Flooding of Process Industry sites

05-06 December 2013

East coast
United Kingdom

Natural risks
Prevention mesures
Communication/crisis
Rupture/dike
Insulation
Reglementation/COMAH

EVENT DESCRIPTION

On 5 and 6 December 2013, a storm surge coincided with high spring tides to produce similar water levels to those seen in the catastrophic East Coast Floods of 1953. The surge affected the north-west, east and south coasts of England. The event was forecast early with guidance issued to Category 1 and Category 2 responders and warnings issued to the public. Advanced preparations and plans undertaken by the multi agency East Coast Planning Group were implemented. There were no fatalities due to flooding and 800,000 properties were protected by flood risk management assets. There were 71 Severe Flood Warnings issued and 2,800 properties flooded along the east coast.

Four Seveso and one IED regulated establishments were extremely badly effected by the event. A large number of other Industrial establishments were also affected indirectly, partly because they paused production during the event and more seriously because their logistics were badly affected as most of the establishments actually effected service production plant.

In summary the incident saw:

- Largest coastal flood incident in 60 years for east coast ;
- Highest water levels ever recorded at all English East Coast Gauges ;
- Maximum surge of 2.5m at Lowestoft and 1.03m at Sheerness on 5 December ;
- Thames Barrier saw highest tide since its completion in 1984 (Thames levels in 1953 were approx 0.6m higher) ;
- The Storm surge affected 3 successive tides.

The Environment Agency (EA) contacted all the registered major hazard sites regulated under the Seveso Directive (COMAH Regulations in the UK) which were potentially at risk of inundation to ensure they had received our flood warnings. They were advised to put Flood Plans in place. This involves actions such as, moving chemicals to higher ground, suspending production and isolating electrical equipment in areas at high risk of flooding.

There are 145 Seveso Directive establishments along the stretch of coast which was impacted by the East Coast surge in 1953. Due to enhanced protection and better incident preparation and planning only five of these were impacted by the December 2013 East Coast event. A cement works, which is an installation regulated under the Industrial Emission Directive (IED), was flooded. This site, and most of the Seveso sites impacted, are considered in more detail below.

IMPACTS ON SITES ON TEESSIDE

Inter Terminals, Riverside Terminal

Site description

Inter Terminals, Riverside Terminal, is located on the north bank of the River Tees. The site provides bulk liquid chemical storage in above ground storage tanks with facilities to carry out import/export operations associated with shipping, road vehicle and pipeline transfers. It is an upper tier Seveso storage operation. The site is substantially automated with remote valve operation to enable transfer routes to be selected automatically.

Source Environment Agency

Preparations for flooding

The Terminal is situated in a highly vulnerable flood location and a flood risk assessment had been carried out ; site plans with topographical information were available. Emergency response plans and evacuation plans were in place and some employees were registered with the EA flood warning system. The river defence protection level was 4.15m AOD (metres above ordnance datum), but lower areas existed along the Billingham Beck around the south side of the site.

During the run up to 5 December, several flood warnings were received with predicted increased water levels as a result of the potential storm surge. Terminal operations including shipping, road loading and pipeline transfers continued during the week. With the site being located several miles inland from the east coast, the impact of the potential surge was not fully recognised until 5 December when operations were shut down and electrical power isolated prior to the arrival of the storm surge.

The flooding on 5-6 December 2013

Figure 2 - View of terminal being flooded from ship moored up on jetty, source Cleveland EPU

The storm surge caused a rise in the tidal river level to rise to 4.3m AOD which over topped the flood defence and Billingham Beck. The overtopping caused erosion thus lowering the effective protection level. The huge volume of flood water entering the site from the embankment and the Beck resulted in the whole site being flooded to a depth of 1.8 m.

Site personnel sought safe refuge in the site control room on the upper floor of the main office building, adjacent to the embankment. Most of the bund walls were overtopped and several tanks with low inventory were floated from their bases, damaging pipework and supports. Mobile equipment floated and moved with the inrush of flood water to cause impact on other stationary infrastructure. There was no loss of containment of any product.

