Exeter to Newton Abbot

Geo-Environment Resilience Study

Executive Summary

for Stakeholders & the Community

Winter 2016/17

Introduction

Established by Brunel in 1846, the section of Western Route between Exeter to Newton Abbot is one of the most iconic railway lines in the UK.

The route runs through the Exe estuary alongside open coastline between Dawlish and Teignmouth, and the Teign estuary. It was selected as it was the only area that offered a level foundation for trains to travel along.

Since its construction the route has been constrained and impacted by its environment.

Rock falls and landslips from the cliffs have led to blockages of the track. Flooding and erosion has also caused sea defence failures, which in turn has led to flooding during storms along the exposed open coast areas.
On numerous occasions train operations have been disrupted owing to waves breaching these defences.

The vulnerability of the route was dramatically highlighted on the 4th February 2014 when, following heavy storms, the original Brunel seawall was breached.

Spectacular images were reported in the national news showing the track hanging across the breached defences (Figure 1).

Less reported, as the route was already closed, was a large landslide on the steep cliffs close to Teignmouth (Figure 2) during March 2014.

It took two months to get trains running again beyond Exeter, and cost
£50million. The overall impact of the disruption to the Southwest economy was estimated to be in excess of a billion pounds.

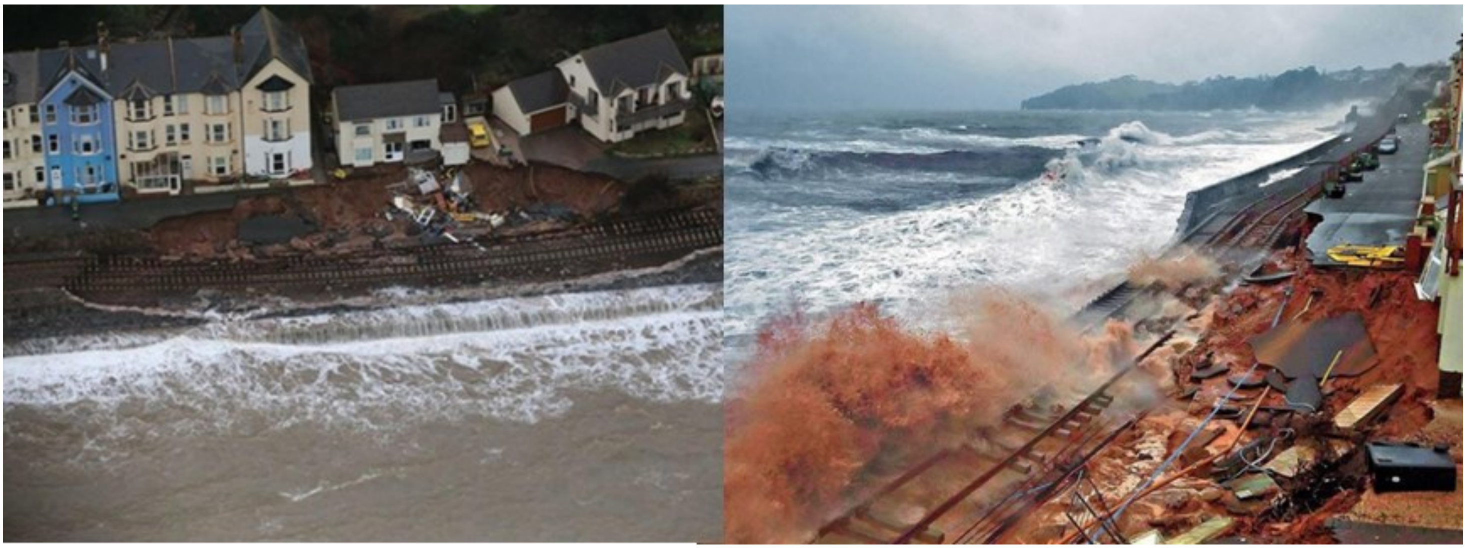

Figure 1 – Images of the breached railway at Dawlish, 4th February 2014.

Figure 2 – Landslip at Woodlands Avenue near Teignmouth, March 2014

The reinstatement of the line following these series of catastrophes was hailed as a success.

However, the events highlighted the fragility of the existing railway assets, the severity of the operating environment and the importance of the route to the national economy.

In response to this Network Rail commissioned the Exeter to Newton Abbot Geo-Environmental Resilience Study in December 2014.

