Steinbeis-Innovationszentrum Angewandte Landschaftsplanung

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Environmental and vegetation assessment report

DredgDikes

[Component 4]

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/2/ DIN ISO 11277: 2002-08 Bodenbeschaffenheit – Bestimmung der Partikelgrößenverteilung in Mineralböden

/3/ Länderarbeitsgemeinschaft Abfall, 2004: Anforderungen an die stoffliche Verwertung von mineralischen Abfällen: Teil II: Technische Regeln für die Verwertung 1.2 Bodenmaterial (TR Boden) LAGA M20

/4/ Henneberg, M. 1992: Untersuchungen zur landwirtschaftlichen Nutzung von Schlickspülfeldern am Beispiel des Spülfeldes Radelsee Rostock, Universität Rostock, Diss.

/5/ Janzen, K.; Henneberg, M. 1995: Ermittlung standortbezogener Unterbringungsmöglichkeiten für Nassbaggergut im Küstenbereich Mecklenburg-Vorpommerns und Erarbeitung einer Methodik zur Standortsuche für Spülfelder und Baggergutmonodeponien - Abschlussbericht für das Ministerium für Bau, Landesentwicklung und Umwelt Mecklenburg-Vorpommerns

/6/ Henneberg, M.; Neumann, R. 2011: 10 Jahre Lysimeterversuche zum Einsatz von gereiftem Baggergut zur Bodenverbesserung in der Landwirtschaft, Abschlussbericht für das Landesamt für Umwelt, Naturschutz und Geologie, Mecklenburg-Vorpommern

/7/ Blume, H.-P., Brümmer, G.W., Horn, R., Kandeler, E., Kögel-Knabner, I., Kretzschmar, R., Stahr, K., Wilke, B.-M., 2010: Schef-fer/Schachtschabel Lehrbuch der Bodenkunde, 16. Auflage

/8/ Gesetz zur Förderung der Kreislaufwirtschaft und Sicherung der umweltverträglichen Bewirtschaftung von Abfällen (Kreislaufwirtschaftsgesetz - KrWG) 2012

/9/ Hrsg. Kuratorium f. Forschung im Küsteningenieurwesen 2002: Die Küste, Archiv für Forschung und Technik an der Nord- und Ostsee EAK 2002 Empfehlungen für Küstenschutzwerke, Boyens Buchverlag

/10/ Schlungbaum, G., Schiewer, U. und Arnst, E.A. 1994: Sanierung und Bewirtschaftung der Darß-Zingster Boddengewässer als Teil der Küstengewässer Mecklenburg-Vorpommerns, Rostock, Beitrag Meeresbiologie 1994(2)

/11/ LUNG 2005: Nährstoff- und Schwermetallbilanzen der Küstengewässer M-V unter besonderer Berücksichtigung ihrer Sedimente, Schriftenreihe des Landesamtes für Umwelt, Naturschutz und Geologie M-V, Heft 2/2005

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1 APPLIED METHODS OF INVESTIGATION

All work was according to the requirements of the investigation of dredged material at the sampling, analytics and quality assurance, described in detail in the appendix 1 of the federal soil protection and contaminated site ordinance (BBodSchV) /1/. From view of the specifics of the dredged material (origin, material composition) additional definitions to the sampling and to the application of certain analysis regulations from the point 3.1.3 methods of analysis in the appendix 1 the BBodSchV were met.

1. In order to give representative samples to analytics, due to the heterogeneity of the dredged material partially due to the technological processes compared with a grown ground, for each sampling area were generate in principle mixed samples. The sampling for a mixed sample took place with the drilling stick on 25 to 30 points, depending upon size of the sampling area.
2. For the investigation of the grain size composition in the dredged material as a substantial guidance parameter became applied E DIN ISO 11 277 /2/ (pretreatment of the sample by destruction of the organic substance and limes) to genuine determination the portions of sand, silt and clay/tone in the mineral fine ground because of often high contents of organic substance and lime (tab. 3 point 3.1.3 (method of analysis) appendix 1 the BBodSchV specified methods).

2 PRELIMINARY REMARKS

The investigations refer to dredged material loads, which were up-rinsed in the pond complex Schnatermann classified and touched from a special dredging down to heaps. A basic evaluation of the materials happened already at the time of heap building in 2009. Before the application in the dike construction project DredgDikes in November 2011 several samples were taken again out of the heaps for soil mechanical investigations. At the same time the sampling from individual samples for the investigation on TOC and granulation after humus and carbonate destruction took place to get relatively homogenous substrates. In summer 2013 and spring 2014 mixed samples were taken for investigation of the status quo from nutrient supply of the material. In the following the material will labeled as **S2** and contain 3 heap areas from 2009 (labeled as S2, S3 and S4/2009). The sampling occurred in the moment of the application in the construction and the samples were given to the laboratory. The analytical extent for the particular sampling can be found in the annex 1. In the following table 1 the origin and quantity, flushing and preparation time as well as time of the basic sampling is noted.

Table 1 origin of investigated substrates

labelling	*origin*	*filling*	*removal and setting of heaps*	*sampling*
Schna09	Marine/navy harbor Hohe Düne	ca. 110.000 m³ in 2004	2008	03/ 2009

Up to the time of the re-examination in November 2011 the maturing process of the materials from 2009 had so far progressed that utilization is possible. In order to be able to offer the substrates for utilization, exact knowledge of soil chemical characteristics is necessary. Aim of the basic investigations in 2009 was it therefore:
- to out-border homogeneous substrate areas in the heap complex,
- to mark the substrates set off in the heaps regarding their composition more near,
- to judge the soil chemical characteristics over the realization of an extensive analysis program and
- to point out applications for the substrate areas based on the won conclusions

An aim of the further investigation in 2011 on granulation, TOC content and water content as well as soil mechanical investigations was:
- to recognize the fluctuation margin within the bordered heap ranges
- to examine the maturing progress (change of water content)
- and to specify the application type (core and poetry) in the dike construction

On the basis of the obtained results there was the possibility to contain the substrate charges sharply bounded according to their suitability of a specific utilization within the dike.

The soil chemical investigation during the dike construction marks the current status of the used dredged material and is the reference level for all further investigations. This could be needful to determine the discharge or dislocation of material trough leaching and erosion. By comparing all results one can construe the actual hazard potential by the dredged material.

