ETR 138 ANNEX
Issue 1 2018

Resilience to Flooding of Grid and Primary Substations
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First published June 2018

Amendments since publication

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<th>Date</th>
<th>Amendment</th>
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Annex 1  GB Electricity Distribution System

A1.1 Overview of the GB Electricity Distribution System and Impact of Flooding

Network businesses in GB operate under licences issued by Ofgem and are subject to a Regulatory framework set by Ofgem. They also are subject to statutory requirements including The Electricity Act and Electricity Safety Quality and Continuity Regulations (ESQCR) which are overseen by BEIS and the Health and Safety Executive (HSE).

Spending plans for the industry are agreed by Ofgem with individual Network Owners every eight years and these reviews govern all expenditure which includes flood mitigation and emergency planning. This provides common oversight and accountability to Ofgem and BEIS.

In GB, electrical power is transported from generating plants to customers over networks managed by Transmission and Distribution Network Owners. The Transmission System operates at typically 400,000 volts (400kV) or 275kV (and 132kV in Scotland) and the Distribution system operates at voltages from 132kV to the normal household voltage of 230V. This is shown below.

Electricity Supply Chain

In England and Wales, National Grid own and operate the Transmission System whereas in Scotland the Transmission Networks are owned by Scottish Power and SSE but operated by National Grid and the interface between transmission and distribution systems takes place within grid substations at 33kV.

These systems comprise a mixture of overhead lines and underground cables that generally are not susceptible to flooding but there is a potential for statutory safety clearances to be affected in flood conditions. In addition there are points on the system, called substations, where voltage transformation takes place and switching and control
equipment are located. The type of equipment operating at these substations can be vulnerable to flooding if water reaches certain critical depths. The loss of supply incidents in 2007 in Yorkshire and Gloucester all occurred as a result of substation flooding when the exceptionally high water levels reached critical depths at some substations.

The relative importance of different types of substation is indicated in Table 1 below and the photographs in Appendix 4 of the main report illustrate the substations and some of the equipment more vulnerable to flooding. This report considers Primary and higher voltage substations. Distribution substations serve a very small geographic area and, if flooded, the customers they supply are also normally flooded and unable to take a supply of electricity. They generally do not supply customers outside the flood area and are easier to protect and much quicker to restore when flooding subsides.

<table>
<thead>
<tr>
<th>Substation Type</th>
<th>Typical Voltage Transformation Levels</th>
<th>Approximate Number</th>
<th>Typical Size</th>
<th>Typical Number of Customers Supplied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid</td>
<td>400kV to 132kV (Transmission system)</td>
<td>377</td>
<td>250m by 250m</td>
<td>200,000 - 500,000</td>
</tr>
<tr>
<td></td>
<td>132kV to 33kV (Distribution system)</td>
<td>1,000</td>
<td>75m by 75m</td>
<td>50,000 - 125,000</td>
</tr>
<tr>
<td>Primary</td>
<td>33kV to HV (Distribution system)</td>
<td>4,800</td>
<td>25m by 25m</td>
<td>5,000 - 30,000</td>
</tr>
<tr>
<td>Distribution</td>
<td>11kV to 400/230V (Distribution system)</td>
<td>230,000</td>
<td>4m by 5m</td>
<td>1 - 500</td>
</tr>
</tbody>
</table>

Table 1 - Types of Electricity Substation

**A1.2 Emergency Planning**

Emergency planning issues of shared interest to the government, industry and the regulator are reviewed and managed through the framework of the Energy Emergencies Executive (E3). The Executive is made up of a senior representative from each of BEIS, industry and Ofgem, and is supported by a committee (E3C) chaired by a Director of National Grid and comprising representatives from electricity companies, trade bodies, BEIS and Ofgem. The committee meets every two months and has a number of active task groups working on various issues. This ENA led review of the resilience of substations to flooding is an example of the work undertaken within the E3 framework.
Network Owners have well developed emergency plans to ensure an effective response to a range of events that can affect both Transmission and Distribution networks. Overhead line systems are susceptible to severe weather conditions, such as wind storms and lightning, and consequently Network Owners are required to implement their emergency response procedures on a regular basis which ensures they are tested and practiced. These plans also cover flooding incidents. Customer communication for problems affecting customers’ supplies is the responsibility of Distribution Network Owners and they have sophisticated telephony systems that are capable of answering very large numbers of simultaneous customer calls.

