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# Forth Replacement Crossing Study

## Report 5 : Final Report

### Non Technical Summary



Grant Thornton 

TRIBAL

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## NON TECHNICAL SUMMARY

### INTRODUCTION

Jacobs and Faber Maunsell were commissioned by Transport Scotland to undertake the Strategic Transport Projects Review (STPR). The STPR commission involves identifying the strengths and weaknesses of the Scottish strategic transport network, identifying gaps between the future demand and capacity of the network and then producing a prioritised list of interventions for the period 2012 to 2022. The commission also covers a study of the Forth Replacement Crossing, the main work packages of which are reported as follows:

- Report 1 : Network Performance;
- Report 2 : Gaps and Shortfalls;
- Report 3 : Option Generation and Sifting;
- Report 4 : Appraisal Report; and
- Report 5 : Final Report.

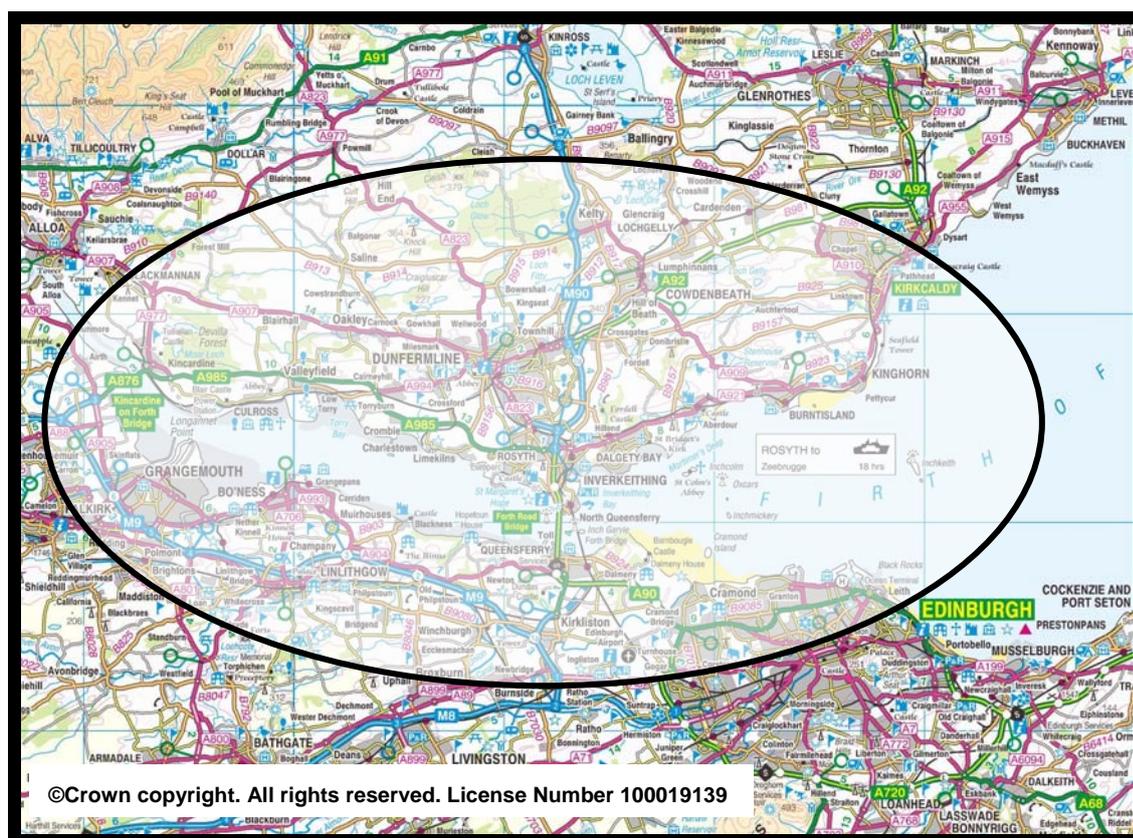
The primary objective of the Forth Replacement Crossing Study (FRCS) was to identify the scope, form and function of any potential replacement to the existing Forth Road Bridge. The need for a replacement crossing is for the following two key reasons:

- there is a lack of certainty that the existing bridge is going to be available in the future; and
- the repair/refurbishment of the existing crossing has too severe a set of impacts on the east of Scotland economy if it were to be closed (or even severely restricted) for a period of time.

This report forms the Non Technical Summary of Report 5 and summarises the findings of all the work undertaken during the course of the study.

The area considered for the Forth Replacement Crossing Study is outlined in Figure 1 overleaf.

Figure 1 - Study Area and Associated Transport Network



Recent reports from the Forth Estuary Transport Authority (FETA) would suggest that the refurbishment of the existing crossing will have severe impacts on traffic flows across the bridge for a period of between three and four years.

Further development is required to determine the role that the existing Forth Road Bridge should play once refurbished. However, this is dependent upon the level of investment that is required to achieve a number of different possible outcomes. A final decision may, therefore, have to be left until further information is forthcoming from, amongst others, the FETA Cable Replacement Study.

