ISM - Integrated Sewage Management

Final Research Report

a project of

KompetenzZentrum Wasser Berlin gGmbH
Cicerostr. 24
10709 Berlin

www.kompetenz-wasser.de

sponsored by

Berliner Wasserbetriebe

and

Veolia Water

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Berlin, January 2006

Abstract

The development of the integrated control of sewage network and wastewater treatment plant has progressed during the last decade. Nevertheless, an operational implementation of the concepts for huge, complex systems has hardly been realised. That was an obvious reason to initiate the project "Integrated Sewage Management (ISM)". The ISM project aimed at the development of strategies for an integrated management of the Berlin sewage system consisting of sewer networks (both, combined and separate system), pump stations, pressure mains and wwtp.

For these purposes a numerical model of the collection system has been built up. Those catchments have been chosen that have a significant quantity of wastewater and are connected to at least one of the three main wastewater treatment plants of Berlin (Ruhleben, Waßmannsdorf and Schönerlinde).

To enable an evaluation of total emissions it was necessary to incorporate not only catchment area and collection system but also the wwtp into the model. Furthermore, the Berlin specific transport of wastewater through pressure mains had to be considered. Both, advective pollutant transport and the limiting pressure situation had to be taken into account. An integrated model of collection system, pressure mains and wwtp has been set up for the catchment of wwtp Ruhleben for the study of a global control concept.

Those processes that were of particular importance for the control concepts or had a significant influence on the criteria (derived from the objectives) had to be simulated adequately. Hence, for the Berlin model the main attention was paid to an accurate reproduction of in-pipe storage activation and the transport of wastewater through the pressure pipes. A sufficient set of data was available to model the system structure. For process parameter estimation the necessary information was taken from the operational SCADA system. Some gaps in the data could be closed by additional measurement campaigns (Bln VII, 2001; Bln X, 2002; Heiligensee, 2003).

For modelling the collection system the dynamic flow routing model InfoWorks CS of Wallingford Software Limited has been chosen due to its user-friendliness (window navigation, GIS) and comprehensiveness (pollutant load calculation, long-time simulation, spatial rainfall distribution, rtc module). A suitable approach to the simulation of the Berlin pressure mains was found to be based on EPANET 2 of the U.S. Environmental Protection Agency. The software SIMBA® 5 of ifak System GmbH has been used to simulate the dynamic treatment processes. For the activated sludge conversion part the Activated Sludge Model No. 1 (ASM 1) has been used. The three models have been coupled in sequence on the basis of simple input and output files.

Further on, in the framework of three sub studies the ISM model has been applied to operational questions.

The applicability of the ISM model for the assessment of the impact of the NPA control on the wwtp was tested. NPA stands for “new pump automatic (Neue Pumpen Automatik)” and signifies a control concept that is implemented in the framework of the LISA project (BWB). The inflow to wwtp Schönerlinde has been simulated for one rain event and the NPA control of the pump stations could be simulated well on the basis of the InfoWorks rtc module.

Furthermore, the ISM model has been applied to evaluate a concept for a level dependant real-time control (Pegelgesteuerte Förderstromregelung) of sewage pump stations. The idea of the concept was to build an easy function that allowed continuously varying the pumpage and implicitly managing available inline storage capacities within the trunk sewers. The objective was to smooth the delivery towards the treatment plant to avoid peak loads. The evaluation showed that it is possible to manage available inline storage volume by applying the control function. But only if there is an adequate retention volume of around 60.0 m³/ha A_{imp} or more a significant improvement of the flow characteristic towards the wwtp is possible. Consequently, in Berlin only two catchments have the potential for the introduced control concept (Charlottenburg III und Ruhleben).

Finally, the effects and the benefit from global pump station control in comparison to local control have been studied on the basis of the integrated model. The assessment of the Berlin drainage system that was carried out before arrived at the conclusion that there is a high potential for the control of the total system. The positive rating can partly be ascribed to the high storage volume that can be activated within the trunk sewers and the high number of pump stations that are used as actuators. However, this potential is already used by locally controlling the pump stations and storing sewage in the collectors. The potential of a global control of sewage pump stations arises from the non-uniform distribution of rainfall and the non-uniform distribution of storage volumes over the system. Those conditions usually lead to a non-uniform utilisation of storage capacities and further on to sewer overflows that cannot be balanced by local control.