The Study Objectives and Extent

The aim of the study was to build an evidence based long-term strategy that identified interventions to improve the resilience, and minimise the potential for catastrophic events over the next 100 years. The objectives were to undertake a review of the route, its assets, and risks; importantly understanding how these risks may be modified with future climatic change.

The study defined key aims that the strategy should achieve:

- Consider a 100-year climate change view;
- Enable future long-term strategic requirements and capacity;
- Enhance resilience regarding safety and performance;
- Identify the most advantageous whole life cost, social, economic, and environmental solution;
- Reduce the frequency of asset failures; and,
- Minimise overall time between service-asset failure.

The study was undertaken in three phases: collation of an evidence baseline, option development, and finalising in an overall strategy.

The route was also sub-divided into five areas based on the environmental characteristics:

1. Exeter St. David's to Dawlish Warren: The low lying Exe Estuary and its floodplains;
2. Dawlish Warren to Kennaway Tunnel: Consists mainly of seawalls backed by low cliffs;
3. Kennaway Tunnel to Parsons Tunnel: Numerous tunnels with portals exposed to the open coast backed by high cliffs
4. Parsons Tunnel to Teignmouth: An existing seawall with high cliffs landward
5. Teignmouth to Newton Abbot: The low lying Teign Estuary

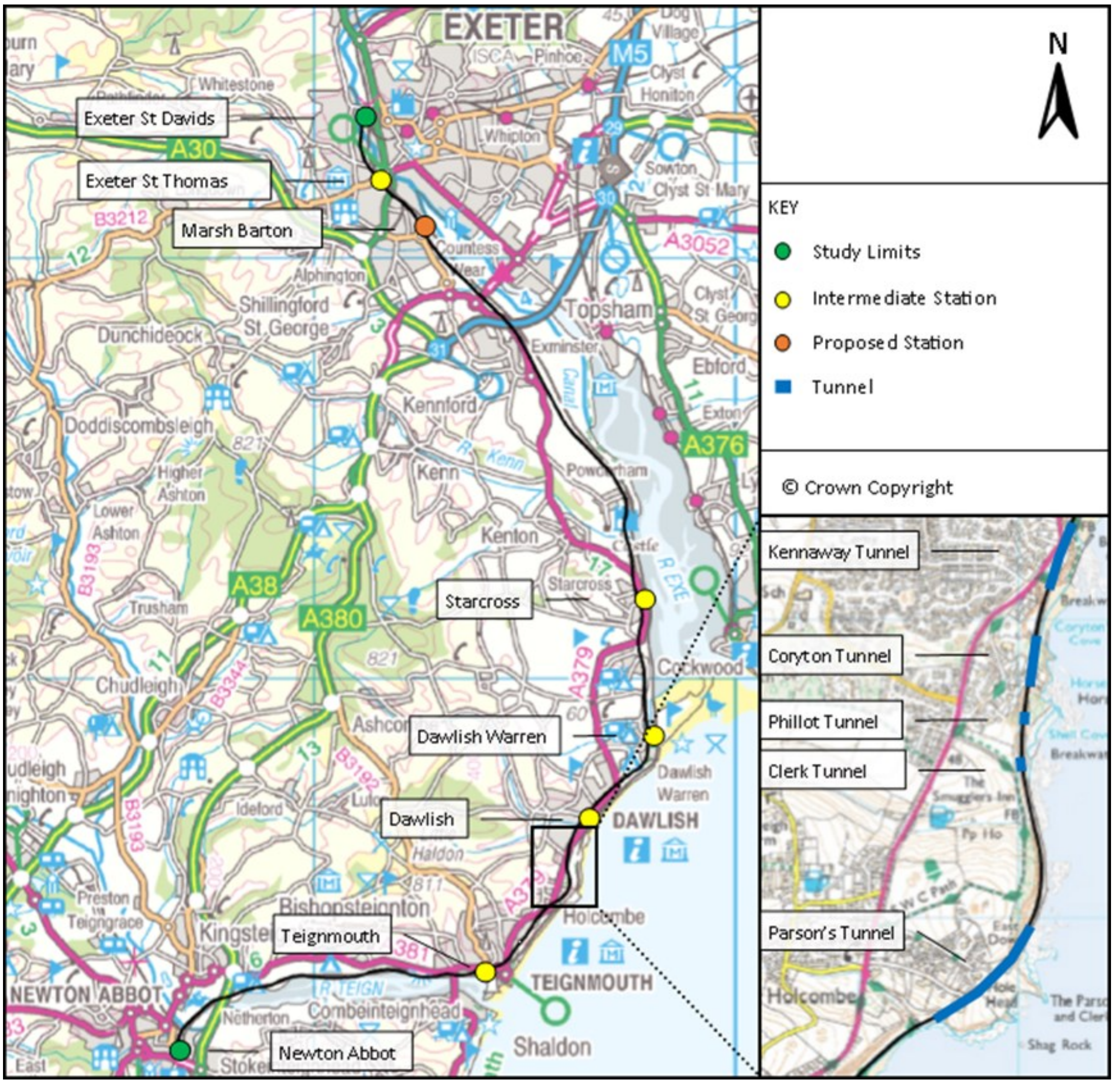

Figure 3 – Geo-Resilience Study Extents

Phase 1: Baseline Understanding

Under the first phase of the study, information was collated to establish an evidence and assessment baseline against which options could be developed and tested. The baseline phase included:

- Review of historic failures and disruptions;
- Assessment of potential future climate change and definition of the parameters to be considered within the study;
- Summary of coastal processes; including,
    - Modelling of waves and water levels that cause flooding;
    - Review of beach levels and sediment transport patterns;
- Collation of information relating to the current assets along the route and their performance; including,
    - Coastal and flood defences;
    - Cliffs and geotechnic properties, including the definition of Cliff Behaviour Units (areas of cliffs with specific geotechnic properties and characteristics); and,
    - Rail infrastructure assets;
- Appraisal of the existing resilience and known future requirements;
- Definition of the economic baseline;
- Details of the natural and social-economic environment, which may require consideration during the option development.

Definition of Climate Change Parameters

The study considered a wide range of climatic conditions predominantly based on the findings of the UK Climate Projections 2009 (UKCP09) that could have a direct impact on the railway within the Study extent (Table 1).

