

Resilient and Sustainable Transport – Dutch Style:

An interim report on bilateral cooperation between FHWA and Rijkswaterstaat



Highway A58 in the Netherlands. US and Dutch colleagues collaboratively tested resilience tools on the A58 expansion project and a highway project in Washington State. Credit: FHWA

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Introduction

Since 2014, US and Dutch counterparts have been collaborating on the topic of infrastructure resilience under a bilateral agreement between the Federal Highway Administration (FHWA) and Rijkswaterstaat (RWS), the Netherlands' Ministry of Infrastructure and Environment. During the first two years, each side learned about each other's tools and approaches. During the second two years of collaboration, FHWA and RWS are testing climate change resilience tools developed in both countries on two infrastructure projects. The Netherlands project is the InnovA58 project, which expands a roadway in southern Holland from two lanes in each direction to three lanes in each direction. The US project is the SR167 completion project, which completes a critical missing link to Interstate 5 near Tacoma, Washington, including approximately 6 miles of new construction and 5 new interchanges. The analysis frameworks and accompanying tools that FHWA and RWS are testing are the European [ROADAPT](#) methodology and the US [FHWA Climate Adaptation Framework](#).

From April 8-15, 2017, a subject matter expert from FHWA, two from the Washington State DOT, and one from the US Department of Transportation Volpe Center traveled to the Netherlands to meet with project managers for the A58 project, climate scientists, and experts in climate adaptation, asset management, emergency management, sustainability, and smart mobility.

This report synthesizes some of the information and perspectives gained during that visit that may be useful for application in the US context. It focuses on the climate vulnerability analysis of the Dutch InnovA58 project, the inclusion of climate resilience specifications in the design contract for the project, and innovations beyond resilience that are being integrated into the InnovA58 project in a complementary manner. An FHWA report to be completed in 2018 will include information on the analyses of both the InnovA58 and SR167 projects, a comparison of the Dutch and US climate resilience tools, and lessons learned to improve the tools and the resilience of future road projects in both the US and the Netherlands.

A58 Background and Analysis¹

The segment of A58 between Tilburg and Eindhoven was built in the 1950s with one lane in each direction. RWS added an additional lane in each direction in the 1960s. The segment of A58 south of Breda was opened in 1989. Since that time, traffic has continued to grow. The route receives extensive international freight traffic, which increased further after neighboring Belgium instituted a toll on an alternative route in that country. Accidents and traffic jams at junctions are frequent. Dutch land use policy for conserving farmland and the landscape results in dense satellite cities rather than urban sprawl. While this reduces the need for travel within cities, it leads to considerable commuting between satellite cities. RWS estimates that smart mobility solutions could reduce future traffic on A58 by 15 percent, but not by enough to obviate the need for lane expansion. As such, RWS decided that the current project will institute smart mobility solutions and add a lane in each direction on two heavily congested 7 and 28 km segments of the highway (namely between Tilburg and Eindhoven and south of Breda).

RWS designated the project as an innovation “living lab” project, with the title InnovA58. As such, the project will test innovations in multiple areas, including smart mobility, climate resilience, social design (public involvement), and circular economy (no waste and adaptive, modular, or reusable elements).

The two project segments cross 11 streams. Many of the culverts are too small to handle projected rainfall levels. Recreation and nature groups are also requesting culvert and bridge expansions to accommodate recreation opportunities and ecological connectivity. InnovA58 has a zero-impact philosophy, meaning an intent to use innovation to keep noise and pollution to a safe level. The project has 23 active stakeholder groups, including recreation and nature groups, bicycle groups, farmers, water boards (discussed further below), and citizens. RWS has committed to completing the project in 2023, and faces the challenge of combining innovations in a high profile, fast moving project.

Resilience Tools

The climate resilience tools that are being tested as part of the collaboration are ROADAPT, developed by the Conference of European Directors of Roads (CEDR), and the FHWA Climate Adaptation Framework and associated tools. ROADAPT uses a risk-based approach for assessing vulnerabilities and identifying adaptation strategies. The ROADAPT methodology involves selecting data for current and future climate; a preliminary, stakeholder-driven climate change risk assessment, called Quicksan; a GIS-based vulnerability assessment; a socio-economic impact assessment; and the selection of adaptation strategies.