A look on the simulated total emissions showed that concerning discharged quantities the load from the wwtp is highly dominant, since most of the time (under dry weather conditions) wwtp effluents are the only impact on the receiving water. Furthermore, the global control concept only works during rain situation and does not have an influence on dry weather effluents. Consequently, the influence of global control on yearly total emissions is marginal. Nevertheless, it could be shown that global control can avoid peak load situations at the inflow to the wwtp and consequently reduce peak loads in the effluent.

The control concepts had a significant influence on the emissions from combined sewer overflows. The reduction of sewer overflows plays a prominent role since they present a highly dynamic impact on the water body. The simulations showed that on average during periods of cso 2.5 t COD/h enter the receiving water. Compared to that load the continuous impact from the wwtp effluent was only 0.4 t COD/h. Moreover, due to the high fraction of biodegradable organic substrate the impact from combined sewer overflows is of special relevance. In contrary to the refractory COD from wwtp effluents, 60 % of the COD from combined sewer overflows are biodegradable leading to extreme oxygen depletion within the receiving water.

It could be shown that under current conditions at the wwtp (rain weather capacity of wwtp Ruhleben = 6700 l/s) a local control (= local automation) of the pump stations has an adverse effect on the performance of the sewage system. In contrary to an optimum coordination of the pump stations local control leads to an overloading of the wwtp and an increase of emissions from combined sewer overflows by 9 % (volume), 15 % (COD) and 20 % (TKN). Due to that reason the current operation provides for manual interventions in case of rain events to coordinate the delivery of the pump stations. This necessity will persist under the LISA automation.

Assuming a future upgrade of wwtp Ruhleben and an increase in rain weather capacity up to 7650 l/s, global pump station control will result in cso emissions that are 19 % (volume), 20 % (COD) and 25 % (TKN) below that under local control (= local automation).

The major deliverable of the ISM project is the model for the Berlin collection system (18 combined and 29 separate sewer systems that are connected to the three main wastewater treatment plants Ruhleben, Waßmannsdorf and Schönerlinde). The further application and maintenance of the sewer model will take place at BWB, department NA-G. The scope of studies that will be supported by the model covers operational planning as well as general, conceptual and investment planning (storage optimisation, problem of parasite water).

Concerning the implementation of the global control concept that has been developed in the framework of the ISM project first tests shall be carried out in 2006 and 2007. Therefore, the follow-up project EVA (Entscheidungshilfesystem zur Verbundsteuerung von Abwasserpumpwerken / Decision support system for global control of sewage pump stations) was planned at KWB to enable support and a further cooperation between KWB and BWB.

The algorithm has to be adapted to the operational and technical boundary conditions and a detailed practical planning in terms of control engineering has to be carried out. The main prerequisite for an implementation of the introduced control concept is the technical ability of the pump stations to increase delivery beyond the value of 2 * $Q_{d,16}$. Simultaneously, an authorisation is necessary to introduce a flexible regulation of the pump station’s rain weather delivery off the value of 2 * $Q_{d,16}$ as demanded nowadays by the Berlin water authority. If the necessary data is available (usually given by the existing scada system of BWB) and if the used pumps can be controlled according to the above-stated technical requirements, the studied control concept can be implemented without any further constructional investment.

Zusammenfassung

Die Entwicklung der integrierten Steuerung von Kanalisation und Abwasserkläranlage ist in der letzten Dekade weiter vorangeschritten. Es mangelt jedoch an der betrieblichen Umsetzung dieser Konzepte bezüglich großer, komplexer Entwässerungssysteme. Diese Situation gab Anlass zur Durchführung des Projektes "Integrated Sewage Management (ISM) / Integrierte Abwasserbewirtschaftung". Ziel des ISM Projektes war die Entwicklung von Strategien einer integrierten Bewirtschaftung des Berliner Abwassersystems, bestehend aus den Komponenten Kanalnetz (Mischsystem und Trennsystem), Pumpwerke, Abwasserdruckleitungen und Kläranlage.

