CENTRE OF DOCUMENTATION, RESEARCH AND EXPERIMENTATION ON ACCIDENTAL WATER POLLUTION

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In situ burning in marshes: rupture of the ORB Exploration pipeline (Louisiana, US)

In early January 2013, in Iberville Parish, Louisiana, an underground pipeline operated by ORB Exploration ruptured at a corroded point in the line, releasing around 28 m^3 of crude oil (API 28.6) in Bayou Sorrel, a marshy water body characteristic of the vast, complex system formed by the meanders of the Mississippi.

The exact date of the spill is unknown: while the National Response Center (NRC) was notified on 9th January, investigations into the weathering of the oil indicated that the incident is likely to have occurred between the 1st and 4th January.

Estimations of the quantity spilt first indicated a small spill initially affecting the ground, before heavy rainfall over the following days caused the polluted area to become flooded under 1 metre of water.

The US Coast Guard (USCG), within a Unified Command (UC) comprising representatives of the federal authorities (e.g. NOAA), the state (Louisiana Oil Spill Coordinator Office -LOSCO) and local authorities, coordinated the response and the implementation of clean-up operations. These operations were penalised from the onset by the difficulty in (i) accessing polluted areas (remote with thick vegetation) and (ii) restricting the spread of the spill due to the flooding of the banks. However, the thick vegetation cover had an advantage: it naturally impeded the drift of floating accumulations of oil. Containment was completed by laying sorbent booms.

Recovery operations were implemented as a priority measure, resulting in the collection of 6 to 7 m^3 of oil according to the USCG (on 19th January)[1]. To treat the remaining oil, the sensitivity and inaccessibility of the affected sites led the UC to decide to implement in situ burning (ISB) operations. On 19th January, some 10 to 15 days after the spill, 3 burns were carried out on the oil under the supervision of the UC by a company contracted by ORB Exploration.

First, to improve the efficiency of ISB operations, conducted in waters around 1 metre deep, the slicks were thickened by containing them with booms. The oil was then ignited using propane torches. The shortest ISB operation lasted 5 minutes, while the two others lasted 25 minutes, and were self extinguished.

During these burns, a 1 mile safety zone was set up for safety and public health reasons, with a public assistance and information service put in place via a hotline run by the Poison Control Center.

ISB operation (source: NOAA)

Slick residues after a burn (Source: NOAA)

[1] In its 2013 annual report, the USCG Region 6 Regional Response Team (RRT6) indicated that an estimated 165 m^3 (43,700 gallons) of oily water had been recovered.

The burn residues and accumulations of unburnt oil were then recovered on the water in various ways: manually using sorbents and by deploying oleophilic skimmers (mainly drum and rope skimmers).

The solid waste collected (e.g. plant debris, oiled sorbents)[2] was evacuated to storage sites using small shallow-draught, flat-bottomed boats, known as jonboats, while liquids were stored in small containers (1 m^3 IBC containers for bulk liquids, aluminium tanks, etc.) before being evacuated for treatment.

Manual recovery of oil remaining at the water surface using sorbents (Source: NOAA)

ISB was concluded to be an efficient strategy given the limitations on mechanical recovery in this marshy environment. The quantity of oil burnt was estimated at between 20 and 30 barrels, i.e. 3 to 5 m^3.

In terms of the lessons learnt by operational personnel, this case of ISB in a bayou (this technique is more commonly implemented in marshes) raised or served as a reminder of the following points:

- the efficiency of ISB being heavily reliant on oil slick containment, which can be difficult to implemented in such complex environments (boom deployment difficulties)
- where relevant, the perceived need for "combustion accelerants" to increase burn duration
- the availability of sufficient lengths of fire booms. In this instance, constraints due to the availability, but also dimensions (given the sometimes shallow depth of water), of fire booms arose. The use of sections of non-fire-resistant booms (unspecified type and quantities) penalised containment and caused the fires to self extinguish earlier than hoped.

For further information:
http://www.rrt6.org/Uploads/Files/Activation%20Call%20--%20Bayou%20Sorrel%20ISB%20--%2001-18-2013.pdf
http://usresponserestoration.wordpress.com/2013/02/12/when-setting-fire-to-an-oil-spill-in-a-flooded-louisiana-swamp-is-a-good-thing/

Heavy fuel oil in an urban area: Pegasus pipeline incident (Mayflower, US)

On 29th March 2013, in the early afternoon, in Mayflower (Arkansas, US), the underground Pegasus pipeline breached, releasing a flow of oil into a residential neighbourhood. This 1,400 km-long, 51 cm (20") diameter pipeline running from Patoka (Illinois) to Nederland (Texas), operated by ExxonMobil Pipeline Company (EMPCo), transports around 15,000 m^3 of Wabasca heavy crude oil each day. This oil is extracted from the Athabasca tar sands (North-East of the Canadian province of Alberta, from the Pelican Lake Oilfield).