Table 1 – Climate Change Parameters

Climate Metric	Change Factors					
	2065			2115		
	Low	Med	High	Low	Med	High
Summer Daily Extreme Temperature	+3.5°C	+4.0°C	+8.2 °C	+4.3°C	+6.5 °C	+15.2 °C
Sea Level Rise	+26cm	+30cm	+55cm	+49cm	+57cm	+107cm
0.5% Probability Storm Surge	n/a	n/a	+47cm	n/a	n/a	+105cm
Winter Rainfall	+11%	+15%	+43%	+15%	+19%	+77%
Summer Rainfall	-28%	-36%	-64%	-34%	-45%	-89%
Rainfall Intensity	+7%	+13%	+27%	+15%	+30%	+60%
River Flows	+2%	+23%	52%	+10%	+40%	+110%

While a range of scenarios were considered the medium scenario values were adopted as a 'target' climate condition against which options should be appropriately resilient. The high scenario values were viewed as a 'sensitivity' test to ensure strategy options were adaptable in the event of more severe climatic change.

Definition of Resilience

The baseline phase defined what Network Rail considered in terms of resilience for the route between Exeter and Newton Abbot. To assess resilience three event categories were defined with the current frequency assessed. The strategy defined targets for the resilience and these are included in the descriptions below:

1. **Extreme** – the closure of the route for a period of one or more weeks. This was currently estimated to occur approximately every 10 years. The final strategy aimed to ensure these events were limited to once per 100 years.

2. **Severe** – the closure of the route for a minimum of 48 hours and up to a maximum of one week. The final strategy aimed to ensure these events were limited to once per 20 years.

3. **Moderate** – disruption of rail operations for up to 48 hours, including frequent individual events that last up to 48 hours, which was currently estimated as occurring annually. The final strategy aimed to reduce the frequency of these events but did not specify a target as the events could be occurred by a freak event. The likelihood is that in addressing the more severe and extreme resilience would automatically result in improvements to the performance against moderate events.

Phase 2: Development of Options

The development of options was undertaken individually for each of the asset groups of coastal, geotechnical and rail infrastructure. Initially the development of long list options considered a wide range of alternatives, with few over-riding constraints. This approach helped to ensure that a wide range of alternatives were considered. The following sections describe a selection of the key options considered with indicative options shown in Figure 4 and 5.

Coastal Defence Options

Options were outlined to address the coastal and estuarine risks based on the environmental influences known to occur now and in the future, as well as the existing type of structure.