Short term site recovery

The low level of the site meant that the flood water was unable to flow back to the river. After receiving authorisation from the Environment Agency, flood water was pumped back into the river to allow access to key parts of the plant. In the short term mobile generators were provided for essential utility power. The terminal remained inoperable during this immediate recovery period.

Figure 3 : Breach in flood defence with temporary staunching, source Inter Terminals

Long term site recovery

The main electrical switchgear and process control systems were rendered inoperable and substantial work to replace the equipment was undertaken. Key systems such as level alarms and tank gauges were prioritised for immediate attention. Transfer operations which were previously automatic controlled were being managed manually and temporary operating procedures were rapidly put in place to cover this operation.

Primary containment systems were inspected from an asset integrity perspective and any remedial works identified which included the repositioning of storage tanks, pipeline replacement and repair, electrical equipment replacement and testing. A post flood review was undertaken which brainstormed events leading up to the and during the flood to identify learning points.

The river defence embankment is now being raised to 4.85m AOD and work to protect the rest of the site boundary to this same level is also planned. The final protection of the site will be 1 in 1000 (0.1 %) annual chance of flooding in any year.

SABIC UK Brinefields

Site description

SABIC UK Petrochemicals Limited is part of the SABIC Group, with the ultimate parent company being Saudi Basic Industries Corporation based in Riyadh, Saudi Arabia. Its main operation is to manufacture bulk petrochemical products (Ethylene, Propylene, Butadiene, Cyclohexane, and Benzene) at a number of plants on the Tees Estuary. This involves a high degree of integration with other operating sites on Teesside and the United Kingdom. Storage of products and intermediates in the Cavities on the brinefield is a vital element of this integration. The brinefiled has a multi-million pound turnover and is part of an upper tier Seveso site holding large inventories of hydrocarbons.

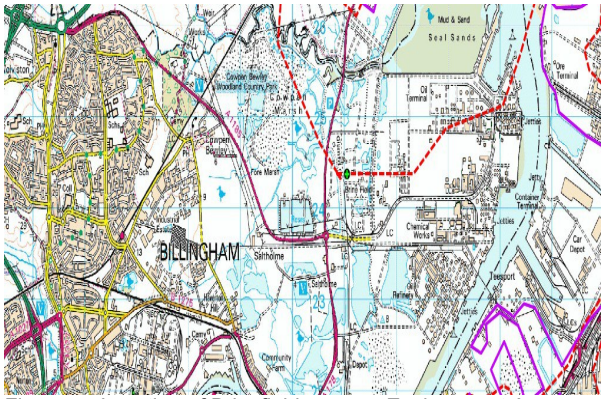

Figure 4 : Location of Brinefields source Environment Agency

Preparations for flooding

SABIC participated in the National Flood Preparation Exercise 'Watermark' in 2011 and the many valuable lessons learnt from that exercise were incorporated into the existing emergency response protocols. The protocols were further tested as part of the Serveso 'Live Play' exercises in subsequent years. When flood warnings were received during the first week of December, SABIC implemented standard operating practices to prepare for the tidal surge. These preparations included; emptying the effluent treatment facilities, isolation of all non-essential electrical equipment; sandbagging of vulnerable areas such as switch houses and removal of all containers that could float. As such when the high tide occurred on the late afternoon of 5 December 2013, the Site was prepared and monitored for a breach of the Tees estuary flood defences.