Having detected a drop in pressure in the pipeline, the EMPCo employees rapidly isolated the leaking section and shut down the pipeline. The National Response Center (NRC) was immediately notified, as were the US Environmental Protection Agency (US EPA) and the other competent agencies. In accordance with the system in place in the US, a Unified Command (UC) placed under the auspices of the US EPA was rapidly set up, comprising local bodies (e.g. the City of Mayflower, Faulkner County, etc.), state organisations (Arkansas Department of Health -ADH- and Arkansas Department of Environmental Quality -ADEQ; Arkansas Game and Fish Commission, etc.) and federal bodies involved in crisis management, as well as representatives of the oil company and its contractors. The UC remained in place for 7 months.

An initial estimation of the volume spilt, set at around 320 m^3, was issued in the first few days following the spill. This estimation was increased, following field observations by US EPA agents, to between 640 and 1,100 m^3 (4,000 to 7,000 barrels) as the first week following the spill came to a close.

[2] According to the USCG RRT6 2013 annual report, 420 m^3 of oiled waste was collected during clean-up operations.

Day of the incident: heavily oiled ground in the leak area (**left**); Spread of the spill into the residential neighbourhood (**right**), across the ground and in water systems – note the flow of the oil into a storm drain (source: US EPA)

It was not only the question of quantity which was subject to deliberation; the nature of the pollutant was a point of confusion and debate: heavy crude oil or diluted bitumen?[3] Wabasca heavy crude oil is in fact a highly viscous heavy crude oil – similar in this respect to bitumen – which, to be transported by pipeline, requires flux to be added to decrease its viscosity and density.

Whatever the case, the extent and location of the spill – in the midst of a residential neighbourhood – meant that the priority for emergency response was to ensure the safety of local residents, in particular given the risk of atmospheric pollution by the light compounds present in the substance spilt. More than twenty residents were rapidly evacuated as a preventive measure, as the atmospheric concentrations of various volatile organic compounds (VOCs), in particular benzene, as well as those of hydrogen sulphide (H_2S) and sulphur dioxide (SO_2), exceeded acceptable levels in areas of high concentrations of the pollutant. Once emergency measures had been taken, in order to prevent risks of exposure for the local residents, an air quality monitoring programme was established and continued until May, conducted by the Center for Toxicology and Environmental Health (CTEH).

The response strategy was established based on a spill in an urban area spreading at the surface (roads, ground, homes and various structures, developed and undeveloped land, etc.) but also liable to travel underground, via sewage systems for instance.

The many operations aimed to clean the oiled soil/ground, but also to rapidly pump accumulations of free crude oil, naturally contained in various cavities and depressions (e.g. pavement edges, buildings, etc.).

These operations rapidly involved the mobilisation of major logistical support and the implementation of a complex organisation into operational sectors, summarised by ExxonMobil and its contractors in the form of regularly updated maps, providing the UC with the evolution of the situation in terms of the types of operations in progress and the organisation of associated resources (equipment storage, primary waste storage sites, decontamination areas for vehicles and personnel, etc.).

Decontaminating personnel (Source: US EPA)

Oiled waste storage area (Source: US EPA)

Separation of liquids and solids with a hydrocyclone (Source: US EPA)

One of the priorities of clean-up operations, which made rapid progress in the incident area (see aerial photos below), was to contain and recover the free crude oil as efficiently and rapidly as possible, so as to protect the watercourses and water bodies connected to the contaminated area, in particular Lake Conway, a major reservoir which also hosts significant recreational activity, potentially

[3] During the first few days of the incident, the US EPA asked Exxon: "can the oil accurately be described as oil sands oil, or a type of diluted bitumen (dilbit)?" (see http://insideclimatenews.org/news/20130418/dilbit-or-not-wabasca-crude-question). Exxon replied that the terminology of Canadian producers considered Wabasca heavy to be a type of bitumen. To support this reply, we note that certain material safety datasheets describe Wabasca Heavy as containing bitumen with added hydrocarbon diluents, see http://www.cenovus.com/contractor/docs/Heavy-Crude-Wabasca.pdf; http://www.phmsa.dot.gov/pv_obj_cache/pv_obj_id_CD99534E66C31702296257E41870A6227F5B7600/filename/ExxonMobil_MSDS_Sheet_for_Wabasca_Crude_Oil.pdf

threatened by the spread of the spill.