The reference period for the vegetation evaluation is from 12/2013 till 12/2014. The development of the grass turf on the pilot dike and the environmental aspects will be also part of this report. The development is photo-documented in extracts within this report.

3 POSITION AND STATE OF THE MATERIAL

The examined heaps are on the spoil field complex Radelsee (Fig 1). The heap areas are opened by a flag road. The drainage of the heaps is made by a ditch system, which brings the water into the recipient outside of the pond dike. During the time of the first sampling relatively homogeneous substrate ranges (approx. 5 - 6,000 m ³), separately according to sandy and poor in humus charges as well as in fine grained and rich in humus charges, were displayed.

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Fig 1. Spoil field Schnatermann with marked heap complexes from 2009 (S2, S 3 and S4)

In 2011 through soil chemical and mechanical investigations applicable charges were chosen and sharply bounded for the pilot dike (table 2).

Table 2 Analysed substrate in 2011

project labelling	origin label	substrate	amount
S2	Schna 2009 S2/S3/S4	fine grained and rich in organic	ca. 9000 m³

In summer 2013 the first m³ of S2 were transported to the construction site and stockpiled for further use in autumn. The heap vegetated till in December 2013 the first application in the pilot dike was carried out (Fig 2 & 3).

Fig 2. Heap of material in Körkwitz, storage at the construction field since summer 2013

Fig 3. Material in December 2013 during the first application at the pilot dike

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In spring 2014 the last material was transported to the dike construction site and the heap complex was almost cleared (Fig 4).

Fig 4. Cleared heap complexes in 2014 (S2, S 3 and S4)

4 SAMPLING, SAMPLE PREPARATION AND ANALYTICS AS WELL AS STANDARD OF COMPARISON FOR ASSESSMENT OF INVESTIGATIVE RESULTS

4.1 Sampling

The first sampling of disturbed mixed samples took place at the time specified in table 1. Connected heaps as sampling ranges, which approx. contained 5 - 6,000 m³ material of a kind of substrate were displayed to soil chemical marking of homogenously evaluated substrates. The sampling ranges are shown in the layout plan fig. 1. For each sampling range a mixed sample about 1.5 to 2 kg was taken, consisting of 25 to 30 individual samples. In this sampling range 3 to 4 samples were taken on presentable spots with a second sampling in November 2011. Each sample effects an investigation for soil mechanics as well as the water content, TOC and granulation after humus and carbonate destruction.

The samples for the investigation of soil chemical characteristics during the dike construction in summer 2013/2014 were taken from the material heaps ready for use at the Körkwitzer Bach construiction site (Fig4). Mixed samples of 1 – 1.5 kg were gained (ca. 30 penetrations with soil penetrometer on different spots in the material heaps on site).

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Fig 5. During construction at the Körkwitzer Bach

4.2 Sample preparation and analytics

The individual samples of the basis investigation from a sampling range were combined by intensive mixing to a sample. Afterwards a splitting for the different laboratories was done. The sub-samples were freshly handed over within 24 h during constant cooling to the laboratories. The investigation on the general parameters (pH, salt concentration, organic substance, lime, and grain size after humus and carbonate destruction) and nutrient contents accomplished the LUFA Rostock. The investigation on heavy metals and organic pollutants in the solid as well as in the eluate accomplished the laboratory Kiwa in Tessin.
The examination (granulation and TOC) in the chosen dredged material charges in November 2011 and the investigation of the status quo (general and nutrient parameters) was accomplished by the laboratory of the LUFA Rostock. The laboratory protocols and the applied analysis regulations are to be inferred from the appendix.

4.3 Standard of comparison for assessment of investigative results

The application of earthy construction material in the surface sealing of a costal dike or a river dike is an application in the range of the topsoil (root zone) and cover layer (beneath the topsoil). The federal soil protection and contaminated site act and ordinance are the regulations for utilization in topsoil and the derived soil target values are consulted for the evaluation of the test results in accordance with control installations. It is assumed that the whole cover layer will be rooted because of the composition of the dredged material. The application of the consultative document requirements of the utilization of mineral residual substances/wastes of 2004 LAGA M20 /3/, which is also recommended, is not possible without further ado because of:

1. Guideline LAGA M 20 is only for the application of soil material below the top soil (root zone)
2. In principle LAGA M 20 is only applicable for dredged material composed of sand or gravel with a maximum of fine fraction < 10% by weight.

The application of DM is always a single case decision and has to clarify with the responsible authorities. One possibility to evaluate the DM is to estimate the top soil layer according to the BBodSchV and the layer beneath analogue to the LAGA M20 TR soil with the exception of TOC content; conductivity and the salt aspect. In the following the test results will be compared with both regulations.

5 ASSESSMENT OF ANALYTIC RESULTS

The different individual results from the 3 investigations can be find in a table, annex 3. All three investigations are containing the same dredged material charge in which the investigation area was narrowed more and more. In doing so individual samples were taken and mixed afterwards by the basis investigation and the status quo investigation from summer 2013 and spring 2014 summer. In July 2013 presentable individual samples were taken and put together to a mixed sample, the same in spring 2014 with the second storage heap at the Körkwitzer Bach. The deciding localization of the materials was done by the investigation of soil mechanics for compaction. Therefore by comparison of the results variability of the investigated charges as well as certain incertitude of the laboratories are attended. The results of selected parameters cause only marginal variations to the basis investigation.

5.1 Common parameters

Dry matter

Due to an already long waiting time of the maturation process (4 years) and to the relatively dry weather in summer 2013 dry matter contents between 65.7 and 70 % were achieved. Particularly with regard to long maturation time in the material the dry matter content increased about 10 % since 2009. From dry matter content of 50 % a good handling of the materials is possible.

Lime content (as calcium carbonate, CaCO3) and pH

Within the basis investigation of material 1 the content of calcium carbonate compared to previously maturing materials tested was with 3.6 – 4.2 % are on similar level like other fine grained and organic substrates and significantly higher than in agriculturally used soils (generally <1%). The results in 2013/2014 were on a lower level than in 2009 (3.1 %). The generally high lime content causes high pH values in the mildly alkaline influence (7.4). They will last several years to decades and will cause a neutral to mildly alkaline soil reaction. The investigation in 2013/14 accordingly showed values between 7.2 and 7.5.

Total organic Carbon

The contents of TOC determined in 2013/14 are comparable with previously maturing substrates. The difference to the basis investigation account ca. - 1 % and lies in a passable range. The conversion of the contents of TOC into organic matter takes place via the multiplication with the factor 1.724 tor (approximately 58% of organic matter is carbon). Thus the substrates have an organic matter content of 7.4 to 8.3 %.