The flooding on 5-6 December 2013

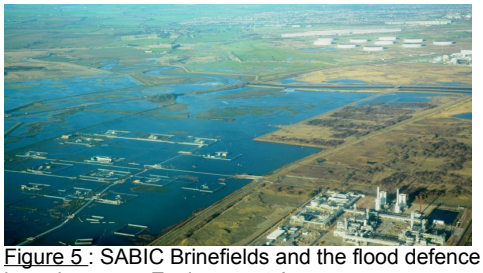
Figure 5 : SABIC Brinefields and the flood defence breach, source Environment Agency

When the high tide occurred on the late afternoon of 5 December 2013, monitoring of river levels was focused on the banks of the river Tees where SABIC has a processing plant and jetty facilities. Whilst there was some localised flooding, it was considered to be manageable in context of the flood preparations that had taken place. Hence by early evening, the Site was moving into clean-up mode and, returning to normal operation. What happened next was unprecedented, unforeseen and not planned for in any flood damage assessment or Seveso Major Accident scenario.

At approximately 11pm, whilst undertaking a routine tour of the Brinefields and Cavities area, a process technician heard a large crashing sound and observed what he later described as a tsunami like wall of water coming from Greatham Creek and heading toward the Brinefields and Cavities area which stores thousands of tonnes of hydrocarbon in underground salt cavities. Fortunately the technician was in a safe location away from the incoming water.

The Site Alarm was raised immediately and the cavities placed into a safe operating condition by closing the Remote Operated Shut-Off Valves. It was extremely difficult to make a full damage assessment in the darkness so the decision was taken to cease all hydrocarbon movements to and from the area. This decision not only affected operations within SABIC but had immediate consequences for other local businesses that have infrastructure and product storage within the area.

SABIC has a Crisis Management protocol that is brought into action following incidents that have the potential to cause significant societal impact or business impact. On the early morning of the 6 December, the Crisis Management Team


Figure 6 : Control room on the Brinefield – note flood level mark on control room wall, Source Sabic UK Ltd

convened. It was clear that a number of Seveso Major Incident scenarios were feasible given the initial damage assessments and that SABIC would need to be directly involved with the broader flooding incident management that was being co-ordinated by Government Agencies. Contact with the Local Authority Emergency Control centre was established and recovery operations started.

Site recovery

From SABIC's perspective the simplified view of the major emergency centred on two main objectives, these being:
1. To maintain safe containment of the hydrocarbon inventories whilst the flood defences are being repaired.
2. To safely return the area back to operation as soon as practicable without endangering people or the environment.

In a reasonably short period of time, SABIC was able to establish a routine of damage inspection during low tide. This enabled integrity assurance of the operating area and a limited amount of damage assessment to be made. What became apparent was that all the equipment containing materials under pressure was secure and that there had been limited damage to the cavity wellheads and piping infrastructure. The major damage sustained was to the electrical distribution, instrumentation and control systems including all telemetry networks. What followed were 5 months of intense electrical and instrumentation repair and replacement work whilst controlling the risks and hazards associated with working within and eventually returning to service under normal management arrangements.

The SABIC insurance loss assessment was in excess of £10 million (including both asset replacement and business losses).

Discussions are ongoing with Government Agencies regarding the ongoing integrity of the established flood defences in the Teesport Area.

IMPACTS ON SITES ON HUMBERSIDE

Inter Terminals, Immingham

Site description

Inter Terminals, Immingham, is located on the south bank of the River Humber. The site provides bulk liquid oil and chemical storage in above ground storage tanks with facilities to carry out import/export operations associated with shipping, road vehicle, rail and pipeline transfers. It is an upper tier Seveso site and also operates IED storage operations.

Preparations for flooding

The Terminal was situated in a highly vulnerable flood location and a flood risk assessment had been carried out; site plans with topographical information were available. Emergency response plans and evacuation plans were in place and some employees were registered for flood warnings. The river defence protection level was approximately 6.0m AOD, but the dock entrance level was only 3.37m AOD

During the run up to the 5 December, several flood warnings were received with predicted increased tide levels as a result of the potential storm surge. Terminal operations including shipping, road loading and pipeline transfers continued during the week.

