently sized free-running ferry for the Windermere crossing would require more than twice the propulsive power of a cable ferry. A free-running ferry would also require more complex propulsion and control systems than a chain ferry and would have to meet more onerous certification and manning requirements. As such a free-running ferry would be more expensive to build and to operate than an equivalent cable ferry.

6.2 Two Ferries?

Brief consideration was given to the feasibility and advantages of replacing the current ferry with two smaller ferries. Such an arrangement could provide additional vehicle capacity and reduced unloading/loading times in the Summer with both ferries operational, and the opportunity for single ferry operation with reduced costs in the Winter. In the event of one ferry being out of service for maintenance or inspection or due to breakdown, the other could maintain the service. Smaller ferries would be easier to slip for their 5-yearly out of water surveys.

The benefits of two ferry operation in general are well known, however, to implement two ferries on the Windermere crossing would require either the widening of both slipways so they could accommodate two cable ferries operating side by side (in a similar manner to the three chain ferries that operate across the River Tamar in Plymouth), or the removal of the cables and introduction of two free-running ferries that could alternately use the existing slipways. The former would require significant civil engineering works which is considered unlikely to receive planning approval, and the latter would increase the cost of the ferries as free-running ferries need more propulsion power and must meet more onerous certification and manning requirements than cable ferries.

In addition, the capital cost and operation of two smaller cable ferries will inevitably be higher than one larger cable ferry as each vessel will require similar equipment and systems, albeit different in size, and require the same number of crew members in operation.

6.3 Summary

It is not considered viable or cost-effective to replace the current ferry with either two smaller ferries, whether cable driven or free-running, nor with a single larger free-running ferry. The only realistic solution for Lake Windermere is to replace the current ferry with another cable ferry.

7. ISSUES WITH THE CURRENT FERRY

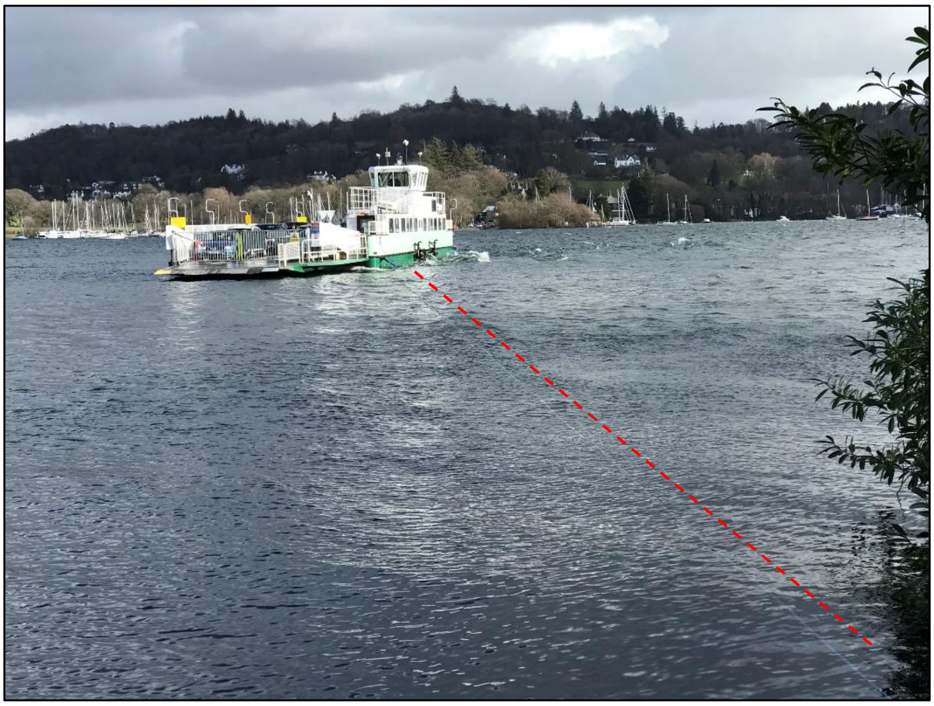
7.1 Introduction

The current ferry has several issues that reduce her ability to maintain the service, either due to issues with the drive cable, or limits on her ability to operate in more extreme environmental conditions. These issues are described below and it is a requirement to address these issues with the new ferry.

7.2 Drive Cable Issues

The current ferry experiences ongoing issues related to her drive cables leading to their premature failure and replacement and one of the requirements for the new ferry is to resolve this issue and increase the service life of the drive cables.

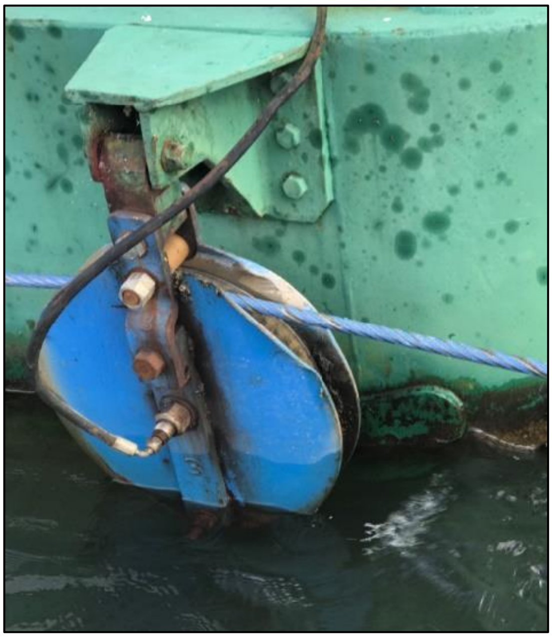
The high rate of wear leading to their premature failure of the cables is considered to be due to a several factors related to Mallard's design. The most significant of these is that there is no independent control of the drive wheels on each side of the vessel, so there is no ability to adjust the orientation of the ferry relative to the drive cables. As a result, there is no ability to control the yaw angle of the ferry as it crosses the lake and at times the ferry crosses almost diagonally to the direction of travel. This is shown below.



Mallard crossing at a high yaw angle (Ref. F), the cable is highlighted for clarity

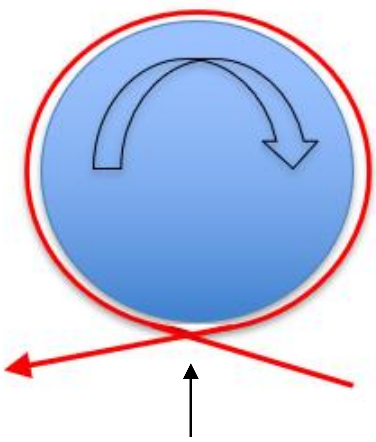
The high yaw angle increases the power required to propel the ferry but also results in increased cable wear and increases the difficulty of aligning the ferry with the slipways. The inability on the current ferry to control the two drive wheels independently prevents any adjustment of the ferry relative to the cables to compensate for this, and the solution on the new ferry is the ability to operate the drive wheels independently from the other and thereby correct the yaw angle whenever required.

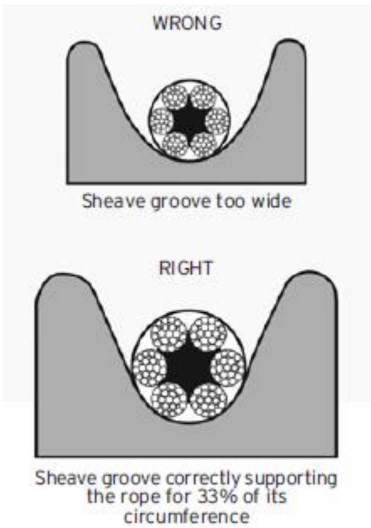
The high yaw angle sometimes experienced by the current ferry increases cable wear because there is insufficient articulation of the cable guide wheels fitted at each of the four corners of the ferry to allow for such a high yaw angle. The four guide wheels are hinged to swing inboard and outboard, but they have more limited articulation inboard. This results in the cable wearing against the drive wheel cheek plates when the ferry is at high yaw angles, as illustrated below.



Mallard's cable guide wheels showing adequate articulation outboard (left), but inadequate articulation inboard leading to the drive cable wearing against the cheek plates (right)

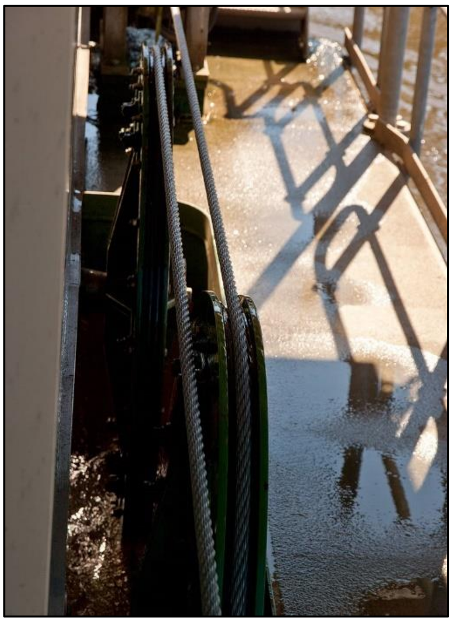
There is also another contributor to the premature wear of the drive cables, the arrangement and design of the drive wheels on Mallard. As previously mentioned, Mallard is fitted with a single drive wheel on each side of the vessel and the cable is wrapped around the entire circumference of the drive wheel and overlaps at the bottom of the drive wheel. This arrangement results in the cable rubbing overt itself as it overlaps at the bottom of the drive wheel, and to accommodate the two overlapping cables the groove in the drive wheel is larger than it would ideally be to support the cable correctly. These aspects are illustrated below.

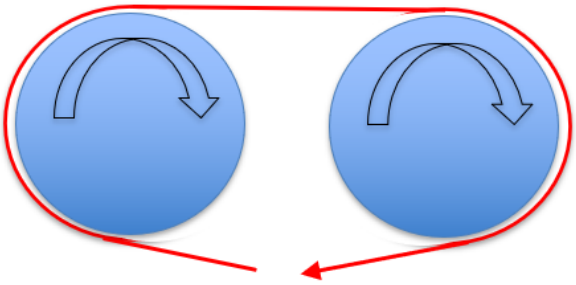




Mallard's single drive wheel results in the cable rubbing over itself where it overlaps at the bottom of the wheel (left) and to accommodate the overlapping cable the groove is larger than ideal to support the cable correctly (right) (Ref. H).

To avoid these issues some cable ferries are fitted with a pair of drive wheels on each side of the vessel that are deliberately misaligned by a small amount to enable the cable to wrap around half the circumference of both wheels and then pass forward and aft without rubbing over itself, and the groove of the drive wheels can be of the optimum size and shape to support the cable.





Deliberate misalignment of drive wheels means that the cable does not rub over itself

The twin drive wheel arrangement of some other cable ferries (Ref. I, left)

There are several issues that contribute to the premature wear and reduced service life of the current drive cables, and all are linked to the design of the ferry itself. To avoid these issues the new ferry must have twin drive wheels on each side configured correctly to avoid cable wear, the ability to operate the drive wheels on each side independently of the other, and cable guide wheels that can hinge fully inboard and outboard. Detailed design of the cable drive system will form part of a future phase of the project but all these measures in combination will reduce cable wear and increase its service life.

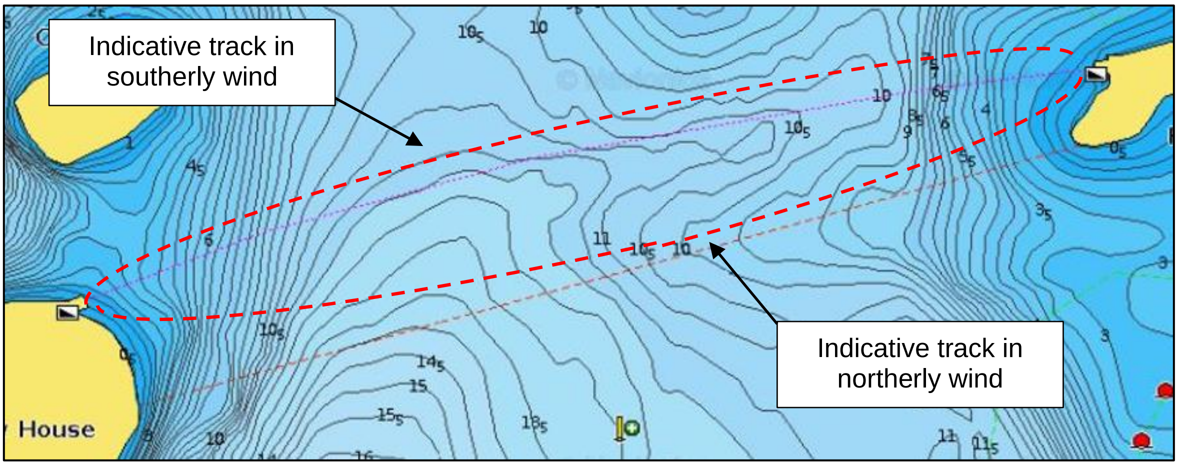
It is understood that in recent years, drive cables with a plastic coating have been used and the reason for this is unclear. It is inevitable that this plastic coating will wear and break down at some point even without the accelerated wear currently experienced. As the reason for adopting the plastic coating is unclear and as the plastic debris all falls into the lake it is recommended that uncoated cables are used in the future, including with the new ferry.

It is possible that the new ferry will require or benefit from larger drive cables than the 19mm diameter wire cables currently employed, and this will be addressed in the next phase of the project.

7.3 Operation in Higher Wind Speeds

The current ferry is unable to operate in wind speeds above about 25mph (11m/s or Beaufort Force 5) and that wind from the north is more of an issue than from the south. A Beaufort Force 5 is defined as a fresh breeze.

The wind speed operating limit is due to the wind pushing the ferry either north or south of her "nominal" track (her track on a still day). To load and unload, the ramp and hence the ferry must be aligned relatively closely (within around 10 degrees) of the slipway. At any greater angle there is a step between the ramp and the slipway that prevents cars from loading or unloading. As the current ferry cannot operate the two drive wheels independently there is no means of adjusting the ferry's alignment to the cables or to the slipway and a fresh breeze from the north or the south pushes the ferry out of alignment with the slipways.



Indicative track of the ferry in north and south winds (chart image from Ref. G)

The new ferry will be larger than Mallard and hence will have a larger transverse profile area so the wind force pushing her off track for a given wind speed will be greater, but the new ferry will have independent operation of the drive wheels on each side of the vessel and so will be able to adjust her alignment to the cables and hence to the slipway.

The cable tension is also a factor and there is no reliable means of assessing the tension in the cables or of the impact of changes in tension on ferry operation. This issue will be addressed in the next phase of the project.

7.4 Operation in Reduced Visibility

The current ferry has limited ability to operate in conditions of reduced visibility due to mist or fog. The current ferry has no radar fitted so maintaining a lookout is visual only. It is planned to install a radar on the current ferry as a trial to see if it enables the operating limit of the ferry in reduced visibility to be extended.

7.5 Operation at Higher Lake Water Levels

Lake Windermere experiences changes in water level due to the rainfall within the catchment area of the lake. There is a monitoring station at Far Sawrey close to the west slipway and the usual range is between 0.23m and 1.00m, over the last 12 months the range has been between 0.26m and 1.22m, and the highest ever recorded level was 2.90m in 2009 (Ref. M).

At the end of October 2021, the level rose to 2.1m which results in the overtopping of the brow of the slipways and local flooding of the road adjacent to the slipways, as shown below.

The Ferry House (west) slipway with the lake water level at 2.1m (from Ref. N)

The Ferry Nab (east) slipway with the water level at approximately 2.1m (from Ref. O)

The current ferry cannot operate when the water level is so high that the ramp cannot land onto the inclined surface of the slipways. The length of the two ramps and limits to their downward declivity mean that they cannot be landed onto the brow of the slipway, they can only be landed on the inclined section of the slipway.

Based on a review of the lake water levels (Ref. M) and the Windermere Ferry Twitter feed (Ref. O) for 2021, the water level at which the current ferry can no longer operate is approximately 1.3m. From Ref. M, the water level has exceeded 1.3m on 22 occasions in the last 8 years, including at the end of October 2021.

To increase the operating envelope of the new ferry it is planned to increase the length of the ramps and to increase the angle to which they can be lowered with the aim of being able to land the ramps onto the brow of the slipways. This design work will be carried out with the accurate geometry of the slipways to ensure that grounding clearances are increased and maximised over those of the current ferry.

The hydrographic and topographic survey of the lakebed and slipways will reveal the height of the approach roads to the slipways as well as the heights and geometry of the slipways themselves, recognising that the two slipways have different geometry. The approach road to the Ferry House (west) slipway is estimated to be at a height of approximately 1.9m and the Ferry Nab (east) slipway approach road at approximately 1.8m and it may be possible for the new ferry with improved ramp design to operate at lake levels up to around 1.6m.

From Ref. M, the water level has exceeded 1.6m on five occasions in the last 8 years, including at the end of October 2021. If it is required to operate the ferry at water levels higher than this, then the height of the slipway approach roads will need to be increased and the slipways modified.

7.6 Summary

This review of the issues that limit the operation of the current ferry has shown that as well as being electrically powered and having greater capacity and improved facilities, the design of the new ferry must also address the issues that limit the current ferry's operation, reduce its reliability, and increase its operating costs.

8. CONCEPT DESIGN OF THE NEW FERRY

8.1 Introduction

The driving factor for the design of the new ferry is the vehicle capacity. Mallard can carry up to 18 cars but as car sizes have increased since Mallard was designed, more usually she can accommodate between 10 and 15 modern cars. As well as the number of cars to be carried it is also a requirement to increase the space between the cars to ensure that in the event of an emergency all car passengers, whether able bodied or those with restricted mobility, can be evacuated from their cars and from the ferry.

The number of cars and the space required between them determines the size of the vehicle deck of the ferry and then additional deck space is required for the passenger saloon and other facilities for the passengers and crew. The design of the new ferry was developed in this manner to concept design level, and it was this concept design that was issued to several shipbuilders to obtain preliminary proposals and budgetary pricing for the detailed design and build of the new ferry. The design process is summarised below.

8.2 Vehicle Deck Arrangement

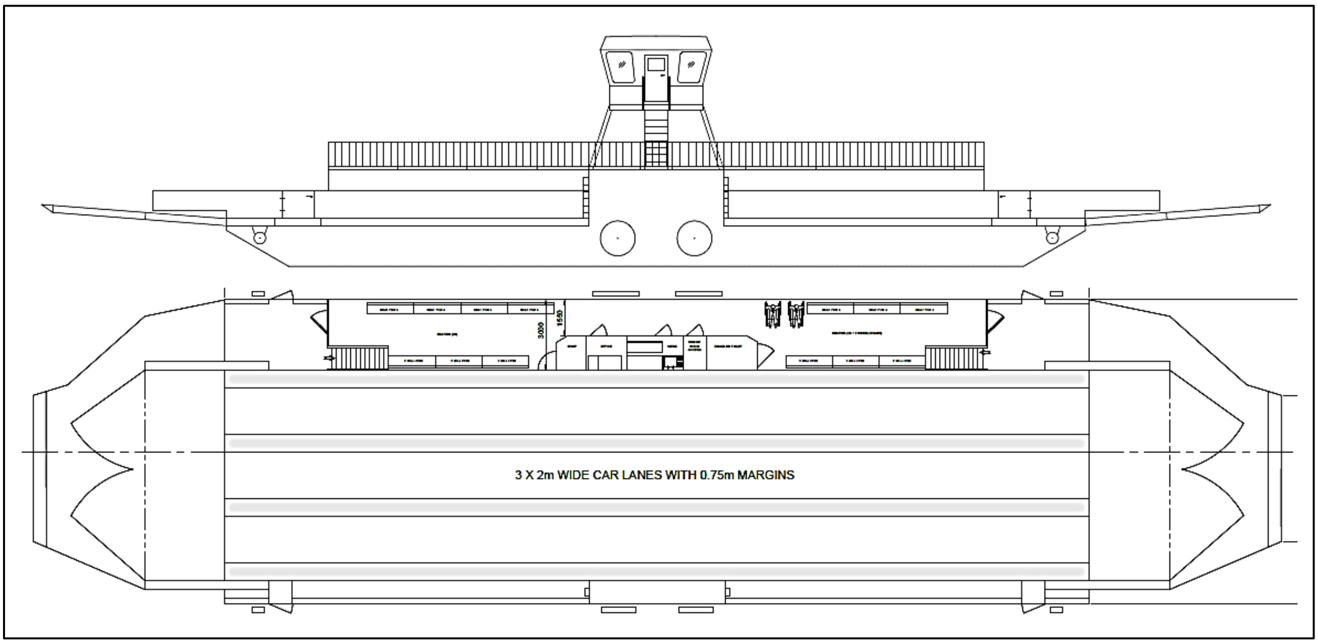
Mallard was designed to carry up to 18 cars but as car sizes have increased over the 30 years since Mallard was designed, more usually she can accommodate between 10 and 15 modern cars. A key issue that affects the car capacity is the space available between each car to open car doors and allow drivers and passengers to be evacuated from their cars and from the ferry in an emergency.

The requirements (Annex A) specified a target of 21 cars and at least 18 cars for the new ferry. To determine the appropriate vehicle deck size to accommodate these numbers of cars, a study was carried out of modern car sizes and some recent small car ferry designs. Please refer to Annex C for details.

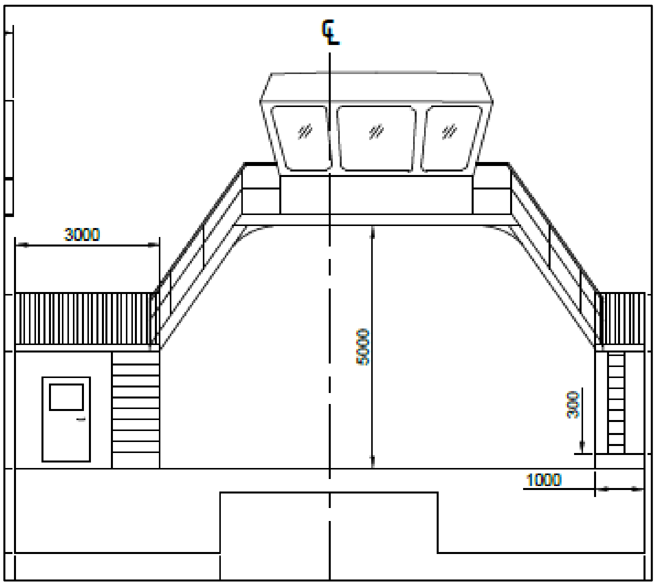
In summary, a space of 5m long and 2m wide was adopted for each car, reflecting the size of the largest modern cars, and a space of 0.75m allocated between each row of cars and between the outer rows and the structure and fittings of the ferry to allow access to/from all cars in an emergency. Adopting these car sizes for the new ferry will provide a good degree of future proofing the design against further increases in the average car size over its 30+ year service life.