According to the classification of humus content in soils the material is estimate as very strong humic.
Due to the very high lime content the loss of ignition should not determined. Because of the annealing at temperatures of 550 ° C the lime incinerate too and thus the values are significantly higher than they are in reality.

Salt concentration and concentrations of chloride (Cl-) and sulfate (SO42-) and sodium (Na2+)

The level of salt concentration in the investigated material is at the time of the construction in 2013/14 comparable with maturing substrates and a bit higher (ca. 0.2 %) as in the basis investigations. At this for dredged materials from brackwaters typical salt concentration level (very high in comparison to normal soils < 0.1 %) no depressions of growth (seeding of grass) could be considered so far by using this materials /4/ /5/. Therefore a damage of the grass development due to the salt during the test dike will not be probable.

Chloride

The values of chloride lie in the same range according to the basis investigation values in 2009. Generally it is assumed that trough precipitation by application of dredged materials the content of the readily soluble chloride will decrease in a relatively short period. That is also certified through the investigations in lysimeters with dredged material which last one decade /6/.

Sulfate

The determined contents are in accordance with the value range of previous maturing materials. From experience the contents increase with the maturing progress, because of the aeration of the subtrates sulfidic bounded sulphur was transformed into sulfate. About this relatively long period of 4 years and the removing of vegetation at the heaps before transport to Körkwitzer Bach the content of sulfate decreased already because of the progressive discharge (- 32%). But sulfate will be delivered again from the bounded sulphur.

Sodium

The contents of sodium were in the same range with compared IAA materials. Compared to the basis investigation no significant decrease of the contents in the material is determined.

Grain size composition in the substance without humus and carbonate

The consecutive investigations (2009 und 2013/14) of the granulometry with humus and carbonate destruction basically certify the grain fractions of the materials. According to the classification of soil types the dredged material is characterize as follows:

- **Material S2 (Schna-2009-S2/3/4) – sandy to clayey loam (Ls2 to Lt2)**

The material is classified as main soil type loam. Key factor is the content of clay. If the content lies above 12 % the soil is a loam, if not it is sand. Important is this classification for the assessment of the hazardous substances after precautionary values for soil from the BBodSchV. These values are geared to the main soil types because the chemical bond capability has a significant influence of the total content as well as the mobility of the hazardous substances. Besides the fine fraction the organic matter and the pH value are important. The material owns a relative high fine fraction with 5.6 – 5.8 % humus and a neutral pH value and a high cation exchange capacity (18 - 20 cmol(+)/kg soil, in scale of a high sorption black earth – main soil type loam) /7/.

5.2 Plant available macronutrients

Phosphorus

The level of plant-available phosphorus in the material at the basis investigation is about 9 mg/100 g of soil. Nevertheless, usually the dredged materials from the IAA are compared to agriculturally used soils considered low (supply level A <3.1, high maintenance fertilization or B level medium fertilization 3.1 to 5.5 mg/100 g of soil). The striving towards optimal P-content in loam locations lies at 5.6 to 8.0 mg/100 g LTM. But however the previous horticultural experiments showed the low plant-available P level in the fine grained and organic material does not set any P-deficiency problems. In the mentioned experiments have been always determined an adequate P supply for crop, which is probably due to P uptake from non-covered P-fractions in fine grained organic fractions /4&5/. In the second investigation in 2013/14 the P-level in the first sample was about 3.8 and in the second sample 9 mg/100 g of soil.

Potassium

The level of plant-available potassium clearly differentiates according to the nutrient retention capacity (amount of fine fraction and organic matter) of the substrates. The material offers a high level (24-28 mg/100 g of soil) of potassium supply.

The contents decreased since the basis investigation through discharge and plant deprivation. For loamy soils 9 - 15 mg K/100 g of soil are considered for an optimum level.

Magnesium

Higher contents of organic matter and fine grain fractions cause a higher content of plant available magnesium (145 – 178 mg/100g soil). The values did not change much since the basis investigation. In comparison to the optimal management of loamy arable soils (9 - 20 mg/100 g soil) a very high supply with plant-available magnesium is provided.

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Cation exchange capacity (T-value)

The ion exchange is important for the soil fertility. Cations can be bonded through sorption on clay minerals and humins in soils and be protected against elutriation. However they stay plant available. The more clay and organic a soil contains the higher is its cation exchange capacity. The cation exchange capacity is the amount of cations which a portion of soil can be bonded under specific conditions. This effect is important for the capability of hazardous substances too.

The materials for the dike construction gain a very high cation exchange capacity (18 - 20 cmol(+)/kg soil). Within the maturing progress the content increases.

5.3 Contaminant content in solid matter

For the evaluation of the load of hazardous substances the results from the basis investigation were used. In the second marge of the material from Schnatermann for the dike project in Körkwitz also an investigation of contaminants was done. They showed differences.

Heavy metals

A significant dependency of the content of the organic matter and fine fraction related to total contents of heavy metals in all elements is visibly. The higher both contents the higher the heavy metal content. The total content of heavy metals could estimate as low in all samples. Assuming that the studied material is classified as main soil type loam the heavy metal contents lies in the first evaluation significant under specific precautionary values for soil of the BBodSchV. Overruns are recorded at zinc and lead in the material only in the second investigation at the Körkwitzer Bach in spring 2014. At the final investigation these overruns could not find in the material. All parameters are at a low level. They fall below the precautionary values of the soil ordinance and the classification values of the LAGA M20 Z0 and Z1.

Organic pollutants

The levels of organic pollutants are differenced by humus content and the fine grain fractions. Higher contents of organic matter and larger fines usually lead to higher values of pollutants. The content of hydrocarbons lied during the basis investigation under 50 mg/kg soil in the material. Based on the fact of the progressed maturing through oxidative reactions and biological degradation there should be a reduction of hydrocarbons. But at the second investigation higher contents were found (82 mg/kg). The BBodSchV does not contain any precautionary values for hydrocarbons; the LAGA M20 (Z0) gives a value of 100 mg/kg. The contents of PAH and PCB are well below the precautionary values for soil of the BBodSchV in the second investigation. At the basis investigation two samples showed a higher PCB-content of 0.095 and 0.074 mg/kg. The precautionary value of the BBodSchV

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is 0.05 mg/kg soil. In this connection one have to take into account the high humus content (<8%); in this case a single specific estimation has to conduct according to the BBodSchV.