Just prior to the flood, precautions were taken to protect key equipment as much as possible and to restrict transfer operations. Hours before the flood, it was reported that the Teesside terminals had been badly hit by the surge and that the surge was heading southward. The site landlord, Associated British Ports (ABP), was also issuing its own alerts based on different information, with confusion between Chart Datum, Ordnance Datum and tide table data. All operations were ceased and soon after electrical power, supplied from ABP, was isolated. All systems were made safe and non-key staff evacuated. Safe refuge was identified in the upper floor of the operations office for the remaining staff.

The flooding on 5-6 December 2013

The surge caused a rise in the river level to 5.1m AOD which overtopped the dock entrance gates and filling the dock until it overflowed into the dock estate. The terminals were flooded up to 1m deep from the opposite side to the river via the dock entrance. The embankment protection itself failed in several areas causing a further flow into the terminal.

None of the tank bund walls were overtopped and the bunds remained dry throughout the flood. Although mobile plant equipment was floated, there was little mechanical damage to infrastructure. All ABP and site switchrooms were flooded and the waste water treatment was rendered inoperable, but there was no loss of containment of any product.

Short term site recovery

The level of the site allowed most of the flood water to recede to the river and dock. After receiving authorisation from the Environment Agency, residual flood water was pumped back into the river. Electrical power remained off in the short term but mobile generators provided essential utility power. The terminal remained substantially inoperable during this immediate recovery period. Priority systems were eventually regained after extensive remedial works had been undertaken to key mechanical and electrical infrastructure but temporary power remained in place.

Long term site recovery

Electrical infrastructure were badly affected and temporary power enabled priority systems to be brought back on line. The site was surveyed for damage to any primary containment systems. A post flood review was undertaken which brainstormed events leading up to and during the flood to gain learning points. Eventually, after each switchroom had been overhauled and tested, full power was regained.

The main offices which saw the maximum flood depth were also overhauled and brought back into service.

Meetings with ABP and other dock users have resulted in a major undertaking to raise the outer dock entrance gates to gain a protection level of 6.5m AOD which stands a 0.1% (1 in 1000 year) likelihood of being exceeded in any one year.

CEMEX UK

Site description

South Ferriby cement works is located approximately 1.5km west of the village of South Ferriby in North Lincolnshire and is one of three cement producing sites making up CEMEX UK Cement. The plant has the capability to produce approximately 700,000 tonnes of cement per annum and directly employs 122 people, many of whom live in the surrounding area.

The site is operated under an Environmental Permit and Greenhouse Gas Permit, both issued by the Environment Agency. As such, the site has regular contacts with the Environment Agency at various levels, and these contacts helped with the awareness of event to come.

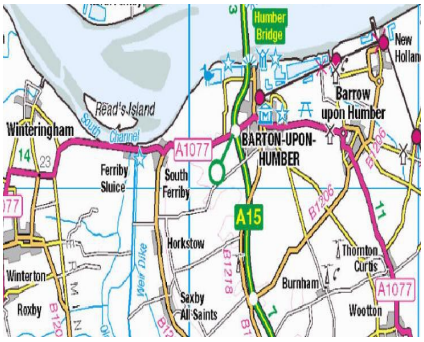

Figure 7 : Location of Chemex UK, source Environment Agency

Preparations for flooding

During the week before, the cement works was prepared for a minor flood – sandbags etc. despite being told that the site should not be affected. The cement works was in an amber warning area on the 5th December 2013. However, as soon as it became apparent that there was a high risk of flood defences being breached along the Humber, the local internal incident management team and UK rapid response team were established and flood contingency plans were put in place.

As a top priority, health and safety, all non-essential employees were sent home, shift times altered and those on site stayed in safe positions. Mobile machinery and plant was moved to higher ground where possible. Power was cut to operations when it was clear sub-stations would be threatened and shutdown of the cement kiln was initiated. Containment of oils and waste fuels was implemented to minimise potential loss. All contingency plans worked and support was provided to the local village in evacuating and preparations, albeit for a minor flood.