The FHWA Climate Adaptation Framework is a guide for transportation agencies interested in assessing their vulnerability to climate change and extreme weather events and integrating the results into decision-making. The Framework discusses the key steps in conducting a vulnerability assessment and provides options for how the process can be conducted with varying levels of effort and resources – for example, through a stakeholder-based assessment or a project-level engineering analysis. The Framework is accompanied by four [tools](#) that assist transportation planners with assessing criticality, conducting a sensitivity analysis, processing downscaled climate data, and scoring a vulnerability assessment.

Climate Resilience²

RWS partnered with Deltares, an independent research institute, to analyze climate change vulnerabilities and adaptation strategies for InnovA58 using the ROADAPT framework and FHWA’s sensitivity matrix and Vulnerability Assessment Scoring Tool (VAST), which are tools that accompany the FHWA Climate Adaptation Framework.

Deltares convened the InnovA58 project team, operations and maintenance staff, and local governments for three workshops using the ROADAPT Quick Scan methodology. The team developed a matrix of current risks, and then translated that to future risks by adjusting the likelihood of the different impacts using a higher and a lower climate impacts scenario. The highest risks for A58 identified in the workshops are, in order:

- Flooding of road at creek crossings
- Pluvial flooding (road flooding as a result of heavy rainfall – surface runoff, increase in groundwater level, puddle forming)
- Erosion of roads due to undersize culverts
- Erosion/loss of bearing capacity in the road sub-base due to prolonged water alongside road
- Landslide/road subsidence of embankment in periods of extreme precipitation
- Loss of driving safety due to restricted visibility during snow or showers, including spray
- Driver safety due to water on roads (hydroplaning when water film is thicker than 3 mm)
- Flooding of underpasses

The top risks for the area surrounding the roadway are (in order):

- Flooding in stream valleys following periods of prolonged precipitation
- Flooding in urban areas due to intense precipitation
- Fall in groundwater levels leading to a change in the ecology and/or agricultural earnings
- Increase in groundwater levels leading to flooding in villages/towns/cities

Notably absent from the list are coastal and riverine flood risks. In the specific case of the InnovA58 this is due to the distance to the coast and larger rivers, and because of the slight elevation of this part of the country. Roads nearer to the sea and rivers are protected from flooding by RWS's comprehensive system of coastal and riverine flood protections (known as the Delta Works) providing protection up to the 1 in 10,000 year storm for heavily populated areas. In response to increased flood risks from climate change, RWS is raising levees, adding natural protective features, and making room for the rivers (expanding floodplains to allow for more water storage). The Dutch are taking an adaptive management response to increase protections over time as conditions change.

Given the high level of flood protection provided by the Delta Works, RWS finds that Dutch highways are at relatively low risk from coastal and river flooding. RWS's primary concern for highway flooding is from localized flooding from heavy rain events (pluvial) and flooding from small streams, especially given the flat topography of the country. The current standard is to protect against 1 in 10 year pluvial flood. RWS anticipates that these floods can now occur every 5 years in the future and may cause unacceptable disruptions to the national highway network.



Pluvial flooding in the Netherlands in 2010. Photo Credit: RWS, Nu.nl

A Long History of Coastal Flood Control

Twenty-six percent of the Netherlands is below sea level and much of the country is close to major rivers, which makes 60 percent of the Netherlands prone to flooding from the sea, rivers, and canals. For hundreds of years, the Dutch have been taking collective action to prevent flooding. The Dutch formed local government entities known as water boards as early as the 13th Century to provide protection from flooding and manage water resources. A disastrous flood in 1953 spurred a national consensus that a large program of strengthening flood protections was warranted. In response, the Netherlands funded and constructed the Delta Works. Presently, RWS and local authorities own and maintain storm surge barriers, dikes, dunes, sand nourishment projects, and other structures that provide comprehensive flood protection up to the 1 in 10,000 year storm for heavily populated areas.