8.3 General Arrangement

The concept general arrangement of the new ferry is shown below.



Concept general arrangement of the new ferry



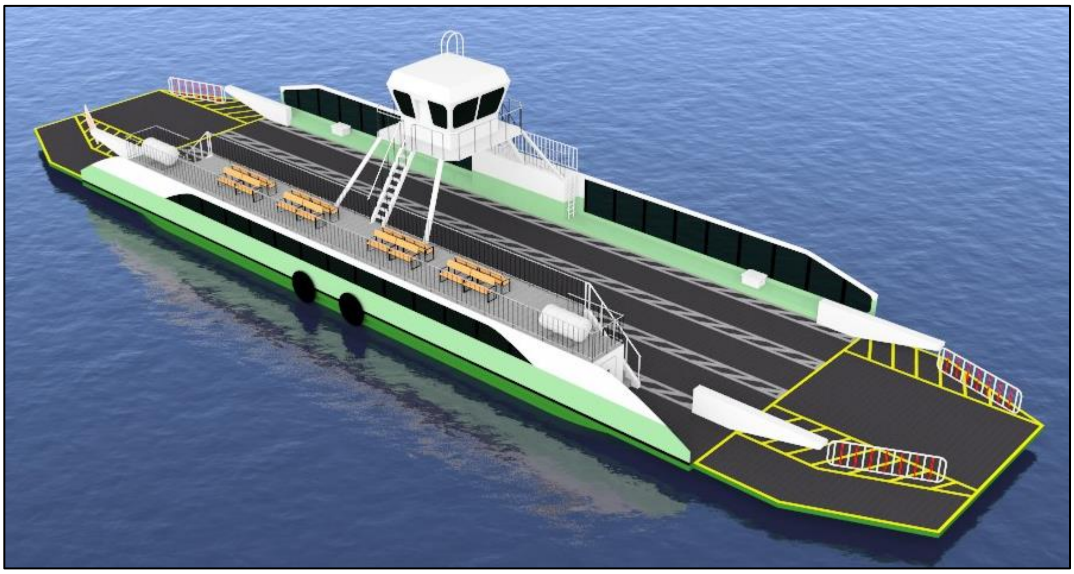
Transverse section showing the wheelhouse on a bridge over the vehicle deck

The table below compares the approximate principal dimensions of Mallard and the new ferry.

	Mallard	New ferry	Increase
Length Overall	42.9m	55.0m	28%
Length of Hull	26.5m	37.0m	40%
Beam Overall	10.6m	13.5m	27%
Beam of Hull	9.8m	13.0m	33%
Depth of Hull	1.26m	1.75m	39%

Comparison of Mallard's and the new ferry's approximate dimensions

Images of the concept design of the new ferry are shown below.



Perspective view of the South side

Perspective view of the North side

Waterline view of the South side

9. ELECTRIC PROPULSION

9.1 Introduction

Cumbria County Council specified that the new ferry should be powered by electricity and that Electricity Northwest Limited is providing a new power supply to the Ferry Nab (east) slipway to supply the new ferry.

Electric propulsion technology for smaller ferries is now well proven with many electrically powered small car ferries in operation especially in Scandinavia. The world's first fully electric car ferry has been in service in Norway since 2015 and an electric ferry in Denmark currently serves the longest route with a 22 nautical mile crossing. These ferries are entirely battery electric and have no onboard charging capability or hybrid propulsion system. Operating experience reports their safety, reliability, reduced operating and maintenance costs, and low noise and vibration of electric ferries.

The 80m car ferry Ampere entered service in Norway in 2015 and carries 120 cars on a 20-minute crossing 34 times a day

The 60m car ferry Ellen entered service in 2019 and carries 31 cars on a 22nm crossing in Denmark

The examples of electric ferries shown above are free-running ferries rather than cable or chain ferries, but several electrically powered cable-driven car ferries are in operation in Sweden. These are illustrated later in this report.

The starting point in the assessment of electric propulsion options is to estimate the power requirements for the new ferry and this is addressed in the following section.

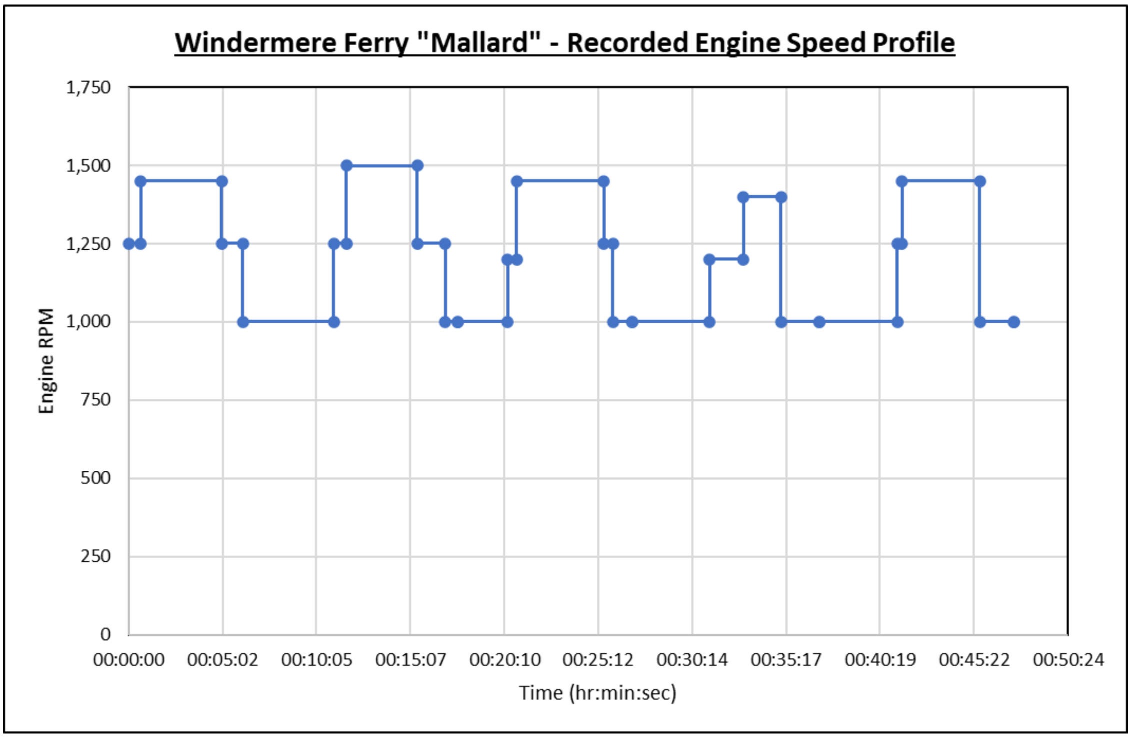
9.2 Power Requirements for the New Ferry

9.2.1 General

With a battery-operated electric ferry all the power required, both for propulsion and for the services onboard (auxiliary machinery, lighting, heating, etc.) must come from the onboard batteries, whether these are charged only overnight or also during the day. The propulsive power required for the new ferry was estimated by assessing Mallard's power requirements and by reference to other chain and cable ferries, supported by in-house performance prediction analysis.

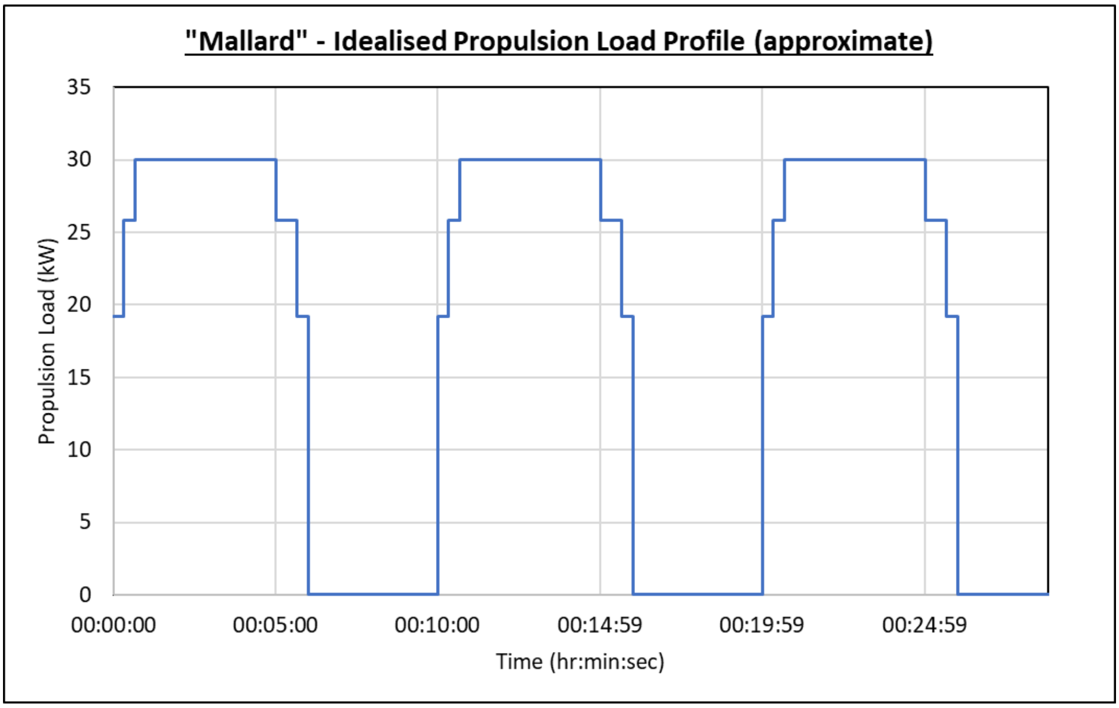
9.2.2 Mallard's Propulsive Power

The timetable of the Windermere ferry indicates the ferry departing each slipway at 10-minute intervals. The 10-minute crossing cycle includes a crossing time of approximately 6.5 minutes and an unloading/loading time of 3.5 minutes. To estimate the propulsive power required for each crossing the engine speed (RPM) profile was monitored over several crossing cycles. The results are shown in the figure below.



Mallard's engine speed profile recorded over five typical crossing cycles

Mallard is fitted with two 64kW diesel engines, only one of which is running at a time. The running diesel engine drives a hydraulic pump that in turn drives a hydraulic motor that via a gearbox drives the shaft that is connected to the drive wheels on each side of the ferry. The configuration of Mallard's propulsion machinery combined with the limited instrumentation of her dated engines makes it difficult to assess her propulsion power requirements accurately, but this has been done by converting the engine speed (rpm) to engine power using the power/rpm curves for the engine. The resulting approximate idealised propulsion load profile for Mallard is shown below.



Mallard's idealised propulsion load profile over three crossing cycles

9.2.3 The New Ferry's Propulsive Power

The propulsive power required for the new ferry was estimated by reference to the current ferry and to other chain and cable ferries including two of the grid-connected ferries operated by the Swedish Highways Agency (see below) and a maximum propulsive power of 45kW was estimated for the new ferry.

9.2.4 New Ferry's Services Power

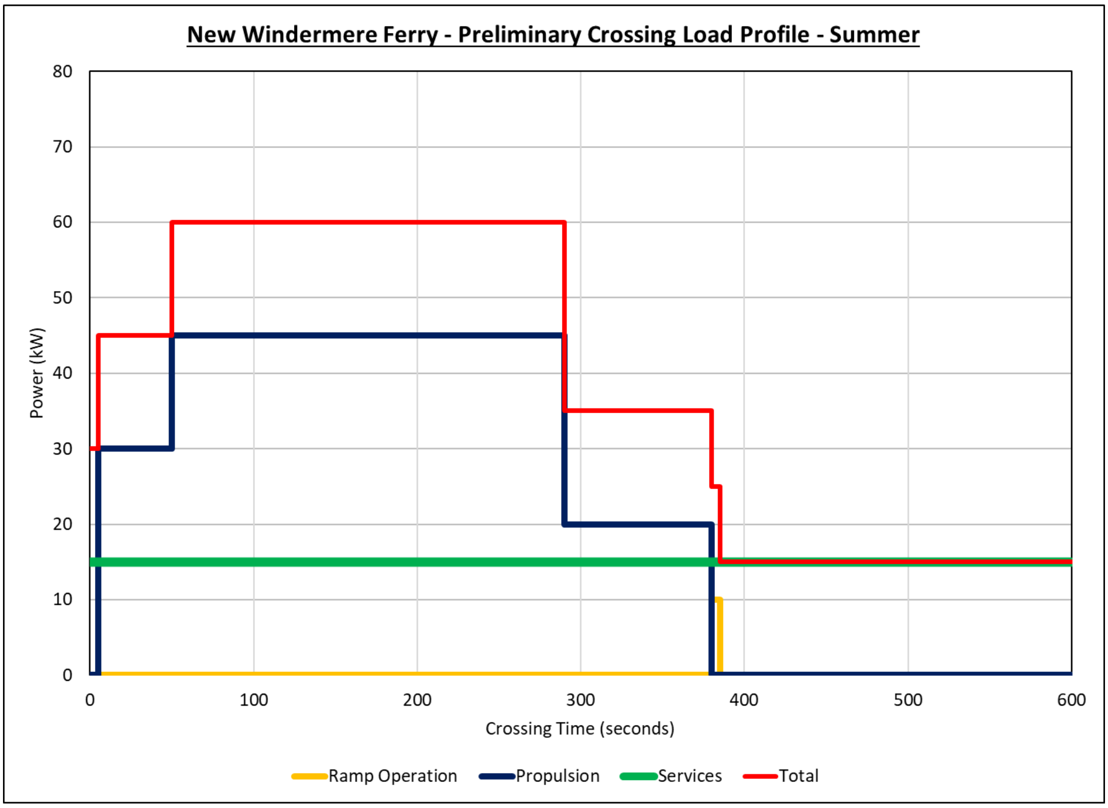
The service load of the new ferry was estimated by identifying the likely number and power rating of the auxiliary machinery, lighting, heating, communication equipment, etc. and carrying out an electrical load analysis. By this method the summer and winter service loads were estimated. While the propulsive power is largely the same throughout the year, the service load is greater in the winter due to the heating in the passenger saloon, wheelhouse, and other occupied compartments as well as the greater use of windscreen wipers and lighting.

It was estimated that the summer service load would be approximately 15 kW and the winter service load approximately 30kW. These figures were adopted and added to the propulsive power and ramp operation load to estimate the total electrical load of the new ferry.

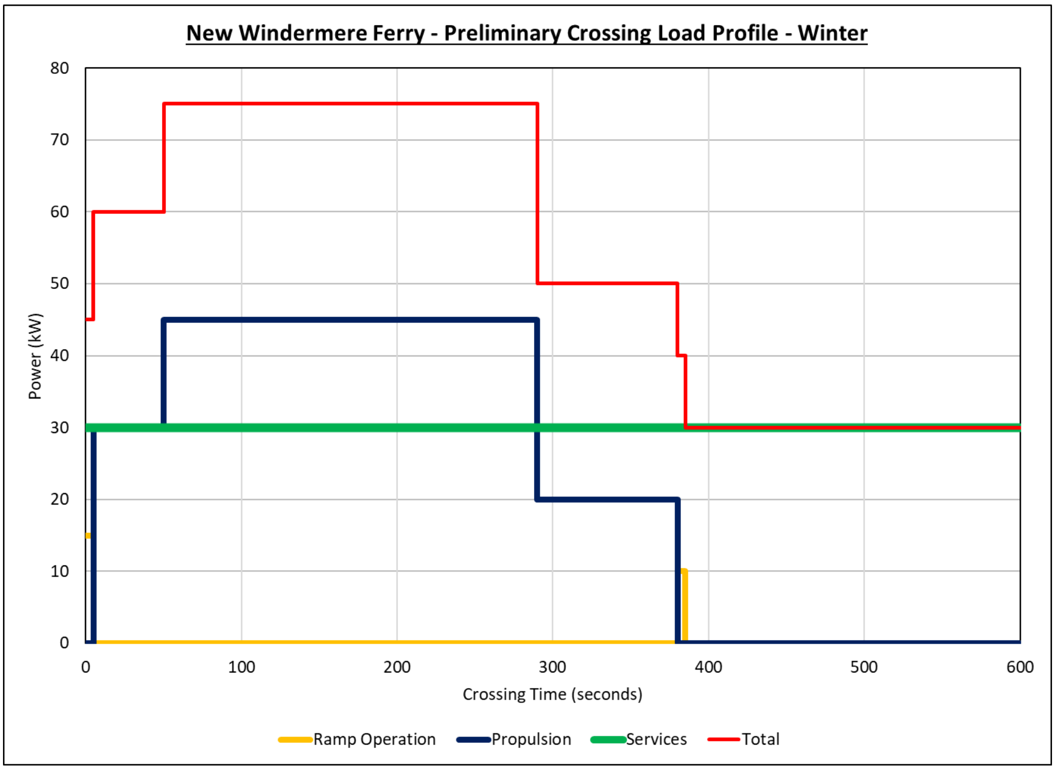
In addition, the power needed to operate the ramps was estimated as 10kW.

9.2.5 New Ferry's Total Power Requirements

With the loads estimated above, the two figures below show the estimated power requirements for the new ferry for Summer (top) and Winter (bottom) plotted for one 10-minute (600 second) crossing and unloading/loading cycle.



New ferry preliminary load profile for one crossing cycle in summer



New ferry preliminary load profile for one crossing cycle in winter

These plots show the variation in propulsive power, the very short duration of ramp operation, and the constant service load over one crossing and unloading/loading cycle. By multiplying the power of each function (propulsive, ramp or services) by its duration the total power requirement of one crossing cycle and hence for the total daily number of crossings can be determined. This is shown in the table below. As well as the services power differing from summer to winter, the scheduled number of daily crossings also changes (92 in the summer, 86 in the winter) and this is reflected in the calculation.

IDEALISED CYCLE - SUMMER

Time (sec)	Duration (sec)	OPERATION	RAMP OP. (kW)	PROP-ULSION (kW)	SERVICES (kW)	TOTAL (kW)	RAMP OP. (kWh)	PROP-ULSION (kWh)	SERVICES (kWh)	TOTAL (kWh)	NO. CROSS'GS (Summer)	TOTAL (kWh)
0	5	Lift Ramp	15	0	10	**25**	0.02	0.00	0.01	**0.03**		
5	45	Accelerate	0	30	10	**40**	0.00	0.38	0.13	**0.50**		
50	240	Constant Speed	0	45	10	**55**	0.00	3.00	0.67	**3.67**		
290	90	Decelerate	0	20	10	**30**	0.00	0.50	0.25	**0.75**		
380	5	Lower Ramp	10	0	10	**20**	0.01	0.00	0.01	**0.03**		
385	215	Unload	0	0	10	**10**	0.00	0.00	0.60	**0.60**		
600	**600**						0.03	3.88	1.67	**5.58**	**92**	**513**

IDEALISED CYCLE - WINTER

Time (sec)	Duration (sec)	OPERATION	RAMP OP. (kW)	PROP-ULSION (kW)	SERVICES (kW)	TOTAL (kW)	RAMP OP. (kWh)	PROP-ULSION (kWh)	SERVICES (kWh)	TOTAL (kWh)	NO. CROSS'GS (Winter)	TOTAL (kWh)
0	5	Lift Ramp	15	0	30	**45**	0.02	0.00	0.04	**0.06**		
5	45	Accelerate	0	30	30	**60**	0.00	0.38	0.38	**0.75**		
50	240	Constant Speed	0	45	30	**75**	0.00	3.00	2.00	**5.00**		
290	90	Decelerate	0	20	30	**50**	0.00	0.50	0.75	**1.25**		
380	5	Lower Ramp	10	0	30	**40**	0.01	0.00	0.04	**0.06**		
385	215	Unload	0	0	30	**30**	0.00	0.00	1.79	**1.79**		
600	**600**						0.03	3.88	5.00	**8.91**	**86**	**766**

Single crossing and daily power requirements for new ferry in summer and winter

In summary, the new ferry is estimated to have daily power requirement of 513 kWh in the summer and 766 kWh in the winter. For a battery-operated electric ferry that is only charged while it is out of service overnight, the onboard batteries must be able to provide this much power. In other words, when the ferry starts operation in the morning, she must have enough power onboard in her batteries to last the entire day of operation. As the batteries must deliver the service throughout the whole year the batteries must be sized to meet the daily load in winter. Battery sizing is addressed in a subsequent section of this report.

9.3 Power Supply to the New Ferry

Electrical power to the new ferry will be provided by a new power supply that Electricity Northwest Limited (ENWL) is providing to the Ferry Nab (east) slipway. Discussions have been held with representatives of ENWL the key points of which are recorded in Annex E. In summary:

- ENWL will be installing a 2 MVA, 11 kVA,3 phase, 50 Hz supply to the east slipway (location TBD). The supply will not be a secure supply (it will have no back feed), so in the event of a failure the supply will be off.
- Overnight load on this supply (ie. for battery charging) is no issue, daytime is the greater challenge but considering the low power requirements for the new ferry this is not believed to be an issue.
- ENWL preference is not to have a submarine cable to supply the west slipway (it would be expensive, may be vulnerable to damage, and slow to repair).

As part of the development and assessment of options for electric propulsion, the daily electrical load profiles of the new ferry have been estimated. The ferry load profiles allow the resultant profile of the electrical load on the grid to be estimated for each of the options considered. These grid load profiles are shown in Annex F and have been issued to ENWL for assessment.

9.4 New Ferry Electric Propulsion Options

Several potential options for the electric propulsion of the new ferry have been identified and each of these has been developed and its feasibility, advantages and drawbacks, risks and budgetary costs identified and assessed. Three primary options were identified, as follows.

1) **Battery Powered** – the electric cable drive machinery is installed on the ferry and powered by batteries on the ferry that are charged overnight and possibly at one slipway.

2) **Grid Connected** - the electric cable drive machinery is installed on the ferry and powered via a power cable that permanently connects the ferry to the grid.

3) **Shore-Mounted Winches** – there will be no propulsion machinery installed on the ferry and the ferry will be pulled across the lake by electric winches mounted next to each slipway.