The flooding on 5-6 December 2013

At 6.44 pm hours on 5 December, the flood defences on the Humber Estuary were breached and the site was inundated with flood water from two directions. Fortunately, all employees were safe with the final three employees being rescued from site by the emergency services.
Despite the activation of the flood contingency plans, the breach was much greater than expected and the entire site was submerged in water with flood waters being up to 3 metres in depth in places. The site lost all power and communication links.

The flood water and silt caused catastrophic un-repairable damage to control systems, the power supply network, compressed air systems, buildings and the cement kiln which was currently operational due to insufficient cooling time. High and low voltage systems were wiped out by water tracking into the terminated ends of the cables. Production was not possible due to the flooding.

All normal communication channels were lost leading to the use of social media, to provide a direct an reliable communications channel for all employees, and temporary offices were installed in a cabin at the unaffected nearby quarry. Most of the workforce was kept off site for up to three weeks whilst the site was professionally cleaned, decontaminated and made safe.

The site was without electricity for many weeks and production did not start until the summer of 2014. The main lesson learned was to protect electrical systems such as transformers from flooding by building walls around them or raising them above the level of flood water.

Source CEMEX ARR

Site recovery

Site recovery has been extensive, initially involving cleaning and removal of unsafe structures along with implementing plans to ensure customers could be supplied with cement from the other CEMEX UK Cement sites.
Re-commissioning of the site commenced late in November 2014, nearly a year before the first anniversary of the flood.

Repairs have involved significant time and investment with up to 400 contractors on site at any one time. They included the installation of new primary sub-stations, a new compressor building, a new control room, 6.4 kilometres of new high voltage cables, with none of the original high voltage system being reusable, along with low voltage and control cabling and 22 metres of new kiln shells. 86 skips of electrical equipment alone have been removed from site.

Cement works such as South Ferriby are very capital intensive, with new sites costing several hundred million pounds with operational lives typically over 40 years. The current systems at South Ferriby had been operational since the 1970's and as such, much of the equipment that was damaged in the flood was no longer directly replaceable. Recovery costs to bring the site back into operation are therefore very high, tens of millions pounds.

Flood defences managed by the Environment Agency have been repaired along the Humber with discussions ongoing to implement further defences for the village of South Ferriby.

On site, wherever possible, cables and equipments have been elevated to 2 metres above ground level. For example the new compressor building, as shown on the picture has been built on concrete plinths.

Source Environment Agency

LESSONS LEARNT

Risk assessment and Planning

On the 5 December 2013, a combination of spring high tides and a deep depression caused a tidal surge in the North Sea that affected the UK coast from Scotland to Suffolk. In places, this was more severe than the similar event which occurred on 31 January 1953 which is now considered to have been the worst peacetime disaster ever to strike Brittan. The consequences of the 1953 flood were even more severe in the Netherlands. Since 1953, considerable effort has been put into flood risk assessment, flood defences and planning. The effect of these can be seen in the adjacent table.

	1953	Dec 2013
Breaches	1200	2
Properties Flooded	24,000	1,400
Deaths	307	2, not flood related
Agricultural Land	65,000 ha	6,800 ha
People evacuated	32,000	18,000
Infrastructure	2 Power Stations	Impacts on Industry on Teesside and operations at Immingham Port
Flood Warnings		71 severe flood warnings. Over 160, 000 warning messages sent directly to homes and businesses

As a result of the December 2013 flooding, it is now recognised that:

- Many major hazards sites are located on an indicative flood plain and are therefore susceptible to river, sea or tidal flooding. These locations were deliberately chosen because they provide level building land, access to good transport links, a supply of cooling water and a discharge route for liquid effluents);
- Many sites were built during the 1950s and 60s and the flood defences provided at the time might not be adequate to protect against the anticipated effects of sea-level rise and climate change;
- Many sites have never experienced flooding hence flood risk might not have been properly addressed as part of the on-site and off-site emergency plans;
- Flooding of major hazards sites could lead to the loss of containment of dangerous substances and have a significant effect upon the environment. Pollution could affect the water courses themselves, adjacent sensitive habitats and necessitate closing drinking water intakes with consequent disruption to public water supplies;
- Flooding could also have significant financial and operational implications for the site concerned. It could lead to some operators going into receivership, leaving the Agency and Local Authorities to deal with land contamination and clean-up issues.