Feasible solutions would either improve or replace existing structures to increase the operational performance and remaining structural life. Examples of the solutions considered are outlined below:

- Raise the height of the seawall. Through encasement of the existing seawall or provision of new structures to reduce wave overtopping and protect against increased water levels.

- Provide rock revetments in front of existing or modified structures, to reduce impact, erosion and overtopping by waves.

- Beach Management. Reducing the size of waves reaching the existing structures using beach nourishment, sand engines and/or beach control structures such as toe berms and groynes to help maintain and extend beach levels in front of existing structures.

- Provision of Offshore Breakwaters. These structures would prevent large waves reaching the existing shoreline reducing wave overtopping and erosion. They also have potential to enhance marine biodiversity.

- Moving the railway away from the toe of the cliff by providing a reclaimed foundation. This option moves the track away from cliff fall risks and where required provides room to accommodate geotechnical solutions such as toe buttressing.

Geotechnial Options

To address the geotechnical risks, options were proposed based on the known geotechnical conditions, the type of risk and the proximity to the track. Where the cliffs were particularly high and at increased risk of failure (along Parson's Tunnel to Teignmouth) a combined geotechnical and coastal solution was proposed.

- Barriers provided along the cliff toe. This would prevent falling and washed out cliff material from spilling onto the track, contaminating the ballast or blocking the track;

- Improve or provide additional cliff drainage to reduce groundwater levels within the cliffs, particularly during heavy rainfall;

- Rock mesh and soil netting combined with soil nailing. This would both stabilise cliff slopes and contain loose material preventing it reaching the track;

- Regrade the cliffs to reduce their gradient. This would decrease the potential for slips and falling material.

- Extend existing or provide new rock fall shelters over vulnerable sections of track, particularly between tunnel portals. To prevent falling material reaching the track;

- Combined with the coastal option to move the track seawards, provision of a toe buttress along the base of the cliffs to stabilise them against landslips.