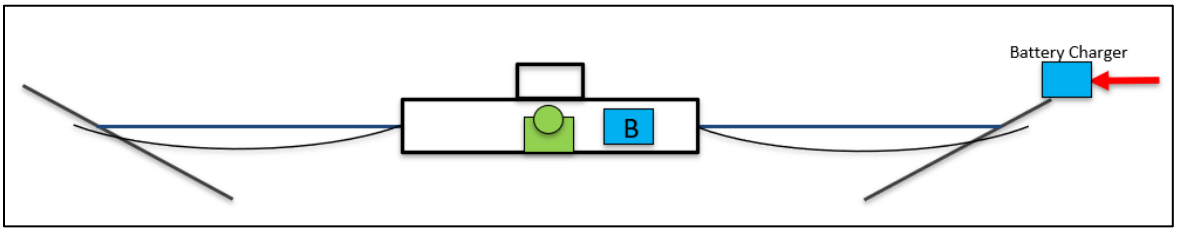
Each of these options are developed and assessed in the following sections.

9.1 Battery Powered Electric Propulsion

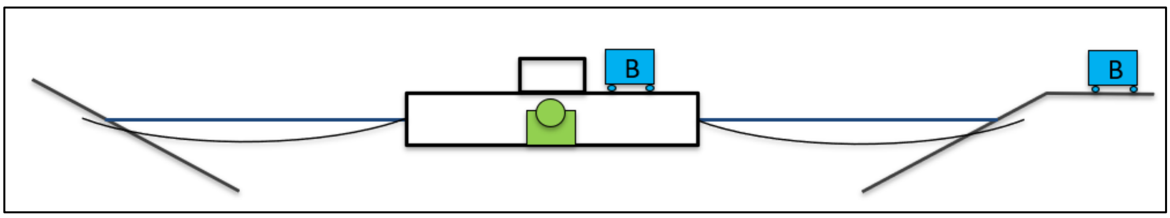
9.1.1 General

In the same way as an electric car, a battery-operated electric ferry has an onboard battery bank that can be charged more slowly overnight when the ferry is not being used, and if required during the day ideally using a fast charge.

Two options were considered for the new ferry, an installed battery pack of the total capacity required for a day's service, and two portable battery packs each of half of the capacity required for a day's service. These options are shown schematically in the figures below.



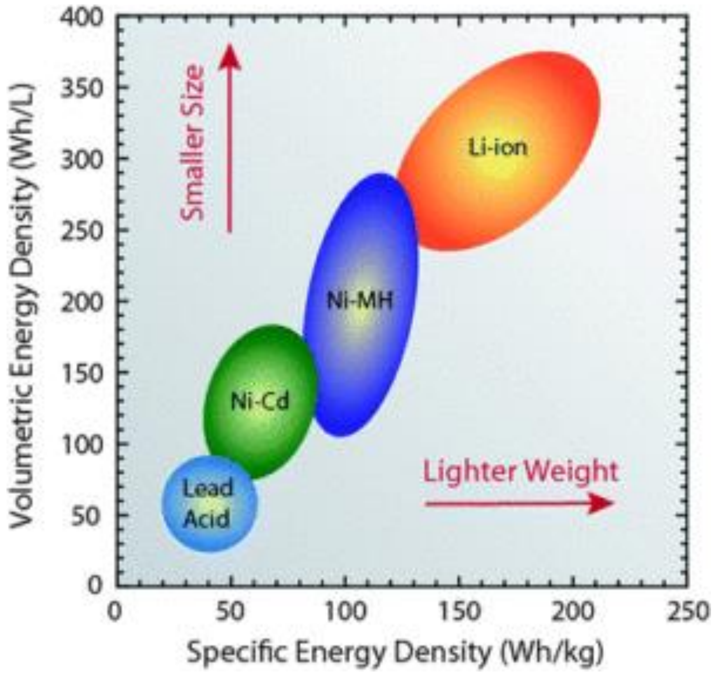
Option 1A – Installed Battery Bank



Option 1B - Portable Battery Bank

9.1.2 Battery Specification

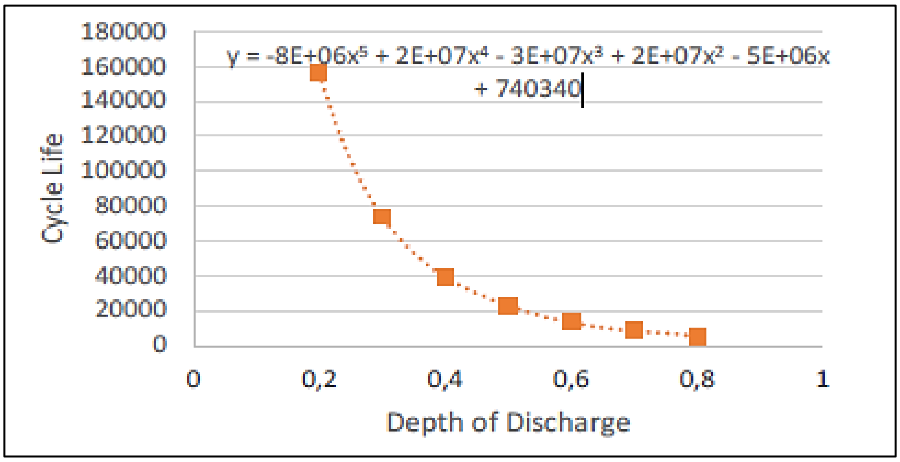
As with current electric cars, batteries for ferries are currently based on Lithium-Ion battery technology as this provides the highest power density (kWh per kg of battery weight and kWh per unit volume). The figure below illustrates the volumetric and weight power densities of four battery technologies. Packaged Lithium-Ion batteries for ships typically have a power density of around 120 Wh/kg (or 0.12 kWh/kg).



Power densities of four battery technologies

Battery technologies with higher power densities, such as Aluminium-Air and Lithium-Sulphur, are being developed but are not expected to be commercially available for several years.

The nature of Lithium-Ion batteries is such that the battery life (the number of charge/discharge cycles) is directly related to how much the battery is discharged (the depth of discharge) during each cycle. This is illustrated in the figure below. In this example, if the depth of discharge is only 20% (0.2) the battery life will be around seven times longer than if the depth of discharge is 50%.



Indicative Lithium-Ion battery life against depth of discharge

Manufacturers of Lithium-Ion batteries for ferries typically recommend that the depth of discharge is no more than around 65% with an optimum charge range of between 25% and 90%, ie. the batteries should not be discharged less than 25% of their capacity or charged more than 90%. This means that the vessel must be fitted with a battery capacity that is some 50% greater than the energy required for operation.

In addition, Lithium-Ion batteries deteriorate over time and lose capacity at a rate of approximately 1% per year. So, to deliver the required energy after say 10 years of service the ferry as new will have to be fitted with batteries that have a capacity approximately 10% higher than required.

The combination of the limited depth of discharge and battery aging means that the ferry must be fitted with batteries of approximately 70% (1/(0.65 x 0.9)) more capacity than required for the daily operation when the batteries are new. Although this is a significant but unavoidable penalty, the 25% unused capacity at the bottom of the battery's charge does provide a very significant reserve of power which may be used in the event of, for example, a grid power cut that means the ferry cannot be recharged.

The new Windermere ferry has an estimated daily power requirement of 513 kWh in the summer and 766 kWh in the winter, and hence the batteries must be sized to meet the daily load in winter.

Assuming overnight charging only, to deliver a daily power requirement of 766 kWh after 10 years of service and with an allowable depth of discharge requires a battery capacity of approximately 1,300 kWh to be installed.

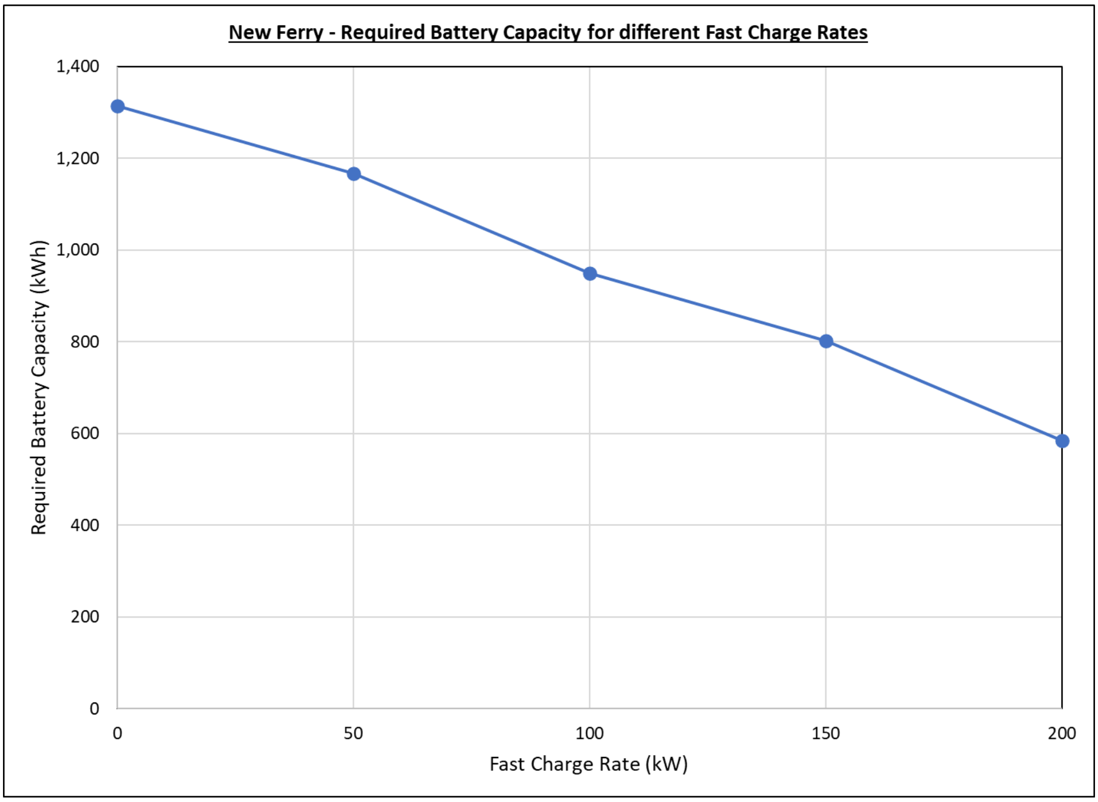
Lithium-Ion batteries are heavy and expensive, and batteries totalling 1,300 kWh will weigh nearly 8 tonnes, occupy a space of 14 cubic metres and cost approaching £600,000 (at 2022 prices).

In addition, for best performance Lithium-Ion batteries must be maintained at around 20˚C and so are expected to require heating in the winter and cooling in the summer. To meet applicable safety standards batteries must be enclosed in a fire-rated compartment with fixed fire detection and suppression systems. The size, weight and cost of these facilities will be related to the size of the battery bank and in addition to the size, weight, and cost of the batteries themselves. The manufacture of the batteries and their associated systems also has an environmental impact and for all these reasons it is clearly desirable to minimise the battery capacity.

To achieve this, as well as being charged when out of service overnight many electric ferries also receive a "fast charge" when docked at one or both ends of their crossing. This fast charge may only be for only a few minutes while unloading/loading but for ferries with many crossings per day these fast charges can significantly reduce the battery capacity required.

The Windermere ferry makes 92 crossings per day in the summer and 86 in the winter and on each crossing cycle spends around 3.5 minutes at each slipway. There is no plan to install a power supply to the Ferry House (west) slipway so a fast charge would only be available at the Ferry Nab (east) slipway. Taking the lower (winter) number of crossings this would provide the opportunity for 43 fast charges during the day's operation.

The impact of this number of fast charges on the required battery capacity depends upon the charge rate available for the fast charge, the higher the charge rate the smaller the installed battery capacity can be. This is illustrated in the figure below for fast charge rates of zero (ie. no fast charge) to 200 kW.



Required battery capacity for different fast charge rates for the new ferry, based on 43 fast charges each of 3.5 minutes duration

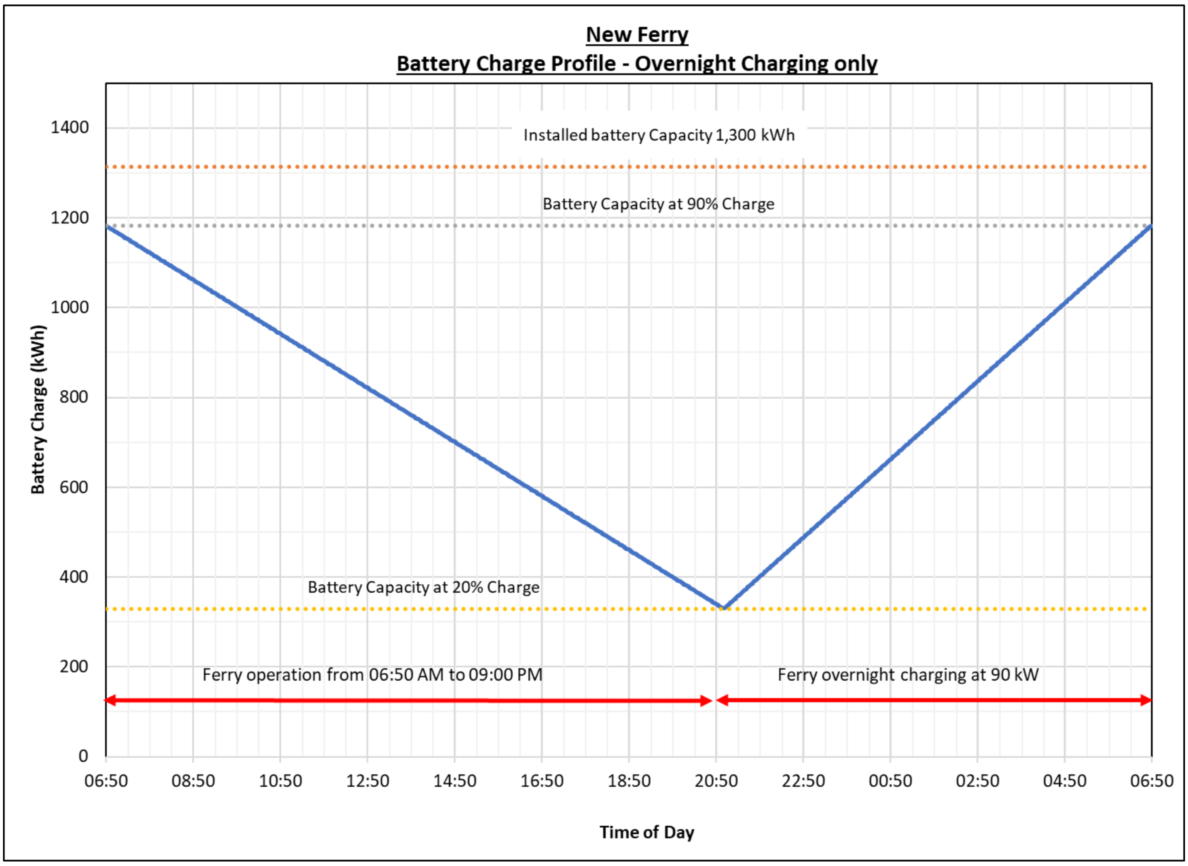
The figure above shows that the battery capacity can be reduced from 1,300 kWh if there is no fast charging, to 600 kWh with a fast charge rate of 200 kW. A charge rate of 200 kW is very modest for a ferry, some larger ferries have fast charge rates of up to 4 MW (4,000 kW). It should also be remembered that many electric vehicle chargers are rated at 150 kW.

The table below shows the indicative battery specifications and costs for three scenarios: overnight charging only, and overnight charging plus fast charges of 100 and 200 kW. This is for winter operation. In the summer the ferry operates for an additional hour and hence has one less hour for charging overnight.

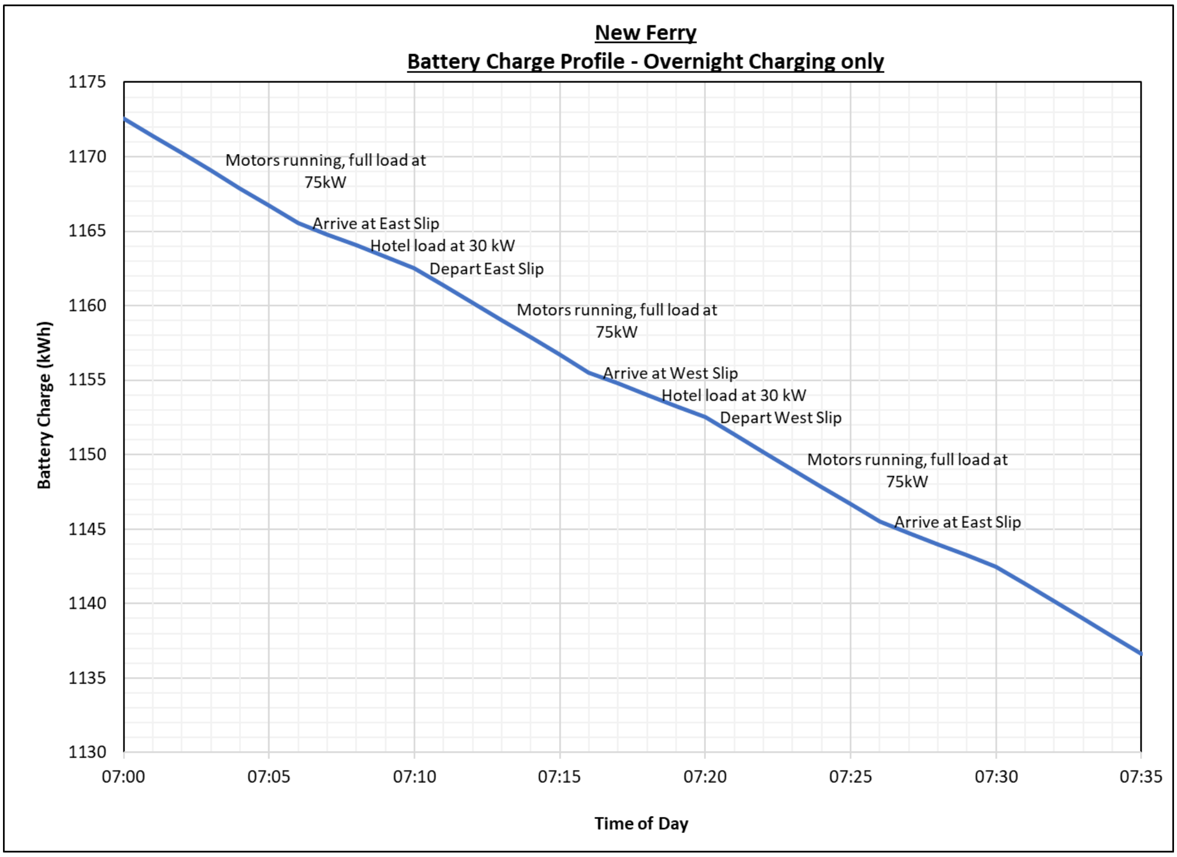
Overnight charging duration	9.5 hours	9.5 hours	9.5 hours
Overnight charging rate	90 kW	70 kW	50 kW
Number of Fast Charges per Day	0	43	43
Duration of each fast charge	0	3 mins	3 mins
Fast Charge Rate	0 kW	100 kW	200 kW
Installed battery capacity	1,300 kW	1,000 kW	650 kW
Installed battery weight	7.8 tonnes	6.1 tonnes	3.9 tonnes
Indicative battery cost (2022)	£560k	£450k	£280k

Indicative battery parameters for new ferry with different charging scenarios (winter)

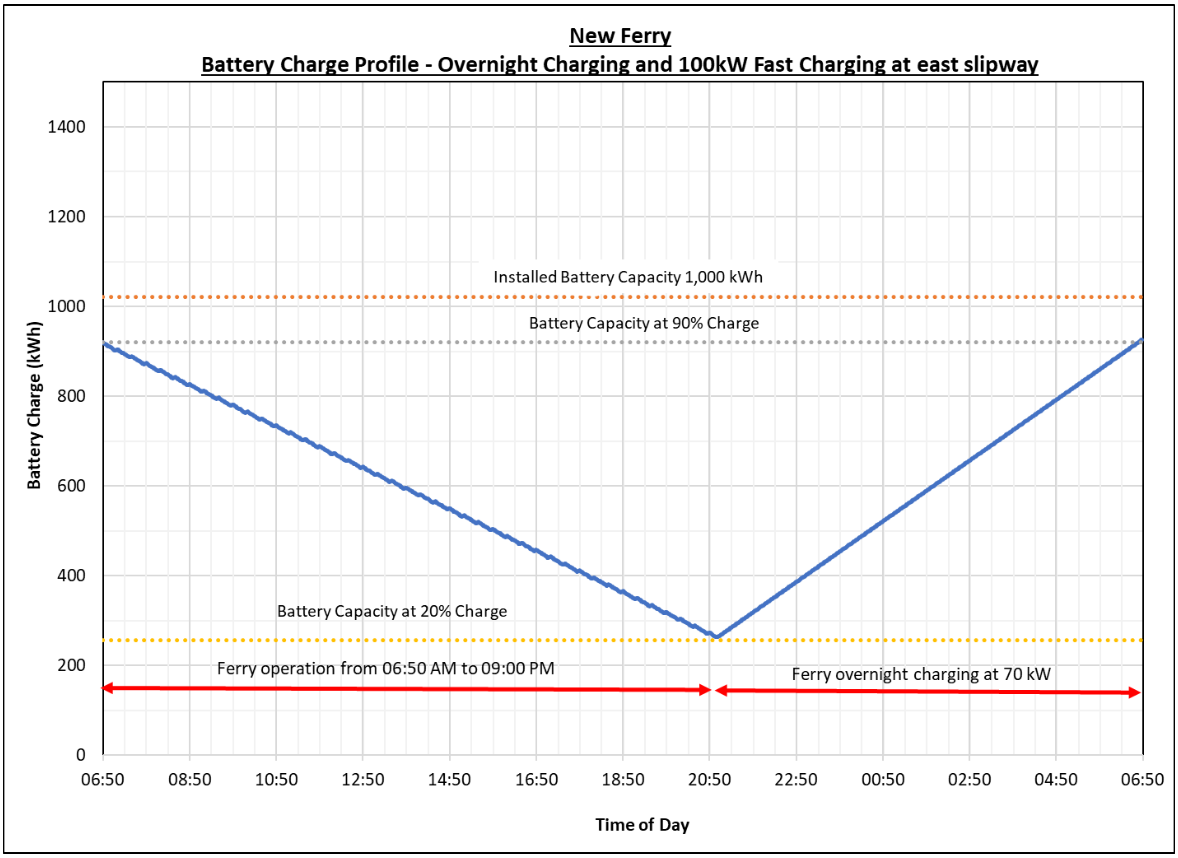
The figures below illustrate the daily battery charge cycle for the three charging scenarios shown in the table above. They are shown at the same scale to illustrate the difference in installed battery capacity. The variation in power consumption, and for the second and third scenarios the fast charge, of each crossing cycle can be seen in the close-up view.