5.4 Content in eluates

The contents in eluate characterize the possible discharge behavior or mobility of substances. As expected (high sorption capacity and weak to neutral alkaline pH values) the mobility of heavy metals and organic pollutants is limited. The concentrations in the eluate are therefore usually below the detection limit.
Due to natural conditions, because the substrates are from brackish water, very high levels of salinity that are comparable to those of other substrates from Rostock were determined. The discharge of salt via leachate could be problematic for ground water because of the high contents in the eluate (multiple higher than in natural low-salt soils). The original investigation records are attached in annex 3.

The results after construction, seeding and water storage through precipitation show that the contents do not change significantly. The high contents at the second sampling in spring 2014 (investigation 04/2014) at lead and zinc don´t reflect the other investigations in 2009 (S2/S3/S4), in 2013 (investigation 07/2013) and the final investigation in 2014. The final investigation shows no actual risk potential according to the heavy metals in the solid and eluates. The organic contaminants differ from the basis investigation to the final investigation. While in 2009 the hydrocarbons were at a low level the PCB contents in the material (S2/S4) overruns the limit values. In 2014 at the final investigation the hydrocarbons show higher contents than in the basis investigation but below the limit values. PCBs could not find in the material anymore. Only the salt and nutrient contents possess an environmental impact potential whereas the nitrogen and phosphorus contents are of concern of the authorities. Here the investigations from the test dike (environmental assessment report, 2014) as well as other experiments with dredged material could prove that these elements don´t cause environmental impacts /6/.

6 FINAL INVESTIGATION 2014

A completion analysis on geochemical parameters in September 2014 at the pilot dike was carried out. Soil samples were taken and mixed for the laboratories to determine the nutrients, salt ions as well as the contaminants (heavy metals and organic pollutants) in the solid and the eluate. The results were compared with precautionary values of the BBodSchV for rooting layers and the assignment criteria of the recommendation for wastes (LAGA M20 technical rules soil, Z0, Z 1 and Z 1.1) for the application in technical structures.
The pilot dike was built near the village Neu Heide at the Körkwitzer Bach (Fig. 1 and 2) about 30 km from Rostock. For the final investigation samples were taken all over the new dike surface up to the depth of 50 cm.

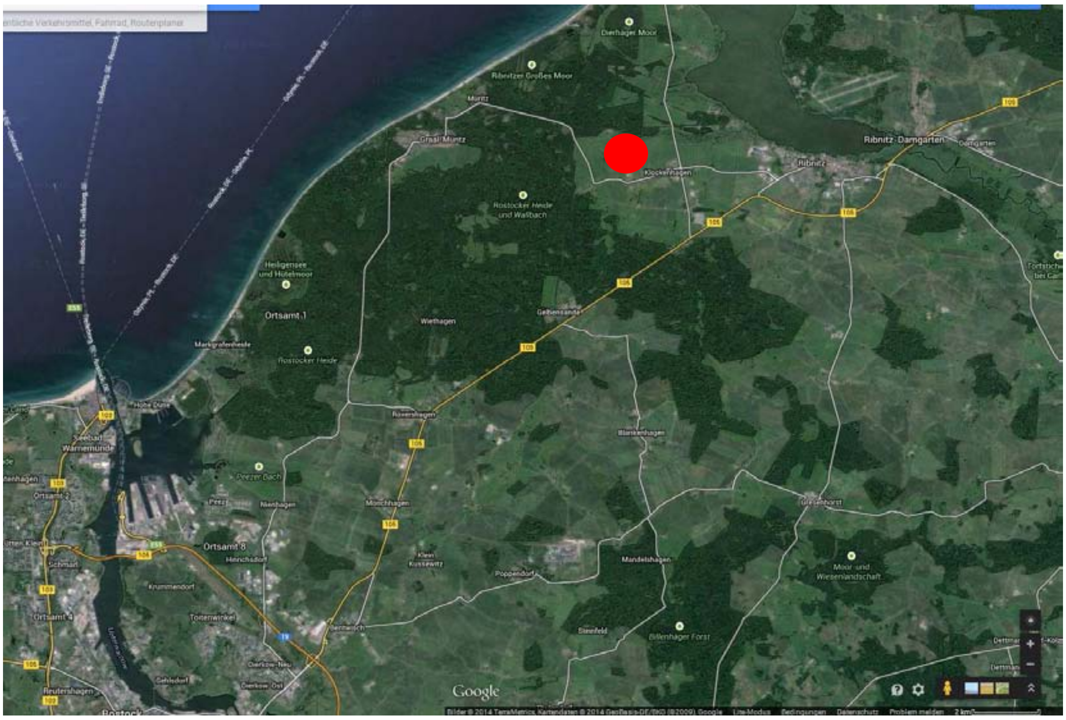

Fig 6. Location of the construction site about 30 km from Rostock (google maps)

Fig 7. Construction area with old dike line at the Körkwitzer Bach (google maps)

Fig 8. Constructed pilot dike in April 2014 (GAIA MV)

6.1 Common parameters

Dry matter

In September 2014 after a relatively dry summer (only the June brought some necessary rainfall) value (68 % dry matter) of the applied material in the pilot dike was in the same range like at the construction period.

Lime content (as calcium carbonate, $CaCO_3$) and pH

Within the final investigation the content in the material were at the same level like the previous investigations (1.5 %; investigation before application between 0.8 and 3.1). The generally high lime content causes high pH values in the mildly alkaline influence; they do not change over several decades (7.5).

Total organic Carbon

The contents of TOC determined in September 2014 are comparable with previously investigations and lie between 4.4 to 5.6 %.

Salt concentration and concentrations of chloride (Cl^-) and sulfate (SO_4^{2-}) and sodium (Na^{2+})

The level of salt concentration in the investigated material is 1.9 % and a bit higher as in the basis investigations but similar with the investigation from the material heaps in 2013 and 2014.

Chloride

In the final investigation the level of the chloride lies under the previous investigations (82 mg/kg). Through precipitation the content in the first half meter decreases constantly.

Sulfate

After the application of the material in the pilot dike at the Körkwitzer Bach the content of sulfate didn´t change (337 mg/kg DM).

Sodium

No significant change in the content of sodium in the material is determined (176 mg/kg DM)

6.2 Plant available macronutrients

Phosphorus

The content of phosphorus didn´t change significantly (3.2 mg/kg air DM).