Zu diesem Zweck wurde ein numerisches Modell der Kanalnetze erstellt. Es wurden alle Einzugsgebiete berücksichtigt, die einen signifikanten Abwasseranfall aufweisen und deren Pumpwerk in Richtung eines der drei großen Berliner Klärwerke fördert (Ruhleben, Waßmannsdorf and Schönerlinde).

Um eine Bewertung der Gesamtemissionen zu ermöglichen, war es notwendig neben dem Einzugsgebiet und den Kanalnetzen einschließlich ihrer Sonderbauwerke auch die Kläranlage in das Modell aufzunehmen. Ausserdem mussten der für das Berliner System spezifische Abwassertransport durch Druckleitungen (advektiver Stofftransport) und die sich hierbei ergebenden Drucksituationen berücksichtigt werden. Solch ein die Kanalnetze, Druckleitungen und die Kläranlage umfassendes integriertes Modell wurde für das Einzugsgebiet der Kläranlage Ruhleben erstellt, um ein Konzept zur Pumpwerksverbundsteuerung am Beispiel dieses Teilsystems zu untersuchen.

Prozesse, die für das Steuerungskonzept von Bedeutung waren oder einen signifikanten Einfluss auf die Bewertungskriterien hatten (abgeleitet von den Zielstellungen), wurden mit entsprechender Sorgfalt simuliert. Für das Berliner System wurden der akkuraten Abbildung der Speicherraumaktivierung und dem Abwassertransport durch Druckleitungen besondere Aufmerksamkeit geschenkt. Für die Modellierung der Systemstruktur und Anlagen stand ein quantitativ und qualitativ ausreichender Satz an Daten zur Verfügung. Die für die Paramterbestimmung notwendigen Daten wurden vom Prozessleitsystem der BWB herangezogen, wobei einige verbleibende Datenlücken durch zusätzliche Messprogramme geschlossen werden konnten (Bln VII, 2001; Bln X, 2002; Heiligensee, 2003).

Die Kanalnetze wurden mit Hilfe des hydrodynamischen Kanalnetzmodells InfoWorks CS der Firma Wallingford Software Limited abgebildet. Das Programm empfahl sich durch seine Bedienungsfreundlichkeit (Windows-Navigation, GIS) und seinen Leistungsumfang (Schmutzfrachtberechnung, Langzeitsimulation, räumliche Niederschlagsverteilung, Steuerungsbaustein). Ein geeigneter Ansatz zur Abbildung der Berlin Abwasserdruckleitungen wurde in Form des Programms EPANET 2 der U.S. Environmental Protection Agency (US Umweltbundesamt) gefunden. Zur Simulation der Abwasserreinigung wurde die Software SIMBA® 5 der ifak System GmbH angewendet. Die Abbildung der Belebtschlammprozesse basierte hierbei auf dem Activated Sludge Model No. 1 (ASM 1). Die Kopplung der drei Teilmodelle wurde sequentiell auf der Basis einfacher Eingabe- und Ausgabedateien realisiert.

Im Rahmen von drei Teilstudien wurde das ISM Modell auf betriebliche Fragestellungen angewendet.

Die Eignung des Modells zur Abschätzung des Einflusses der NPA (Neue Pumpen Automatik, eingeführt im Rahmen des LISA Projektes) auf den Kläranlagenzufluss wurde untersucht. Hierzu wurde der Zufluss zur Kläranlage Schönerlinde infolge eines Regenereignisses simuliert. Basierend auf dem Steuerungsbaustein der InfoWorks Software konnte die Regelung der Abwasserpumpwerke nach NPA zufriedenstellend nachgebildet werden.