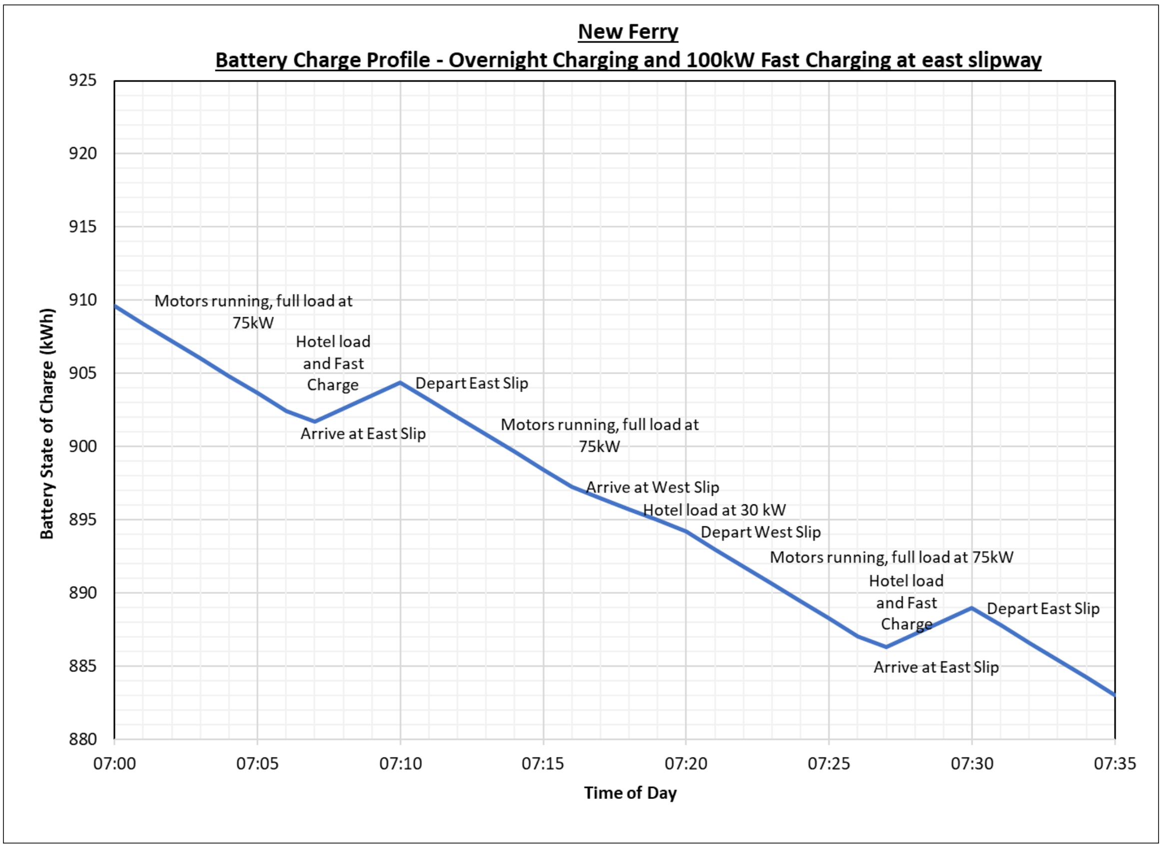
Daily battery charge cycle for overnight charging only (24-hour period)



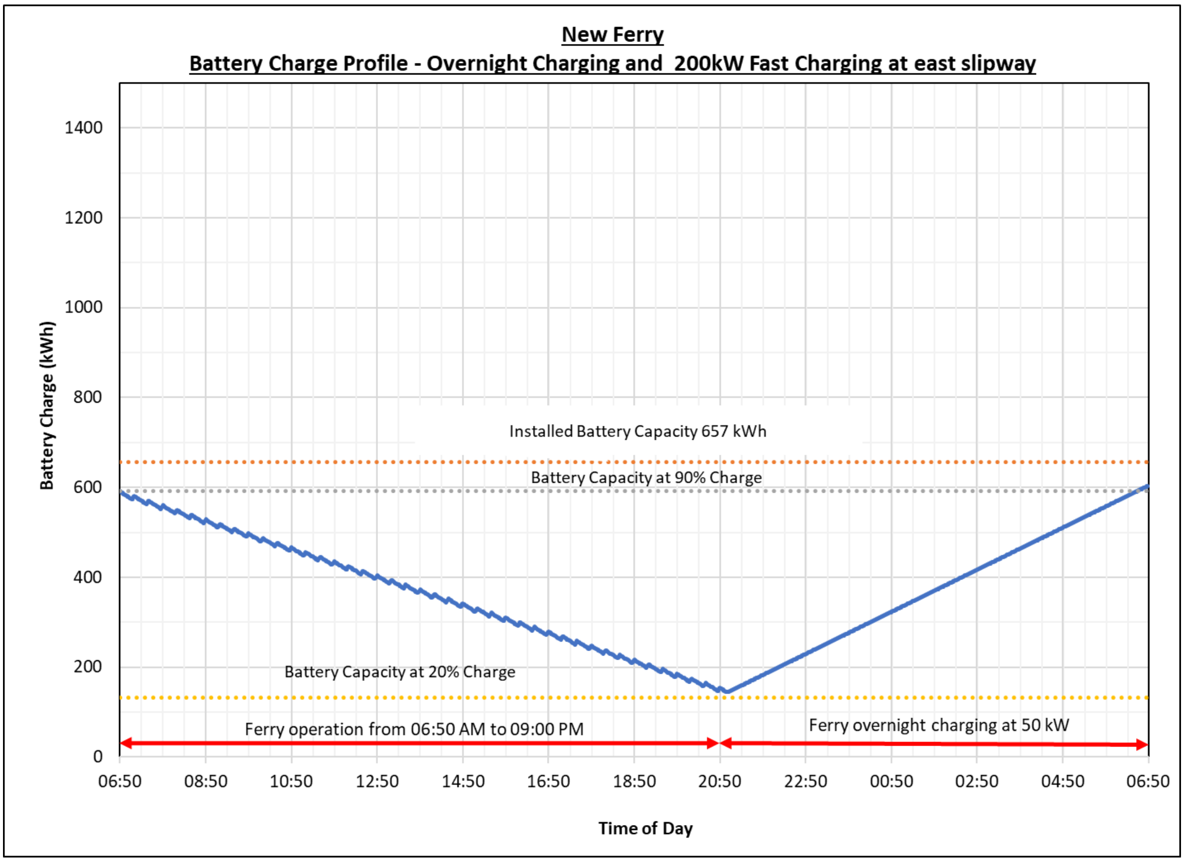
Battery charge cycle for overnight charging only (detailed view)



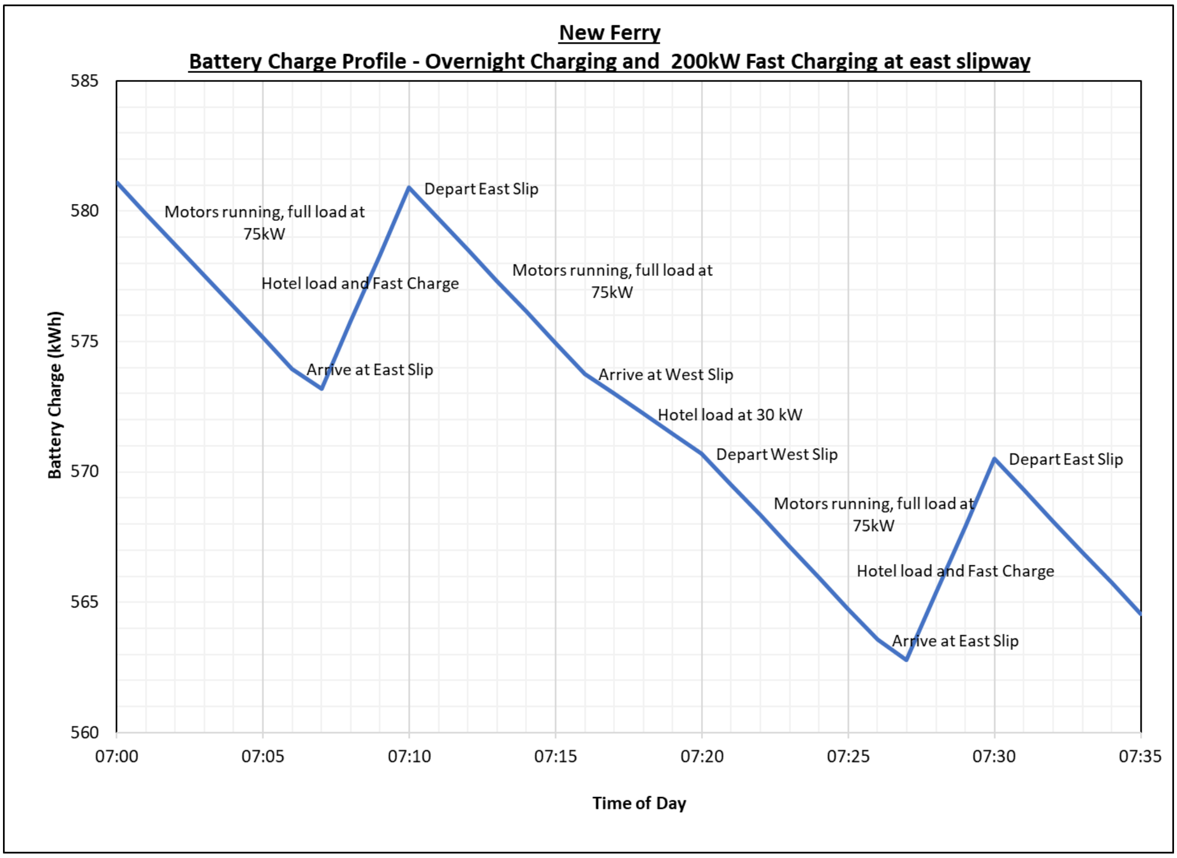
Daily battery charge cycle for overnight charging and 100kW fast charge at the Ferry Nab (east) slipway (24 hour period)



Battery charge cycle for overnight charging and 100kW fast charge at the Ferry Nab (east) slipway (detailed view)



Daily battery charge cycle for overnight charging and 200kW fast charge at the Ferry Nab (east) slipway (24 hour period)

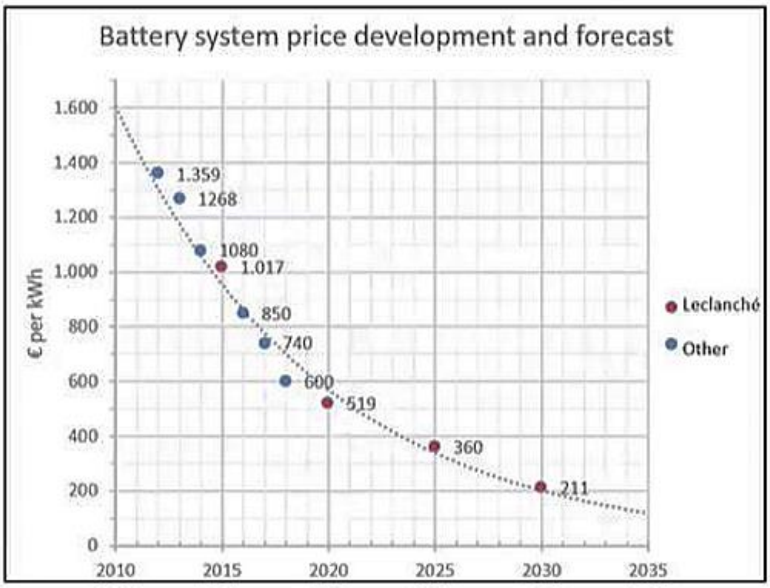


Battery charge cycle for overnight charging and 200kW fast charge at the Ferry Nab (east) slipway (detailed view)

The fast charge at the Ferry Nab (east) slipway) could be achieved most simply and cost-effectively with a manual plug-in system using a standard electric vehicle charger. The charging unit would be mounted close to the top of the slipway and the cable rigged along a simple framework on one side of the slipway with the plug hanging close to where the ferry stops for manual plugging into the ferry by one of the crew members. Examples of 150kW electric vehicle chargers are shown below. Although automatic charging connection systems exist for larger ferries these are too large and expensive, and not suitable for ferries that operate from a slipway such as the Windermere ferry. Any charging system will need to be mounted above the highest likely lake water level.

150kW electric vehicle chargers of the type that could be used to charge the new ferry

The illustration above is based on a 10-year battery replacement cycle, which is typical for many ferries. Operational experience from the larger electric ferry Ellen which has now been in service for 2 years (Ref. P) indicates that the Lithium-Ion batteries are performing well and aging at a slower rate than expected. However, the batteries are likely to need to be replaced in around 10 years and the expectation is that their replacement will be at a lower cost than their original purchase as the cost of Lithium-Ion batteries is continually reducing, as indicated in the figure below.



Predicted Lithium-Ion battery costs (Ref. P)

It can also be expected that when the time comes to replace the batteries in the new Windermere ferry, new battery technology is likely to reduce the battery size and weight for the same capacity, although the cost of the next generation battery technology is not known.

There is also the potential to increase the Lithium-Ion battery life beyond 10 years by installing a greater battery capacity in the new ferry than needed. By doing so the depth of discharge is reduced thereby extending battery life.

The photograph below shows one battery bank module of an electric ferry. The batteries are housed within a fire-rated compartment fitted with heating and cooling to maintain the batteries at close to 20ºC, and fire detection and fire suppression systems, in accordance with Classification Society and MCA requirements.

One battery bank module of an electric ferry

In place of a permanently installed battery bank, the potential benefits of two portable battery banks were explored. Such a system would allow one battery bank to be charged during the day while the ferry is in service, and the two banks swopped halfway through the day's service. While this would not reduce the total battery capacity required, it would enable the charging facility to be located further away from the slipway but only if the fast charge option was not adopted. The drawbacks of such a system are that each of the two portable battery banks would require all the services (fire containment, heating, cooling, etc.) and connections as a permanent installation, which would probably double their cost. The portable battery module would also take up valuable space on the vehicle deck, and the ferry would still need a small onboard battery bank to maintain supplies while the portable banks are changed over. On balance, there is insufficient benefit and more significant drawbacks to the portable battery bank system.

A further option that may be possible because of the low power requirements of the new ferry is to fit pre-used (second hand) batteries, possibly those removed from a larger electric ferry. This would mean installing more pre-used batteries, of reduced capacity, and with the associated increased weight, installation requirements and costs. But the battery cost compared to new batteries may be significantly reduced.

9.1.3 Summary

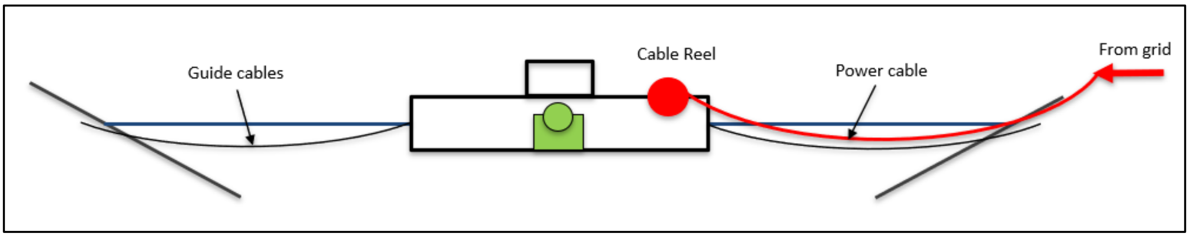
The low power requirement of the Windermere ferry makes it very suitable for battery operated electric propulsion. It is feasible for the ferry to be charged only overnight during the 7.5 hours it is out of service although this requires the largest, heaviest, and most expensive onboard battery installation. The battery bank size can be significantly reduced by taking on a fast charge for about 3 minutes during each unloading/loading stop at the Ferry Nab (east) slipway. The low power requirements also allow a standard electric vehicle charger with manual plug in/out to be used for the ferry.

With battery operation there are numerous options available and if this solution is selected these options need developing further in the next phase of the project.

9.2 Grid Connected Electric Propulsion

9.2.1 General

The significant advantage of the ferry being permanently connected to the grid via a power cable is that there is no need for a large onboard battery pack. The size, weight and cost of the battery pack has already been discussed, and virtually all of this is avoided if the ferry is connected to the grid. The only necessity for an onboard battery pack is to provide emergency power to maintain safety systems, lighting and communications, and to return the ferry to the slipway in the event of a grid power cut or failure of the power cable. The grid connected propulsion option is shown schematically below.



Option 2 – Grid Connected by Power Cable

An alternative technically feasible grid connected option is an overhead power cable supported at each slipway by pylons and connected to the ferry by a loose cable or a pantograph in much the same way as a tram is connected to overhead power cables. This option was rejected for further consideration as the overhead cable would prevent the passage of sailing yachts on the lake, and significant infrastructure works would be required, and the system would be unlikely to gain planning approval.

9.2.2 Swedish Grid Connected Cable Ferries

The Swedish Highways Agency operates seven grid connected electric cable ferries of similar size and configuration to the Windermere ferry and have another four in procurement. Two of these are shown below. The power cable reel on the side of the ferry can be seen.

Two of the grid-connected electric ferries in service with the Swedish Highways Agency

The length of the crossings of these ferries is between 130m and 250m. The Swedish Highways Agency is working on a new cable ferry for a 500m crossing which is more challenging due to the size and weight of the cable to transit the power required without unacceptable voltage drop and the size of the cable reel to accommodate the power cable.

The Swedish Highways Agency has reported that the power cables on their busiest ferry routes last between 12 and 18 months depending upon the conditions (which can include ice) and that they need replacing due to wear on the outside of the cable. Both the power cables and drive cables normally lay on the riverbed.

It is interesting to note that the Swedish ferries have two propulsion motors that can independently operate the drive wheels on each side of the ferry, so it is possible to correct any misalignment (yaw) of the ferry to the drive cables. As previously noted, this is one of the issues with the current Windermere ferry, which does not have the ability to operate the two drive wheels independently.

9.2.3 System Specification

The Swedish ferries have an AC power supply to the ferry, but there is no reason why this cannot be a DC supply with the power conversion equipment ashore rather than on the ferry. A DC supply to the ferry enables the ferry to have a DC propulsion and electrical distribution system which would be the same as if it was fitted with onboard batteries.

In either case, the power cable needs an automatic powered system to reel the cable in and out at the same speed as the ferry, allowing for the change in the stowed cable radius on the reel which depends upon the length of cable on the reel, and so affects the speed of rotation of the reel even at constant ferry speed. Enquiries with specialist suppliers confirm the feasibility of this, as installed on the Swedish ferries and on dockside shipping and container cranes. The photographs below illustrate example cable reel solutions.

Examples of power cable reel systems installed on dockside cranes

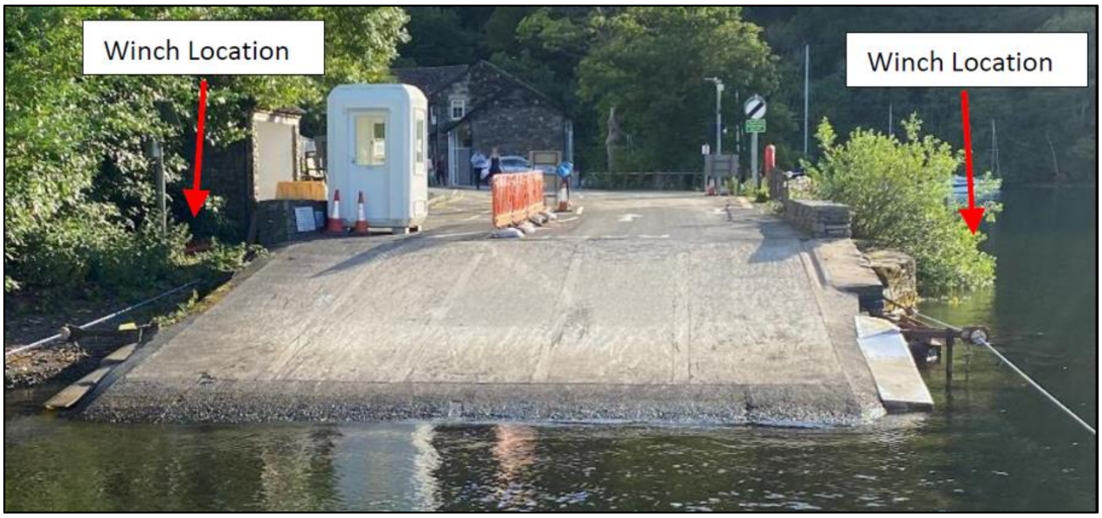
9.2.4 Summary

Grid-connection offers clear benefits and is technically feasible. It is only the length of the Windermere crossing that introduces technical risk and that is linked to the size and configuration of the cable reel to accommodate the necessary cable length, and the voltage drop in the longer cable which can be countered by a larger cable diameter, albeit this then increases the size of the cable reel to accommodate it. It is considered that these inter-related issues can be resolved, and this will be address during the next phase of the project.

9.3 Shore-mounted Winches

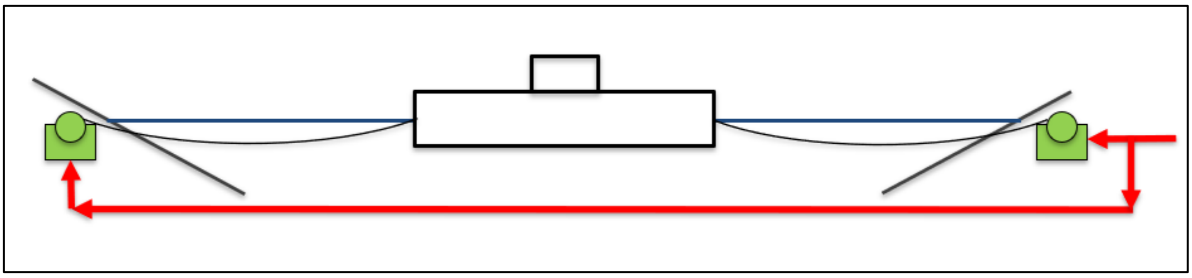
9.3.1 General

The principle of this option is to move the winches that drive the cable ferry from the ferry onto the shore next to one or both slipways. Doing so would greatly simplify the design and construction of the ferry as it would become an un-powered pontoon with no propulsion machinery. The shore-mounted electric winches would be permanently installed next to the slipways and electrically supplied directly from the grid. The indicative winch locations are shown in the image below.