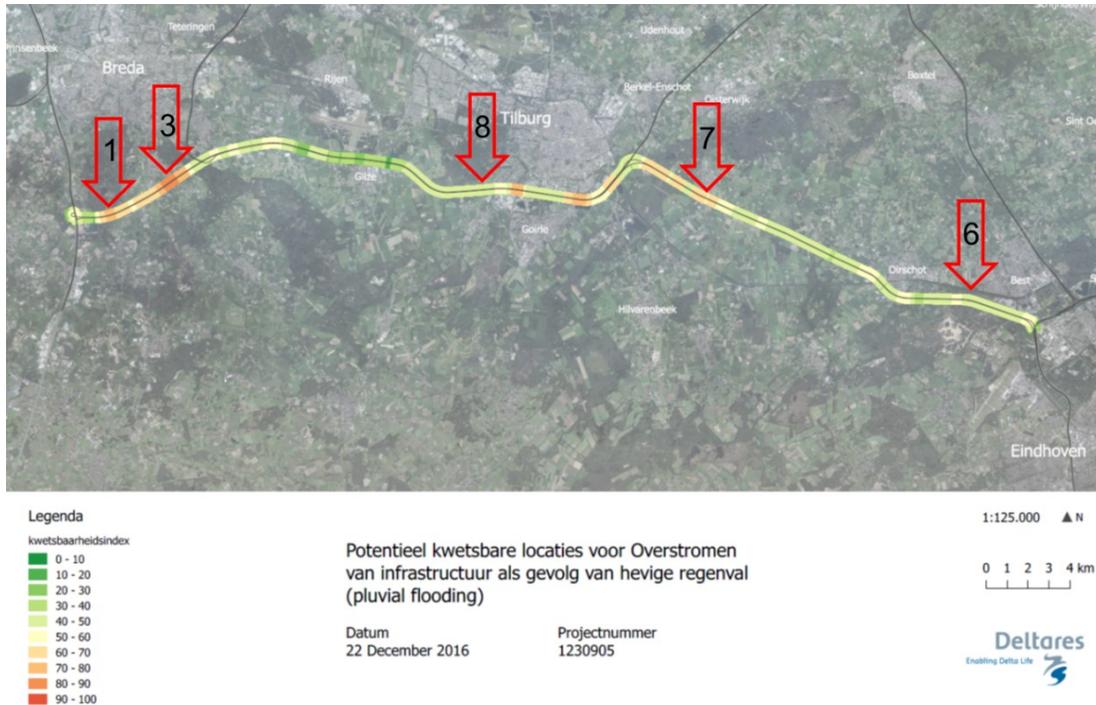


The Eastern Scheldt storm surge barrier in southern Holland. Photo Credit: FHWA

After developing the risk matrices through the Quicksan workshops, Deltares developed vulnerability scores for sections of the roadway using ROADAPT's Vulnerability Assessment (VA) and FHWA's VAST. Deltares combined data sets from Alterra Research Institute, Blue Spot (an earlier flood risk analysis by RWS), a site visit assessment, road drainage system records, elevation difference between the road and the surrounding area, and presence of culverts and ditches. The rankings that came from the two tools were similar, though not identical. The five locations identified with both tools as the most vulnerable areas for pluvial flooding are:

- Kriekampen (Parking areas beside A58) (6)
- A58 near Ulvenhout (3)

- Exit / access ramp near Moergestel (7a)
- A58 near Galderse meren (1)
- A58 – eco-passage Leij crossing (8)