Desweiteren wurde das ISM Modell verwendet, um das Konzept einer lokalen, pegelgesteuerten Förderstromregelung der Abwasserpumpwerke (PGF) zu bewerten. Die zugrundeliegende Idee sah eine kontinuierliche, auf einer einfachen Funktion basierende Variation der Pumpwerksfördermengen vor, die implizit zu einer Bewirtschaftung des vorhandenen Kanalspeicherraumes in den Hauptsammlern führte. Die Zielstellung der Steuerung war die Vergleichmäßigung des Kläranlagenzuflusses und somit die Vermeidung von Stoßbelastungen für die Anlage. Die Bewertung zeigte, dass es mit Hilfe eines solchen lokalen Steuerungskonzeptes grundsätzlich möglich ist, Kanalspeicherraum zu bewirtschaften. Erst ab einem verfügbaren Retentionsvolumen von circa 60.0 m³/ha A_{imp} in einem Kanalnetz ist jedoch eine signifikante Verbesserung der Zuflusscharakteristik zur Kläranlage erzielbar. In Berlin eignen sich somit lediglich zwei Einzugsgebiete für das entwickelte Steuerungskonzept (Charlottenburg III und Ruhleben).

Schließlich wurden mit Hilfe des integrierten Modells für das Einzugsgebiet der Kläranlage Ruhleben Wirkung und Nutzen einer Pumpwerksverbundsteuerung im Vergleich zur lokalen Steuerung der Anlagen untersucht. Die zuvor durchgeführte Abschätzung des Steuerungspotentials gelangte zu dem Schluss, dass das Berliner Gesamtentwässerungssystem als hoch steuerungswürdig zu betrachten ist. Diese positive Beurteilung kann zu einem großen Teil auf das aktivierbare Stauraumvolumen in den Hauptsammlern und die hohe Anzahl von als Stellglieder nutzbaren Abwasserpumpwerken zurückgeführt werden. Dieses Potential wird jedoch bereits durch eine lokale Steuerung der Pumpwerke und die hiermit einhergehende Bewirtschaftung der Kanalnetze genutzt. Das Potential einer Verbundsteuerung begründet sich in der ungleichmäßigen Verteilung des Niederschlags, der auf das System trifft und der ungleichmäßigen Anordnung des verfügbaren Speichervolumens im System. Diese Gegebenheiten führen in der Regel zu einer ungleichmäßigen Auslastung der Speicherkapazitäten und in der Folge zu Mischwasserüberläufen, die durch eine lokale Steuerung nicht ausgeglichen werden können.

Die Simulation der Gesamtemissionen aus dem Einzugsgebiet Ruhleben über ein Jahr zeigte, dass die Kläranlage den überwiegenden Anteil am Gesamtstoffaustrag in die Gewässer trägt. Dieser Umstand ist darauf zurückzuführen, dass die Emissionen während Trockenwetter in der Summe dominieren. Das untersuchte Steuerungskonzept hingegen findet seine Anwendung bei Regenwetter, was dazu führt, dass es keinen signifikanten Einfluss auf den Stoffaustrag aus der Kläranlage hat. Durch die Dominanz der Kläranlage am Gesamtstoffaustrag in die Gewässer, sind durch eine Verbundsteuerung auch keine Verbesserungen bezüglich der Gesamtemissionen (als Jahresfrachten) zu erzielen. Es konnte jedoch gezeigt werden, dass die Pumpwerksverbundsteuerung in der Lage ist, Stoßbelastungen im Zulauf und daraus resultierende Konzentrationsspitzen im Ablauf der Kläranlage zu vermeiden.