Through the ENA, Network Owners meet regularly to review emergency planning and response arrangements including such issues as Black Start and rota disconnection.

Network Owners are all members of a mutual aid consortium called NEWSAC. In an emergency affecting one or more member companies, the NEWSAC group representatives will assess the availability of resources from those companies least affected and agree the allocation of these resources based on the level of damage. The NEWSAC agreement was successfully implemented during the 2007 floods when Northern Power Grid received assistance from Scottish Power and Western Power Distribution. It was also implemented very successfully in the South of England floods in 2014 and North of England floods in 2015 when temporary flood barriers and generators were also dispatched.

Network Owners also work closely with other Utilities, the Emergency Services and Local Authorities under the terms of the Civil Contingencies Act. This includes working with Local Resilience Forums on emergency planning, taking part in exercises and participating in Gold, Silver or Bronze Commands. The Electricity Act and the ESQCR already include powers for the Secretary of State in relation to continuity of supply and if necessary, to give directions for preserving security of electricity supply. The Minister twice exercised these powers in 2002 in the setting up of independent reviews of “Resilience of the Electricity Supply Industry”. These arrangements have proved effective and it is recommended that any improvements in the resilience arena are implemented through the existing BEIS/Ofgem oversight.

A1.3 Flooding Events and Flooding Resilience

Prior to 2007, widespread flooding events occurred in 2000 and 2005. In 2000, serious floods affected large parts of the country including the South East of England, Shropshire and Yorkshire, when electricity supplies were affected. In 2005, severe flooding affected Carlisle including Carlisle Grid Substation. This resulted in power outages across most of Carlisle for approximately 36 hours. The joint Industry/BEIS survey following the Carlisle incident in 2005 sought to identify primary and higher voltage substations at risk against the then published EA Flood Maps for England and Wales for 1 in 100/200 and 1/1,000 return events. A total of 1,040 substations were identified but flood depth prediction was not generally available and therefore the likely impact of any flooding was not assessed. No appropriate national flood datasets were available in Scotland at the time.
A1.4  Comparison of Normal Supply Security Standards with Flooding Resilience

Standards for the design and resilience of the electricity networks are set out in the GB Security and Quality of Supply Standard and Engineering Recommendation P2/6. Although these Standards help to deliver one of the most reliable electricity supply systems in the world, they specifically exclude common mode failure, like flooding, from their standard approach. This is because they do not consider the performance of individual assets and explicitly exclude the loss of busbars (as might occur if a substation were flooded). In view of this it is essential that other organisations ensure that their services are as resilient as possible to the loss of electricity supplies for any reason and that any societal risks are managed through Local Resilience Forums.

All incidents are categorised and reported to Ofgem. The pie chart below indicates the main causes of customer minutes lost (CML) in the ten years between 2005 and 2015.

During the period April 2005 to March 2015 losses of supply due to flooding accounted for approximately 0.7% of the total customer minutes lost. By comparison, other weather related events such as high winds and lightning strikes accounted for some 29%.

In view of this, expenditure to reduce the overall level of customer minutes lost is unlikely to be targeted at flood risk by only taking into account CMLs lost. However the societal impact of electricity supply loss during a flooding incident, in particular the possibility of a large concentration of consumers being disconnected in a single incident, provides a substantive focus for any additional investment to improve resilience to flooding.
Annex 2  Societal Risk

Experience underlines the particularly severe impact on society of a combination of flooding and loss of electricity supplies to a community, especially if this affects other critical infrastructure.

National policy in this area is set out in the Cabinet Office, Strategic Framework and Policy Statement on Improving the Resilience of Critical Infrastructure to Disruption from Natural Hazards.

Important national infrastructure comprises those sectors which supply essential services to the citizen on which normal daily life in GB depends. These are Energy, Water, Communications, Transport, Finance, Government, Health, Food and Emergency Services. The most important sites, physical assets and information or communication networks within these sectors, whose loss would have a major impact on the delivery of essential services, are deemed the Critical National Infrastructure. A key element of this definition is the concept of ‘criticality’. Thus, whether infrastructure is ‘critical’ should be determined by the impact of its loss on the delivery of essential services and hence people’s wellbeing. Distinguishing between critical and non-critical infrastructure in this way enables a risk-based and appropriate approach to work to prevent and prepare for emergencies, including flooding.