Therefore, it is important that any replacement crossing that emerges from this study allows sufficient flexibility to accommodate the findings of this further work, as appropriate. Specifically, should the Forth Road Bridge be refurbished and re-opened then consideration would have to be given as to how it could be used in combination with any replacement crossing. Therefore, this report also considers how such a strategy may operate. The guiding principle of the operation of this combination would be that there should be no more than two lanes available for general traffic in each direction. Additional capacity offered by the presence of the two crossings would be reserved for sustainable modes such as public transport or high occupancy vehicles.

An assessment of complementary measures, such as additional rail services or bus/high occupancy vehicle lanes, has also been undertaken as part of this study. These measures could be implemented prior to any replacement crossing being constructed, they have also been considered in the context of a twin crossing strategy in the event that the refurbished Forth Road Bridge is brought back into commission.

## EXISTING AND POTENTIAL PROBLEMS

There is likely to be an increased requirement for significant maintenance on the existing Forth Road Bridge in the future regardless of the problems associated with cable corrosion. This maintenance cannot be undertaken without temporary traffic management measures, such as contraflows, being put in place which will restrict the capacity of the crossing. Evidence from occasions earlier this year (2007), when maintenance on the bridge has taken place at weekends, indicates that serious congestion is experienced. Delays of between 60 and 90 minutes have been recorded, despite the fact that traffic flows were some 30 per cent lower than the corresponding weekend in 2006.

The forecast increases in daily traffic crossing the Forth will exacerbate the high levels of congestion experienced during restrictions or closures on the Forth Road Bridge. It is also envisaged that, due to the type of maintenance works expected to be undertaken on the bridge in future, it will not be possible to limit these traffic management restrictions to weekends as is currently the case.

It is envisaged that in the future road users will be faced with an increased number of occasions when restrictions are placed on vehicles using the bridge on both week days and weekends. Due to the growth in traffic the delays and queues experienced are likely to be greater than those currently encountered during maintenance periods. Further information can be found regarding existing and potential problems within Report 1.<sup>1</sup>

## PLANNING OBJECTIVES

Current and emerging policies that are relevant to the STPR and in particular the Forth Replacement Crossing Study have been considered in detail. The recently published National Transport Strategy and associated documents have been particularly important in guiding the development of the study objectives. The objectives have also drawn extensively on previous work undertaken by both the South East Scotland Transport Partnership (SEStran) and FETA. Consideration has also been given to the consultation that has already taken place in the development of current policy and undertaken directly as part of this study.

Following careful consideration of the above factors, a number of study specific objectives have been developed and tested, leading to the establishment of a final set of study objectives. These have subsequently informed work in the latter phases of this project.

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<sup>1</sup> Forth Replacement Crossing Study – Report 1- Assess Existing, and Forecast Future, Conditions of the Transport Network within the Vicinity of the Forth Road and Rail Bridges, Transport Scotland/Jacobs/Faber Maunsell – February 2007

Therefore, the Forth Replacement Crossing Study objectives are to:

- maintain cross-Forth transport links for all modes (of transport) to at least the level of service offered in 2006;
- connect to the strategic transport network to aid optimisation of the network as a whole;
- improve the reliability of journey times for all modes;
- increase travel choices and improve integration across modes to encourage modal shift (use of alternative types of transport) of people and goods;
- improve accessibility and social inclusion;
- minimise the impacts of maintenance on the effective operation of the transport network;
- support sustainable development and economic growth; and
- minimise the impact on people, the natural and cultural heritage of the Forth area.

In addition the government's five key objectives have been built into the appraisal methodology:

- Safety;
- Economy;
- Environment;
- Integration, and
- Accessibility and Social Inclusion.

Specific performance indicators, such as journey times between key locations, have also been identified to highlight gaps and shortfalls between the future performance and expectations of the transport network in the vicinity of the Forth bridges.

Further information regarding planning objectives can be found within Report 2.<sup>2</sup>

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<sup>2</sup> Forth Replacement Crossing Study – Report 2 – Gaps and Shortfalls , Transport Scotland/Jacobs/Faber Maunsell – February 2007

## OPTION GENERATION AND INITIAL SIFTING

A long list of 65 potential options was generated and this was subjected to an initial sifting process. This was undertaken with a view to reducing the list by eliminating options which did not satisfy the objectives of the study or were not technically feasible. Following this process, the approach adopted was to consider the crossing location and whether bridges and/or tunnels would be feasible solutions in the following five corridors:

- A – Grangemouth (West of Bo’ness);
- B – East of Bo’ness;
- C – West of Rosyth;
- D - East of Rosyth/West of Queensferry; and
- E – East of Queensferry.