Potassium

The level of plant-available potassium ranges at the same level as the previous investigations (24 mg/kg air DM).

Magnesium

No change could determine at the magnesium value (184 mg/kg airDM).

Cation exchange capacity (CEC)

The cation capacity did not change in the time from the last investigation in spring 2014.

6.3 Contaminant content in solid matter

For the evaluation of the load of hazardous substances the results from the basis investigation were used. In the second lot of the material from Schnatermann for the dike project in Körkwitz also an investigation of contaminants was done. They showed differences. The final investigation of samples from the pilot dike in autumn 2014 was used for a broad evaluation.
At the final investigation in October 2014 the organic contaminants are also below the precautionary values and the classification values of BBodSchV and LAGA M20 (hydrocarbons 99 mg/kg, PAH 0.3 mg/kg and PCB 0 mg/kg).

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Heavy metals

The overruns that were recorded at zinc and lead in the material only in the second investigation at the Körkwitzer Bach in spring 2014 could not verify. At the final investigation these overruns could not find in the material. The content of lead with 9.7 mg/kg and the content of zinc with 68 mg/kg are at a low level. These results lie in the range of the basis investigations and the investigation of the first investigation at the Körkwitzer Bach in summer 2013. They are under the precautionary values of the soil ordinance and the assignment criteria of the LAGA M20 Z0 and Z1.

Organic pollutants

At the second investigation in spring 2014 higher contents as in the basis investigations were found (82 mg/kg). In the final investigation a content of 99 mg/kg DM was found and verifies the last value. The BBodSchV does not contain any precautionary values for hydrocarbons; the LAGA M20 (Z0) gives a value of 100 mg/kg. So the content is near the pass from Z0 material to Z1 material (restricted open application) if to follow the recommendation of the LAGA M20 technical rules soil. The contents of PAH and PCB are well below the precautionary values for soil of the BBodSchV in the final investigation (0.3 mg PAH/kg and 0 mg PCB/kg). The higher PCB-content of 0.095 and 0.074 mg/kg (precautionary value BBodSchV 0.05 mg PCB /kg) at the basis investigation in two samples could not find again.

6.4 Content in eluates

All investigated eluate samples from the basis investigation over the investigation of the material heaps at the Körkwitzer Bach to the final investigation showed no critical contents in heavy metals or other parameters like cyanide or phenol. The material can keep the assignment criteria from the LAGA recommendations Z0 and Z1.1 in every case.

The results after construction, seeding and water storage through precipitation show that the contents do not change significantly. The critical contents at the second sampling in spring 2014 at lead and zinc don´t reflect the five other investigations (2009 and 2014). Also the higher PCB contents in the basis investigation were not verified in the later samples. The final investigation shows no actual risk potential according to the heavy metals and organic contaminants in the solid and eluates. Only the salt and nutrient contents possess an environmental impact potential whereas the nitrogen and phosphorus contents are of concern of the authorities. Here the investigations from the test dike as well as other experiments with dredged material could prove that these elements do not have a substantial adverse environmental effect /6/.

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7 ENVIRONMENTAL RELEVANCE OF THE RESULTS

At both federal and state level, there is consensus that the onshore accommodation, storing, preparation and beneficial use is subject to waste regulations, as dredged material is classified as waste. According to its material composition (content of value-adding contents and contaminants) it is a waste for disposal or waste for beneficial use.

A possible reuse has to be proper § 7 Recycling Management act (KrWG) /8/ (i.e. in accordance with the KrWG and other public law) and not harmful (i.e. no deterioration of the public interest, in particular, no accumulation of pollutants in the recycling process).

The EAK 2002 /9/ "Recommendations for the design of coastal structures" (p. 441 ff) said under notes and comments as follows: *An explicit regulation to soil conservation law or waste-law tailored for reuse of dredged material in dike construction does not exist yet. Accordingly there are no relevant classification or limit values for the installation of dredged material. The existing soil conservation and waste regulations allow only a restricted definition of pollutant limits for the use of dredged material (TEMMLER et. Al, 1999). Nevertheless, an analog classification to the mentioned soil and materials in these regulations is needed and attention to be paid so the basic usability and the application requirements may be clarified in individual cases.* And further is to point out that: *A use of dredged material in dike construction is possible in specific individual cases only.*

For the evaluation of materials for reuse in dike constructions the classification according to BBodSchV and LAGA M20 is possible. The BBodSchV can be applied in terms of reuse in topsoils (root zone, cover profile with dredged material). For the application of material below the topsoil layer (compact installation in the core of the dike of dredged material of sand or gravel with maximum fine fraction of 10%) the LAGA M20 graduated classification (Z) values can be used. Fine grained and organic dredged material can be used if it comply the substrate-specific precautionary values for soil from the annex of BBodSchV and sandy-gravel dredged material below the topsoil if it complies with the respective Z values of LAGA M20. The classification of fine grained dredged material within the LAGA M20 TR soil can carry out only as approximation and in agreement with the responsible authorities.

7.1 Conclusions for the application of dredged material

The investigated material from the spoil field Schnatermann is fine grained material rich in organic and lime (assigned soil type loam). The assessment of the reuse could carry out according to the recommendations of the interstate working group LAGA M20 technical rules soil with the substrate-specific assignment criteria. Clearly the material do not underlie the recommendations but the listed parameters with the assignment criteria gives information for the responsible authorities about the potential environmental impact and guidance for a single case decisions in case of reuse. Table 3 gives an overview where single values overrun the criteria of the BBodSchV and LAGA Z0; the criteria Z1.1 for restricted open application under the rooting zone were complied in every case.

Table 3. Compliance with and exceedance of precautionary values for soil and assignment criteria for reuse of mineral waste in soil like applications (BBodSchV/LAGA M20 TR soil)

criteria number of mixed samples	Basis sampling n = 3	Second sampling n = 2	Final sampling n = 1
Lead	x	●/x	x
Cadmium	x	x	x
Chrome	x	x	x
Copper	x	x	x
Nickel	x	x	x
Mercury	x	x	x
Zinc	x	●/x	x
Arsenic	x	x	x
Hydrocarbons	x	x	x
PAH	x	x	x
PCB	●/x	x	x
EOX	x		x

x *compliance with precautionary values/assignment criteria*
● *exceedance of precautionary values/assignment criteria*

The determined heavy metal and organic contaminant values do not possess a risk potential for the various subjects of protection soil, groundwater and plants, animal or human from this point of view. Heavy metals and organic contaminants are chemical bonded and hardly available in fine grained materials rich in organic matter and with high sorption capacity (set out by the high lime content and the CEC). A change of these conditions can occur by reversing conditions (reduction oxidation). This means that possibly contained heavy metals could be remobilized and washed out.