The Environment Agency did not have Seveso site plans readily available for Incident Management use, which created some confusion during the first few days after the storm surge. This is being addressed by putting the Seveso site boundaries and site entrances data onto the EA Incident Management mapping system.

The Environment Agency supports operators with a range of products and services to ensure they can meet their obligations to manage flood risk for their sites:

- The Environment Agency and the Met office jointly operate the Flood Forecasting Centre (FFC), to provide daily flood risk guidance for England and Wales. A similar service operates in Scotland with SEPA;
- The Environment Agency operates an extensive river flow and sea level monitoring network, the results of which are available online;
- A series of computer models are available and used by the Environment Agency for local flood forecasting including for tidal sites;
- Publication of indicative flood plain maps on the internet;
- Publicity campaigns to increase public awareness and to encourage at-risk stakeholders to develop a flood plan;
- A system of automated telephone messaging to disseminate flood warnings.

The UK Government recognises that a wide area coastal flood is one of the most significant natural hazards facing the UK. More serious events have the potential to seriously stretch local responders and resources. The Government's Coastal Flood Group Response and recovery guide was revised in November 2014 following the country's learning from the December 2013 floods.

National Flood Defence Repairs

The Environment Agency is also responsible for planning, constructing and maintaining the critical flood defence infrastructure for England. Since the 1953 floods, drainage work was carried out on many rivers, many flood defence banks were built and the Thames Barrier was completed in 1982. The Environment Agency is currently responsible for the expenditure of about £500m/year on new and improved flood defences throughout the country. To enable the Environment Agency to do this effectively, it has a sizable team of specialist engineers who were available for redeployment for the emergency repairs that became necessary following the December 2013 flooding. A number of major flood defence projects were scoped, planned and implemented between 06 December 2013 and 02 January 2014 when the next extremely high tide was expected. The UK Government authorised a total of £30m emergency funds in the days following the flood for this work to be undertaken.

Learning for Industry

- It must be recognised that flood defence structures can fail completely during a flooding incident; walls and embankments might be over-topped or collapse under the weight of water or flap valves and sluice gates might not close properly.
- The site emergency plan should include a Layers of Protection Analysis (LOPA) which considers flood defence structures to be simply one layer of protection. If a flood defence structure fails, other layers of protection should be capable of preventing a major accident and avoiding the site going out of business.
- Flood risk assessment and emergency plans should be reviewed on a regular basis to ensure they are up to date. For example there were a few sites that had registered to receive flood warnings but did not receive an automatic warning because the site staff had moved into new roles, site telephone numbers had changed or the warning was sent to the wrong location.
- The site flooding emergency plan should use the Environment Agency flood warnings as trigger points to initiate the different stages of the plan.
- Emergency exercises with a flooding scenario have a vital role to play in ensuring an effective response to a flooding incident.
- Sites should consider the need to relocate existing safety critical equipment and to install new build above the maximum flood level.
- Electricity supply in an emergency must be considered. One of the biggest difficulties faced by the sites during the initial recovery phase was the lack of an electricity supply. This was a particular problem in December and January because there were only 8 hours of daylight.
- Storage tanks containing small inventories should be partially filled to prevent them from floating when surrounded by flood water.
- Floating objects can cause significant damage when they are swept along by flood water and collide with other fixed infrastructure. Any objects that can float should be secured or removed from site as part of flooding preparations.

The joint Environment Agency / Chemical and Downstream Oil Industries Forum (CDOIF) guidance note on preparing for flooding at IED and Seveso sites has been revised to include all the lessons learned during the December 2013 event. The guidance is published on the CDOIF Section of the Health and Safety Executive (HSE) website .