As indicated in Section 6 of the main report, the relevant planning standards define a level of resilience to be installed at a given site. In reviewing the reliability of a particular network, it is likely that the risk due to equipment failure / typical weather-related events (high wind, lighting storms etc) at any given site could result in a risk of failure higher than that indicated by the flood risk analysis. However, in understanding the consequence and impact of flooding, not only must the risk of power failure be considered, but also the duration of any failure and the social distress at a time when it’s likely that all other critical infrastructure is fully stretched.

The impact of widespread loss of electrical power extends well beyond the immediately obvious consequences. For example, loss of traffic lights can lead to traffic chaos and motorway gridlock, with knock-on impacts on the Emergency Services’ ability to respond. Mobile telephony will quickly overload and probably fail completely within six hours. Domestic central heating – even gas fired – will fail as boilers and central heating pumps require power. Water supplies and sewerage will be affected to varying levels. Petrol pumps don’t work, cash tills and cash machines fail. Radio and TV broadcasts fail to reach the affected population, as there is no power to for TVs radios or internet. Fires resulting from using candles and asphyxiation from alternate cooking practices indoors become increased risks.

The loss of electricity at any time can be a cause of disruption and annoyance and, depending on the duration, can have a significant impact on consumers wellbeing. In addition, it was noted in the Pitt Review that during the 2007 flooding and at a time when the local community was already distressed:-
“Loss of power caused fear and distress. It meant that people could not get information from the television, radio and internet, and also prevented people from communicating with others, as many modern landline and mobile telephones required power to charge batteries. Loss of power could also cause serious health consequences”.

The 2007 flood events occurred in the summer when the public were not overly reliant on power for heating & lighting. If the flooding had occurred in winter then the consequences of power loss would have been significantly greater.

The floods of winter 2015/16 affecting large numbers of customers in the North of England, particularly in Cumbria and Yorkshire, and demonstrated again the extremely severe impact that flooding can cause for local communities.

It is clear that, in considering the case for investment in flooding resilience at individual substations, great account must be taken of potential societal impact.
Annex 3  
Photographs of Electricity Substations

Photograph 1  
400kV Transmission Substation

Photograph 2  
132kV Grid Substation

Photograph 3  
Primary Substation

Photograph 4  
Distribution Substation

Photograph 5  
132kV Grid Substation: main power conductors at high level

Photograph 6  
Primary Substation: low-level conductor in HV switchgear & control wiring
Annex 4  Flood Protection Solutions, Costs and Comparisons

A4.1 Background
This appendix covers the findings from the review of flood defence systems used by the Network Operators and a high level review of systems that could be used. Information was provided by a number of Distribution Network Operators (DNOs) on costs of flood protection projects they had completed.

To allow for comparison of costs these were ‘normalised’ by relating them to ‘standard’ Transmission Grid Substations or Supergrids (400 or 275kV to 132kV), Distribution Grid Substations or Bulk Supply Points (132kV to 33kV) and Primary (33kV to 11kV or 6.6kV) substations as indicated in Section 6 below.

The options considered for flood risk management have been grouped as follows:

- Permanent
- Demountable
- Temporary
- Other measures

To support this analysis Section 4 provides definitions so that it is clear what is meant by each option. A tabulated summary of results is also included.

A 4.2 Recommendations
That individual Network Owners refer to this appendix for information when selecting the most suitable flood defence strategy at a substation site following the completion of the site-specific risk assessment.

A 4.3 Solution Comparison, Pros & Cons
Permanent

a) Flood Defence Walls & Flood Earth Embankments (Provided by EA or Local Authorities)

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removes flood risk up to designed flood level (assuming risk of flash floods etc resolved)</td>
<td>Possibly high cost solution</td>
</tr>
<tr>
<td>Little Disruption to Communities</td>
<td>Dependent on EA risk assessment &amp; funding allowance meeting the cost benefit requirements</td>
</tr>
<tr>
<td></td>
<td>Flood water displacement issues in legislation</td>
</tr>
<tr>
<td></td>
<td>Long lead time solution</td>
</tr>
</tbody>
</table>

b) Flood defence of key buildings & critical assets – Property Level Protection (PLP)

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Removes flood risk up to designed flood level (including flash flood) | Medium cost solution
---|---
Access to critical plant maintained if double gate entry system installed | Height of protection limited to 1 metre (dependant on building construction). Buildings would need strengthening for higher protection
Seals all entries to building | Medium lead time solution
Site does not require to be manned during flooding incident
Flood warning / level alarms can be fitted
Low opex cost
Unlikely to have a NPPF planning issue.