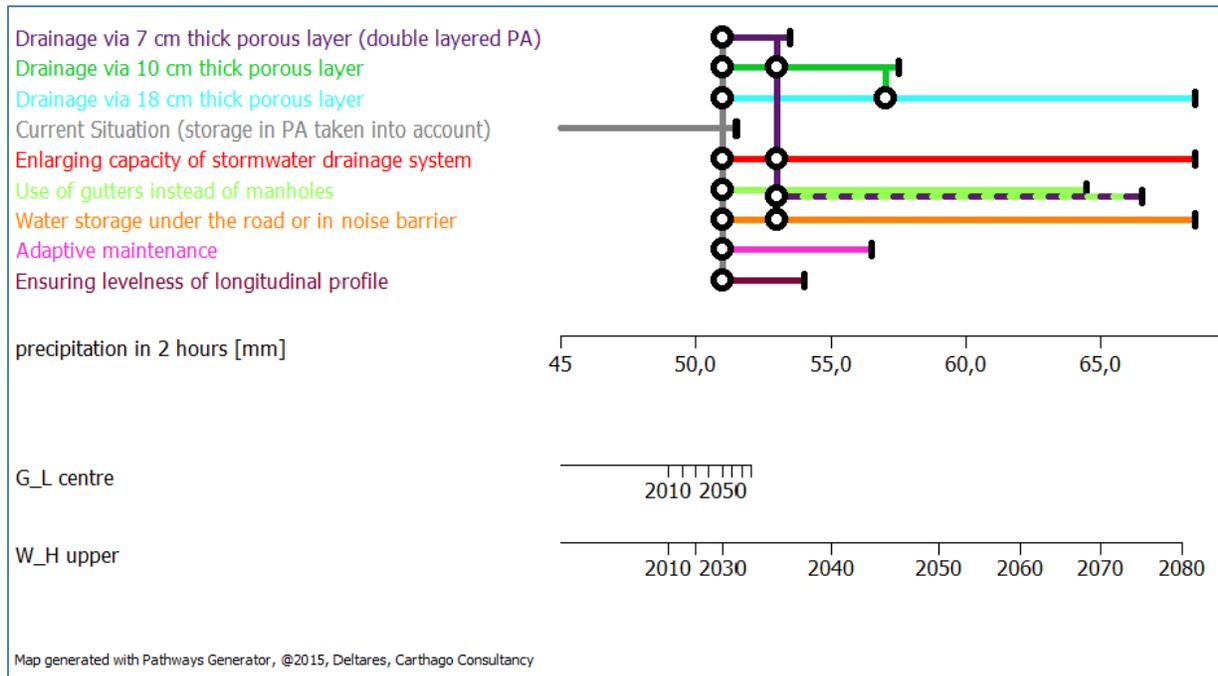
Output from GIS-based ROADAPT tool showing sites potentially vulnerable to pluvial flooding. Green indicates relatively low vulnerability while orange indicates relatively high vulnerability. Arrows indicate areas of highest vulnerability and contain reference numbers which match to the site name in the bulleted list above. Credit: Deltares.

Deltares used the adaptation measures matrix from ROADAPT Part E to identify adaptation measures for InnovA58. Deltares used the following set of criteria for evaluating adaptation measures:

- Relevance/effectiveness
- Costs/benefits
- Flexibility
- Robustness and soundness
- Maintenance and Life Cycle costs
- Context and secondary benefits

In considering adaptation measures, Deltares used the concept of dynamic adaptation pathways, in which the analyst considers a range of options that allow for switching to different strategies as the climate changes and new information becomes available. The timeline below shows when different pluvial flood mitigation strategies would stop working for two different climate scenarios, and which

other strategies could be implemented at that point (identified by the open circles). “G_L centre” is a lower impact climate scenario and “W_H upper” is a higher impact climate scenario.



Flexible adaptation pathways for increased pluvial flood risk to A58. For example, business as usual practices (grey line) are adequate for up to about 52 millimeters (2 inches) of rainfall in two hours, or until about 2032 under a high climate impacts scenario (W_H upper) or until about 2050 under a low climate impacts scenario (G_L centre). Credit: Deltares.

Contracting Documents Include Climate Resilience Requirements

RWS issued the request for quotations (RFQ) for the design of Innova58 in April 2017. The RFQ includes a section with requirements for the contractor related to climate resilience. That section requires the contractor to develop robust and flexible climate adaptation measures for Innova58 and advise on how they can be integrated into the project. It also requires usage of climate scenarios developed by the Royal Dutch Meteorological Institute (KNMI), RWS climate guidance, and the dynamic adaptation pathways approach. It requires cost-benefit analysis of adaptation measures and analysis of their potential impact on other issues, such as noise and ecological impact. Finally, the RFQ requires that climate resilience of the road and the surrounding area be considered in conjunction with each other. The RFQ includes the Deltares climate resilience analysis as an appendix.