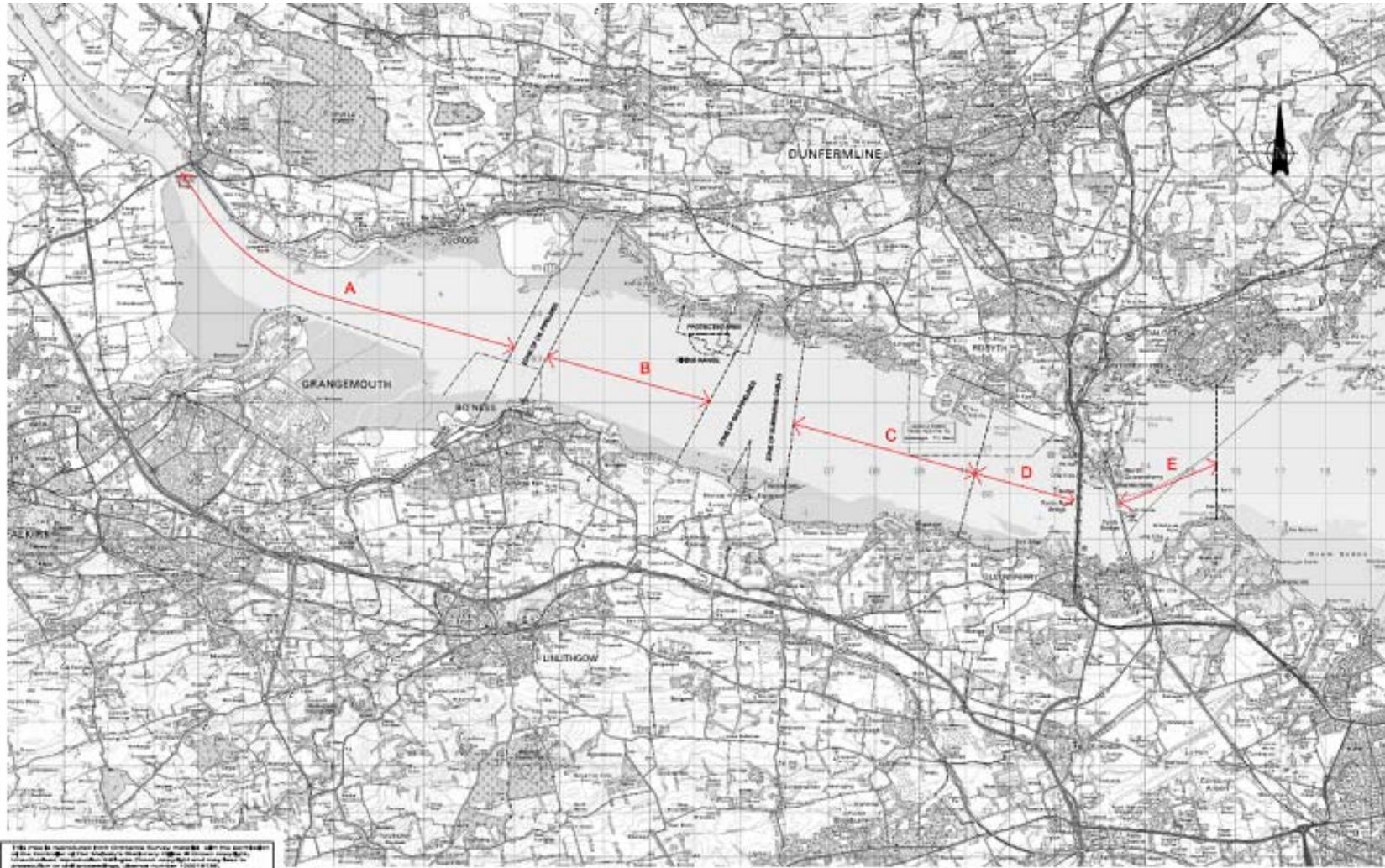
Figure 2 overleaf outlines the five corridors considered.

The work undertaken confirmed that Corridors A and B did not meet the objectives of the study and were, therefore, rejected. It was concluded that these corridors would not be considered further within the study. Corridors C, D and E did, however, perform to varying degrees against the objectives and these were taken forward for further appraisal as part of the Scottish Transport Appraisal Guidance (STAG)<sup>3</sup> process with bridge and tunnel options considered for all three corridors.

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<sup>3</sup> Scottish Transport Appraisal Guidance (STAG), Scottish Executive - September 2003

Figure 2 - Study Crossing Corridors



## STAG PART 1 APPRAISAL

In order that more detailed STAG appraisal could be developed, initial route alignments were developed as part of Report 3 – Option Generation and Sifting<sup>4</sup>. These alignments then formed the basis for STAG Part 1 appraisal.

Whilst the majority of the planning objectives were met by each of the proposals, it was evident that the degree to which they were met varied across corridors and crossing types.

Assessment of the performance of the proposals against the appraisal criteria identified that the critical issues related to the STAG environment objective and the study specific planning objective to “minimise the impact on people, the natural and cultural heritage of the Forth area”. The bridge proposals in Corridors C and E performed particularly badly in this regard as both the northern and southern landfalls cross, or come very close to, the Forth Special Protected Areas which may lead to loss of Special Protected Area habitat. Both were considered to have major adverse impacts on a European designated site and are unlikely to be permitted when viable alternatives exist that have less or no adverse impact. The bridge in Corridor D was considered to avoid this impact.