*Short term results of clean-up operations at the surface in the residential area close to the leak point: Aerial view 2 days after the incident (1st April 2013; **left**) and 6 days later (5th April 2013; **right**) (Source: City of Mayflower.com).*

*Various forms of containment of Wabasca heavy crude on the water: by sorbent booms (**top left**); by backfill (**top right;** note the penetration of the oil through the gravel); by filter barriers (bunds with pipes) in rivers (**bottom left**) and in a storm drain (**bottom right**) (source: US EPA).*

A wide range of containment techniques (e.g. berms, floating booms, sorbent booms, filter systems, etc.) and pumping techniques (e.g. vacuum trucks, with or without suction heads) were deployed on the various types of contaminated surfaces: ponds, trenches, rivers, drains, storm drains, etc.).

Over and above response operations, the spill rapidly raised concerns over the compatibility of the North American pipeline network with this type of substance, whose transport requirements (heating of oil, viscosity, etc.) were believed to generate more corrosion than in the case of a "conventional" crude oil.

Exxon indicated that the line had been assessed and pigged in July 2010, and that an inspection of the faulty sections had been performed recently, in February 2013 (NB: the results of this most recent inspection had not been received at the time of the incident).

Impact and environmental quality

In terms of environmental impacts, US Environmental Services established a wildlife rescue and care programme for the Mayflower site: by 13th April, 30 oiled birds (mainly water birds), 5 oiled mammals, 108 captured reptiles (including turtles) and 68 other wild animals had been handled by the specially set up Wildlife Response Center, resulting in the release of around 100 animals at the end of the month.

An environmental quality monitoring programme was implemented under the supervision of ADEQ. In addition to the atmospheric component mentioned above (air quality monitoring in residential areas near to the source), this programme included monitoring of the concentration of polycyclic aromatic hydrocarbons (PAHs) in the water and sediment, in particular in Dawson Cove, a hydrographic system including wetlands and a lake, flowing into Lake Conway. Sediment monitoring came to a close in September 2013, while the PAH concentrations in the water were monitored until summer 2014, due to the long term persistence of visible sheen at the water surface.

This persistent sheen led to the drafting of a Mitigation Action Plan, produced a year after the spill, for the contaminated sections of Dawson Cove by the environmental consultant Arcadis, contracted by

ExxonMobil Environmental Services[4]. This plan was submitted to and accepted by ADEQ, before being implemented in August 2014 by Arcadis, under the supervision of the state department.

On the whole, the remedial measures in place in late 2014 (preparation work implemented in August 2014 to be launched in September) concerned 2 operational sectors:

- in the vicinity of the properties affected, with oiled sediment removal and replacement operations
- upstream of Lake Conway: this is an area of wetland through which the Dawson Cove watercourse runs and is the focus of the plan submitted in August 2014. This area was divided into 3 sub-sections (upstream to downstream: Inlet Channel, Open Water Area, then Heavily Vegetated Area) and its treatment included:
    - major site preparation operations, in particular with vegetation clearance and the preparation of polyethylene-lined paths for vehicle access.
    - in the inlet channel, sediment removal with an amphibious excavator after drying by pumping off the water and sending it downstream (to the open water area, where sorbent booms were laid to contain any remobilised traces of oil). The dredged sediment was transported in skips to a stabilisation/solidification area set up behind the clean-up site, before being evacuated to approved treatment facilities. The removed sediment was to be replaced in the most heavily dredged areas (depth > 15 cm) with clean sediment, analysed prior to use (content of organic matter, various pollutants - plant health products, PCB, etc.) and subject to approval by ADEQ.
    - in the open water area, "reactive capping" using CETCO Organoclay PM-199, placed on the sediment surface from which the sheen was emanating. This in situ treatment method was chosen to minimise the risks of impact (pollutant placed in suspension again) and reduce costs (storage, offsite treatment of mud, etc.) which would be entailed with extensive dredging operations. This method consisted in spreading a layer (3 to 6 inches thick, giving a total mass of 360 tonnes) of a mixture of sand and organoclay, from pontoons and amphibious caterpillar-tracked systems. Organoclay has a high capacity to adsorb organic compounds and was therefore intended to prevent upwellings of the residual oil through the water mass.
    - in the marshland downstream of the spill, sediment amendment by spraying organoclay (PMFI, 43 tonnes in total) using pneumatic broadcasting equipment onboard a small barge or airboat, according to ease of access.