RWS divided project features into three packages:

- Package 1: measures necessary for functionality of the road
- Package 2: measures that improve functionality of the road

- Package 3: measures that match with measures in surrounding environment and meet the goals of the “Stream Valley Report,” which was developed by stakeholders for improving nature, recreation, cultural history, and landscape

RWS intends to ask stakeholders to co-finance anything above Package 1.

Combining Multiple Innovations in Complementary Fashion

RWS emphasizes that InnovA58 must consider the resilience of the road in conjunction with its surroundings and integrate resilience with other goals. Combining challenges of noise reduction, recreation, adaptation, etc. stimulates innovative solutions that provide benefits in multiple areas. This integrated approach also avoids situations in which an innovation in one area causes unintended negative consequences on another goal. This approach requires iterative “zooming out” to the larger picture and “zooming in” to the specific issue or location.



RWS needs a solution that will prevent frequent flooding of the section of A58 near this culvert (left photo). But RWS also recognizes it needs to consider upstream and downstream effects of alterations to the culvert, impacts on other areas of the alignment, impacts on other goals such as recreation and nature, and impacts on the surrounding community that the road serves. Photo credits: FHWA and RWS, respectively. Second photo is of Utrecht ring road showing features that integrated the road into its surroundings.

Social Design³

A58 cuts through the scenic and historic village of Oirschot, which dates to medieval times and hosts multiple UNESCO World Heritage sites. Citizens were concerned about the impact of the highway expansion project on their village. RWS sought village input on the A58 expansion project through an innovative process called “Social Design,” in which village members co-designed noise and environmental mitigation aspects of the project. In the United States, it would likely be referred to as a highly structured and effective public involvement / co-design / context sensitive solutions approach. RWS hired a public involvement firm that organized interested Oirschot citizens into a design team. Each member of the citizen team was tasked with gathering input from members of the community

about the project. The consultants facilitated a design process with the citizen team over a series of workshops that moved from origin of the problem, through stakeholder analysis, themes, frames, and



Scenes from the picturesque village, Oirschot, which A58 bisects. Photo credit: FHWA

solution scenarios. The citizen team then presented their design proposal to RWS management at a fitting venue, Oirschot's local, historic brewery. The process succeeded in transforming a contentious, adversarial situation into a partnership. It also resulted in design elements that would not likely have arisen otherwise. For instance, citizens did not want noise barriers to block the view between the highway and the village because they wanted travelers to be able to see the village so that they would be more likely to visit.

Smart Mobility⁴

RWS has a "Traffic Innovation Campus," where RWS offices are co-located with mobility start-up companies and university research centers. Under this public-private partnership, the participants combine public data (traffic data from inductive loops on roadways, traffic cameras, etc.) with private data (GPS and cell phone data on vehicle speed and location) and test smart mobility solutions. For instance, researchers can deploy new messages on variable message signs or new smart phone applications and watch user reaction in real time. RWS also has a test highway segment where they can test truck platooning, connected and autonomous vehicles, and other innovations. They are also testing smart cameras that can detect if there is a disabled vehicle in the shoulder lane and open the lane to traffic if it is clear. The center is experimenting with cell phone apps and road signs to prevent "shockwave traffic" jams on A58, which result when one vehicle slows down and the slow down propagates even though there is not an accident. The experimental apps provide speed suggestions to drivers in order to smooth traffic and prevent shockwave jams. The center is also experimenting with gaming and social media applications for traffic management.