In terms of nutrients can be concluded that there is an over-supply in the materials. Analog the salinity is at a high level. Especially chloride is a very easily soluble and therefore leachable salt ion. The risk of dislocation of salt and nutrient ions exists mainly through discharge with leachate at flood events and the natural precipitation and on the dike surface when there is an inadequate vegetation cover, where the attacking water can cause erosion and elutriation. In this topic the construction site of a dike plays the most important role. In areas where this kind of materials will accumulate the discharge of salt and nutrient ions like magnesium and potassium will not affect any additional impact. Nitrogen and phosphorus – always the more concerning nutrients – will not discharge in significant amounts. These scientific findings are proved in certain experiments with dredged materials.

For further information about the environmental issues see the following report:

Environmental and vegetation assessment report component 3 (test dike)

7.2 Potential environmental impact

The construction site of the pilot dike is situated near the Darß-Zingster-Boddenkette (DZKB). These shallow bays (average depth 2 m) are connected only over a small influx with the open sea. The water exchange is very limited between bays and Baltic Sea. The Körkwitzer Bach is connected with the DZKB on its west end. Despite that there are some other rivers/inland waters who bring fresh water into the DZKB the influx of water from the Baltic sea is higher. Near the estuary of the Körkwitzer Bach conductivities about 5000 µS/cm were measured [10]. The conductivity of fresh water (Rostock) is about 300 - 500 µS/cm. At stormy weather conditions from east the water from the DZKB will also pressed upstream into the Körkwitzer Bach and lead to impounding along the dikes at the Körkwitzer Bach. In November with slightly impounding situation a conductivity of 1070 µS/cm was determined at the pilot dike.

The application of the dredged material and the potential discharge of salt and nutrient ions will not result in a harmful impact according the position of the dike construction and the fast discharge into the DZKB. The Körkwitzer Bach covers a drainage area of more than hundred km² and has an annual average discharge of 0.855 m³/s. In the Ribnitzer See where the Körkwitzer Bach flows in average salt level of 2.4 psu (max. 5.0 psu) is determined. The Baltic Sea at the coast of Mecklenburg-West Pomerania contains values between 8 and 12 psu (salinity 0.8%) /11/. In the 1985 the impact with nutrients like phosphor and nitrogen from the Körkwitzer Bach was very high (4 t P/a and 330 t N/a). A measurement in the year 2000 showed that the discharge of these two nutrients was reduced dramatically of 0.92 t P/a and 137 t N/a. Surely this was reached also through the construction of the waste water treatment plant in 1990. But the local imports of nutrients (agriculture) and also but less important the impact from the direct discharger like waste water treatment plants pollute the DZKB. In the report component 3 is shown that through the application of dredged material the load with the nutrients phosphor and nitrogen is to neglect. The heavy metal contents in sediments investigated in the Ribnitzer See (estuary Körkwitzer Bach) show background level in the range of the low contents from the final investigation at the pilot dike /11/. Long term investigations regarding the mobilization of contaminants and the discharge of salt and nutrients and investigation of the stability of organic compounds in the dredged material would be of great interest.

8 VEGETATION ASSESSMENT

An important aspect with costal protection structures of earthy materials for stability at storm flood occurrence is the vegetation cover. The turf gives protection against washing-up and marine abrasion of the soil layers and at least partial against moisture penetration.

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In line with the EU project DredgDikes the vegetation assessment should document the development of the turf and evaluate their achievements. The conclusions of these analyses will be shared in the multilingual guideline.

8.1 Evaluation of the weather trend in comparison with the longtime climatic average

In the following the estimation of the weather conditions in 2014 will be explained. The data from the German Weather Service will be use as approximation. An own weather station was installed in xxx 2014 but delivered data only discontinuous till November 2014. Surely the micro climate at the dike construction area diverges from the micro climate in Rostock Warnemünde in the dunes near the coast line but the general trend is given and the long time average (LTA) can take into account. The longtime average from 1961 – 90 shows the time period before the climate change and the longtime average from 1980 to 2010 for the years in which the climate change is already noticeable. If comparing these time rows the weather is warmer and wetter than before. Annex 1 table 1 shows the monthly average for temperature and the sums for the monthly precipitation in 2014; also the days with less than 0.0°C and days warmer than 25 and 30 °C. In the following the deviation of the LTA will listed in brakes (Dev. LTA).

2014 was a warm and dry year. Also in comparing with the new longtime average from 1980 to 2010 it was very warm and relatively dry. All month were warmer than the LTA (only August – 0.5 °C) and the deviation from the LTA was partly more than 1 °C; in exception more than 2 °C (February, March, October and November 2014). Mostly it was too dry; only in June and October it was significant too wet.

The December 2013 will be put into the seasonal consideration for the winter 2013/2014. The winter 2013/14 was with 3.8 °C too warm (Dev. LTA 1961-1990 +0.9 °C and dev. LTA 1980-2010 1.8°C) and with only 98.5 mm too dry (dev. LTA 1961-1990 123.6 mm and dev. LTA 1980-2010 134 mm). This is surprisingly because of the fact that warm winter develop from so called distinct west weather conditions (inversions) and these weather conditions are affected by low pressure and therefore rather wet.
In the winter 2013/14 there was only one period with cold conditions in the third decade of January with – 6°C in average and the daily maximum temperatures were not above 0 °C. The remaining winter decade averages were clearly in the positive range (between 3 and 6.5 °C).

Fig 9. Ice after winter flood at the agricultural area, compactor at the construction road

Due to the mild winter plant diseases and vermin (mice etc.) could spread out unobstructed. The strong but short frost period could not avoid the spreading.

Despite that the spring start at the 1th march the vegetation dormancy was finished according to the warm weather conditions at the second decade in February. Often daily maximum temperatures of more than 10 °C were reached and with 5.2 °C in monthly average the February was too warm comparing with the LTA (dev. LTA 1961-1990 0.7 °C and dev. LTA 1980-2010 1.7°C).