### c) Flood defence walls (site perimeter)

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removes flood risk up to designed flood level (assuming risk of flash floods etc resolved)</td>
<td>Medium cost solution</td>
</tr>
<tr>
<td>Access to critical plant maintained if double gate entry system (dependant on flood level)</td>
<td>Maintaining safety clearances may be an issue</td>
</tr>
<tr>
<td>Flood warning / level alarms can be fitted</td>
<td>Flood water displacement Issues</td>
</tr>
<tr>
<td>Low opex cost</td>
<td>Ground water seepage issues</td>
</tr>
<tr>
<td></td>
<td>Site will require resources during flood conditions e.g. Staff &amp; Pumps</td>
</tr>
<tr>
<td></td>
<td>Medium lead time solution</td>
</tr>
<tr>
<td></td>
<td>Height of protection limited before size of walls become impractical</td>
</tr>
</tbody>
</table>

### d) Raise substation / critical plant

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removes risk of flood up to designed flood level (assuming risk of flash floods etc resolved)</td>
<td>Very high cost solution</td>
</tr>
<tr>
<td>Little disruption to communities</td>
<td>Additional land may be required to allow construction of new equipment on site to allow supplies to be maintained</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Planning permission may be required.</td>
</tr>
<tr>
<td></td>
<td>Long lead time solution</td>
</tr>
</tbody>
</table>

### e) Relocation of the substation

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removes flood risk (assuming risk of flash floods etc resolved)</td>
<td>Very high cost solution</td>
</tr>
<tr>
<td></td>
<td>Alternative sites are unlikely to be available</td>
</tr>
<tr>
<td></td>
<td>Long lead time solution</td>
</tr>
<tr>
<td></td>
<td>Disruptive to local communities during construction</td>
</tr>
</tbody>
</table>

### Demountable

#### f) Building perimeter & critical assets

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduces flood risk up to designed flood level (assuming risk of flash floods etc resolved)</td>
<td>Medium cost solution</td>
</tr>
<tr>
<td>Access to critical plant maintained if double gate entry system installed</td>
<td>Building may require resources during flood conditions e.g. Staff &amp; Pumps</td>
</tr>
<tr>
<td>Flood warning / level alarms can be fitted</td>
<td>Medium lead time solution for original installation</td>
</tr>
<tr>
<td></td>
<td>Ground water seepage issues through ducts and drains</td>
</tr>
<tr>
<td></td>
<td>Trained resources required to deploy system, when warning received. Experience has shown they may not be able to be deployed in a timely manner</td>
</tr>
<tr>
<td></td>
<td>Medium opex cost</td>
</tr>
<tr>
<td></td>
<td>Management system to maintain trained staff and to check all equipment is in place and fit for purpose at all times</td>
</tr>
<tr>
<td></td>
<td>Ongoing theft risk of demountable barriers</td>
</tr>
</tbody>
</table>
### g) Site perimeter

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduces flood risk up to designed flood level (assuming risk of flash floods etc resolved)</td>
<td>Medium cost solution</td>
</tr>
<tr>
<td>Access to critical plant maintained if bunded double gate entry system installed</td>
<td>Site will require resources during flood conditions e.g. Staff &amp; Pumps</td>
</tr>
<tr>
<td>Flood warning / level alarms can be fitted</td>
<td>Flood water displacement issues</td>
</tr>
</tbody>
</table>

- Ground water seepage issues
- Trained resources required to deploy system, when warning received. Experience has indicated they may not be able to be deployed in a timely manner.
- Management system to maintain trained staff and to check all equipment is in place and fit for purpose at all times
- Medium opex cost
- Medium lead time solution for original installation
- Fails to protect from sudden flash flooding
- Ongoing theft risk of demountable barriers
- Dependent upon early warning systems working in good time to permit installation

### Temporary

#### h) Site perimeter

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduces flood risk up to designed flood level (assuming risk of flash floods etc resolved)</td>
<td>Risk management system required to decide where to store materials and where to deploy during flood warning</td>
</tr>
<tr>
<td>Low cost solution</td>
<td>Site will require resources during flood conditions e.g. staff &amp; pumps</td>
</tr>
<tr>
<td></td>
<td>Flood water displacement issues</td>
</tr>
</tbody>
</table>
A 4.4 Definitions

Types of Flood Protection

a) Permanent

**EA Flood Defence Wall**
This assumes that the EA or Scottish Local Authorities will or have installed permanent flood defences to protect a specific area which is within the flood plain.