STAG indicates that any proposal which fails to meet the Part 1 appraisal test should be rejected. In this case, given the importance of the Special Protected Area and the likely impact which these bridge proposals would have on it, it was considered that the bridge proposals in Corridors C and E should be set aside and not carried forward to the more detailed STAG Part 2 appraisal.

The outcome of the STAG Part 1 appraisal was that the following proposals were taken forward for further development:

Corridor C – tunnel;

Corridor D – bridge;

Corridor D – tunnel; and

Corridor E – tunnel.

## CORRIDOR PROPOSALS

The design detail and construction methodology of each of the four remaining proposed crossings was examined. Also, included for each option was a summary of the network connections required to connect the new crossing to the existing road network. Attention was placed on developing technically and operationally robust and efficient solutions for each option.

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<sup>4</sup> Forth Replacement Crossing Study – Report 3 – Option Generation and Sifting, Transport Scotland/Jacobs/Faber Maunsell – February 2007

The tunnel in Corridor C would be 8.5 kilometres in length and would be constructed through a combination of conventional Tunnel Boring Machine (TBM) and Sprayed Concrete Lining (SCL) tunnelling techniques. These techniques are discussed in more detail in Report 4<sup>5</sup>. It is expected to take 7.5 years to construct with the capital cost of construction estimated to be £2.3 billion, including network connections and Optimism Bias<sup>6</sup> in Quarter 4 2006 prices. Figures 3 to 8 inclusive are taken from Report 5, Chapter 6<sup>7</sup>.

Figure 3 – Typical Cross Section for a Tunnel Boring Machine Tunnel

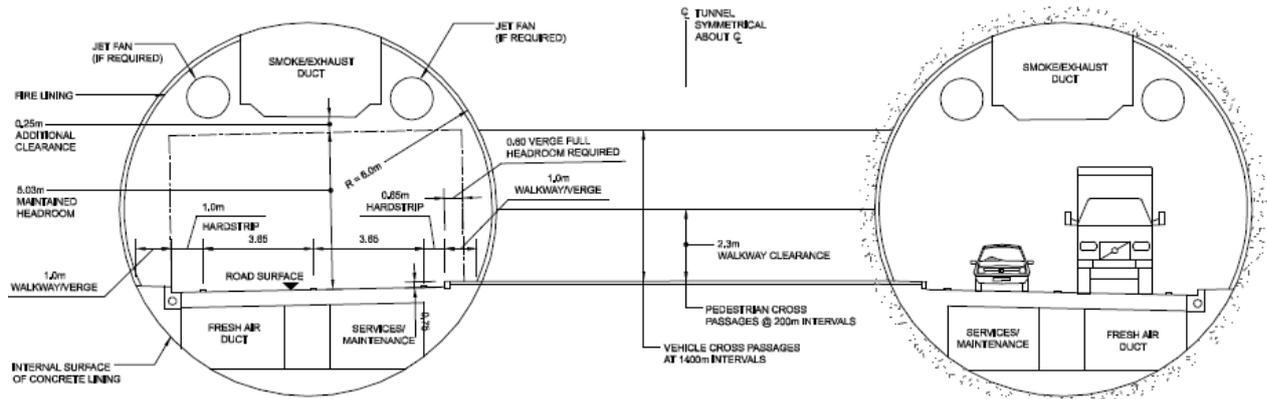
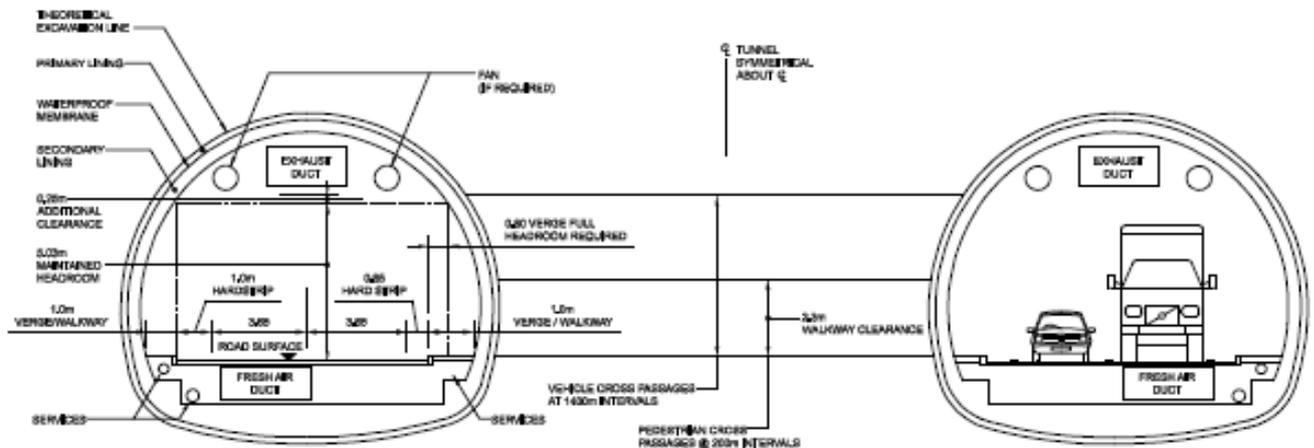