Die Verbundsteuerung hat zudem einen nicht unwesentlichen Einfluss auf die Emissionen aus Mischwasserentlastungen. Dies ist von besonderer Bedeutung, da die Gewässerbelastung durch Mischwassereinleitungen einen hoch dynamischen Charakter aufweist. Die Simulationen zeigten, dass während Mischwasserüberläufen im Jahresmittel 2,5 t CSB/h auf diesem Pfad in das Gewässer gelangen. Verglichen hiermit wurde für die kontinuierliche Einleitung aus der Kläranlage Ruhleben lediglich ein Fracht von 0,4 t CSB/h ermittelt. Hinzu kommt, dass durch den hohen Anteil an biologisch abbaubaren Stoffen im Mischwasserüberlauf (60 % des CSB ist biologisch abbaubar) die Gewässerbelastung nicht nur in akkumulierender, sondern vor allem auch in akuter Form auftritt, was zu hoher Sauerstoffzehrung im Gewässer führt.
Es konnte gezeigt werden, dass unter den aktuellen Randbedingungen auf Seiten der Kläranlage Ruhleben (Regenwetterkapazität = 6700 l/s) eine lokale Steuerung/Automation der Abwasserpumpwerke (entspricht LISA ohne manuellen Eingriff) nicht zielführend sondern vielmehr systemschädlich ist. Eine Überlastung der Kläranlage, sowie eine Erhöhung der Mischwasserentlastungen gegenüber der aktuellen Situation um in etwa 9 % (Volumen), 15 % (CSB) und 20 % (TKN) wären zu erwarten. Die aktuelle Fahrweise der Pumpwerke sieht eine manuelle Koordinierung (manuelle Verbundsteuerung) der Förderströme im Regenwetterfall vor. Die Notwendigkeit einer solchen Koordinierung wird auch nach Umsetzung der Automation nach LISA bestehen bleiben. Bei Erweiterung der Kläranlagenleistungsfähigkeit und einer damit verbundenen Erhöhung der Regenwetterkapazität auf 7650 l/s ist im Vergleich zu einer lokalen Steuerung der Abwasserpumpwerke eine Reduzierung der Mischwasserentlastungen um 19 % (Volumen), 20 % (CSB) und 25 % (TKN) durch das Verbundsteuerungskonzept erreichbar.

Hauptprodukt des ISM Projektes ist das Modell der Berliner Kanalnetze, das 18 mischentwässerte und 29 trennentwässerte Gebiete umfasst. Hierbei handelt es sich um die Teilsysteme, die Abwasser in Richtung einer der drei großen Kläranlagen fördern (Ruhleben, Waßmannsdorf und Schönerlinde). Die weitere Anwendung und Pflege des Kanalnetzmodells wird bei den BWB (NA-G) stattfinden. Mögliche Einsätze umfassen Studien zur operationellen Planung sowie generellen, konzeptionellen und Investitionsplanung (Speicheroptimierung, Fremdwasserproblematik).
Betreffend der Umsetzung der im Rahmen des ISM Projektes entwickelten Pumpwerksverbundsteuerung sollen erste betriebliche Tests in den Jahren 2006 und 2007 durchgeführt werden. Um diesbezüglich eine weitere Kooperation zwischen KWB und BWB zu ermöglichen, wurde das Folgeprojekt EVA (Entscheidungshilfesystem zur Verbundsteuerung von Abwasserpumpwerken) geplant.
Der Steuerungsalgorithmus muss hierfür an die technischen und betrieblichen Randbedingungen angepasst und eine regelungstechnische Ausführungsplanung durchgeführt werden. Die Grundvoraussetzung für die Einführung des Konzeptes besteht in der maschinentechnischen Ausstattung der Abwasserpumpwerke, die eine Erhöhung der Regenwetterfördermengen über den Wert von 2 * $Q_{t,16}$ hinaus gewährleisten muss. Zugleich bedarf es der wasserbehördlichen Genehmigung, eine flexible Steuerung der Pumpwerke im Regenwetterfall einzuführen. Nur bei

einer dynamischen Anpassung der Regenwetterfördermengen einschließlich der zeitweisen Über- und Unterschreitung des Wertes von 2 * $Q_{t,16}$ lassen sich Förderströme und die Bewirtschaftung der Speicherräume optimal koordinieren.
Bei Verfügbarkeit der notwendigen Daten (in der Regel gegeben durch das vorhandene Prozessleitsystem) und unter der Voraussetzung der Steuerbarkeit der verwendeten Pumpen, entsprechend der oben genannten technischen Anforderungen, ist eine Umsetzung des Konzeptes ohne weitere Investitionen in abwassertechnische Anlagen möglich. Die Umsetzung der globalen Steuerungsstrategie ist dann eine erfolgversprechende Methode, um bei der derzeitig vorherrschenden Ungleichmäßigkeit in der Verteilung der Speicherräume eine Verbesserung der Mischwasserüberlaufsituation herbeizuführen.