The spring 2014 was with 9.6 °C significantly too warm (dev. LTA 1961-90 6.9 °C and dev. LTA 1980 -2010 8.0°C) and also too dry (dev. LTA 1961-1990 -45.6 mm and LJM 1980-2010 -46.7 mm). Particularly the March and the April were very dry and showed for since some years the typical spring aridity. However, many plants suffered under dry stress to end of April because there was no water supply from the winter and the months were also too warm (dev. LTA > 2°C). The May delivered more precipitation but was also below the longtime average (dev. LTA 1961- 1990 -5.6 mm and dev. LTA 1980-2010 -12.6 mm). The warm weather conditions and the precipitation lead to a faster growth of the vegetation. Also the summer 2014 was warmer than normal (dev. LTA 1961-90 1.5°C and dev. LTA 1980-2010 0.6°C). Interesting seems that the summer though too warm had no single hot day (daily maximum temperatures > 30 °C). The warm summer reached its warmth mainly from the mild night temperatures. Altogether the summer was normal in precipitation (dev. LTA 1961-90 0.8 mm) respectively with the LTA 1980-2010 there was only little less precipitation (-9.3 mm). This is due to the June; it brought the important precipitation but was therefore too wet (dev. LTA 1961- 1990 21.8 mm and LJM 1980-2010 10.8 mm). While the July was normal the August was again too dry (dev. LTA 1961- 1990 -18.9 mm and dev. LTA 1980-2010 -27.3 mm).

Despite all the weather conditions enabled a moderate vegetation development. In the second half of August appeared some problems of aridity at light grounds. In autumn the warm and dry weather continued. The autumn was significant too warm (2014 12.3 °C; LTA 1961-1990 9.7°C / 1980-2010 10.0°C) and very dry (2014 107.9 mm, LTA 1961- 1990 147.8 mm / 1980-2010 155 mm). All three month are more than 2 °C above the longtime average (only September comparing with dev. LTA 1980 – 2010, only 1.8 °C too warm).

The development of the precipitation is very discontinuous. Of a September with higher single rain events but still too dry followed an October with more precipitation than normal. At first the vitality of the vegetation decreased but in October rich in precipitation and warm the growth increased again. This situation continued also in the warm November (> 2 °C comparing the dev. LTA) even if it had only small amounts of precipitation (2014 12.3 mm, dev. LTA 1961- 1990 51 mm und LJM 1980-2010 49 mm) and the decreasing evaporation in November promote the enduring soil moisture. Till the end of November a dormancy of the vegetation was not noticed only with the first frosts from the 29th of November the dormancy began.

Diagrams of temperature and precipitation during the project period in comparison with the long-time average are attached in annex 2.

8.2 Material and Methods

The construction of the pilot dike began in November 2013 with relatively good weather conditions. In January 2014 the construction site was flooded through a storm event that pressed the water in the Körkwitzer Bach from the Saaler Bodden (Bay). In February the frost made the further construction impossible. The construction started again in March and in April the cover layer was finished (Fig 10). The sowing started at the 4th of April in different sections.

At first the compacted dike was stripped off soil material to get the right cubature (Fig 11). The surplus material was used to produce a crumbly surface at the pilot dike (Fig 12). In the most areas was a loose layer of 4 to 5 cm thickness. The sowing was done by hand with a seeding mixture with 60% *Festuca rubra*; 30% *Lollium perenne* and 10% *Poa pratensis*). The relative evenly spread seeds were raked in the loose dredged material (Fig 13). A rolling was not carried out. A starting fertilizer was avoided intentionally.

Fig 10. delivery of material for cubature

Fig 11. Fine crumbly material for the embankment

Fig 12. Fine crumbly seedbed before seeding

Fig 13. Seed raked in

The weather conditions were quite good. At the beginning of April the soil temperature was too low for an optimal seeding time (should have about 8 °C). But the air temperatures got higher within some days and the dark dredged material could save the sun energy. The soil moisture was good. Only the wind was too strong for a good sowing by hand. The result of the seeding is to estimate as good. In large part the seed is covered slightly with soil, only few laid bare at the surface (Fig 14).

Fig 14. Seed mixture at the dike surface

After the seeding the control of the vegetation development was carried out weekly. Since May the evaluation of the vegetation cover was realized all two weeks. The vegetation cover at the dike surface was estimate optical and photograph. In the next days there were some slightly precipitations. But also the temperatures got down again. Unfortunately the precipitation was in the whole April only about 10 mm.

After the seeding in beginning of April an unfavorable weather was coming in. It was often too sunny and windy. The conditions lead to high evaporation rates and aridity in the upper cm of the seeding bed. Till the beginning of May (4 weeks since seeding) there was only 10 mm rainfall. The normal precipitation from the long time average is about 40 mm. The germination of the grass was delayed. At the end of April a slightly green shine could observe in the section that was seeded at first. Only few grasses were visible at a whole overview (Fig 15).

Fig 15. a) First photo site with seeding at the 8th April.4. b) Third photo site with seeding at the 4th of April (Photo 29th of April)

Fig 16. Photo at the 12th of May a) first photo site b) second photo site view in the North

The delayed germination through missing moisture in the soil showed the lower embankment where trough ascending moisture the germination layer had a better water supply. After the precipitation of 30 mm between the 4th and 12th of May the grass germinated better (Fig 16). However, the germination of the seed was very hesitant and not covering a large area. But weeds like saltbush and quitch grew relatively fast at the seeded areas. In May also at the last seeded areas grass could observe. In the first section more grass showed and also the very compacted dike crest was green in many areas. Nevertheless, altogether the result of the seeding and the condition of the vegetation cover looked poor. In comparison at the 4th of April a small test area was installed at the treatment facility Radelsee where the same dredged material was checked for a grass seeding. At the 10th of April the first grasses germinate evenly over the test area (Fig 17).

Fig 17. Test area Radelsee grass spread at material S2 at the 10th of April, seeded 4th of April

Fig 18 End of May a) second photo site b) third photo site

The inspection at the 21th of May (Fig 18) was followed by a dry and very warm period and with it an increased drying of the surface. The growth of the turf stagnated. After the 5th of June and the following 11 days over 40 mm rainfall was measured and the vegetation growth, unfortunately also the weeds.

In June the germination of grass remains static (Fig 19). In spite of grass a lot of weeds germinated and grew higher and covered in some areas the surface and repressed the grass.