Sustainability⁵

RWS aims to incorporate sustainability features in a wide range of areas in order to meet its sustainability goals. These goals include targets to reduce the use of fossil fuels in the construction phase by 30 percent, institute energy neutral management and maintenance, and attain 50 percent circularity (zero waste) by 2030 and 100 percent by 2050. When asked what sustainability features might be incorporated into InnovA58, Project Manager Wim Leendertse replied, “Of course we will have solar panels.” Measures under consideration include cold asphalt, extra silent asphalt, connected LED lighting, solar panels embedded in the roadway, solar panels embedded in sound barriers, and diffractor and zig zag sound barriers to reduce noise with less material.

Precipitation Intensity – Duration – Frequency Curves⁶

The Dutch meteorological institute (KNMI) developed four climate scenarios for the Netherlands, covering a large span of the uncertainty range for 2050 and 2085. The original version was published in 2006 and updated in 2014. New scenarios will be published in 2021 and KNMI has started meetings with user groups in 2017 as part of the update process.

RWS, like FHWA, is interested in short duration, high intensity precipitation events. Global climate models do not model these well. As such KNMI used historic observations showing precipitation intensity increasing with dewpoint temperature. KNMI has also tried to simulate these short duration, high intensity events with newer climate models.

KNMI’s 2016 memo scales rain curves for short duration showers. KNMI found that the rarer storms (such as the 1 in 250 year) have a disproportionately greater increase in precipitation depth than the less rare events (1 in 10 or 50 years). This is due to the effect of positive feedbacks in the atmosphere on the rain intensity, which occurs when the dewpoint temperature rises above a certain threshold value. RWS is now using a 40 percent increase in precipitation for the 2085 horizon and a 22 percent increase for 2050, for the 1 in 10 and 1 in 50 year storms. RWS is using this in current projects.

RWS standards call for designing to the 1 in 10 year rainfall (horizon 2050) for at-grade highways, 1 in 50 year (horizon 2085) for bridges, and 1 in 250 year (horizon 2050) for tunnels. RWS has found that designing for the 1 in 250 year storm (with a horizon of at least 2085 with climate change) may be too costly, and that conducting cost benefit analysis may be a better approach.

Building with Nature⁷

RWS is part of the Interreg North Sea Region international cooperation program to apply natural and nature-based measures to make coasts, estuaries, and catchments more resilient to climate change. The North Sea project has 3 performance indicators: 1) 700 km of new coastline plans based on Building with Nature principles; 2) 550 km of new catchment areas based on Building with Nature principles; 3) increase climate resilience by 10 percent. RWS staff member Egon Baldal explained that the group found the third performance indicator difficult to define. They decided to define it on a project by

project basis. For instance, increasing water storage capacity in a catchment basin by 10 percent could be considered a 10 percent increase in resilience.

As an example of an Interreg Building with Nature project, the Scotland Eddleston River project re-meandered the river, set back embankments, forested the floodplain, engineered log jams, and created ponds and wetlands to increase temporary water storage capacity. The project delayed the time of peak flow by 20 to 30 min and decreased the volume of peak flow by 20 percent.

Building with Nature approaches span a continuum. On the lower end are “engineering plus” solutions, such as making holes in wave attenuation devices (WADs) to create habitat for aquatic species. Ecodynamic engineering, on the other end of the spectrum, uses the forces of nature to provide protection. The Sand Motor near The Hague provides an illustration. Instead of frequent beach nourishment for coastal protection, the Dutch experimented with placing a much larger amount of sand in a strategic location such that natural currents and sediment transport processes would move the sand along the coastline over time, providing the same level of protection, but with less disturbance to the ecosystem from dredging.

Under the “Room for the River” project, RWS relocated farms and houses and moved dikes to allow rivers more room to spill over their banks to accommodate increases in precipitation. In North Holland, instead of raising a levee, RWS created an artificial dune in front of the levee. Other examples include planting willow trees to reduce the impact of wave forces, which in turn allows clay dikes to be lower and cheaper. Creating wetlands using dredged material provides yet another example.

By RWS Covenant, every water safety project must now consider eco-engineering approaches as part of the design. As part of implementing this policy, RWS seeks to translate ecological and environmental boundary conditions into contract specifications.