Figure 4 – Typical Cross Section for a Sprayed Concrete Lining Tunnel



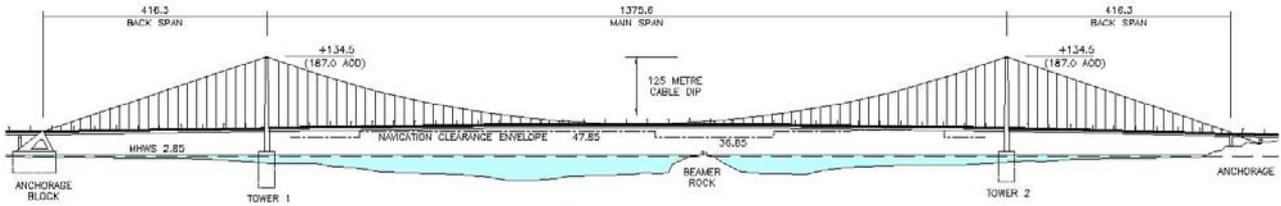
There are two types of bridge options suggested for Corridor D. The first is a suspension bridge with a 1375 metre main span and a 40 metre wide deck. It is estimated that this would take 6 years to construct. Its cost is estimated to be £1.7 billion, including network connections and Optimism Bias in Quarter 4 2006 prices.

<sup>5</sup> Forth Replacement Crossing Study – Report 4 – Appraisal Report, Transport Scotland/Jacobs/Faber Maunsell – June 2007

<sup>6</sup> Optimism Bias – Is an allowance for a project's costs and duration to be underestimated and/or benefits to be overestimated.

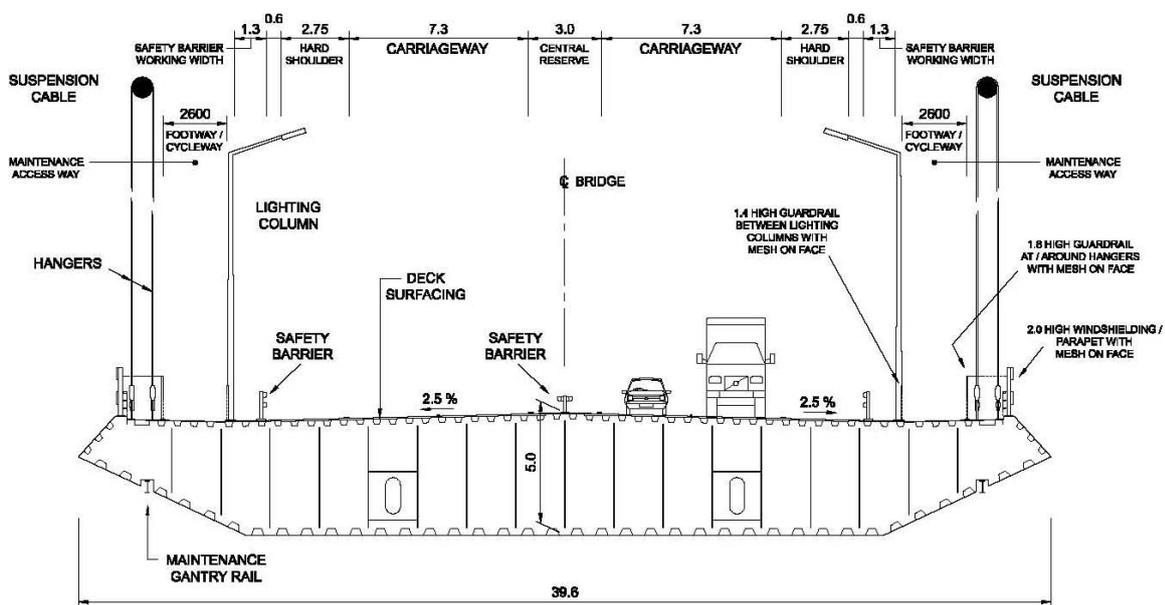
<sup>7</sup> Forth Replacement Crossing Study – Report 5 – Final Report, Transport Scotland/Jacobs/Faber Maunsell – June 2007

Figure 5: Suspension Bridge Option



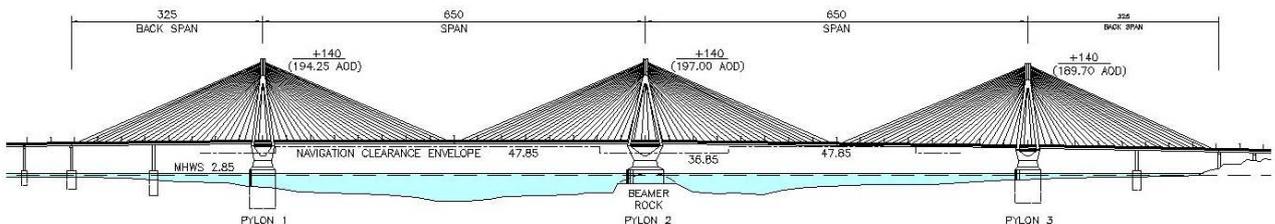
A typical cross section for a replacement bridge crossing deck is shown below.