Finally, corrective actions were prescribed to the ExxonMobil Pipeline Company and began in April 2013, overseen by the Pipeline and Hazardous Materials Safety Administration (PHMSA), in order to repair the pipeline so as to meet regulatory requirements. Once these actions had been carried out, a restart plan for the damaged southern portion of the pipeline was drafted in January 2014: a reduction in pressure to 80% of the operating pressure at the failure site at the time of the incident must be maintained during new operations. This plan was approved by PHMSA in late March 2014; PHMSA requested 24-hour advance notice before restart.

For further information:
http://epaosc.org/site/doc_list.aspx?site_id=8502
http://www.adeq.state.ar.us/hazwaste/mayflower_oil_spill_2013/oil_spill_available_reports.htm

• Main spills of other hazardous substances worldwide

Spill of a soluble substance: derailment of ethanol cars into Little Cedar River (US)

On 20th May 2013, Little Cedar River burst its banks near Charles City (Iowa, US) and washed out a railway line, derailing 5 rail cars from a Canadian Pacific Railway (CPR) train transporting ethanol. Initial reports indicated that the tanks had not been damaged however, when the cars were recovered, four showed signs of leakage. The quantity of ethanol spilt into the environment was estimated at 185 m^3, in addition to 1 to 1.5 m^3 of diesel and around 400 litres of lubricating oil.

Floating containment booms were laid and sorbent pads deployed to contain and recover as much as possible of the floating pollutants, i.e. the diesel and oil. As for the ethanol, a soluble, non-floating

[4] http://www.adeq.state.ar.us/hazwaste/mayflower_oil_spill_2013/files/mitigation_plan_20140519/mayflower_mitigation_action_plan_20140519.pdf

product, the response mainly consisted in implementing environmental monitoring, by measuring the oxygen content in the water (3 monitors: 1.5 and 5 miles downstream of the leak, at the confluence of the Little Cedar and Cedar rivers), as well as the ethanol concentration in the air at the leak site. The levels detected did not exceed normal values according to the Iowa Department of Natural Resources (DNR), and the surveys conducted along the river did not indicate any fish mortality, with observations suggesting rapid dilution of the substance in the watercourse.

Mineral oil leak in Massard Creek (Arkansas, US)

On 1st June 2013, following the explosion of a transformer, employees of Oklahoma Gas and Electric Energy Corporation (OG&E) discovered a leak of insulating oil which was spreading through Massard Creek, a tributary to the Poteau River, near Fort Smith (Arkansas, US).

The firm immediately notified the US Environmental Protection Agency (US EPA) of this spill of an estimated 60 m^3. The emergency response, supervised by the federal agency, aimed to contain and recover the substance, believed to be floating and have low solubility in water. Forty people were involved in the response, for which sorbent booms, skimmers and a vacuum truck were used to recover a total of 29 m^3 of oily water, according to US EPA. The colourless nature of the pollutant raised difficulties during operations, given that its visual detection was problematic from a certain distance. Nevertheless, no propagation of the insulating oil into the Poteau River was detected. Given the context and the moderate extent of the spill, no significant risk for responders or the environment was identified.

Cement spill into a river in a national park (Sugarloaf State Conservation Area, Australia)

In June 2013, as part of a grouting operation to repair subsidence damage due to mining activities, Orica Mining Services injected around 180 m^3 of cement into a crack at the top of a ridge, 75 m^3 of which unexpectedly flowed into a creek below, within Sugarloaf State Conservation Area, after having travelled over 400 metres through cracks in the ground.

The substance spilt, known as Air-O-Cem, is a chemically inert aerated cement, considered non-toxic, commonly employed as grouting for filling voids, consolidating ground and structures, etc.

Given the site's status, the New South Wales Office of Environment and Heritage ordered the firm in charge of the grouting operation (Glencore Xstrata, a multinational specialised in raw material extraction) to clean up the watercourse.

Placing solidified cement in bulk bags
(source: www.environment.nsw.gov.au)

Operations to remove the solidified grout began in October 2013 and were completed 8 months later, in June 2014. Oceanic Coal Australia (the company contracted to carry out clean-up) removed 249 bulk bags of the substance, under the supervision of the National Parks and Wildlife Service. Our sources of information make no reference to the possible impacts of this spill.