**EA Flood Defence Earth Embankment**
This assumes that the EA or Scottish Local Authorities will or have installed permanent flood defences to protect a specific area which is within the flood plain.

**Flood Defences to Buildings and Critical Assets**
This assumes the systems are designed to provide permanent protection without the need for any intervention.

**Flood Defence Walls**
This assumes the system is permanently in place with the flood gates left in position at all times except for access for maintenance etc.

**Raise the height of substation critical assets**
This assumes that;

1. There is space on site to construct a new switch house and to install new switchgear;

2. That transformers and associated auxiliary equipment will be re used with sufficient space on site to construct new plinths etc, re locate a transformer and then re locate the next transformer; and

3. That the transformers are in a condition that will permit reuse.
Relocation of the substation
This assumes that to move the substation out of the flood plain will require relocation approximately 1 km from the existing location, that a site is available at minimal cost and that half the outgoing feeder cables are increased in length by 1 km and the in feed feeder cables are increased in length by 1 km.

b) Demountable
Building & Critical Asset Protection
This assumes that flood protection support structures are permanently installed, with panels etc that are either left in place or stored on site for installation. A requirement is that the defence system can be earthed in accordance with statutory requirements to safeguard the public.

Site flood protection
This assumes that flood protection support structures are permanently installed, with panels etc that are either left in place or stored on site for installation.

c) Temporary
Site protection
This assumes that the flood defence installation is installed post a flood warning, that the material requirements for the site have been pre-measured and have materials, schedules and drawings for installation. The system requirement is that the defence system can be earthed in accordance with statutory requirements to safeguard the public.

Types of Standard Substation
a) Grid Substation (Supergrid)
This is defined as a 400kV or 275kV to 132kV substation, with an average perimeter fence length of 1,000 metres, serving 225,000 customers (ratio customers to metre of perimeter 225 to 1)

b) Grid Substation (Bulk Supply Point)
This is defined as a 132kV to 33kV substation, with an average perimeter fence length of 300 metres, serving 55,000 customers (ratio customers to metre of perimeter 183 to 1)

c) Primary Substation 66kV 33kV Substation (Primary)
This is defined as a 66kV or 33kV to 11kV or 6.6kV substation, with an average perimeter fence length of 100 metres, serving 15,000 customers (ratio customers to metre of perimeter 150 to 1)

Estimating Costs of Relocations
The approximate costs have been derived by inflating the costs in Issue 1 of ETR 138.

1. Bulk Supply Point with 11 (Number) 33kV CBs and two 90MVA transformers fed overhead by 132kV Tower line. Eight Outgoing feeders using solid 33kV XPLE cables. Transformers cannot be relocated from previous location.
   Approximate cost £7.2m
2. As above but with underground cables for 132kV connection.
   Approximate cost £10.8m.

3. Primary Substation with 11 (Number) HV switches fed via two 11.5/23MVA
   transformers with no 33kV local switchgear and overhead fed. Eight outgoing HV ways.
   Approximate cost £2.7m.

4. As 4.3.3 above but underground fed at 33kV.
   Approximate cost £3.4m.

5. As 4.3.3 above but with local 33kV SF₆ switchgear.
   Approximate cost £3.4m. (This option assumes a 33kV overhead supply)

6. As 4.3.4 above but with local 33kV SF₆ switchgear.
   Approximate cost £4.1m. (This option assumes a 33kV underground supply)

Note for sites where there is an infeed of 66kV the prices above will need to be inflated
by an appropriate factor to recognise the increased costs in some components when
compared to 33kV plant, cable and overhead line costs. A multiplication factor of 125%
should be applied to 33kV costs.