Résumé

Le développement des systèmes de contrôles intégrés liant réseau d'assainissement et station d'épuration n'a cesse de croître ces dernières décennies. Toutefois aucune application sur un réseau important et complexe n'a, à ce jour été mis en place. Pour combler ce manque le projet « Integrated Sewage Management (ISM)/Gestion de l'assainissement intégré » a été mené. Le but du projet ISM était de développer une stratégie pour la gestion intégré du système d'assainissement de Berlin, ce système étant constitué de réseau d'assainissement (système mixte et système séparé), de station de pompage, de canalisations sous pression et de stations d'épurations.

A cet effet un modèle numérique du système de collecte des eaux usées a été développé pour des zones particulières de Berlin. Ces entités ont été choisies parce qu'elles représentaient un important volume d'eau usée et parce qu'elles étaient reliés à l'une des trois plus grandes stations d'épuration de Berlin (Ruhleben, Waßmannsdorf et Schönerlinde).

Pour permettre une évaluation du total des émissions par le modèle il a été nécessaire d'incorporer non seulement les zones d'études et leur système d'assainissement mais également les stations d'épuration correspondantes. De plus le transport d'eau usée spécifique à Berlin par des canalisations sous pressions doit être également pris en compte. Encore le transport advectif de polluant et les situations de perte de pression doivent être considérées. Un modèle intégrant le système d'assainissement, les conduites sous pressions et la station d'épuration a été développé pour la zone de la station d'épuration de Ruhleben pour l'étude d'un concept de régulation global.

Les différant phénomènes qui ont une importance particulière ou qui peuvent faire varier les différant critères pris en compte doivent être modélisés avec le plus grand soin. D'où pour Berlin une attention toute particulière a été portée à l'activation de la capacité de stockage dans les canalisations et au transport d'eau usée par conduite sous pression. Une importante base de donnée était disponible pour modéliser la structure du système. Pour estimer les parametres du modèle les informations nécessaires ont été fournies par le système d'exploitation SCADA. Les donnés manquantes ont pu être estimés grâce à plusieurs campagnes de mesure (bln VII, 2001 ; Bln X, 2002 ; Heiligensee, 2003).

Pour modéliser le système de collecte, le modèle hydrodynamique InfoWorks CS commercialisé par Wallingford Software Limited a été choisi pour sa simplicité d'utilisation (navigation sous Window, GIS) ainsi que pour ses nombreuses possibilités de calcul (charge de polluant, simulation a long terme, distribution spatiale des chutes de pluie, élément de contrôle). Une simulation satisfaisante des canalisations sous pression de Berlin a pu être obtenue grâce à EPANET 2 de l'U.S Environmental Protection Agency (agence de l'environnement US). Le logiciel SIMBA® 5 de ifak System GmbH a lui été utilisé pour simuler le procédé de traitement dynamique. Enfin pour la partie conversion de boue activée, Activated Sludfge Model No. 1 a été employé. Les trois modèles ont été couplés en séquence sur la base de simple fichier entrée/sortie.

Par la suite et grâce aux bases de données fournies par les trois sous études, le modèle ISM a pu être appliqué aux questions liées à l'exploitation.

L’emploi du modèle ISM a été testé pour l’évaluer l’impact des NPA sur les stations d’épuration. Les NPA pour « Nouvelle Pompe Automatiques (Neue Pumpe Automatik) » fournissent un outil de contrôle qui est réalisé dans le cadre du projet LISA (BWB). Les influents de la station d’épuration de Schönerlinde ont été modélisés pour des conditions pluvieuses et de plus, le contrôle des NPA des stations de pompages a également être pu correctement simulé sur la base du modèle Info Works rtc.