• Response equipment

Operations in difficult access areas: the Hoverspill project

2013 was marked by the end of the Hoverspill research and development project, partially funded by the 7th European Framework Programme for Research and Technological Development (FP7). This project aimed to develop (i) an autonomous system for response on ecologically sensitive, difficult access sites based on an air cushion vehicle (hovercraft) and (ii) a biphasic oil-water separation system designed to be integrated within the floating slick recovery system (onboard skimmer and pump).

Hoverspill was carried out by a consortium made up of 8 partners from 4 European countries: UK-based HoverTech, Italian firms Innova, SOAnfibi, alongside CRF-PRT (Research centre of the group *Fabbrica Italiana Automobili Torino* -FIAT) and the mechanical engineering institute of the University of Padova, the Romanian firm TerraMediu and, for France, Ylec Consultant and Cedre. Cedre contributed its experience in spill response – in this case in difficult access areas – and in the evaluation of response techniques and equipment.

The vehicle

Based on the definition of the missions and tasks to be performed by this vehicle (surveys, impact assessment, containment and recovery of floating oil, shoreline or bank clean-up operations, etc.), a certain number of related operational and environmental constraints were identified and affected the structure and ergonomics of the vehicle to be developed (dimensions, manoeuvrability, motor power, etc.). A set of specifications was thus defined and SOA and Hovertech, drawing on their technological and practical experience of hovercraft, developed a new prototype: the Multipurpose Air Cushion Platform (MACP), composed of the following elements:

- a new-concept hull (SoftHull^{TM}) designed based on a flexible sandwich structure (Softskin) fixed to an unsinkable rigid frame capable of absorbing shocks and wave impacts.
- a flat deck made of light composite resin, eliminating the “bathtub effect” of traditional hovercraft and covered with an anti-skid grating to improve safety in the presence of oil.
- a skirt system made of flexible, oil-resistant material.
- an innovative driving control system, composed of a directionality surface control system and a simple, intuitive command system known as Unik, for steering, motion-inversion and lateral and longitudinal trim.
- a Modular Propulsion System (MPS) separating propulsion from the lift system.
- an innovative cooling system taking into account 3 critical aspects specific to hovercraft: environmental constraints, amphibious capacity and weight minimisation. CRF-PRT opted for a 130kW Multi-Jet 16V diesel engine with an exceptionally low weight-to-power ratio.

The MACP offers a total floor area of 7.5 m^2 (empty) providing it with stability in up to 10 knot winds, and has a run time of 5 to 8 hours depending on the tasks performed and speed (45 knots max.). The prototype was tested in spring 2013 on the Po River (Italy), then for a week in the Loire estuary (with support from GPMNSN[5] and the municipalities of Saint-Brevin-les-Pins and Paimboeuf), and finally in Brest at Cedre's facilities. The observations recorded during these trials highlighted the platform's remarkable stability and manoeuvrability, ensured that it was unsinkable and able to provide a fast response – confirming the utility of the modular Hoverspill concept for the spill response tasks identified as well as its ability to perform these tasks.

Loire estuary: MACP high speed stability tests (source: Cedre)

Cedre's water basin and man-made beach: towing a boom in a trawling configuration (source: Cedre)

[5] Maritime Port of Nantes-Saint-Nazaire

Recovery/separation system

As one of the tasks intended to be performed by the platform was the recovery of oil slicks, the project included the development of an oil/water separator to optimise the limited storage capacity onboard or in a floating tank.

For this part of the project, Cedre defined a recovery system based on equipment existing on the market, taking into account the size and power constraints dictated by the platform and the rate of the separator developed by Ylec: maximum weight of 25 kg for the skimmer and 50 kg for the pump, requiring a maximum hydraulic power of 25 kW to give a flow rate of less than 10 m^3/h. Eight skimmers and two small pumps, preselected based on their low weight and compact format, were tested at Cedre using the French AFNOR standard, on oils of varying viscosities. Given the results of these evaluations, combined with an assessment of their ease of handling and flexibility of use, a combination of a weir skimmer (DESMI Terrapin) and a lobe pump (Börger AL25) was chosen.

The oil-water separation system also had to comply with strict requirements, in terms of size and weight, but also the range of oil (neat or mixed with water) handled, the inlet flow rate (around 7 m^3/h) and tolerance of air ingestion (intermittent or continuous). It was also required to ensure a cut diameter <100 µm, be easily adjustable and easily dismountable on board for rapid cleaning in case of clogging with debris. To meet these requirements, an entirely new centrifugal separator, Turbylec, was designed. A Turbylec prototype was tested at Cedre and gave very good results for a wide range of oil densities. It proved to be easy to handle and disassemble.