Figure 6 – Deck Cross Section for Dual 2 Lane Motorway Standard



The second type of bridge considered in Corridor D is a cable stayed bridge with two main spans of 650 metres and 40 metre wide deck. This would take around 5½ years to construct and is estimated to cost £1.5 billion, including network connections and Optimism Bias in Quarter 4 2006 prices.

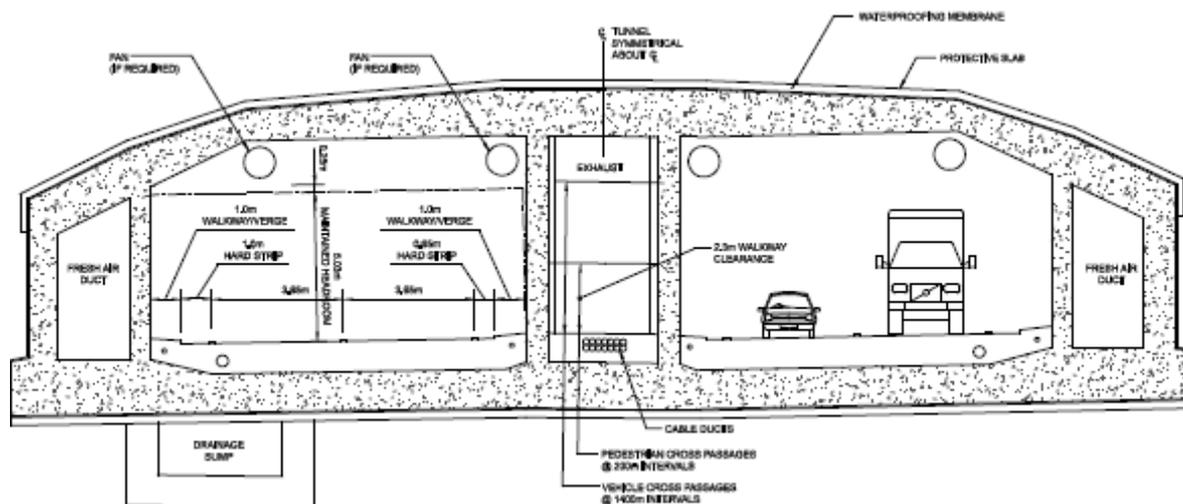
Figure 7: Cable Stayed Option



The tunnel in Corridor D is 7.3 kilometres in length and would also be constructed using a combination of conventional Tunnel Boring Machine and Sprayed Concrete Lining tunnelling techniques. It would take 7½ years to construct and is estimated to cost £2.2 billion, including network connections and Optimism Bias in Quarter 4 2006 prices.

Finally the tunnel in Corridor E is also 7.3 kilometres in length and would be constructed using a combination of conventional Tunnel Boring Machine, Sprayed Concrete Lining and immersed tube techniques. It would take 7½ years to construct and is estimated to cost £2.4 billion, including network connections and Optimism Bias in Quarter 4 2006 prices.

**Figure 8 – Typical Cross Section for an Immersed Tube Tunnel**



## STAG PART 2 APPRAISAL

Following completion of the STAG Part 1 process the remaining corridor proposals were taken forward for more detailed STAG Part 2 appraisal. This includes more detailed assessment of the proposals' performance against the Government's five objectives and the specific planning objections developed for this study. A summary of this assessment is outlined in the following paragraphs.

### Implementability

There are currently a greater number of technical risks for the three tunnel options. This is due to uncertainties in relation to ground conditions and the likelihood of hitting dolerite (hard, volcanic rock). There is also the possibility of the progress of the Tunnel Boring Machine being impeded by the presence of unknown obstructions, such as timber in the glacial deposits (mixtures of clay, silt, sand, gravel, and boulders). Construction difficulties are also envisaged with the formation of the required cross passages required to link the northbound and southbound tunnels. The construction techniques required would involve working at very high water pressures (7 times atmospheric pressure) and would include the use of ground freezing treatment. Corridor E Tunnel also has issues associated with the construction of an immersed tube tunnel, such as the transition from bored tunnel and the likelihood of needing to blast dolerite, both under the Forth. The assessment identified fewer technical risks with the Bridge proposal in Corridor D.

### Environment

An Environmental Appraisal has been undertaken as part of the study to consider the impacts of the crossing and the results are ranked within an established range from "Significant Adverse" to "Significant Benefit". The Environmental Appraisal findings show that the environmental impacts of the proposals would generally be similar, typically minor to moderate adverse. The main exception to this would be the impacts on biodiversity where Tunnel E and Bridge D options may have Major to Moderate Adverse impacts.

For Corridor E Tunnel this is due to the proposed immersed tube that would disturb sediments and may impact on the Firth of Forth Special Protected Area and Forth Islands Special Protected Area, which are protected at the European level, as well as other European protected species such as cetaceans. In addition, approach roads at the southern end of Corridor E Tunnel pass through the Dundas Castle Gardens and Designed Landscapes, which is a national designation.