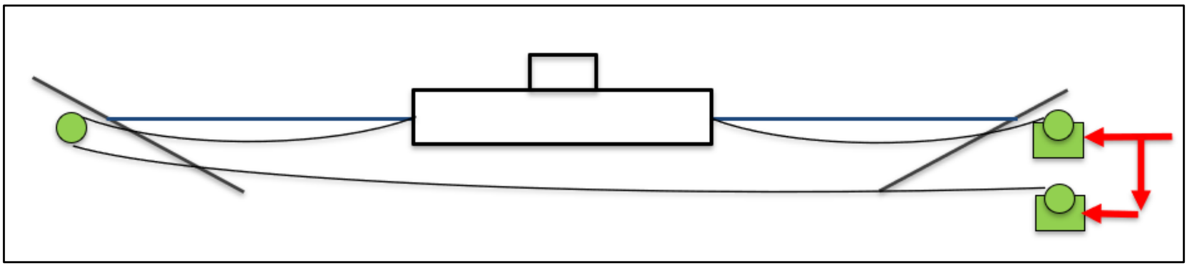


The Ferry House (west) slipway showing indicatively the location of the winches

It is technically feasible for the system to work with a pair of winches on both slipways, although this would require a power cable to be installed across the lake to the east slipway, or with all four winches on the west slipway which would require the cables from two of the winches to pass around fixed pulley blocks mounted on the opposite slipway. These options are shown in the schematic diagrams below.



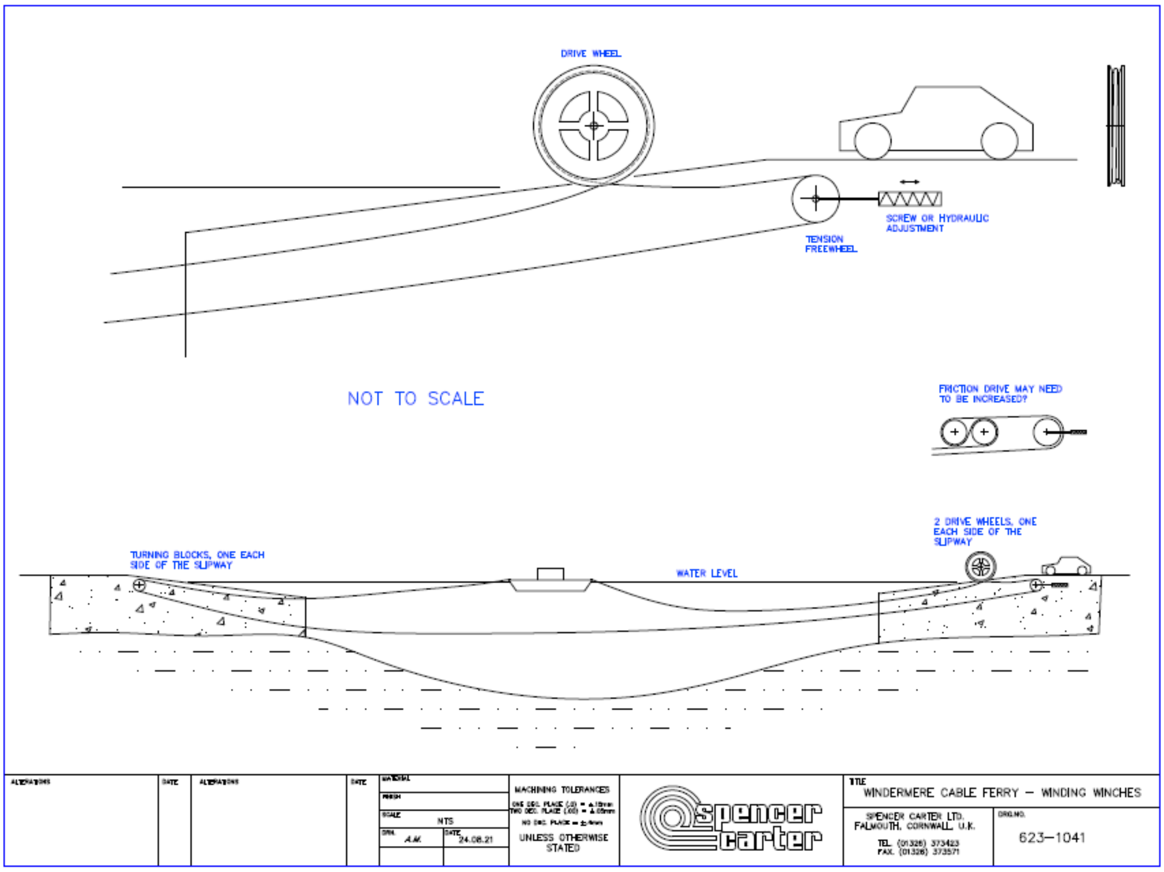
Option 3A – Shore-mounted winches – winches on both slipways



Option 3B – Shore-mounted winches – winches on one slipway only

The challenge for both options is in the control of the hauling-in and paying out winches such that cable tension is maintained at the correct level. If the tension is too great then the drive cables will remain in a catenary just below the water surface where they will be an obstruction to other boats, but if the tension is too low the cables will not spool correctly onto the winch drums and a “bird’s nest” of wire will result. Also, the cable speeds will be constantly changing as the winch drum empties and fills, requiring accurate synchronisation of each winch speed as the pulling winch drum fills and the letting out winch drum empties. This accurate synchronisation would not only be required for each pair of winches but also between the pairs of winches on the north and south sides. These control issues can probably be overcome but not without some considerable technical risk. It is perhaps for these reasons that there appear to be very few cable ferries pulled by winches mounted on the shore, and those that do exist are very small and have only a single drive cable, rather than two like the Windermere ferry.

To reduce these challenges one marine winch manufacturer has proposed a cable car type of arrangement with a continuous cable and winch on each side of the ferry/slipway. Their indicative arrangement is shown below and includes a hydraulic cable tensioner and potentially twin drive wheels to provide sufficient grip on the cable.



Indicative proposal of a continuous cable system by Spencer Carter

This arrangement is also not without its technical challenges as the two winches and tensioners would still need to be synchronised and controlled. Other aspects that would also require development include the control of the winches and tensioners from the ferry which would have to be via a wireless system.

A critical drawback with all the shore-mounted winch options is that the cables will be continuously dragged over the lakebed as the ferry crosses. The hydrographic survey has shown that there are no rocks or obstacles that would pose a risk to the cables but even without such features, the abrasion of the cables being dragged over sand or sediment up to 92 times a day, 7 days/week will inevitably reduce the cable life, probably to an unacceptable level.

Another aspect to be considered is that although the complexity of the ferry will be significantly reduced with this option, thereby reducing its design and construction cost, there would be a significant amount of infrastructure works at both slipways to construct foundations for the winches and pulley blocks and install the machinery. In addition, once operational the noise from the winches is also likely to be problematic.

In conclusion, although the option of shore-mounted winches is appealing in many ways, the technical challenges and risks outweigh the benefits and for the reasons stated this propulsion option was not considered further.

9.4 Propeller Propulsion

One shipyard has proposed that the new electric ferry, whether battery operated or grid connected, is driven by two propellers on steerable propulsion units, and only uses the cables as a guide. This solution has the benefit that the ferry will be operable and steerable, for movement or maintenance, without the need to be towed by other vessels. The drawback is that marine propellers are less efficient than a cable drive system, by 30 or more percent, and as such a propeller driven ferry will need more power and higher operating costs. This option is not preferred but will be considered further in the next phase of the project.

9.5 Summary

Based on the assessment summarised above the only two electric propulsion options considered to be technically feasible, cost effective and of sufficiently low risk are battery operated and grid connected. The crossing distance poses some challenges and risk for the grid connected option, but the benefits are reduced ferry complexity, operating and ongoing costs compared with the lower risk battery powered solution. Further work is required to confirm the feasibility of this option.

10. OUT OF WATER SURVEY

10.1 Introduction

As mentioned, the MCA Code of Practice for Chain/wire ferries (Ref. C) requires the ferry to be removed from the water every 5 years so that the underwater hull can be inspected by an MCA surveyor. The current ferry has been subject to this inspection regime at significant cost, downtime, and lost revenue.

In addition, the requirement for increased car capacity and improved facilities on the new ferry necessarily results in the new ferry being larger and heavier than Mallard and as such she will be too big and too heavy for the largest slipway on the lake.

For the new ferry an alternative and cost-effective solution to the 5-yearly out of water survey is required, or a means of increasing the out of water survey interval that could be agreed by the MCA.

Potential options identified and explored for the inspection are as follows.

a) Lift the ferry ashore with cranes

b) Partially dismantle modular ferry and lift ashore by crane

c) Slipping the ferry up the East slipway

d) Lift the ferry on a dismantlable dry dock system

e) Agree a regime of in-water hull inspection and increased out of water inspection interval with the MCA

These potential options are discussed below.

10.2 Lift the ferry ashore with cranes

Heavy lift cranes were employed to launch the MV Swift into Lake Windermere and a similar process could be employed to lift the new ferry ashore for her out of water inspection. Swift was launched by a tandem lift of two 500 tonne mobile cranes hired from the specialist heavy lift company Mammoet.

The launch of MV Swift into Lake Windermere by two 500 tonne mobile cranes

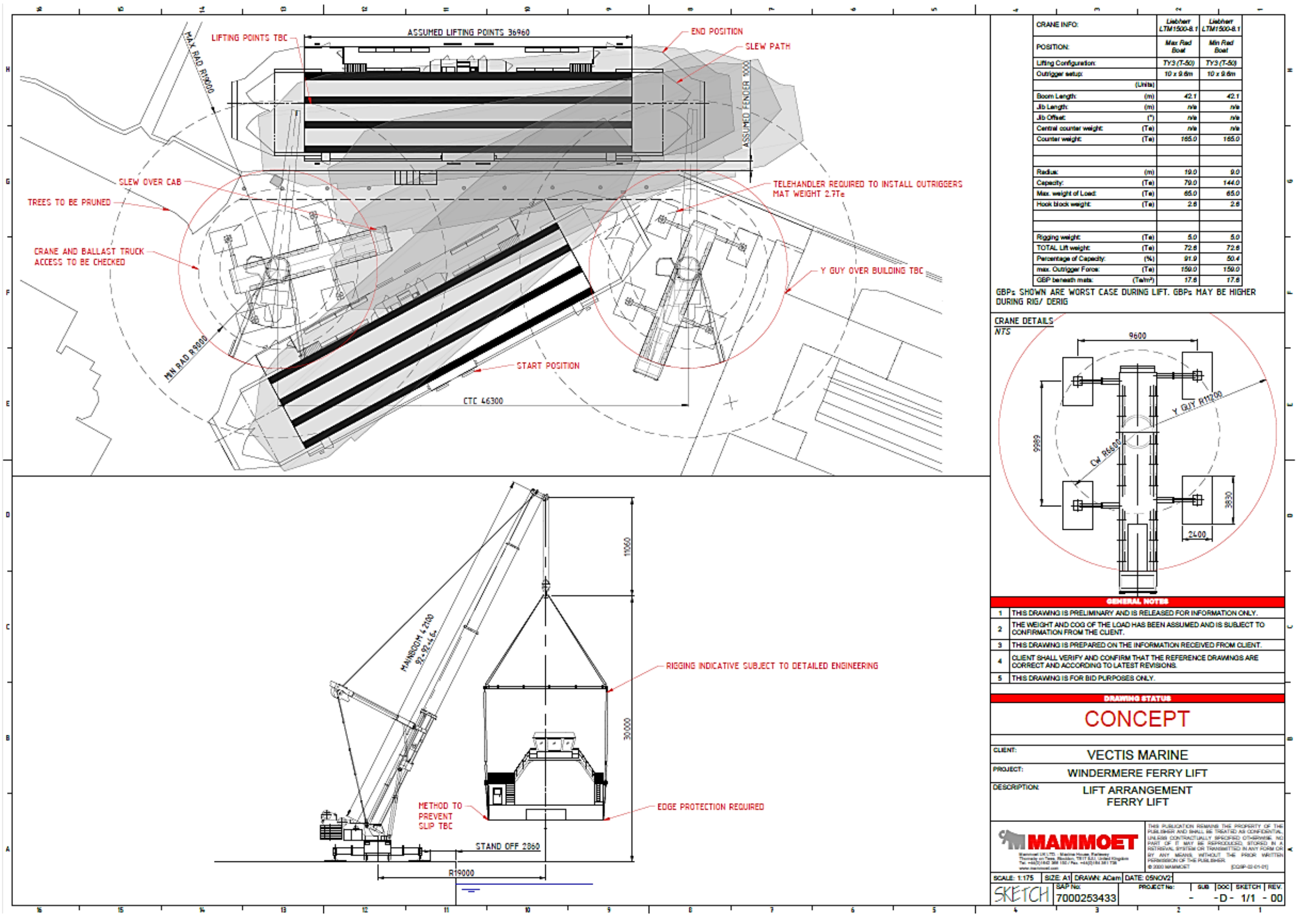
The constraints of road access across Newby Bridge and past the Swan Hotel means that 500 tonne mobile cranes are realistically the largest that could be deployed onto the Lakeside car park site where Swift was launched. The 500 tonne mobile cranes each have a capacity of approximately 80 tonnes at 20m lift radius which with the weight of lifting gear would limit the weight of the ferry to around 130 tonnes. At the time of her launch, Swift reportedly weighed 150 tonnes (Ref. D); her smaller size would have enabled a smaller lift radius and hence higher lift weight.

The new ferry is expected to weigh more than this in a light load condition and some weight reduction is likely to be necessary such as removal of the ramps, as is currently carried out on Mallard before she is slipped. If the ferry can be lifted ashore in this manner, then it should only need to be out of service for around 6 days.

At the time of writing, the budgetary cost of the 2 to 3-day hire, mobilisation, and lift of two 500 tonne mobile cranes is in the region of £40,000 (Mammoet budgetary price).

The beam of the ferry is the primary factor affecting lift weight as it drives the lift radius. If the beam of the ferry was reduced by 1m then the weight of the ferry could increase by 10 tonnes to 140 tonnes (ref. Mammoet e-mail dated 23/11/21).

The figure below shows the preliminary lift arrangement for the ferry produced by Mammoet for the current concept design of the new ferry (55m overall length x 13.5m overall beam, 21 car capacity).



<u>Preliminary lift arrangement of the new ferry prepared by Mammoet</u>

10.3 Partially dismantle modular ferry and lift ashore by crane

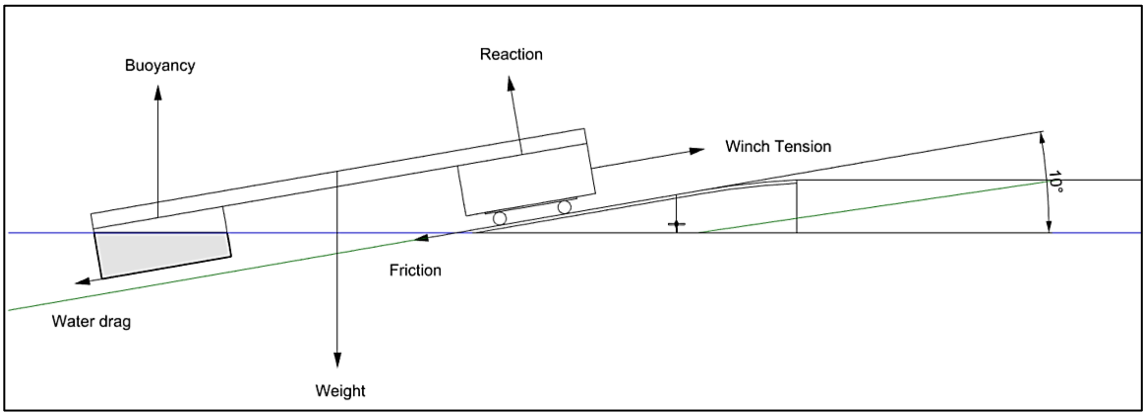
If the new ferry is of modular design, then it will be feasible to partially dismantle the ferry while afloat and lift sections ashore by crane for inspection. Depending upon the design, the ferry could be separated into say four sections each weighing in the region of 50 tonnes which could be lifted by one crane of 500 tonne or smaller capacity.

The details and sequence of the dismantling and re-assembly with the ferry afloat will need careful planning, not least to ensure the stability of the partially dismantled ferry and it will probably be necessary to re-join each section before the next section is disconnected. As such the hire period for the crane is likely to be around 10 days and the ferry likely to be out of service for around 14 days.

The crane hire cost will therefore be in the region of £50,000 (TBC) and the entire cost of the operation significantly higher than if the ferry can be lifted ashore in one operation.

10.4 Slip the ferry up the East slipway

One of the options for the new ferry is a catamaran where the buoyancy is provided by two hulls. A catamaran offers the benefit of reduced resistance compared with a monohull but more importantly it supports the construction and launch of the new ferry onto the lake as each of the two hulls could be fully constructed and completed prior to delivery to the lake side for final assembly and launch. A catamaran design could also provide a solution to the out of water survey, either by slipping or lifting out each hull at a time, or more readily by hauling each hull sideways up one of the ferry slipways. This is illustrated below. This solution could also apply to a monohull design.



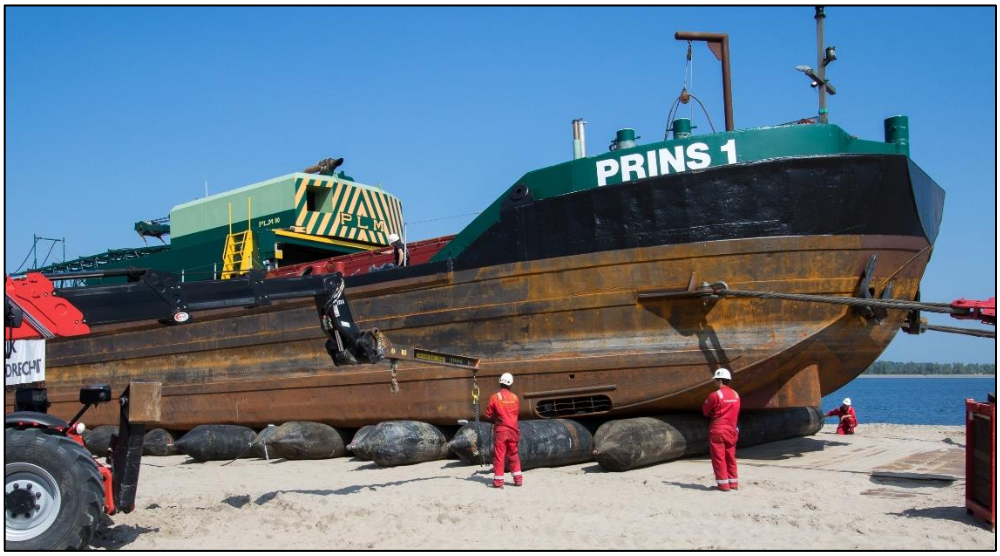
Potential side slipping of the new ferry

It was initially considered that this solution could make use of the shore-mounted winches that form one of the electric propulsion options for the new ferry. However, the force required to haul one hull of the ferry up the slipway is far greater that required to propel the ferry so an alternative means of hauling the ferry ashore would be required.

The possibility of slipping the ferry has been discussed with the heavy-lift contractor Mammoet and is considered feasible. Mammoet has experience of hauling a much larger and heavier vessel out of the water by a similar process, albeit that vessel was hauled out longitudinally, as can be seen in the photographs below.

Example of hauling a vessel up a slipway (courtesy of Mammoet UK)

The vessel is rolled out of the water on air bags which serve to spread the load on the hull and on the slipway. For the Windermere ferry, permanent anchor points could be installed on each side of the access road to the slipway.



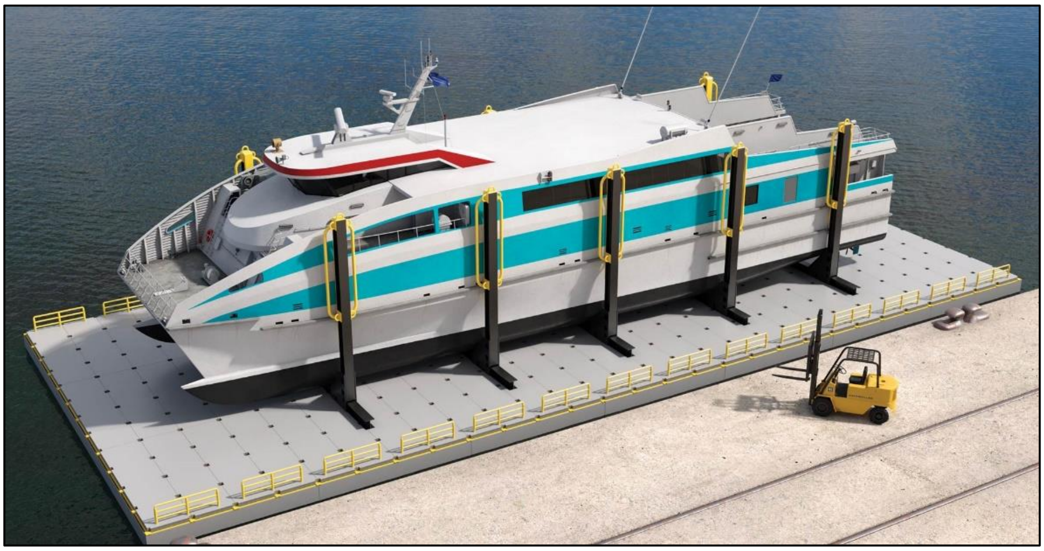
The vessel is rolled on air bags (courtesy of Mammoet UK)

The ferry would need to be designed from the start for slipping in this manner. The hull structure would need be designed to withstand the bending moments and local pressure loadings that will result, and the ferry will need to be designed with integral tow points on each side. Incorporating these aspects within the design and build of the new ferry will result in a cost increase but this will be a small percentage of the total cost of the new ferry.

It is estimated that the exercise to prepare and slip the ferry for inspection will require the ferry to be out of service for around 8 days. Preliminary costs indications are around £95,000 but further work is required to confirm this.

10.5 Lift the ferry on a dismantlable dry dock system

A UK company, TugDock has developed a road transportable dry dock system for smaller vessels. The system relies on air bags to provide the buoyancy and is modular so vessels of different sizes can be lifted. Three modules would be needed for the new Windermere ferry. The system is illustrated below.