Testing the Turbylec, at Cedre, together with a DESMI Terrapin skimmer and a Börger AL25 pump (Source: Cedre)

This project resulted in the production of 2 innovative prototypes and led to 4 patents being filed (3 for the MACP and 1 for the Turbylec). While the Hoverspill MACP was designed for response to oil spills in sensitive, difficult access sites, its stability, safety, low construction and running costs and its ability to house different types of equipment and devices mean that it could easily be adapted for other purposes, for example in case of flooding, fire, for police operations or health evacuation operations, or even to support knowledge and environmental management of wetlands.

For further information:
http://ec.europa.eu/research/transport/projects/items/hoverspill_en.htm
http://www.softhull.com/index.html

Kerambrun L., Peigné G. & Laurent M. (on behalf of the Hoverspill consortium), 2014. *Hoverspill: a new amphibious vehicle for responding in difficult-to-access sites*. International Oil Spill Conference Proceedings: May 2014, Vol. 2014, No. **1**, pp. 649-659. doi: http://dx.doi.org/10.7901/2169-3358-2014.1.649

Maj G., Laurent M., Mastrangeli M., & Lecoffre Y., 2014. *Turbylec: Development and experimental validation of an innovative centrifugal oil-water separator*. International Oil Spill Conference Proceedings: May 2014, Vol. 2014, No. **1**, pp. 634-648. doi: http://dx.doi.org/10.7901/2169-3358-2014.1.634

• In situ oil detection/monitoring

Oil in Water Monitoring Buoy

The UK-based firm Ocean Scientific International Ltd (OSIL), specialised in oceanographic instrumentation, has made a recent addition to its range of measurement systems with a buoy designed to monitor dissolved hydrocarbon levels in water that can be quickly deployed in the event of a spill.

Powered by solar panels, this buoy measures 60 cm in diameter, is 2 m high and weighs 25 kg. Its central structure accommodates (and protects) a submersible sensor to detect dissolved hydrocarbons in the water column. It can also house various sensors to measure different parameters relating to water quality. The buoy is easily visible (e.g. fitted with lights) and is fitted with the necessary equipment for telemetric transmission of the data collected and its position (in various modes: mobile phone network - GSM, GPRS, UHF/VHF radio, satellite...).

This relatively compact device is designed to be deployed from small vessels, possibly by a single operator (e.g. response in semi-sheltered shallow waters, etc.), while enabling long deployment periods (up to 2 years of monitoring according to OSIL).

For further information:
http://www.osil.co.uk/Products/MarineInstruments/tabid/56/agentType/View/PropertyID/358/Default.aspx.

SHOAL project: robot prototypes for in situ pollutant monitoring

Partially funded by Information and Communication Technologies (ICT), under the Seventh European Framework Programme for Research and Technological Development (FP7), the SHOAL project, led by BMT (British Maritime Technology Group Ltd)[6], recently resulted in the development of an "intelligent robotic fish", an autonomous underwater vehicle (AUV) capable of detecting and identifying pollution in a given water mass.

Source: http://www.roboshoal.com/

The aim of this technological development was to result in near real-time detection and analysis of pollutants dissolved in seawater, using chemical sensors fitted to systems equipped with software instilling them with "artificial intelligence" (AI). These systems take the form of robotic fish, designed to identify a source of pollution and promote rapid (and allegedly efficient) implementation of response actions.

In short, the AI system aims to enable the robot to autonomously implement a certain number of actions in the environment, including navigating around obstacles, locating the source of a spill, positioning itself in relation to the spill to take in situ measurements, etc. Furthermore, the device developed could communicate and coordinate its actions with a certain number of similar devices, automatically return to a predetermined location to be recharged or for maintenance, etc.

This prototype falls within the category of autonomous underwater vehicles (AUVs), which have recently become popular in major oil spill management, whose use met with great success in the Gulf of Mexico following the *Deepwater Horizon* spill.

For further information:
http://www.roboshoal.com/

• Containment

Containment/protection in fast-flowing estuaries or rivers: Current Buster trials

The Norwegian firm NOFI recently extended its Current Buster range – systems designed to contain and separate floating oil in strong current – in particular with the addition of the Current Buster 6[7]. With a change in terminology, the 3 pre-existing models previously known as Harbour, Current and Ocean Buster (in order of size) have been renamed Current Buster 2, 4 and 8 respectively.

[6] SHOAL is a consortium of 6 European structures including BMT Group, the University of Essex, Tyndall National Institute, the University of Strathclyde, Thales Safare - which recently became Thales Safarepons, and Gijon port authority – the prototype test location).