For Corridor D Bridge there is a significant risk of indirect disturbance to protected species particularly within the Forth Islands Special Protected Area but also relating to the Firth of Forth Special Protected Area. This may impose significant seasonal constraints during construction, as the Forth Islands Special Protected Area protects breeding birds (i.e. spring and summer) whilst the Firth of Forth Special Protected Area protects over-wintering birds. In addition, the northern landfall of Corridor D Bridge passes through the St Margaret's Marsh SSSI, protected at national level, and would involve the partial loss of areas of ancient woodland.

## Safety

Typically the proposals result in marginal reductions for all accident types in all options. Corridor D Tunnel, Corridor E Tunnel and Corridor D Bridge perform similarly, with accident savings valued at around £220 million. Corridor C Tunnel produces benefits at a slightly lower level of approximately £180 million.

No specific security issues have been identified which would differentiate between the options. The majority of issues can be managed through best practice in relation to bridge and tunnel operations.

## Transport Economic Efficiency

The direct economic impacts of a project are captured by a “cost-benefit” analysis which is expressed in monetary terms. The project costs (PVC) to Government and benefits (PVB) to society (such as savings in distance travelled) are combined to produce a Net Present Value (NPV). All values are discounted back to a common base year, which is currently 2002.

A positive NPV implies that the benefits to users are of greater value than the costs whereas a negative NPV implies the benefits have a lower value than the costs. The benefit cost ratio (BCR) is a simple calculation (PVB divided by PVC) to illustrate the net benefit of spending each £1 on the project. In purely economic terms, a BCR greater than 1 suggests that a project is worth undertaking.

A summary of the results is given in the table below.

### Monetised Summary of Costs and Benefits (£millions, 2002 values and prices)

Corridor	C	D	D	D	E
Crossing Type	Tunnel	Tunnel	Cable-Stayed Bridge	Suspension Bridge	Tunnel
Present Value of Benefits (PVB)	4,655.6	5,303.1	6,026.1	6,026.1	6,317.1
Present Value of Costs (PVC)	-2087.4	-1967.7	-1,397.3	-1,574.9	-2,172.2
Net Present Value (NPV)	2568.2	3,335.3	4,628.8	4,451.1	4,144.9
Benefit to Cost Ratio (BCR)*	2.23	2.70	4.31	3.83	2.91

\*ratio, not monetary value

In all scenarios analysed as part of the detailed appraisal the benefits were found to be greater than the costs.

Corridor D Bridge produces the most favourable results, with the lower cost of the cable-stayed variant giving the highest NPV and BCR. The most favourable tunnel option in economic terms is that of Corridor E. This option produces the highest level of monetised benefits, but at a significantly higher level of cost than Corridor D Bridge. This results in a lower NPV and BCR. The higher level of benefits is a consequence of the proximity of the southern connections with routes into the city of Edinburgh. However, this is contrary to current regional and local policies which are aiming to discourage vehicular traffic growth in Edinburgh.

### Economic Activity and Location Impact

At the national level, the main positive impacts will be felt by existing businesses. At the regional level, existing businesses and new businesses are forecast to experience positive impacts. At the local level, all the corridors are anticipated to have positive economic development effects with Corridors C and D tending to favour West Lothian while Corridor E tends to favour north and central Edinburgh.

### Integration, Accessibility and Social Inclusion

All options perform similarly in relation to the integration, accessibility and social inclusion criteria. This is particularly the case when a replacement crossing is being compared against a scenario where the Forth Road Bridge is closed to all traffic.

## TWIN CROSSING STRATEGY

This part of the study considers how a new Forth Crossing might operate alongside the existing Forth Road Bridge if this were to be refurbished and brought back into use.

The key objective was to develop an operational arrangement, which complied with the requirements of the study brief, current national policies, complements the proposed alignments and allows flexibility during abnormal conditions.

Based on the assessment of some 160 different operational arrangements the following options are recommended:

- **Option OP1:**  
Replacement crossing: Two lanes for any vehicles;  
Existing Crossing: One bus lane and one high occupancy vehicle lane.
- **Option OP3:**  
Replacement Crossing: One lane for any vehicles and one lane for bus and high occupancy vehicles;  
Existing Crossing: One lane for any vehicles and one lane for bus and high occupancy vehicle

The final recommendation for the operational arrangement will require to be confirmed later in the development of the replacement crossing project once the future of the Forth Road Bridge is better understood.

## COMPLEMENTARY MEASURES

Possible complementary measures have been identified that would be used to improve the performance of the network on, and in the vicinity of, the Forth bridges and on any replacement crossing. These measures might be considered interim measures prior to the construction of any Forth crossing but should also be considered in terms of how they might be maintained as part of the final strategy. Measures considered for further assessment include high occupancy vehicles lanes, bus priority measures, park and choose sites, further bus services, additional rail capacity, ferry services, active traffic management and variable tolls. The last option may no longer be available given the likelihood that tolls will be removed in the near future.