“Will I flood?” Smart Phone App⁸

RWS developed an emergency preparedness smart phone application called “Will I flood” that allows users to enter their zip code and see their flood risk. The app provides flood probabilities, icons, and real pictures of flood impacts. It then provides information on what to do. The app includes tips and storytelling, including video interviews with people who experienced the 1953 flood. RWS lessons learned include: communicate the worst case scenario, keep it personal and simple, and educate school children. The app is available (in Dutch) at www.overstroomik.nl.

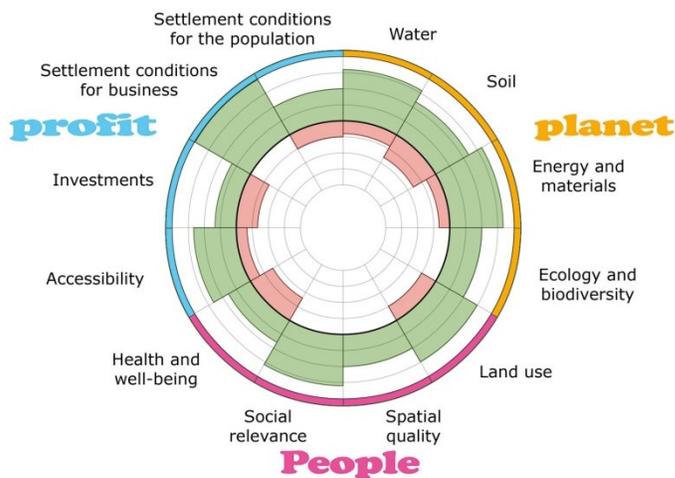
RWS finds it challenging to communicate flood risk to the general public, since Dutch citizens often do not worry about flood risk given the high levels of protection provided by the extensive system of dikes and storm surge barriers. The app is intended to help educate the general public.

The Dutch rely on a multi-layer safety concept with three layers of protection. These are, in order:

1. Prevention: dikes, dunes, storm surge barriers
2. Sustainable land use planning – limit the effects of flooding
3. Crisis and disaster management

“Sustainability-Check”⁹

Similar to FHWA’s INVEST, RWS has a sustainability self-assessment tool called the Sustainability-Check. The tool helps transportation project managers balance profit (economic), people (social), and planet (environmental) outcomes and go above and beyond requirements. It serves as a quick, qualitative check for discussion and a visualization tool. It can be used as a check list, a method for comparing alternatives, or to ensure consistency between project stages. It also provides an early risk analysis, identifying areas that could be contentious or pose problems. RWS finds that the tool’s more inclusive scope helps the agency improve projects and avoid project risks.

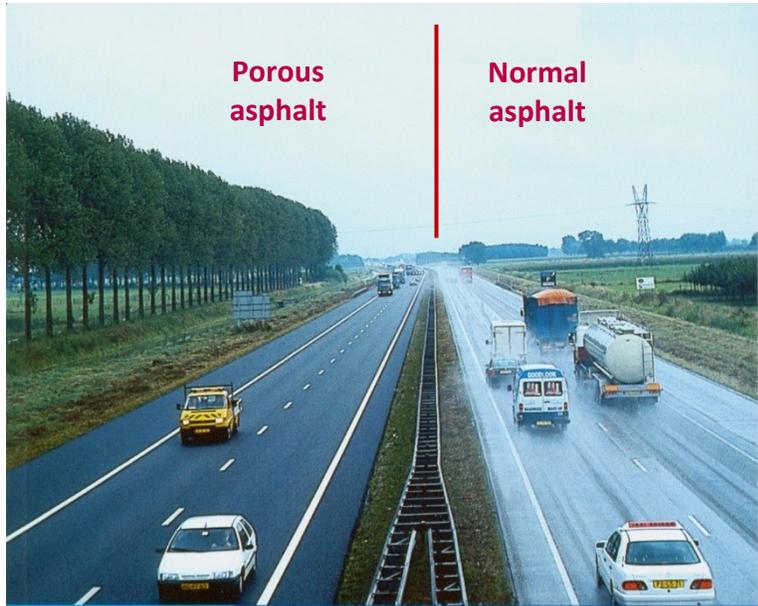


The Sustainability Check shows positive impacts in green and negative impacts in red. Credit: RWS