[7] Model designed for offshore use, given its dimensions (34 m opening; 63 m long), and which benefits from technical improvements based on the lessons learnt from its recent deployment, in particular as part of the response to the Gulf of Mexico spill in 2010.

Given the plentiful and generally positive feedback on the Current Buster concept following its use on several recent spills, Cedre evaluated the Current Buster 4 model (22 m opening, 35 m long), designed for use inshore, in ports, in estuaries and even in rivers.

These trials were carried out upon request by both public (CEREMA) and industry (Total) partners, and were held in 2013 in the Loire estuary, with logistical support from the Maritime Port of Nantes Saint-Nazaire (GPMNSN).

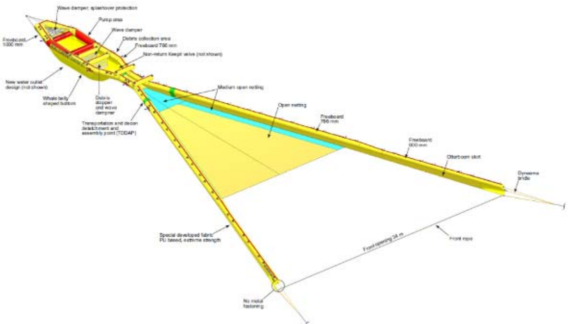


Diagram of the Current Buster 6 (source: NOFI)

The aim was to test various deployment conditions, in dynamic mode (towed behind 2 vessels, or 1 vessel with a boom vane) and in static mode (moored to a fixed point on the quayside and opening by a boom vane; reversal when the tide turned).

The in situ tests enabled the manoeuvrability of this type of equipment to be evaluated in the different configurations tested, but also its collection and concentration capacity on floating pollutant (simulated with oranges and popcorn) with a current speed of up to 3.5 knots. Additional information was also gathered in terms of the auxiliary resources required to deploy the device (handling, towing, etc.). Furthermore, this site, characterised by strong current and a sudden turn in the tide, required a rapid repositioning procedure to be defined and tested for when the tide turned.

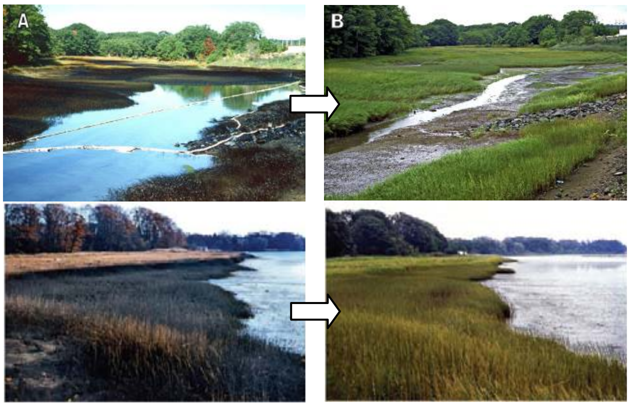
Static mode: the Current Buster 4 moored to a fixed point, deployed using an ORC BoomVane.

Dynamic mode: Left: pair towing (by a 19 m buoy tender provided by the Saint Nazaire subdivision of Phares et Balises + a small 7.5 m cruiser belonging to FOST); Right: towing by a single vessel, with deployment by an ORC BoomVane (Source: Cedre)

- **Impact**

Oiled marshland: feedback and recommendations

A recent article published in the Marine Pollution Bulletin offers a review, based on 32 spills and in situ experiments, of the main trends that can be identified in terms of the recovery times required by marshland vegetation, and the main influencing factors (e.g. oil type, extent/intensity of the pollution, hydrodynamics, season, specific sensitivity of the vegetation, etc.) controlling the rate of recovery.



Past experience: natural self-cleaning of marshland along the Fore River (US). **Left**: heavy fuel oil (IFO 380) spill during senescence (die-back) (September 1996); **Right**: recovery of the habitat at the first growing season (July 1997). (*in* Michel and Rutherford, 2013; 2014)

Drawing upon knowledge obtained from concrete cases – ranging from the 1970s (work of Baker) to the Macondo spill – providing basic considerations in terms of marshland ecology and the effect of oil (toxicity, coating, etc.), and reviewing the real impacts observed, this paper identifies clean-up techniques and criteria liable to promote as rapid a recovery as possible of the oiled habitats.

Based on this experience, the authors deduce a certain number of points, summarised as follows:

- In most of the cases analysed, habitat recovery occurs within 1 to 2 growing seasons.
- The longest recovery times recorded were in the following situations: cold climates, low hydrodynamics, thick layers of oil, large spills of light oil, thick persistent clusters (heavy fuel oil), aggressive clean-up techniques.