The TugDock road-transportable drydock system (tugdock.com/)

The dry dock would be delivered by road to Lake Windermere and assembled and commissioned while the ferry remains in service thereby minimising the time the ferry is out of service. It would not be necessary to remove the ramps from the ferry for lifting by this method and it is estimated that the ferry would need to be out of service for about 4 days. At the time of writing, the budgetary cost of the hire of the three TugDock systems needed to lift the new ferry is in the region of £65,000 (TugDock budgetary quote) however it should be noted that the system is not yet operational.

10.6 Agree a new inspection regime with the MCA

At the time of writing the MCA have been approached to commence discussions on the potential of extending the out of water survey interval for the new Windermere Ferry from 5 to 7 or more years. It is considered that such a change can be justified because the vessel operates in fresh water in benign conditions and the out of water survey could be supported by a regime of intermediate in-water inspections that could include an NDT thickness survey of the hull plating and an external inspection by ROV or divers.

It is understood that for Mallard there are no in-water inspection requirements in between the 5-yearly out of water survey.

The external in-water inspection could be carried out by a Remotely Operated Vehicle (ROV) and/or by divers. Cumbria County Council in partnership with Gaist have developed and operate a BridgeCat mobile bridge inspection vehicle that enables the foundations of bridges to be visually inspected without divers. Such a system could be employed to support the in-water inspection of the new ferry although the ferry's deckhouse and the geometry of the ferry hull, especially if it is a catamaran, may limit the area that can be accessed by BridgeCat.

The BridgeCat inspection system developed by Cumbria County Council and Gaist

There are other ROV systems available that are designed specifically for cleaning and inspecting vessel hulls and these may be more appropriate. An example is the Keelcrab ROV which is shown below. Such a unit could also clean the hull as well as enabling its inspection.

The Keelcrab hull cleaning ROV with integral lights and camera for hull inspections (www.keelcrab.com/en/boat/the-keelcrab)

10.7 Summary

There are several potential solutions to the out of water inspection of the new ferry but there is no straightforward or low-cost solution, and all need further development and confirmation. These are summarised in the table below.

POTENTIAL SOLUTION	ROM COST	ISSUE	POTENTIAL SOLUTION
Lift ferry ashore with two 500 tonne cranes	£40k	Limits ferry lift weight to 130/140 tonnes. Requires use of Lakeside car park.	Minimise ferry size and consider designing down to this lift weight. Grid connected lighter than battery operated.
Partially dismantle modular ferry and lift ashore by crane	£50k	Sounds easier than it will be due to ferry arrangement and services. Requires use of Lakeside car park. Not an ideal solution.	A better solution is to define removable items (eg. ramps and possibly others) to reduce weight to crane capacity.
Winch ferry up East slipway	£95k	Potentially feasible but needs developing to confirm. Potential issue of noise/containment/ contamination during cleaning, blasting and painting in public location. If selected, then anchor points should be installed at East slipway.	Develop with heavy-lift contractor to assess feasibility, implications, and costs including structural assessment of the slipway.
Lift the ferry on a dismantlable dry dock system	£65k	Potentially viable solution but system not yet in operation.	Monitor system introduction.

Potential solutions for the slipping the new ferry

There is clearly a benefit in continuing discussions with the MCA with the aim of extending the out of water inspection period from 5 to 7 or more years. But regardless of the outcome of those discussions there will always remain the necessity to lift the ferry periodically out of the water for inspection, and potentially for repairs, so a solution does need to be identified.

The headline budgetary costs of all the potential solutions identified above are in the range £40,000 to £65,000 although there are clearly other costs in addition to these figures. A key consideration and cost driver is the time that the ferry is out of service. For Mallard's last out of water inspection in 2019 she was out of service for around 3 weeks (Ref. A). It is estimated that this time would be reduced to between 4 and 14 days for the inspection on the basis that no other work is required.

11. BUDGETARY PROJECT COSTS

11.1 New Ferry Design, Build and Commissioning

To obtain budgetary prices for the new ferry, a preliminary Request for Proposals (RFP) for the design, construction & commissioning of a new electric cable ferry was prepared (Ref. Q). After making initial contact with them, the RFP was issued to six shipyards: four in the UK and two in Europe. Responses with budgetary/ROM pricing and indicative project durations were received from three shipyards: two in the UK and one in Europe. Their prices are summarised in Annex G.

Allowing for any items stated as being not included in their pricing and taking the average of the three shipyard prices for the battery operated and grid connected ferry options indicates the following budgetary/ROM prices for the new ferry including documentation, spares, training and 2-years of in-service support.

- Battery-operated ferry design, build and commissioning £5.2 million
- Grid-connected ferry design, build and commissioning £4.8 million

11.2 Overall Project Costs

The overall project cost estimate is shown in Annex H. Including battery charging or grid connection systems, shore-side infrastructure, consultancy, civil engineering allowance and a 7.5% margin, the following overall project costs are envisaged.

- Battery-operated ferry project cost estimate £6.8 million
- Grid-connected ferry project cost estimate £6.5 million

These figures do not include any allowance for any slipway strengthening work to enable the slipping of the new ferry if this proves to be feasible and if strengthening is required.

11.3 Operating Costs

The routine operating cost of electricity, crew, etc. will be similar for both the battery operated and grid connected options. A battery-operated ferry will consume more power from the grid than a grid connected one due to the efficiency of the batteries. Lithium-Ion batteries are typically higher than 97% efficient meaning that for every 100 kWh of power charged into the battery at least 97 kWh will be available from the battery, the remaining 3 kWh or less is lost as heat energy during charging.

Both propulsion options rely on the same drive cable arrangement and there will be no difference in the resulting life of the drive cables. Routine maintenance of both options is expected to be similar and minimal.

The major in-service cost of the battery-operated ferry is the replacement of the batteries after around 10 years in service, although based on initial feedback from in-service electric ferries it may be possible to extend this to every 12 years. However, for a ferry life of 30 years this would still require two battery replacements. It would be feasible to specify a battery bank for a 15-year life, but this would incur significant additional capital cost and weight.

The major in-service cost of the grid connected ferry is the replacement of the grid connection cable every 12 to 24 months, based on the experience of the Swedish ferries.

The table below compares the indicative through-life replacement cost of batteries and grid connection cable based on a 30-year ferry service life.

Propulsion Option	Primary Replacement Item	Replacement Budget Cost (2022)	Replacement Interval	Number of Replacements	Through-life Budget Cost (2022)
Battery operated	Battery replacement	£280k	10-12 years	2	£560k
Grid connected	Power cable replacement	£18k	18 months	20	£360k

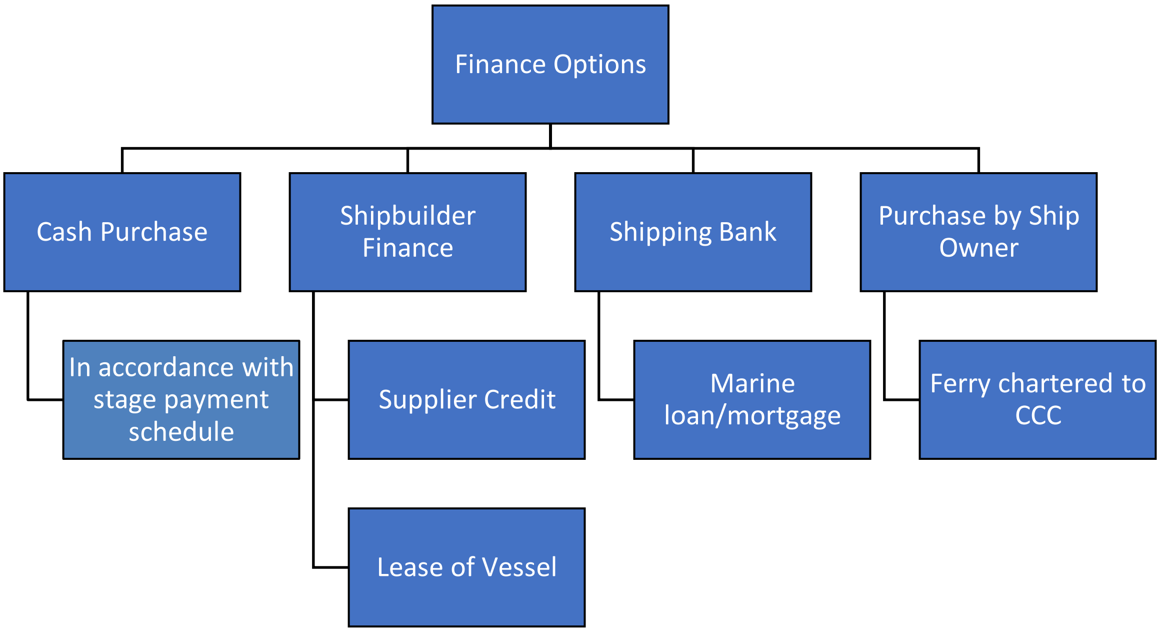
Comparison of primary through-life replacement costs for battery operated and grid connected propulsion options

12. FINANCE OPTIONS

12.1 Introduction

The potential options for finance for the new ferry can be summarised as:

1) Cash purchase by CCC in accordance with the stage payments schedule agreed with the ship builder.
2) Finance from the shipbuilder. This may be in the form of a supplier's credit agreement, or lease of the vessel from the builder. However, not all ship builders offer these facilities.
3) Finance from a shipping bank. This may be in the form of a loan or marine mortgage from a specialist marine bank.
4) Purchase of the vessel by a Ship Owner who charters the vessel to CCC.



Summary of potential finance options

12.2 Cash Purchase

Shipbuilders inevitably require stage payments that correspond to agreed milestones in the design, construction, commissioning, and acceptance of the vessel. In this scenario, CCC would self-fund the build of the ferry via between 3 and 5 stage payments to the ship builder, each of between 15 and 35% over the 18-24 months of the build period.

12.3 Shipbuilder Finance Options – Damen example

12.3.1 Introduction

The Netherlands-based shipbuilder, Damen have a Customer Finance organisation and could offer either Supplier's Credit or lease of the vessel under bare-boat charter from Damen LeaseCo. Other shipbuilders may offer similar finance options while others will offer no finance options.

12.3.2 Damen Supplier's Credit

Damen offer credit up to 80% of the vessel price through the Dutch bank Atradius. Hence, a down payment of 20% would be required from CCC. Repayments would start 6 months after delivery of the vessel and be due every 6 months for around 7 years. The figures below summarise the main feature and indicative terms and conditions of the Damen Supplier's Credit scheme.

Main features
Atradius Dutch State Business, the export credit agency of the Netherlands, provides credit risk insurance at a (small) premium
Lowest interest rate possible, due to AAA rating of Atradius
Documentation and processes are standardized. No legal costs. Takes around 2 months to arrange.
Downside: bound to OECD rules and therefore less flexible.

Indicative Terms and Conditions	
Buyer / Borrower	County of Cumbria
Lender	Damen Customer Finance
Loan amount	Up to 80% of purchase price (20% down-payment)
Insurer	Atradius
Tenor	Around 7 years
Interest rate	Around 1,9%
Costs	• Arranger fee: 1% • Interest rate : subject to evaluation and market conditions
Premium	• Can be included in financing and spread during tenor of loan • 3,93% - 5,75% depending on risk profile (BBB- to BB+ used in this example), construction period and tenor • Concerns a one-off payment and covers full tenor • Premium will cover manufacturing risk and credit risk

Damen Supplier's Credit scheme

12.3.3 Damen LeaseCo

Damen Customer Finance also offers the potential to lease the vessel from Damen LeaseCo. Under this scheme the ferry would be purchased by Damen LeaseCo and chartered to CCC under a bareboat charter agreement, whereby CCC would be responsible for manning, operating costs, maintenance, and insurance. CCC would be required to make a 5% down payment. LeaseCo would own the ferry for the duration of the agreement, which is typically 5 years, and on payback, CCC would be required to purchase the ferry for the lump sum of the remaining value (which could be as much as 50% of the cost). The figures below summarise the main feature and indicative terms and conditions of the Damen LeaseCo scheme.

Main features
Certain liquid assets can be financed through this conduit: standard workboats and high-speed transfer vessels
Dutch banking institutions act as main financial backers
Lowest down-payment possible
Structured under bareboat charter standard processes. No legal costs. Takes around a month to arrange.
Vessel customization can reduce liquidity of assets and impact the risk profile

General Terms and Conditions	
Charterer	Client
Lessor	SPV designated by Damen Global Ship Lease
Facility amount	Up to 95% of purchase price (5% would be down-payment)
Tenor	Up to 5 years
Expiration	Obligation to purchase the vessel
Refinancing	Free of charge after one year.
Charter contract	Bareboat charter agreement. All costs to sail, maintain and insure the vessel are for the account of the charterer.
Financial costs	• Arranger fee: 1% • Hire rate: subject to evaluation and market conditions

<u>Damen LeaseCo scheme</u>

12.3.4 Comparison of Damen Options

The figure below compares the two Damen finance products.

	LeaseCo	Supplier's Credit (Atradius-covered)
Financing cost	Based on the risk profile of the customer Fixed rate	Lowest possible, based on AAA rating of Atradius and risk profile of the customer Fixed rate
Frequency of payments	Monthly	Semi-annually
Down payment	5%	20%
Tenor	Up to 5 years	Around 7 years
Refinancing	Yes, after Y1	No
Balloon	Yes	No
Arranging fee	1%	1%
Corporate guarantees	Yes	Optional, but improves the risk profile
Vessel type	Standard vessels (workboats and transfers) Low level of customization	All Damen vessels

Comparison of Damen Finance Options

The LeaseCo scheme offers the benefit of a lower (5%) down payment but a significantly higher overall cost.

12.4 Shipping Banks

Specialist shipping banks such as Close Brothers and Hambro Rabben offer marine mortgages on ships. Loans are typically for 80 to 90% of the cost and paid back at a fixed interest rate with constant regular payments over up to 8 years.

Close Brothers would typically be seeking up to 30% equity from the customer and generally do not get involved until after the vessel is complete and commissioned to earn revenue. However, when the builder is Damen they do fund later stage payments after the vessel is structurally complete.

A consideration is that the bank usually considers the resale value of the vessel within their risk assessment and in the case of the bespoke and lake-locked Windermere ferry the resale value is very limited.

12.5 Purchase by a Ship Owner

There is potentially the option of an agreement for an independent ship owner to purchase the ferry on CCC's behalf and then charter it to CCC. This would be under a bareboat charter agreement, whereby CCC would be responsible for manning, operating costs, maintenance and insurance. Details of the agreement and the ultimate purchase of the vessel by CCC need to be determined but are probably similar to those of the Damen LeaseCo scheme.

12.6 Initial Conclusions

A finance solution offered by the shipbuilder will inevitably provide the simplest and quickest solution and require the least time and involvement of CCC's lawyers. However, not all potential ship builders will offer finance and it needs to be considered whether this should be an ITT requirement.

Of the Damen schemes, Supplier's Credit appears the most attractive. Options from other potential builders are being sought.

In any case, the ship builder needs to be fully guaranteed by its bank to protect CCC in the event of the builder going bankrupt or defaulting on the contract. This applies both during the design and build but also post-delivery to protect the warranty on the new ferry.

12.7 Key Questions

1) What sort of finance agreement is CCC seeking and over what term?
2) How much of a down payment is CCC seeking to provide?
3) Will the new ferry be operated by CCC directly? Or will it be operated by a company set up by CCC and if so will CCC be able to provide a guarantee for the company?
4) How will CCC protect themselves from shipbuilder default or bankruptcy during the build. Appointing a specialist marine lawyer is recommended.

13. PRELIMINARY PROJECT DURATIONS

The project durations indicated by the three shipyards are shown in Annex I. In summary, the overall durations from contract to acceptance range from 10 to 21 months depending upon the shipyard and the ferry option. The table below shows the range of durations

	Shipyard A
Design of the new ferry	2 to 6 months
Construction of the new ferry	5.5 to 12 months
Delivery of the ferry to Windermere Lake side	0.5 to 1 month
Completion of the new ferry at the lake side	1 to 4 months
Commissioning, installation, trials, and acceptance	1 to 2 months
TOTAL	10 to 21 months

Range of project durations indicated by the three shipyards

The design duration will depend upon the extent the shipyard can adopt existing design solutions, such as an existing modular system design, for the new ferry. A project duration of 18 to 20 months is considered likely.

Regarding the time to complete the ferry at the lake side, a period of 4 months is considered too long as it indicates the need for more extensive assembly and finishing work at the lake side than desirable. The aim must be for the design of the new ferry to enable complete construction, fitting out and testing in the shipyard before it is dismantled for delivery to the lake side for rapid re-assembly, launch, installation, and commissioning.

14. SUMMARY AND CONCLUSIONS

14.1 Summary

This study has confirmed the feasibility of a new electric ferry for the Lake Windermere service that meets the requirements identified for the new ferry, that addresses the operational and reliability issues of the current ferry, and that takes into account the constraints associated with the delivery and out of water inspection of the new ferry.

The following is proposed as offering the best solution for the new Windermere ferry.

a. A catamaran or monohull ferry of semi-modular construction designed for complete construction, fitting out and (partial) testing in the shipyard before dismantling for delivery to the lake side for rapid re-assembly, launch, installation, and commissioning.
b. The electric propulsion system may be powered by either an onboard battery bank with the associated charging regime, or by permanent connection to the grid by a power cable. Grid-connection offers the lowest initial and ongoing cost and environmental impact but is a greater technical challenge and needs further development and de-risking.
c. There are several potential solutions for removing the new ferry from the water for inspection and repair but there is no straightforward or low-cost solution, and this aspect also requires further development in the next phase of the project.
d. Communication with the MCA with the aim of achieving agreement to an out of water inspection every 7+ years is to be concluded.

14.2 How the requirements will be met

The table below summarises how the requirements for the new ferry will be met.

REQUIREMENT	HOW REQUIREMENT WILL BE MET
An electric propulsion system	Either with a battery operated or grid connected electric propulsion system.
A propulsion system with a high degree of safety, reliability and redundancy	Appropriate safety standards will be met by compliance with Classification Society and MCA rules and requirements for electric propulsion systems. The new ferry will have two independent propulsion systems, each capable of driving the ferry.
Increased drive cable service life	By reducing cable wear by providing independent operation of the drive wheels on each side, and by specifying twin drive wheels on each side. The suitability of cable spacing and size for the new ferry is to be assessed.
Means of improving the alignment of the ferry with the slipway	By providing independent operation of the drive wheels on each side of the ferry.
Improved visibility from wheelhouse, especially of ramps	By locating the wheelhouse on a bridge over the vehicle deck.
Vehicle capacity increased to 18 or ideally 21 cars with adequate space between them	By increasing the size of the vehicle deck to accommodate 3 lanes of 7 cars, each 5m x 2m, with 0.75m between each lane.
140 passengers and crew	As per the current ferry.
Improved passenger facilities (WC, kiosk, Wi-Fi, information screens)	Space for these has been incorporated into the concept general arrangement and specification for the new ferry, and they will be specified in the contract specification.

REQUIREMENT	HOW REQUIREMENT WILL BE MET
Improved crew facilities (mess room, office)	Space for these has been incorporated into the concept general arrangement and specification for the new ferry, and they will be specified in the contract specification.
Improved emergency evacuation routes	An emergency evacuation gate has been shown in each corner of the new ferry in the concept general arrangement which with 0.75m minimum spacing between car lanes is considered sufficient, however this will be agreed with the MCA in the next phase.
Increased ability to operate in high winds	By providing independent operation of the drive wheels on each side of the ferry.
Increased ability to operate in poor visibility	By specifying radar for the new ferry subject to trials on Mallard.
Increased ability to operate in high lake water levels	By improved ramp design (longer and with greater down angle) enabling the ramps to land on the brow of the slipways at road height.
A service life of at least 30 years	By design and specification.
Compliance with the MCA Code of Practice for … chain/wire ferries …	By design and specification and Classification Society and MCA approval.
A solution to the requirement for a 5-yearly out of water survey of the ferry hull	Develop the four potential solutions and identify the most-cost effective and continue discussions with the MCA to extend the inspection interval to 7+ years.

How the requirements for the new ferry will be met

14.3 Inter-related Issues

It will be recognised that several of the issues above are inter-related, such as, how the size and hence weight of the new ferry has a bearing on the potential solutions for removing the new ferry from the water and the potential modularity of the new ferry also affects this issue. The following comments summarise the inter-related issues.

- The final assembly and launch of the ferry are one-off events and they should not compromise its design or operation over a 30+ year service life.
- A modular design may benefit the final assembly and launch, and removal of the ferry from the water, but will increase weight, resistance, power requirements, capital, and operating costs.
- A grid-connected ferry will be lighter than a battery-operated ferry and as such assists the final assembly and launch, and the removal of the ferry from the water.
- The length and beam of the new ferry are driven by the car capacity and lane spacing respectively. Length and beam are direct drivers of ferry weight and any reduction in car capacity and/or lane spacing will reduce weight and assists the final assembly and launch, and the removal of the ferry from the water.

These inter-related issues will be addressed and finalised in the next phase of the project.

14.4 Conclusions

This study has identified, developed, and assessed the options for the electric propulsion and other aspects of the new Windermere ferry. The issues related to the assembly, launch and slipping of the ferry have been identified and potential solutions identified and assessed. Several of the design aspects of the ferry are inter-related with the assembly, launch and slipping of the ferry and final decisions are required primarily on the car capacity of the new ferry before these issues can be addressed and finalised.

The study has shown that there are potentially two feasible electric propulsion options for the new ferry.

14.5 Phase 2 of the Project

The second phase of the project is to develop the selected solution/options and prepare the Invitation to Tender (ITT) for the design and construction of the new ferry. As part of the next phase the following specific aspects are to be developed and concluded:

- Options for battery operation (battery capacity, charging regime, pre-used batteries)
- Grid connection (power cable size, weight and handling, further communication with Swedish Highways Agency)
- Drive cable tension, spacing and sizing for the new ferry
- Agree emergency evacuation routes on the new ferry with the MCA
- Identify most cost-effective solution to out of water inspection and repairs
- Discussions with MCA about extending the out of water survey interval from 5 to 7+ years.
- ENWL to confirm acceptability of the new ferry's power loading on the new supply
- Windermere ferry representatives to visit other modern chain/cable ferries

15. ANNEX A – CUMBRIA COUNTY COUNCIL REQUIREMENTS FOR THE NEW FERRY

The table below summarises the key requirements of Cumbria County Council for the new ferry and their priorities. Priority 3 = Essential, 1 = Nice to have.