Porous Asphalt¹⁰

For noise reduction purposes, RWS uses a 5 cm (2 inch) porous asphalt layer on top of regular, impervious asphalt. This reduces noise by 3 to 4 dB at speeds greater than 30 to 55 km/h (19 to 34 mph) and is less expensive than the same reduction of noise by a traditional sound barrier. Currently, more than 85 percent of the Dutch National Road network uses this surfacing. RWS plans to expand its use to cover the entire national highway network, except in vulnerable locations like tunnels (where it would pose a fire hazard from trapped oil). In addition to noise reduction benefits, the porous asphalt layer also reduces splash, spray, and hydroplaning; stays cooler; filters pollutants; and provides 9 mm of water storage in the pavement. Deltares considered thicker porous asphalt as a potential strategy for reducing pluvial flooding of A58 due to this water storage capacity. The drawbacks are that it experiences more black ice in the winter and needs additional preventive maintenance. To manage black ice on porous asphalt, RWS uses higher doses of salt, preventive winter maintenance, advanced rain radar, and rubber ends on snow plows. Vehicle traffic cleans the pavement on the travel lanes, depositing residue on the shoulder, which then needs to be cleaned by a maintenance crew twice per year. After 11 years, the most heavily trafficked lanes of pavement need to be renewed and rejuvenated. Then all lanes must be replaced after 17 years. Porous asphalt is not recommended for areas with extreme cold climates,

narrow curves, roundabouts, urban areas, or junctions. The heat resilience of porous asphalt is better than that of regular asphalt because of porous asphalt's stone skeleton. Stones do not deform at high temperatures and as such, pavement rutting at elevated temperatures in summer is less common for porous asphalt than regular asphalt.



Porous asphalt has considerably less splash and spray when wet than does normal asphalt. Photo credit: RWS.

FHWA has a [technical advisory from 2015 on porous asphalt](#). However, the technical advisory focuses on porous asphalt over a permeable stone layer, not porous asphalt over an impermeable layer as used by RWS. The FHWA technical advisory refers to a porous layer over an impervious layer as open graded friction course (OGFC). FHWA also has a [technical advisory on OGFC from 1990](#) and a [safety report](#) from 2015.

Conclusion

US and Dutch analysts will complete the climate resilience analyses of the two road projects and compare processes and results. The collaboration will be used to enhance tools used on both sides and implement resilience strategies for InnovA58 and SR167 as well as future highway projects. In the meantime, the collaboration has already yielded valuable insights and a collection of innovative practices. Washington State DOT and FHWA staff are meeting with subject matter experts within their agencies to discuss these practices and their applicability in the US.

¹ Information in this section is from author meetings with Wim Leendertse, Myrthe Leijstra, and Peter Hoernig of Rijkswaterstaat and Jos Arts of Rijksuniversiteit Groningen, April 10 – 11, 2017.

² Author meeting with Stan Kerkhofs of Rijkswaterstaat and Thomas Bles and Mike Woning of Deltares, April 10 – 15, 2017.

³ Author meeting with Julie Hornix of VanBerlo Company, April 10, 2017 and <https://vanberlo.nl/work/116/when-citizen-participation-becomes-co-creationm>

⁴ Author meeting with Peter Hoernig of Rijkswaterstaat, April 10, 2017

⁵ Author meetings with Wim Leendertse and Gerrald Goselink of Rijkswaterstaat, April 10 and 13, 2017.

⁶ Author meeting with Janette Bessembinder and Marcel Molendijk of KNMI, April 11, 2017.

⁷ Author meeting with Egon Baldal and Pieter de Boer of Rijkswaterstaat, April 12, 2017.

⁸ Author meeting with Ellen Moens of Rijkswaterstaat, April 11, 2017

⁹ Author meeting with Henriette Stoop of Rijkswaterstaat, April 11, 2017

¹⁰ Author meeting with Rob Hofman, Rijkswaterstaat, April 13, 2017.