Le modèle ISM a été par la suite employé pour évaluer un concept de contrôle de niveau en temps réel (Pegelgesteuerte Förderstromregelung) des station des pompage des eaux usées. Ce contrôle était basé sur une fonction simple permettant des variations en continu du volume pompé et permettant implicitement une possibilité de gestion des capacités de stockage dans les conduites du réseau d’assainissement. L’objectif était de lisser les pics en entrée des stations d’épuration. L’étude a montrée qu’il est possible de gérer le volume de stockage disponible dans les canalisations grâce a cette fonction de contrôle. Ainsi avec un volume de stockage de 60 m³/ha A_{imp} on obtient une amélioration substantielle des variations volumiques en entrée de la station d’épuration. Par conséquent, a Berlin, le concept de contrôle ne peut être utilisé que sur seulement deux zones : Charlottenburg III et Ruhleben.

Enfin les effets et les bénéfices d’un contrôle global des stations de pompage en comparaison avec un contrôle local ont été étudiés dans le cadre du modèle intégré. Les estimations du potentiel de contrôle faites avant l’étude ont abouties à la conclusion que la totalité du système de d’assainissement berlinois est simple à piloter. Cette observation est liée à l’important volume de stockage qui peut être activé dans le réseau d’assainissement et au nombre important de stations de pompage qui peuvent être utilisées comme servocommande. Ce potentiel est cependant déjà utilisé par un contrôle local des stations de pompage et par l’exploitation parallèle des canalisations. Le potentiel de contrôle global des stations de pompage des eaux usées résulte de la distribution non uniforme des chutes de pluie et de la répartition inégale des volumes de stockages à l’intérieur du système. Ces conditions mènent généralement à une utilisation non uniforme de la capacité de stockage et plus tard au débordement du réseau d’assainissement qui ne peut pas être compenser au niveau local.

La simulation sur plus d’une année de la totalité des émissions dans le quartier de Ruhleben a montré que la charge déversée par la station d’épuration est de loin dominante. Cette situation est due au fait que les émissions dominent globalement par temps sec. L’étude du concept de pilotage montre en revanche son efficacité par temps de pluie et amène donc au fait qu’il n’y a pas d’influence signifiante sur la distribution des substances sortant des stations d’épuration. Finalement en temps de pluie les pics d’entrée des stations d’épuration sont réduits diminuant par la même les pics en sortie.

Le concept de contrôle a une influence signifiante sur les émissions des débordements des systèmes d’assainissements mixtes. La réduction des débordements des réseaux d’égout joue un rôle prédominant car ils présentent un fort impact dynamique dans le réseau. Les simulations ont montrées que pour une période moyenne, 2,5 t DCO/h entrée dans le récepteur. Comparativement l’impact continu de la station d’épuration était seulement de 0,4 t DCO/h. De plus de part l’importante fraction de substrats organiques biodégradables présent dans les systèmes d’assainissements mixtes, l’impact des débordements potentiels est très relevant.

Contrairement à la DCO réfractaire des effluents de station d’épuration, 60 % de la DCO des débordements d'égouts mixtes sont biodégradable et conduisent à l'épuisement extrême de l'oxygène dans l'eau de ruissellement. On pourrait montrer que dans des conditions normales des stations d’épurations (capacité de temps de pluie de STEP Ruhleben = 6700 L/s) une commande locale (= automation local) des stations de pompage a un effet nuisible sur le fonctionnement global du système d'eaux d'égout. Dans le cas contraire à une coordination optimale des stations de pompage, la commande locale mène à une surcharge de la STEP et une augmentation des émissions de l'égout mixte par débordement : 9 % (volume), 15 % (DCO) et 20 % (TKN). Pour cette raison les méthodes actuelles d’exploitation prévoient des interventions manuelles en cas de pluie pour coordonner le fonctionnement des stations de pompe. Cette nécessité persistera malgré l'automation de LISA. Assumant une future mise à niveau de la STEP de Ruhleben et une augmentation de la capacité de temps de pluie jusqu'à 7650 l/s, la commande globale de station de pompage aura comme conséquence les émissions qui sont 19 % (volume), 20 % (DOC) et 25 % (TKN) au-dessous de celle sous la commande locale (= automation locale).