- The shortest recovery times were for the following cases: hot climates, spills during the dormant period for vegetation (autumn/winter), oiling of vegetation only, spills of medium crude oils, non-aggressive response techniques.

This study covered various types of marshes: coastal, estuarine and even freshwater marshes. Freshwater marshes are more contained areas and – generally speaking and for similar spills (type, quantity, spread, etc.) – are at greater risk of being impacted than an exposed section of coastal marsh for example.

General technical guidelines[8] for site clean-up – ranging from natural self-cleaning to burning, not forgetting scything, scraping, etc. – are put forward, according to the type of pollutant or the distribution and severity of oiling: free-floating oil, accumulations on the ground (> or < 0.5 cm) or on vegetation (heavy to light), etc. These elements are also presented in another recent publication by the same authors (Michel and Rutherford, 2013; published by the American Petroleum Institute), to which readers may refer for further information (feedback from concrete cases, etc.).

Manual recovery + use of sorbent mops on floating oil in a marsh (Patuxent River, Maryland, Spring 2000) (Source: J. Michel)

For further information:

Michel J. and Rutherford N., 2014. Impacts, recovery rates, and treatment options for spilled oil in marshes. Marine Pollution Bulletin, **82** (1-2):19-25. doi: 10.1016/j.marpolbul.2014.03.030.

Michel J. and Rutherford N., 2013. Oil spills in marshes: planning & response considerations. Seattle: Office of Response and Restoration, National Oceanic and Atmospheric Administration, Seattle, WA and American Petroleum institute, Washington, DC, 120 pp.

• Legislation/Convictions

$1.7M fine for Yellowstone River spill

In March 2013, the US Department of Transportation (DoT) fined ExxonMobil Corp $1.7M (approximately €1.3M) for pipeline safety violations, relating to the 2011 spill into Yellowstone River (Montana) of around 240 tonnes of crude oil due to a crack in the Silvertip pipeline (see LTEI N°17).

To explain this decision, we remind readers that the Pipeline and Hazardous Materials Safety Administration (PHMSA, a DoT agency) linked the incident to the rise in water level and increased flow of the Yellowstone River, due to ice melting. The bank erosion incurred is believed to have caused a section of the line to be pounded by floating debris (tree trunks, etc.) carried by the river. However, according to the federal agency, "the risk of flooding on Yellowstone River was a known threat that could cause the pipe in the river to lose physical support and potentially rupture". This observation came on top of the opinion expressed by PHMSA in January, stating that the extent of the spill could have been reduced by 2/3 if company workers had responded more quickly.

We remind readers that Exxon estimated clean-up costs covered by the company at $135M.

Crau spill: disputed fines and damages

In late July 2014 the *Société du pipeline sud européen* (SPSE) was sentenced to a €77,000 fine and €400,000 in damages, for a spill of approximately 4,700 m^3 of crude oil, polluting 5 hectares of a sensitive habitat in the Coussouls de Crau nature reserve (Bouches-du-Rhône) in August 2009 (see LTEI n°13 and 18).

This sentence was announced by the court of Tarascon based on "failings considered to constitute negligence"; the SPSE had failed to replace a section of the line whose fragile condition had been reported in 2003.

The fine, imposed for a "spill of a harmful substance in groundwater, surface water or seawater", was however lower than that called for by the prosecutor (€250,000 for "persistent negligence") which the court justified by citing "SPSE's care in the management of its pipelines" and the firm's collaboration in spill response operations. The amount of damages was also far below the several million euros called for by the parties claiming civil damages (local authorities, joint union, *Conservatoire d'espaces*

[8] Indicating a certain number of environmental constraints (site sensitivity, load bearing capacity, access, etc.) to be taken into account in their selection and implementation.

naturels, environmental associations, etc.), considered excessive by the court.

Despite these amounts being considered insufficient by some and excessive by others (the SPSE defence decried the fact that the recognition of good crisis management had not led to complete dismissal of the charges), neither SPSE nor the court have announced any intention of appealing this decision, a move made by the *Conservatoire d'espaces naturels* (CEN) of the Provence-Alpes-Côte d'Azur (PACA) area, in relation to the damages with which it had been awarded (€20,000 for non-material damages). According to CEN, this insufficient sum constitutes "a worrying signal for nature protection in France and its defenders", in particular in an environment such as that of Plaine de la Crau, to which protection and remediation measures have applied since the early 2000s.