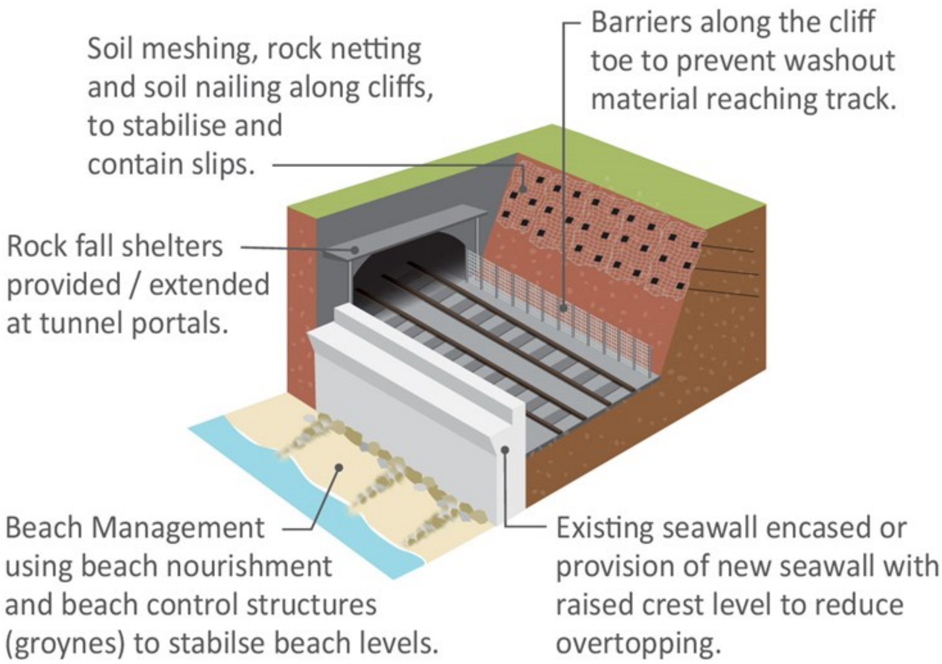

Figure 4 – Options for Open Coast Sections 2 and 3

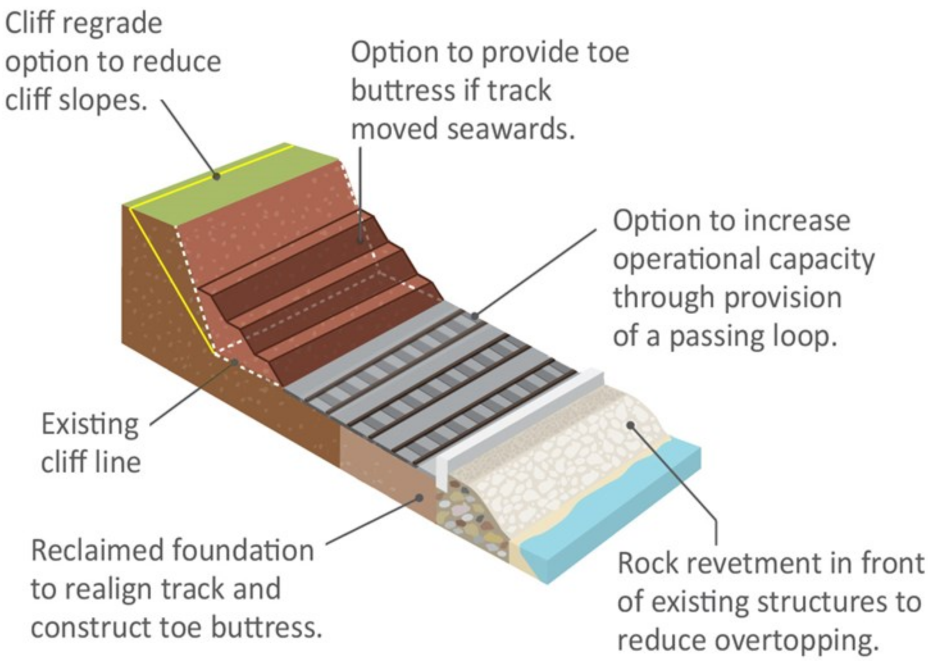

Figure 5 – Options for Section 4 adjacent to Teignmouth

Rail Infrastructure Options

It was evident that significant improvements in operational resilience would not be achieved by improvements to rail infrastructure alone. Technology such as signalling and communications are constantly changing and generally rail infrastructure assets have significantly shorter life cycles. Therefore, improvements in resilience could be achieved through standard maintenance lifecycles or addressed within implementation of a larger scheme. The specification of capital works packages focusing solely on rail infrastructure assets was subsequently discounted within the strategy.

Improvements to the rail infrastructure for consideration during maintenance or as part of capital works were identified as:

- Considering the location and material specification of protective cabinets for electrical equipment where wave overtopping or flooding may occur;
- Gluing or containing the rail ballast to prevent it from washing away during overtopping or flooding;
- Specification of corrosion resistant materials and coatings for equipment and assets; and,
- Monitoring equipment to detect problems or failure.

Short-List and Preferred Options

With the long-list options defined an appraisal process was undertaken which refined options further along discrete sections of the route. The assessment of the options was based on the knowledge gathered during the baseline phase and assumptions around the option implementation. Figure 6 shows the option selection process, and the objectives or criteria at each stage.