Fig 19. Germination remain static, high weed pressure at the beginning of June a) 1th site b) 2nd site

Since this time period the wild plants dominate. The turf got less light and suffered in its growth under the pressure of the weed (Fig 20). At this time a deep cut of the weed would be necessary with a mower which cut the grass about 5 – 10 cm above the surface. So the weed could remove and the grasses could get enough light for growing. In the first decade of July the weed vegetation at the embankments was about 50 cm high (Fig 21). However, in the areas with less weed which covered the surface also the turf developed only hesitant (Fig 22).

Fig 20. Grasses and Salt bush struggle for water and light; cracks at the dike surface swallow the rain but also evaporate much

Fig 21. No close vegetation cover mid June, grass growth delayed a) 3rd site b) look back 3rd site

Fig 22. a) Cracking at blank and compacted areas at the crest b) Increased growth of salt bush

Because of organization problems the deep cut was carried out delayed in the beginning of August from the water and soil agency (Fig 23). The population of weed like reed and saltbush as well as mugwort etc. was at the embankments more than 1 m high.

Fig 23. High vegetation at the pilot dike 5th of August; mowing of the crest

Fig 24. Mowing of the embankmants

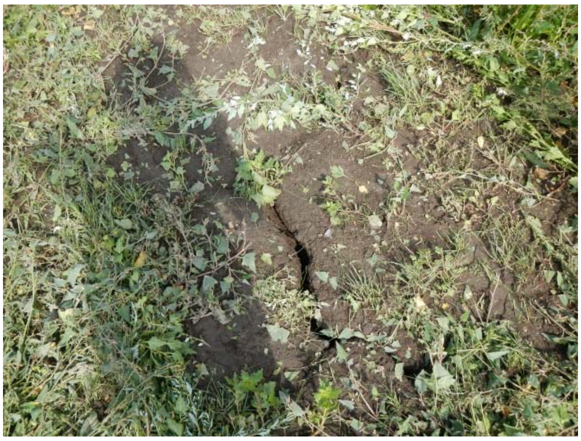

Fig 25. Removed vegetation shows bare areas

At the beginning of August the pilot dike was mowed with mulching technique (Fig 24/25). The mowing rests were for mulching. This is a common procedure to leave the mowing rests and to use them like a fertilizer if a mowing will repeated all second weeks again. If the growth of grass is only small there will be no problem. The grass can grow through the dry rests. If the growth of the grass and the weeds is very high and thick a mulching is not advisable. The DIN 19712 for river dikes recommended that the mowing rests should deleted from the dike surface to prevent surface defects. A control visit (12th of August) confirmed that the salt bush and reed rests as well as other weeds were very compact and were repressing the grass mainly at the embankments. Greater are-as of the dike embankment - altogether the areas with high pressure from the weed - were without turf at this time (Fig 26).

Fig 26 a) Spare turf b) cut dried vegetation one week after mowing

At the dike crest the mowing rests were almost insignificant. Here the grass looked a bit closer too (Fig 27).

Fig 27. Dike crest a) detail b) 3rd photo site looking back

The removing of mowing rests in the beginning of September brought light up to the bare areas where the salt-bush and other weeds covered the seeded grass (Fig 28).

Fig 28. Removing of mowing rests and recovery of the turf a) 2nd site b) 2nd site looking back

Thanks to a long decade with wet and warm conditions from begin of October to mid November many remaining and some newly seeded grass germinate fast. And within November an almost closed turf developed. Mid November the pilot dike is in a good status and looks altogether green and vital. The bare spots are almost closed (Fig 29, 30 and 31).

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Fig 29. a) New spreading grass b) bare areas are closing

Fig 30 a) 2nd / 3rd photo site mid November b) 2nd site end of November

Fig 31. End of November a) closure of blank spots b) rooted top soil

8.3 Conclusions from the investigation period 2013 - 2014

The seeding at the pilot dike Körkwitz showed like the seeding at the test dike Radelsee (report component 3, 2014), that the germination of the seed depends on the weather conditions. Also the early seeding in spring 2014 with favorable soil moisture was not able to reach a fast and vital greening in April. The April was after the seeding period very dry, warm and windy; but the germination is also regulated by the outside influences. The moisture is the main requirement for the start of the germination. So the growth of the grass was delayed. There were deficits at the upper embankments were no seed germinate within the first weeks and also some seed rolled off or run off from water and dislocate to the lower embankment. The compacted dike crest was green. A comparing test area at the treatment facility with the same material S2 of about 1 m² greened within two weeks and brought a close and vital turf. Both wet and warm periods in May and June promoted more the weed species with fast development of leaves like quitch, saltbush and reed. The weeds oust the grass from space and light so that the already germinated grasses stagnated in their development. Especially the areas from the dike crest to the upper embankment were affected by this development. These are the most exposed positions of the dike construction. All over the dike a vital and closed vegetation cover was not reached till the late summer. The necessary deep cut to promote the development of the grasses and to cut down the weed was too late and therefore the grasses could not use the wet and warm early summer period. On one hand the mechanical mowing make sure that a thick and closed vegetation cover will established. On the other hand it is responsible for an increased growth of roots in the top layer of the soil.

In autumn the fast closure of the bare areas after mowing and removing of the rests and re-sowing at some bare areas was reached. Like the result from the test dike showed many grass seeds could germinate after a longer period if there are favorable conditions (report component 3). Also through tillering of the grasses the open areas after the mowing were closed. The crumbly seedbed and the raking of the grasses lead to a good distribution of the seed and a good contact with the soil of the seedbed. The fast greening of the pilot dike in autumn 2014 showed that favorable conditions at an extreme site e.g. dike are given in autumn.

Even in the last 20 years over all in the spring occur longer warm and dry periods. Climate models show that with these conditions in the next year's one have to fight also in the northern lowlands of Germany [DWD 2014]. Therefore the seeding in autumn is to preferable comparing with a spring seeding especially on cohesive soil like dredged material. The vegetation assessment at the pilot dike Körkwitz proved that the significant aspect for the germination of grass seeds at an extreme site (dike) is the sufficient water supply within favorable weather conditions. These favorable conditions are expected in autumn like diverse experiences from the DredgDikes project as well as long term measurements showed. Within some weeks in autumn the vegetation cover at the pilot dike looks closed and vital. According to these findings it is recommended that the seeding on dredged material dikes should carried out in September. A crumbly seedbed seems of advantage; a rolling of the seedbed is not necessary.

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