Estimated costs of raising height of Substation
1. Bulk Supply Point with 11 (Number) 33kV CBs and two 90MVA transformers fed
   overhead by 132kV Tower line. 8 outgoing feeders using solid 33kV XPLE cables.
   Transformers can be relocated from previous location.
   Approximate cost £4.5m.

2. As above but with underground cables for 132kV connection.
   Approximate cost £6.6m.

3. Primary Substation with 11 (Number) HV switches fed via two 11.5/23MVA
   transformers with no 33kV local switchgear and overhead fed. Eight outgoing HV ways.
   Approximate cost £1.9m.

4. As in point 3 above but underground fed at 33kV.
   Approximate cost £3.4m.

5. As in point 3 above but with local 33kV SF₆ switchgear.
   Approximate cost £2.4m.

6. As in point 4 above but with local 33kV SF₆ switchgear.
   Approximate cost £4.1m.

Note for sites where there is an in-feed of 66kV the prices above will need to be inflated
by an appropriate factor to recognise the increased costs in some components when
compared to 33kV plant, cable and overhead line costs. A multiplication factor of 125%
should be applied to 33kV costs.
## Annex 5  Flood Protection System Photographs

<table>
<thead>
<tr>
<th>FLOOD PROTECTION SYSTEM PHOTOGRAPHS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MANUFACTURER:</strong> Total Flood Solutions</td>
</tr>
</tbody>
</table>

**COMMENTS:** Exterior of building flood protection. Access to Substation entrance.

**COMMENTS:** Exterior of building displaying flood protection and bunding to access and emergency exit doors

**COMMENTS:** Raising bund height to critical plant and access steps
<table>
<thead>
<tr>
<th>MANUFACTURER: Flood Control Ltd</th>
<th>DESCRIPTION: Concrete flood defence walls with gates</th>
<th>LOCATION USED: Various sites in Northern Powergrid</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Image" /></td>
<td><img src="image2" alt="Image" /></td>
<td><img src="image3" alt="Image" /></td>
</tr>
</tbody>
</table>

**COMMENTS:** Pedestrian flood protection gates concrete walls and removable panels

| ![Image](image4) | ![Image](image5) | ![Image](image6) |

**COMMENTS:** Flood protection gates and concrete walls

| ![Image](image7) | ![Image](image8) | ![Image](image9) |

**COMMENTS:** Flood protection gates and concrete walls providing protection during a flood.
<table>
<thead>
<tr>
<th>MANUFACTURER: Hesco Bastion Ltd</th>
<th>DESCRIPTION: Container Wall filled with Sand &amp; Stone</th>
<th>LOCATION USED: Walham &amp; Castle Meads Substations</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image 1" /></td>
<td><img src="image2.png" alt="Image 2" /></td>
<td><img src="image3.png" alt="Image 3" /></td>
</tr>
<tr>
<td><img src="image4.png" alt="Image 4" /></td>
<td><img src="image5.png" alt="Image 5" /></td>
<td><img src="image6.png" alt="Image 6" /></td>
</tr>
<tr>
<td><strong>COMMENTS:</strong> Container walls filled with sand / stone</td>
<td><strong>COMMENTS:</strong> Detail of connection between container walls and metal panelling</td>
<td><strong>COMMENTS:</strong> Raising bunding to critical plant using metal paneling</td>
</tr>
<tr>
<td>MANUFACTURER: Geodesign Ltd (Geodesign Barriers)</td>
<td>DESCRIPTION: Galvanized steel frame which supports either aluminum steel, plywood sheets or pallets, covered with a waterproof membrane</td>
<td>LOCATION USED: Walham National Grid Substation (Temporary Protection)</td>
</tr>
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<td>--------------------------------------------------</td>
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<td>---------------------------------------------------------------</td>
</tr>
</tbody>
</table>