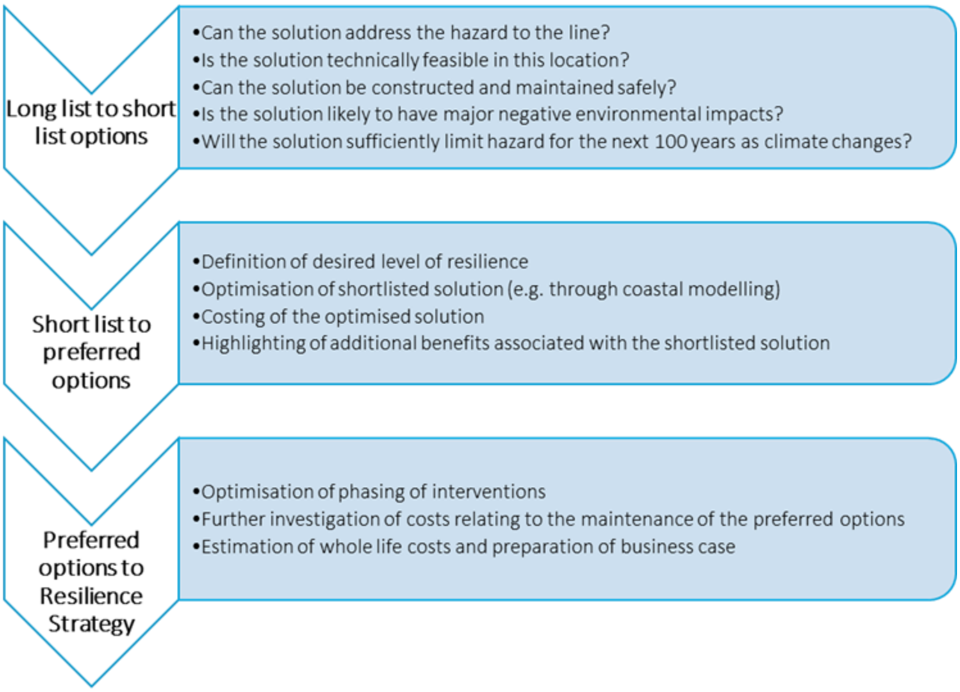

Figure 6 – The option selection process

Phase 3: The Resilience Strategy and Business Case

The final phase of the study combined the work from the option appraisal with intervention timings, costing information to produce a final Resilience Strategy which outlined preferred coastal and geotechnical solutions.

The Resilience Strategy

Details of the preferred options are contained within the Phase 3 Report which should be referenced as to proposals and intervention timings. However, in summary:

1. Exeter St. David's to Dawlish Warren: The low lying Exe Estuary will suffer mainly from flooding issues as sea levels rise. Therefore, providing new realigned embankments and coastal defences are proposed;
2. Dawlish Warren to Kennaway Tunnel: The cliffs along this section require prevention of cliff material falling on to the track. The focus of investment however, is to address the current and increasing risk of wave overtopping through the provision of improved seawall protection;
3. Kennaway Tunnel to Parsons Tunnel: Rock fall from cliffs and wave overtopping between the tunnels are to be addressed in priority order.
4. Parsons Tunnel to Teignmouth: This section is at immediate risk from further cliff instability. The cliff fall at Woodlands Avenue in 2014 highlighted the vulnerability along this section. The preferred option is to move the railway alignment seawards and provide a toe buttress to the stabilise the cliffs.
5. Teignmouth to Newton Abbot: The low lying Teign Estuary is the least vulnerable section of the route. As sea level rise occurs over the next century additional raised wall protection may be required to prevent inundation of the track.

The overall infrastructure investment outlined within the Resilience Strategy is in the region of £650 million, this is an unvalidated preliminary estimate. Network Rail is currently funded in five year Control Periods (CP)

Delivery of interventions is focused on CP6 to CP8 (2019 to 2034) with further significant investments deferred beyond 2050. The investment phasing was targeted to deliver the maximum benefit at the earliest opportunity whilst prioritising sections considering current risks.

The strategy provides a delivery schedule with major interventions aligned to be delivered within Control Periods.

Table 2 shows the prioritised work packages to address the most immediate risks with delivery within CP6. Table 3 shows the remaining interventions and Control Periods.

Table 2 – Prioritised Work for CP6 Delivery

Priority Schemes	Intervention
Priority 1 Sites (Design in CP5, Delivery CP6)	Section 2: Marine Parade between Dawlish Station and Kennaway Tunnel – Provision of improved seawall defence to reduce overtopping on to track.
	Section 3: Cliff Behaviour Unit 17 – Provision of additional rock fall protection and cliff stabilisation works at Parson's Tunnel north portal.
	Section 4: Parson's Tunnel South Portal to Teignmouth – Reclamation foundation to allow realignment of the track and provision of a toe buttress to address cliff stability.
Priority 2 Sites (Design in CP6, Delivery CP6/7)	Section 2: Dawlish Cliffs – Remedial works to prevent cliff debris reaching the track through netting, drainage, and toe barriers.
	Section 3: Central Tunnels – Cliff stabilisation and Tunnel Portal Protection along with short sections of coastal defence improvements between tunnels.