ID.	REQUIREMENT	PRIORITY	NOTES
1.0	**PROPULSION**		
1.1	Electric propulsion system		
1.2	Two independent propulsion systems	2	
1.3	Increased cable life	1	
1.4	Means of improving alignment of ferry onto slipway	1	
2.0	**CAPACITY**		
2.1	Three lanes for 21 cars	1	Will accept 18
2.2	140 passengers	2	Standing with 10% seated and DDA compliant
2.3	HGV and bus capability	1	Maximum 44 tonnes, 1 of each max.
2.4	Cycle parking	3	
3.0	**CREW/PASSENGER FACILITIES**		
3.1	WC for crew and passengers	1	
3.2	Crew mess room	2	
3.3	Office for 2	2	
3.4	Wi-Fi	1	
3.5	On deck screens	1	
3.6	Coffee shop counter/kiosk	3	
3.7	Bridge over vehicle deck	1	
3.8	Cashless system	1	
	ENVIRONMENTAL		
	Ability to operate over increased range of water levels		Usual range between 0.23m and 1.00m. Typical recent range over last 12 months 0.26m and 1.05m. Highest ever recorded water level was 2.90m on 20/11/09. https://riverlevels.uk/lake-windermere-windermere-far-sawrey#.YW6IFRrMJPY
	Increased ability to operate in high winds		
	Ability to operate in mist and fog		
	STANDARDS AND CERTIFICATION		
	DDA compliant	1	
	MCA CoP compliant	1	
	OTHER		
	A 30+ year service life for the new ferry.		
	Solution for 5 yearly out of water inspection		

The key design requirements for the new ferry

16. ANNEX B – CONVERT AND MODERNISE EXISTING FERRY?

The table below summarises the advantages and drawbacks of converting and modernising the existing ferry Mallard to meet the requirements for the new ferry.

ISSUE	RETROFIT EXISTING FERRY	NEW FERRY
Age at end of life	The retrofitted ferry will be required to have a service life of 30 years meaning that at the end of her service life the ferry will be over 60 years old.	A new ferry would be 30 years old at the end of her service life.
Condition of the structure	While the structure of the existing ferry is reported to be in good condition there will inevitably be areas of deterioration and the existing structure is unlikely to comply with current Class rules.	A completely new structure designed and constructed in accordance with Class rules.
Condition of fit out and systems	Unless the conversion included completely gutting the vessel back to its structure there will remain aspects of its original fit out and systems that remain, leading to increased future maintenance costs.	All fit out and systems from new, modern equipment and materials.
Design and Build Standard	Even after conversion the existing ferry cannot meet the current MCA Code of Practice for such vessels including the requirements for freeboard.	Compliant with the MCA Code of Practice
DDA compliance	Only with major surgery to widen the vessel would it be possible to increase the space between lanes of cars.	Compliant with DDA regulations
Increased car and pax capacity and improved onboard facilities	Only with major surgery to lengthen and/or widen the vessel would it be possible to increase the car and passenger capacity of the existing ferry and provide improved onboard facilities.	Increased car and passenger capacity and improved onboard facilities in accordance with requirements.
Modern design and styling	Limited scope to implement modern design and styling into retrofitted existing ferry.	Full scope for modern design and styling
Engine Room Access	The existing ferry has limited headroom in the engine room making installation and maintenance of a new electric propulsion system more difficult.	For a new ferry the aim will be to provide standing headroom in the engine room thereby making the installation and maintenance of the propulsion system easier.
Reduction in power requirements	Utilising the existing ferry will prevent any reduction in power requirements, propulsion and services, through optimisation of the hull shape, selection of modern equipment, weight savings, etc..	Propulsion and services power requirements can be minimised through design optimisation and equipment selection.
Continuity of service	The existing ferry will be out of service for probably more than 6 months while being converted, bearing in mind that conversion will have to take place on the lake and without shipyard facilities.	The new ferry can be built while the existing ferry continues to provide the service with probably less than 2 weeks of no service for change-over.
Capital Cost Escalation	The cost of conversion of any vessel, but especially one 30 years old, is likely to escalate due to emergent work and the lack of shipyard facilities.	The design and build contract for a new vessel should be a firm price with minimal scope for cost escalation.
Operating Costs	Higher operating costs due to sub-optimum design	Lower operating costs due to optimised design (not withstanding any increase in size of vessel to provide increased capacity and onboard facilities).
Maintenance Costs	Higher maintenance costs due to remaining original structure, fit out and systems.	Lower maintenance due to new vessel with modern equipment.

ISSUE	RETROFIT EXISTING FERRY	NEW FERRY
Disposal Costs	By retrofitting the existing ferry no disposal costs are incurred until the end of her retrofitted service life (circa 2054)	Once the new ferry is commissioned the existing will require disposal incurring costs in 2024/25
Insurance	Expected increase in cost of insurance and potentially of gaining insurance of the retrofitted vessel.	Expected reduction in insurance for new vessel that is compliant with Class and MCA requirements.
Public perception	Does the retrofit of Mallard really represent value for money?	Positive response to modern, new ferry

Advantages and drawbacks of converting and modernising the current ferry

17. ANNEX C – NEW FERRY VEHICLE DECK SIZING

17.1 Introduction

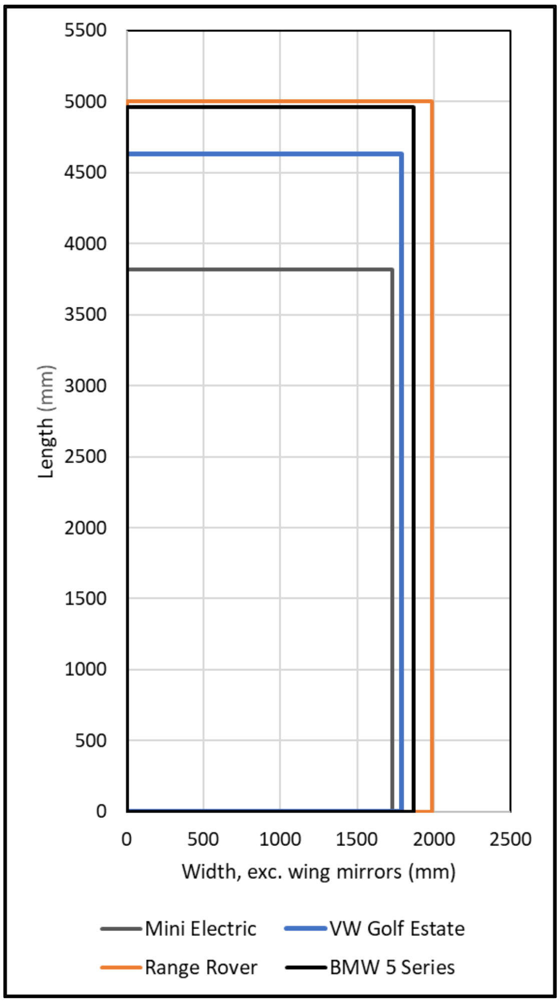
The requirements (Annex A) specified a target of 21 cars and at least 18 cars for the new ferry. To determine the appropriate vehicle deck size to accommodate these numbers of cars, a study was carried out of modern car sizes and some small car ferry designs.

17.2 Modern Car Sizes

The figure below shows the dimensions of a range of four modern cars.

The dimensions of four modern cars (Ref. J)

The length and width (excluding wing mirrors) of these cars are plotted in the figure below.



The length and width (excluding wing mirrors) of four modern cars

It can be seen from the figure above that the modern cars are typically between 3.8m and 5.0m long and between 1.73m and 1.99m wide.

Opening the door of a car fully typically requires between 1.0 and 1.1m, while opening the door to the three-quarters position typically requires about 0.75m.

17.3 Small Car Ferry Designs

17.3.1 Mallard

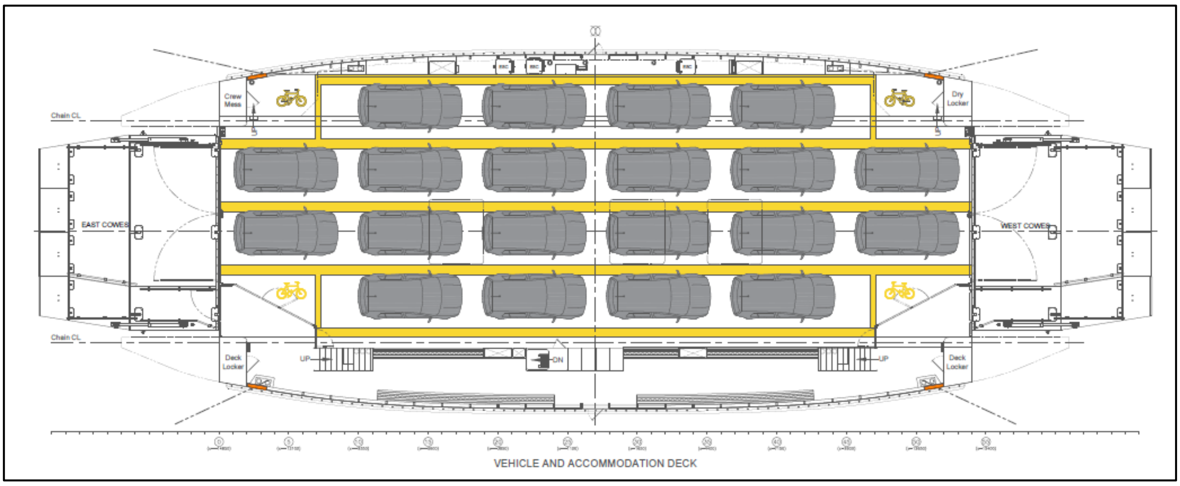
Mallard was designed to carry up to 18 cars but as car sizes have increased over the 30 years since Mallard was designed, more usually she can accommodate between 10 and 15 modern cars. The photographs below show cars on Mallard in 2021. The limited space between the cars and especially between some cars and the deckhouse structure can be seen.

Mallard loaded with 12 cars in Summer 2021

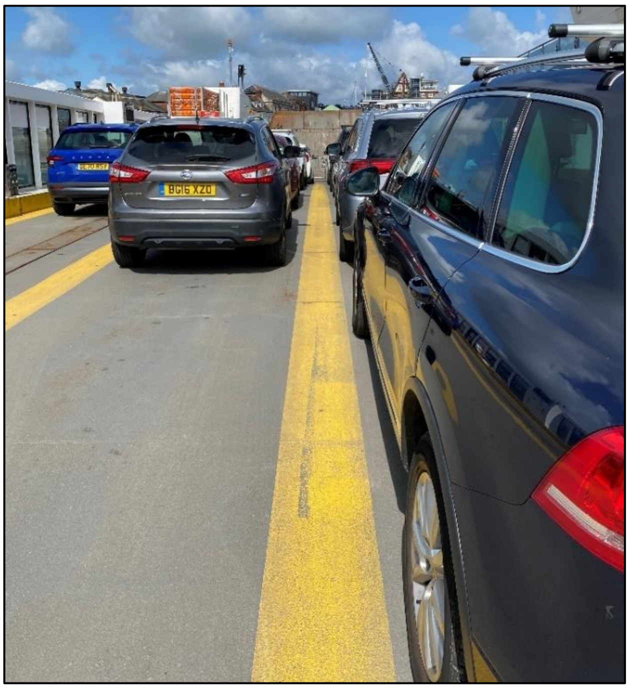
Mallard's car deck has a clear width of approximately 7.25m so with three lanes of cars each lane is 2.42m wide. If all the cars are 1.73m wide, then there would be an average of 0.52m between each of them. If all the cars are 1.99m wide, then there would be an average of 0.32m between each of them.

17.3.2 Cowes Floating Bridge

The current Floating Bridge chain ferry that operates between East and West Cowes on the Isle of Wight was designed in about 2015 to carry 20 cars in four lanes with an allowance of 4.9m x 2.5m for each car (Ref. K). The vehicle deck is illustrated in the figure and photograph below.



Cowes Floating Bridge vehicle deck with spaces for 20 cars (Ref. L)

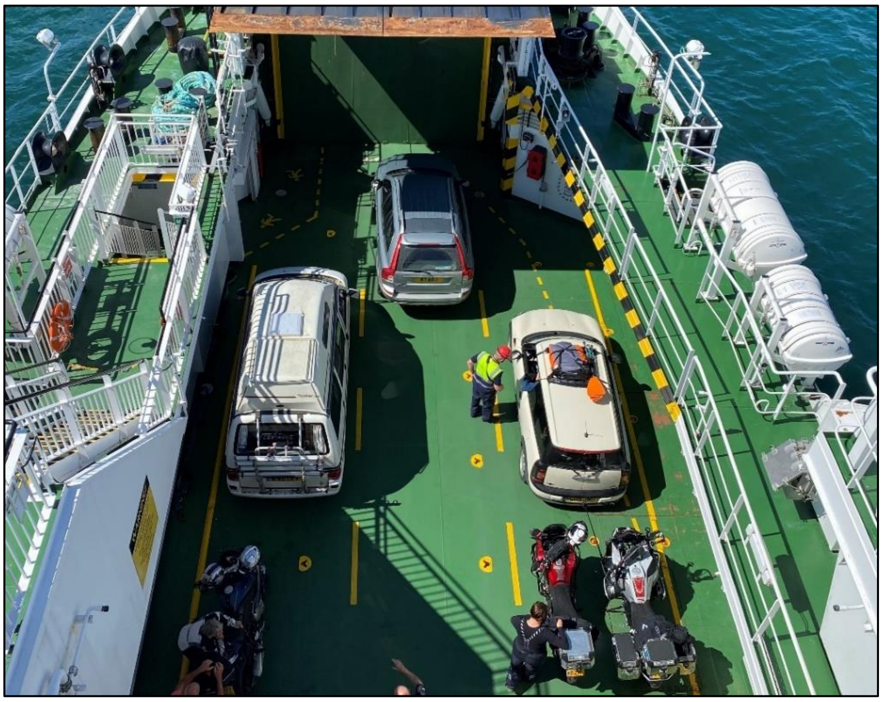


Cowes Floating Bridge vehicle deck

The clear width of the Cowes Floating Bridge car deck is 10.2m so if all the cars were 1.73m wide then there would be an average of 0.66m between them. If all the cars were 1.99m wide, then there would be an average of 0.45m between them.

17.3.3 Caledonian MacBrayne MV Catriona

The CalMac ferry MV Catriona entered service in 2017 and although not a cable or chain ferry, she still provides a good example of a modern small car ferry design. She was designed to carry 23 cars in 3 lanes. The vehicle deck is illustrated in the photograph below.



MV Catriona vehicle deck

MV Catriona has a clear vehicle deck width of approximately 8.27m so if all the cars were 1.73m wide then there would be an average of 0.77m between them. If all the cars were 1.99m wide, then there would be an average of 0.58m between them.

17.4 Discussion

This comparison of two modern small car ferry designs with the design of Mallard illustrates just how constrained the width of Mallard's car deck is. However, it is also surprising that unless adjacent cars are both at the smaller end of the size range the two modern small ferry designs may not provide sufficient space between the cars to open the doors to the three-quarter position. In reality of course, it is more likely that a typical loading will comprise cars of a range of sizes so on the two modern ferry designs there is likely to be around 0.6m between the cars.

Based on this study, it was decided that a clearance of not less than 0.75m between cars should be adopted for the new Windermere ferry. This figure would allow car doors to be opened to the three-quarter position in most cases.

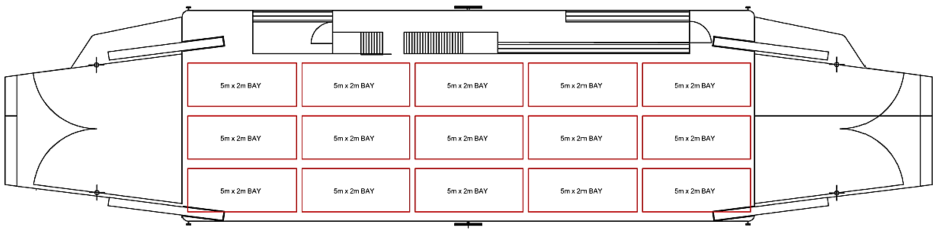
To ensure that this figure would not be compromised it was decided to adopt a car width of 2.0m for the design of the vehicle deck.

A car width of 2.0m is commensurate with a car length of around 5.0m and this car length was adopted for the new ferry.

Adopting these car sizes for the new ferry will provide a good degree of future proofing the design against further increases in the average car size over its 30+ year service life.

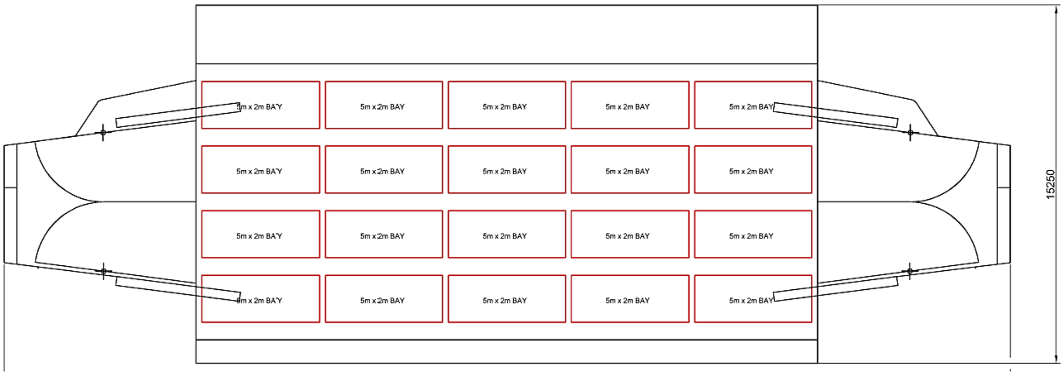
17.5 Vehicle Deck Layout Options

The number and width of the car lanes directly affects the overall beam of the ferry. The current Windermere ferry has three car lanes and consideration was given to three and four lanes for the new ferry. The resultant options for the new ferry are longer and narrower, or shorter and wider, as illustrated below with Mallard shown as a comparison.



Current ferry Mallard with 15 cars in 3 lanes

New ferry vehicle deck option with 21 cars in 3 lanes



New ferry vehicle deck option with 20 cars in 4 lanes

The width of the slipways the ferry operated from limits the width of the ferry's ramps and this in turn affects the number of car lanes. It can be seen from the figures above, that with four car lanes access to the ramps for both outer car lanes would be restricted and to address this either the car capacity would need to be reduced by four cars, or the length of the ferry increased. In either case the loading and unloading time is likely to be greater than with three lanes.

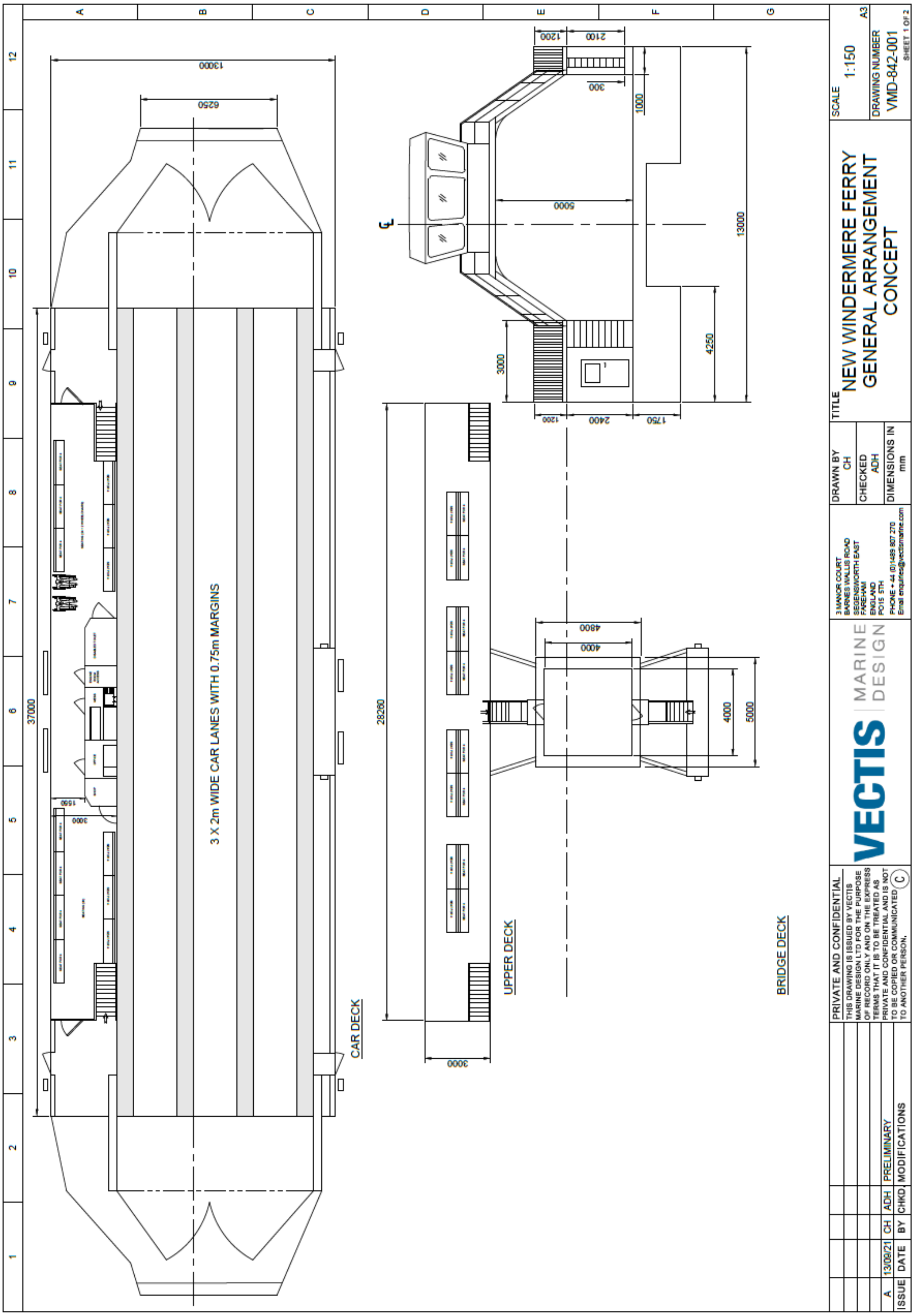
To overcome this the ramps and the slipways would need to be widened by up to 4m. Also, to accommodate the wider ferry the anchor points of the two drive cables at both slipways would require the re-siting to increase their separation by approximately 5m. Such major modifications to the slipways and cable anchor points were not considered viable or desirable.