**COMMENTS:** Positioning of galvanized steel supports and details of heights of installation of the system

**COMMENTS:** System deployed providing flood defences
## Annex 6  Flood System Typical Costs (Costs adjusted by RPI from 2009)

| Application                                      | Link to Manufacturers site | Max Height (m) | Budget Capital Cost Standard Trans.(£) | Budget Capital Cost Standard Grid (£) | Budget Capital Cost Standard Primary Indoor (£) | Comments | Cost per customer Protected (£ per customer) Trans. | Cost per meter perimeter (£ per metre) Trans | Cost per customer Protected (£ per customer) Grid | Cost per meter perimeter (£ per metre) Grid | Cost per customer Protected (£ per customer) Primary | Cost per meter perimeter (£ per metre) Primary |
|--------------------------------------------------|---------------------------|----------------|----------------------------------------|---------------------------------------|-----------------------------------------------|----------|-----------------------------------------------------|---------------------------------------------|-------------------------------------------------|---------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| Cost of Relocating a whole substation            | N/A                       | N/A            | £36 - 72,000,000 option 4.3.1          | £7,200,000 option 4.3.1               | £3,360,000 option 4.3.4                      | See section 4 of appendix for definition of scope of work | 227      | N/A                                                   | 124                                         | N/A                                             | 213                                         | N/A                                             |
| Cost of relocating all key plant                 | N/A                       | 1.2m           | 17,400,000 option 4.4.1               | 4,200,000 option 4.4.1               | 1,920,000 option 4.4.4                      | See section 4 of appendix for definition of scope of work | 73       | N/A                                                   | 73                                          | N/A                                             | 121                                         | N/A                                             |
| Compounds etc                                    | N/A                       | <5.3m          |                                         |                                       |                                               | Designed for individual locations constructed by EA |          |                                                       |                                              |                                                  |                                             |                                                  |
| Compounds etc                                    | www.floodcontrol.co.uk    | 1.2m           | 739,000                                 | 409,000                               | 193,000                                       | Prices based on costs provided for 2 Primary S/S sites (CE Electric) this system is similar to the bauer innercity system | 3.3      | 866                                                   | 7.4                                         | 1364                                            | 12.88                                       | 1575                                            |                                                  |
| Buildings and critical assets                    | www.totalfloodsolutions.c om | <1m            | 239,000                                 | 159,000                               | 159,000                                       | Includes building sealing of ducts & Transformers provision of pumps and all on costs | 1.2      | 280                                                   | 2.8                                         | 531                                             | 10.6                                        | 1446                                            |                                                  |
| Compounds etc                                    | www.hesco.com             | 5m (see comments ) | 409,000                                 | 205,000                               | 114,000                                       | Maintaining safety clearances may be an issue and not suitable for confined sites | 1.9      | 455                                                   | 3.8                                         | 682                                             | 7.6                                         | 1034                                            |                                                  |
| Compounds                                        | www.hydroresponse.com     | <2.4           |                                         |                                       |                                               | Used by EA                                    |          |                                                       |                                              |                                                  |                                             |                                                  |
| Compounds                                        | www.noaq.com              | <0.75          | 341,000                                 | 92,000                                | 28,000                                        | Contractor price only based on tender prices | 1.6      | 379                                                   | 1.7                                         | 308                                             | 1.8                                         | 248                                             |                                                  |
| Compound                                          | www.aquabarrier-systems.com |              | 330,000                                 | 98,000                                | 51,000                                        | Contractor price only based on tender prices | 1.6      | 366                                                   | 1.8                                         | 325                                             | 3.4                                         | 465                                             |                                                  |
| Compound                                          | www.aquafence.com         | <4m            |                                         |                                       |                                               | Scheme in York                                |          |                                                       |                                              |                                                  |                                             |                                                  |

Note: “Trans.” refers to an MNGET transmission site.
References

Environment Agency--What is the updated Flood Map for Surface Water?
This document includes references to other documents on Surface water Flooding.

The latest updates to the Environment Agency’s ‘Flood Map’, ‘Historic Flood Map’ and ‘Recorded Flood Outlines’ for England
Now available through the EA’s DataShare Website.

The Flood Map has also been published on gov.uk, where it is referred to as the ‘Flood Map for Planning (Rivers and Sea)’. Wales and Scotland flood maps can be found respectively at Natural Resources Wales and Scottish Environment Protection Agency (SEPA).

The Flood Estimation Handbook

Comparison of Environment Agency surface water flood maps

Surface water flooding – Suggested methodology for assessment

Fluvial and coastal flooding – Suggested methodology for flood modelling

National Flooding Resilience Review – How the country can be better protected from future flooding and extreme weather events
Review of how we assess flood risk, reduce the likelihood of flooding, and make the country as resilient as possible to flooding, (DEFRA, Cabinet Office, EA, MetOffice, September 2016). Full document located here.