## PROCUREMENT AND FINANCE

An initial assessment of the options to procure, fund and deliver a Forth Replacement Crossing has been undertaken. There are a range of alternatives available for both the procurement and the funding. At this stage, it is still too early in the overall project development to be definitive on procurement and finance options. As the project develops factors may emerge that require a change or refinement of the procurement and funding strategy. However, from the initial assessment of the crossing options it is clear that there is nothing has been identified which would preclude or materially impact any of procurement and funding options identified at this stage.

A variety of statutory mechanisms have been reviewed by which, alone or in combination, the Scottish Ministers would be able to secure the necessary legal authority to construct a Forth Replacement Crossing.

## RECOMMENDATIONS

Following a robust appraisal process adopting Scottish Transport Appraisal Guidance, the principal factors for differentiating between the options were found to be implementability, environmental impact, and economic efficiency.

It is recommended that Corridor E Tunnel should not be considered further for the following reasons:

- the environmental impacts;
- the implementability risks associated with tunnels;
- the impact of drill and blast construction techniques on Hound Point;
- the mine workings on the south side; and
- the high cost of this option.

Of the remaining tunnel options (C and D), there is little to choose between them. Both are estimated to take 7.5 years to construct and have similar costs (£2.2 - £2.3 billion). The monetised benefits of D are marginally better than C due to its proximity to the existing cross Forth corridor. The environmental benefits of both are similar and do not impact on the Special Protected Area. When considered as a replacement crossing the tunnel options would not be able to provide the same facilities as a bridge crossing, as pedestrians and cyclists would not be permitted into the tunnels for safety reasons.

Overall, taking on board all factors considered within this study, it is recommended that the bridge in Corridor D be taken forward as the best overall performing option from this study. This is for the following reasons:

- it is significantly cheaper than the tunnel options;
- it can be delivered quicker;
- it has fewer risks associated with its construction; and
- it demonstrates the best value for money.

Environmentally, however, the bridge options do not perform as well as the tunnel options in Corridors C and D. There are likely to be direct impacts on the St Margaret's Marsh SSSI in the north side of the corridor. There may also be indirect disturbance to protected species within both the Forth Islands and the Firth of Forth Special Protected Areas. These may impose seasonal constraints during construction. The full scale of these impacts would not be known until such time that an Environmental Impact Assessment has been carried out.

Of the two types of bridge structure, the cable stayed bridge has advantages over the suspension bridge in that it is the cheaper option and can be delivered around six months earlier. The use of cable stayed techniques would avoid the need for complex foundations on the landfalls, therefore, avoiding the methane risk on the southern side of the Forth.

Cable stayed bridges are modern forms of long span crossings and provide the opportunity to create a vista across the Forth of three different types of bridge construction comprising the old (Forth Rail Bridge), recent (Forth Road Bridge) and the new (replacement bridge). The visual impact of this vista will require to be discussed further with Architecture and Design Scotland (Scotland's architecture body).

Given all of the above factors, it is recommended that the replacement crossing be a cable stayed bridge in Corridor D. This should incorporate two lanes with hardshoulders plus pedestrian walkways/cycleways in each direction. Network connections should be provided principally to join the A90/M90 to the north of the Forth and to the M9 in the south. The form, type and location of the recommended bridge crossing are shown overleaf in Figures 9 and 10.

Figure 9 -The general form and type of the recommended Cable Stayed Bridge Option

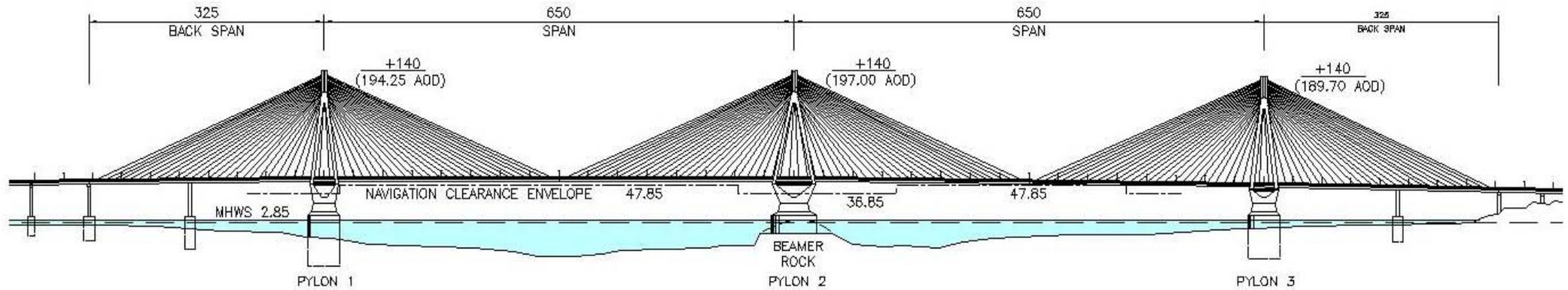


Figure 10 -The Location of the recommended Cable Stayed Bridge D Option