Table 3 – Prioritised Work for CP7 Onwards

Location	Intervention	Proposed Control Period
Section 2: Langstone Rock to Dawlish Station	New seawall and beach management	CP8
Section 2: Dawlish Warren to Langstone Rock	Replacement of existing rock revetment	CP8
Section 1: Powderham	New embankments provided along a set-back alignment	CP8
Section 1: Starcross	New seawall defences along the estuary	CP8
Section 5: Teignmouth Estuary	Defence raising to combat sea level rise along the estuary	CP10
Section 3: Coryton Cove	New sea wall and beach nourishment	CP12
Section 3: Clerk's Tunnel to Parson's Tunnel	New Rock Revetment	CP12
Section 1: Powderham to Starcross	New seawall defences along the estuary	CP12
Section 1: Starcross to Eastdon	New seawall defences along the estuary	CP15
Section 5: Teign Estuary (Shaldon Bridge)	Defence raising to combat sea level rise along the estuary	CP15
Section 1: Exeter Canal to Turf Locks	Reinforcement and raising of defence level by sheet piling through existing embankments	CP15
Section 5: Teign Estuary (Bishopsteighton)	Defence raising to combat sea level rise along the estuary	CP18
Section 1: Eastdon to Dawlish Warren	New seawall defences along the estuary	CP18

To allow for the required planning, design, and procurement processes, it is anticipated that development work on a scheme would start in the control period CP prior to the target delivery period.

Business Case

Alongside the development of the strategy a key objective was to demonstrate that investment in major infrastructure works along the route would be economically beneficial to the UK.

To assure the economic benefit of the proposed strategy the study utilised the Department for Transport's (DfT) WebTAG economic appraisal methodology. A "Do-Minimum" scenario was defined as the baseline or "Business as Usual". Existing rates of maintenance spend and disruption costs were used to estimate the cost and value of the current railway operation. Disruption profiles were modified based on increases in risks owing to climate change.

The estimated Present Value Benefits of the Resilience Strategy considered over 60 years is £485m and the estimated Present Value Cost is £239m. The resulting Net Present Value of £245m provides a Benefit Cost Ratio of 2.03. On this basis the Resilience Strategy falls within DfT's "High Value for Money" classification.

It should be noted that the WebTAG assessment excluded consideration of benefits of the Resilience Strategy to the wider Southwest economy such as impacts to tourism. Assessment of these benefits was outside the scope of the Geo-Resilience Study.

The WebTAG analysis used the default 60-year appraisal period recommended for major infrastructure. Sensitivity testing, to the 100-year horizon and considering the asset value, demonstrated that the strategy would continue to provide economic benefits beyond the default 60-years owing to the design life of solutions.

Next steps…

The aim of the Resilience Strategy was to outline interventions required to improve resilience along the route. Having defined the interventions and their timings it is important for Network Rail to begin to implement the findings of the strategy.

The first stages will be to commence procuring the services required to deliver the interventions of the Priority One Sites.

This section outlines in further detail the drivers behind the Priority One Sites and the works required to be undertaken.

Within Section 2 at Marine Parade, between Dawlish Station and Kennaway Tunnel, significant wave overtopping currently causes disruption to operations.

Along this section the seawall defence is at its lowest and previous storms have caused significant damage to rail assets. The recommendation from the strategy is to provide a raised seawall defence, designed to modern standards.

The wall is likely to incorporate features such as a wave return to minimise the wave overtopping, while limiting the crest level increases required.

Environmental impacts will need to consider:

- maintaining and improving the public access which exists along the crest of the current structure;
- Minimising the impact on the beach in terms of footprint and the impact of scour on beach levels.

Following analysis of a recent drone survey of the cliffs, the works in CBU17 has been re-prioritised as there is additional evidence of cliff instability. This section of works will require the extension of the existing rockfall shelter along 250m of cliff which is assessed as being at high risk.

The largest section of works is along the mile long open coast of Section 4. Here the track is closely confined at the base of cliffs which are elevated up to 90m above the track level. This section contains the Woodlands Avenue cliff that failed in March 2014. The preferred option is to move the track alignment seaward onto a reclaimed foundation; protected by a rock revetment coastal defence. Moving the track seaward allows for the provision of a cliff toe buttress that would protect the cliff, preventing a large slip failure. This option will be undertaken through a Transport Works Act order.

The total construction cost of the proposed Priority 1 Sites work is approximately £260m with an additional £20m for development work for priority sites 1 and 2.

Network Rail is currently in year 3 of CP5, the delivery of the Priority 1 Sites are programmed for delivery within CP6. Given the scale of the works it is necessary that design and planning works are undertaken within CP5 to ensure delivery of benefits by the end of CP6. Currently there is a funding shortfall of £10m to complete development in CP5 to allow implementation to commence in CP6. Network Rail will also seek longer-term commitments through future CP periods to the implementation of the remainder of the Resilience Strategy.