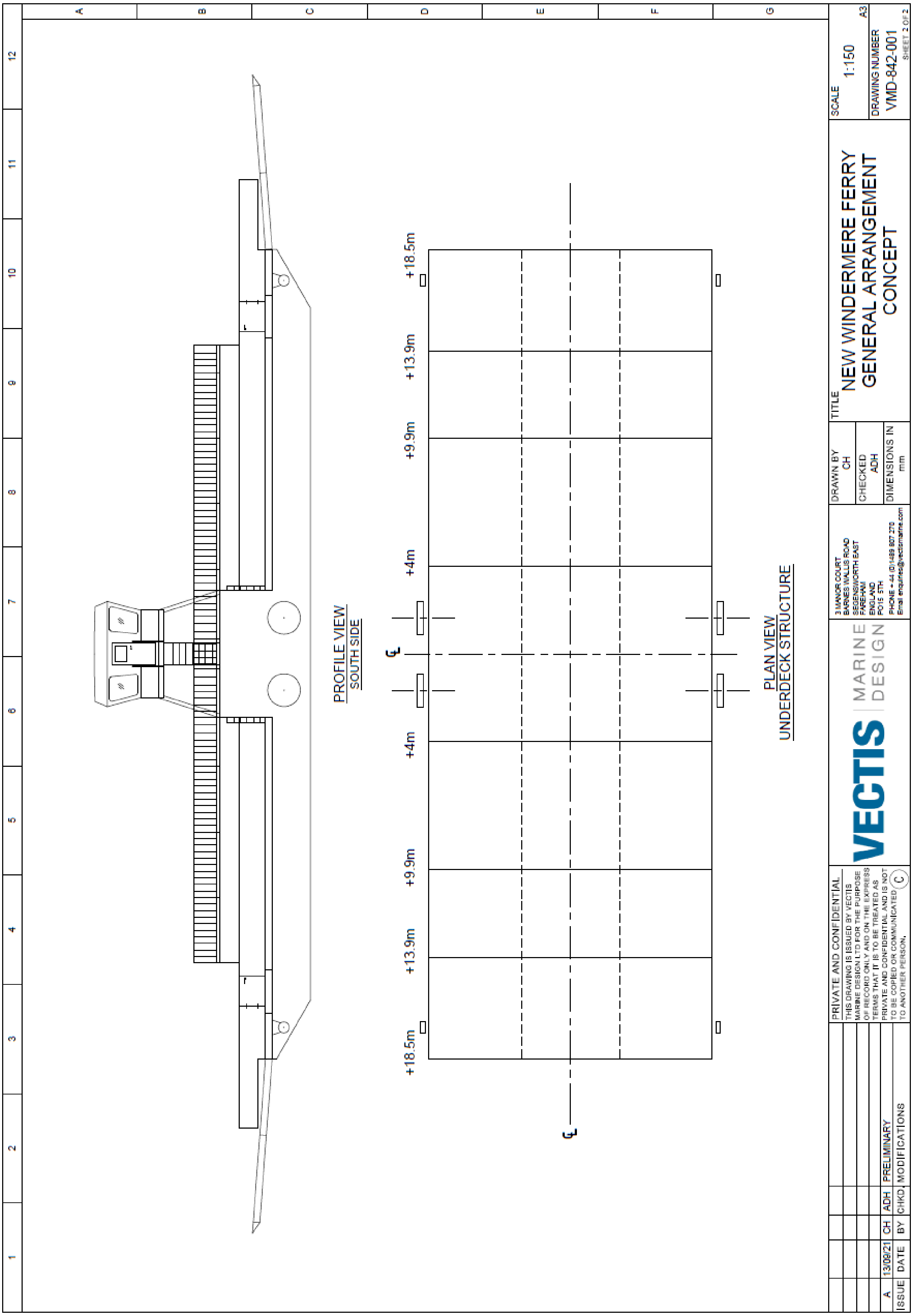
In addition, a shorter wider ferry will have greater resistance than a longer narrower one and so will require greater propulsive power which is also clearly undesirable.

For these reasons three car lanes were selected as the optimum for the new ferry.

18. ANNEX D – CONCEPT GENERAL ARRANGEMENT OF THE NEW FERRY

The concept general arrangement of the new ferry is shown below.




PROFILE VIEW
SOUTH SIDE
PLAN VIEW
UNDERDECK STRUCTURE
+18.5m
+13.9m
+9.9m
+4m
+4m
+9.9m
+13.9m
+18.5m
SCALE
1:150
A3
DRAWING NUMBER
VMD-842-001
SHEET 2 OF 2
TITLE
NEW WINDERMERE FERRY
GENERAL ARRANGEMENT
CONCEPT
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SEGENSWORTH EAST
FAREHAM
ENGLAND
PO15 5TH
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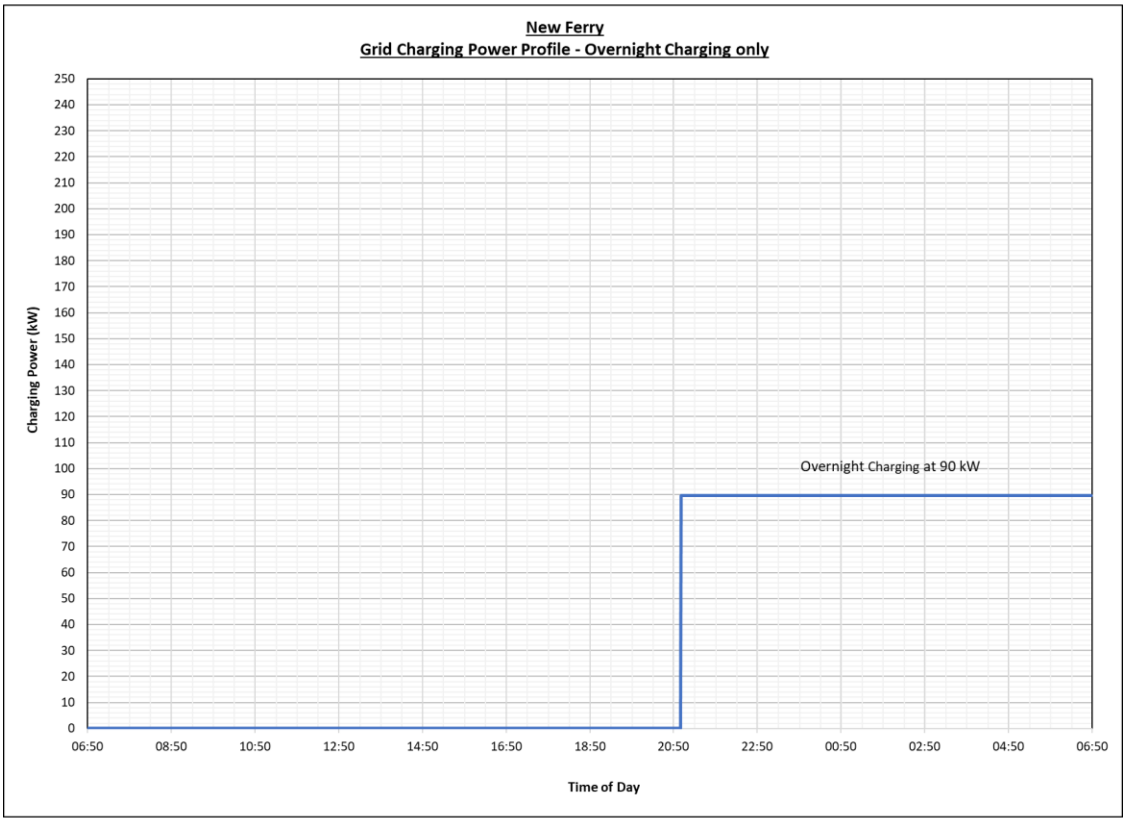
20. ANNEX E – SUMMARY OF DISCUSSIONS WITH ENWL

A meeting was held with Mike Taylor, Head of Customer Engagement and Neil McClymont, Strategic Projects, ENWL on 13 August 2021. The key points from that meeting are as follows.

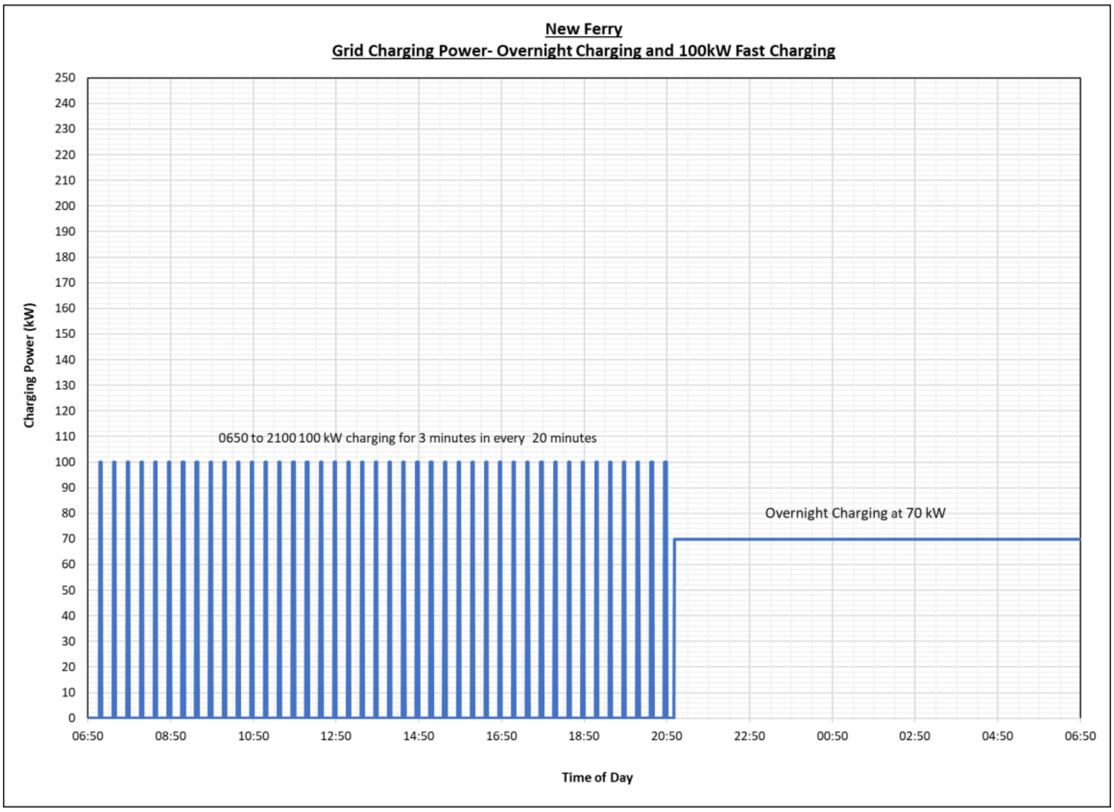
- ENWL presented 2-3 slides showing route of supply to east slipway. The target for the 2MVA supply to the slipway is March 2024. It requires running a new cable through Windermere town.
- 2MVA supply to the east slipway will be 11kVA,3 phase, 50Hz. Location of destination TBD.
- The 2MVA supply will not be a secure supply (it will have no back feed). So in the event of a failure the supply will be off. [We will reflect this in our pros and cons of the different propulsion options; the grid connected and winch options would be immediately affected, the battery operated option not immediately].
- Overnight usage for battery charging is no issue for ENWL. Daytime is the greater challenge.
- ENWL preference not to have a submarine cable to supply the west slipway (it would be expensive, may be vulnerable to damage, and slow to repair). It was not clear whether their scope could include a cable across to the west slip.
- There is some power available on the West side if needed. ENWL to investigate availability of 50 and 100 kW.
- Vectis presented different propulsion options and summary of load profiles.
- Vectis to send ENWL slides shown during meeting (propulsion options).
- Vectis to provide worst-case 24-hour load profiles for different options to ENWL.

21. ANNEX F – GRID ELECTRICAL LOAD PROFILES PROVIDED TO ENWL

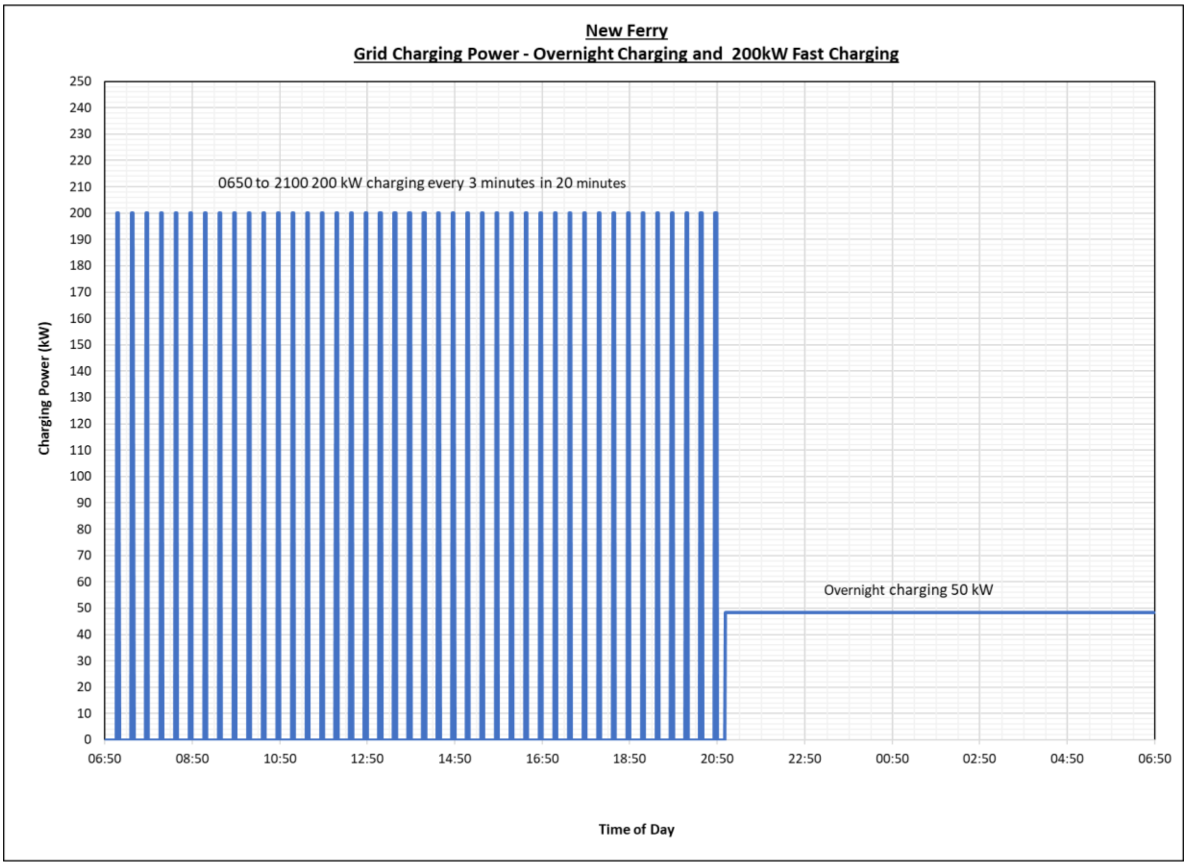
The figures below show the preliminary grid electrical load for each of the propulsion options.



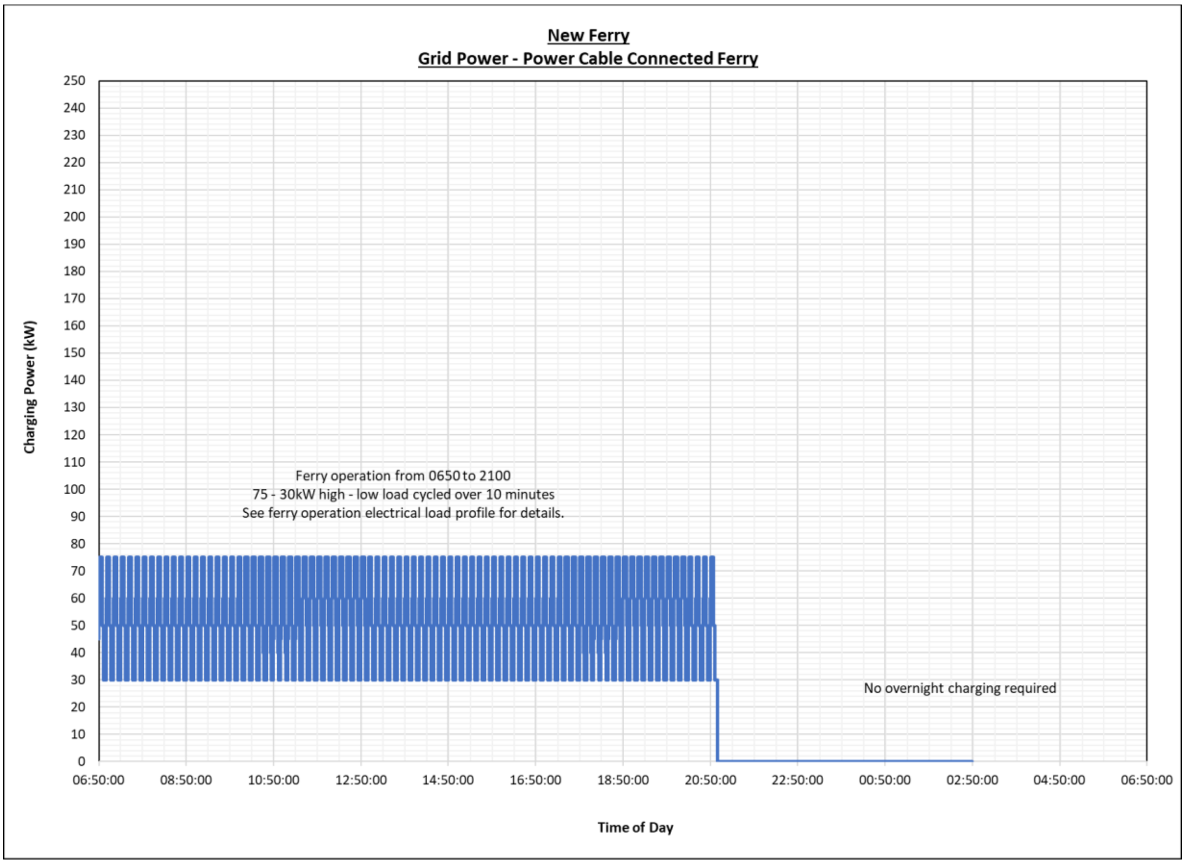
Grid electrical load – battery operated ferry – overnight charging only



Grid electrical load – battery operated ferry – overnight charging plus 100kW fast charge



Grid electrical load – battery operated ferry – overnight charging plus 200kW fast charge



Grid electrical load – grid-connected ferry

22. ANNEX G – BUDGETARY/ROM COSTS FROM SHIPYARDS

The tables below show the budgetary/ROM costs received from the shipyards.

22.1 Option 1 – Battery Operated Electric Ferry

	Shipyard A	Shipyard B	Shipyard C
Design of the new ferry	£338,250	Included	Included
Construction of the new ferry	£4,744,500	Included	Included
Delivery, assembly, and launch including transport and crane hire	£275,900	Included	Not included
Commissioning, installation, trials and acceptance	£34,475	Included	Included
MCA/Class Certification and Fees	Included	Included	Not included
Spares, Special Tools, Training, Documentation	£211,445	Not included	Not included
2 Years In-service Support	£53,855	Not included	Not included
TOTAL	**£5,658,425**	**£4.8 million**	**Euro 5 million (≈£4.3 million)**
Estimated total with *Not Included* items	**£5,658,425**	**£5.1 million**	**£5.0 million**

22.2 Option 2 – Grid Connected Electric Ferry

	Shipyard A	Shipyard B	Shipyard C
Design of the new ferry	£338,250	Included	Included
Construction of the new ferry	£4,478,650	Included	Included
Grid connection system (cable & reel)	Not included	Included	Not included
Delivery, assembly, and launch including transport and crane hire	£275,900	Included	Not included
Commissioning, installation, trials and acceptance	£34,475	Included	Included
MCA/Class Certification and Fees	Included	Included	Not included
Spares, Special Tools, Training, Documentation	£211,445	Not included	Not included
2 Years In-service Support	£53,855	Not included	Not included
TOTAL	**£5,392,575**	**£5.5 million**	**Euro 3 million (≈£2.6 million)**
Estimated total with *Not Included* items	**£5.5 million**	**£5.5 million**	**£3.5 million**

Taking the average of the three quoted prices the battery-operated ferry will be in the region of £5.2 million and the grid-connected ferry in the region of £4.8 million. Note, these figures do not include some associated and infrastructure costs which are indicated in Annex J below.

23. ANNEX H – PROJECT COST SUMMARY

The table below shows the estimated 2022 ROM costs of the project.

Item	Option 1 Battery-operated Electric Ferry	Option 2 Grid-connected Electric Ferry	Source
Design of the new ferry Construction of the new ferry Delivery, assembly and launch including transport and crane hire Commissioning, installation, trials and acceptance Spares, Special Tools, Training, Documentation 2 Years In-service Support	£5.2 million	£4.8 million	Based on ROM costs from shipyards (see Annex G)
Hire of lake side assembly site	£100k	£100k	Allowance
Drive Cables	£15k	£15k	Based on current costs
Grid-connection Cable Reel System	n/a	£100k	Quoted budget prices
Grid-connection Cable	n/a	£18k	Quoted budget prices
Shore charging facilities	£0.25 million	n/a	Allowance
Shore connection facilities	n/a	£0.25 million	Allowance
Civil engineering works	£0.5 million	£0.5 million	CCC allowance
Consultancy	£0.25 million	£0.25 million	Estimate
TOTAL	**£6.3 million**	**£6.0 million**	---
Margin (7.5%)	£0.47 million	£0.45 million	Margin
TOTAL	**£6.8 million**	**£6.5 million**	---

24. ANNEX I – INDICATIVE PROJECT DURATIONS FROM SHIPYARDS

24.1 Option 1 – Battery Operated Electric Ferry

	Shipyard A	Shipyard B	Shipyard C
Design of the new ferry	6 months	6 months	3 months
Construction of the new ferry	12 months	6 months	6 months
Delivery of the ferry to Windermere Lake side	1 month	1 month	0.5 month
Completion of the new ferry at the lake side	1 month	4 months	1 month
Commissioning, installation, trials and acceptance	1 month	2 months	1 month
TOTAL	21 months	19 months	11.5 months

24.2 Option 2 – Grid Connected Electric Ferry

	Shipyard A	Shipyard B	Shipyard C
Design of the new ferry	6 months	6 months	2 months
Construction of the new ferry	12 months	6 months	5.5 months
Delivery of the ferry to Windermere Lake side	1 month	1 month	0.5 month
Completion of the new ferry at the lake side	1 month	4 months	1 month
Commissioning, installation, trials and acceptance	1 month	2 months	1 month
TOTAL	21 months	19 months	10 months