L’apport principal du projet ISM est le modèle pour le système de collecte d’eau usée de Berlin (18 réseaux mixtes et 29 réseaux séparés qui sont reliés au traitement des eaux résiduaires des trois principales stations Ruhleben, Wassmannsdorf et Schönerlinde). L'application et les mises aux points supplémentaires du modèle d’assainissement auront lieu au BWB, département NA-G. La portée des études sera basée sur le modèle de planification opérationnelle de couvertures aussi bien que la planification générale, conceptuelle et d'investissement (optimisation de stockage, problème de l'eau d’importation).

Pour ce qui concerne l'exécution de la commande globale, le concept qui a été développé dans le cadre de projet d'ISM, des premiers essais seront effectués en 2006 et 2007. Par conséquent, le projet EVA (zur Entscheidungshilfesystem Verbundsteuerung von Abwasserpumpwerken / suivi des systèmes interactifs d'aide à la décision pour la commande globale des stations de pompage) a été prévu par le KWB pour permettre l'appui et une autre coopération entre KWB et BWB. L'algorithme doit être adapté à l’utilisation et aux conditions de frontière par une planification pratique et détaillée en termes de commande. Le préalable principal à une exécution du concept présenté de commande est la capacité technique des stations de pompage d'augmenter la fourniture au delà de la valeur de 2 * Qd, 16 ; simultanément, une autorisation est nécessaire pour présenter un régulation flexible de la fourniture en temps de pluie de la station de pompage autre que la valeur de 2 * Qd, 16 comme exigé de nos jours par l'administration d'eaux de Berlin. Si les données nécessaires sont disponibles (habituellement donné par le système existant de SCADA de BWB) et si les pompes utilisées peuvent être commandées selon les impératifs techniques, le concept étudié de commande peut être mis en application sans tout autre investissement de construction.

Acknowledgement

We would like to thank the sponsors, *Berliner Wasserbetriebe* and *Veolia Water*, for their support of the ISM project.
Furthermore, we want to thank our colleagues from *Berliner Wasserbetriebe*, department *NA* and *AE* and our colleagues from *Veolia Water*, especially from *Anjou Recherche* and the *Direction de la Recherche, du Développement et de la Technologie* for the effective and fruitful collaboration.
Special thanks go to the *BWB* department of sewerage and pump station operation and to the laboratory for their intense support of the measurement campaigns carried out in the frame of the project.
Finally, we would like to thank Dr.-Ing. Wolfgang Verworn and his team from bpi Hannover for their reliable work, Prof. Wolfgang Schilling and Dr. Manfred Schütze for their contribution to the Berlin RTC Workshop and all our trainees and graduands for their committed help.

Contents

Abbreviations

Abbr.	Meaning	Unit
A	Area	ha
A_{imp}	Impervious area	ha
ASM	Activated sludge model	
B_d	Pollutant load	kg/s
BOD	Biochemical oxygen demand	
BWB	Berliner Wasserbetriebe	
C	Pollutant concentration	mg/l
COD	Chemical oxygen demand	
COD_{tot}	Total chemical oxygen demand	
Cso	Combined sewer overflow	
DWA	Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e.V.	
$f_{S,Qm}$	Combined water coefficient	
I_g	Mean surface slope at a catchment	%
H, h	Water level	
k	Form coefficient	
KWB	KompetenzZentrum Wasser Berlin gGmbH Berlin Centre of Competence for Water	
LDPC	Level dependant pump control	
n	Return frequency	a^{-1}
N	Rain intensity / height	mm/h, mm
NH_4-N	Ammonium nitrogen	
N_{org}	Organic nitrogen	
N_{tot}	Total nitrogen	
P_{tot}	Total phosphorus	
Q	flow, runoff	l/s
Q_d	Dry weather flow	
$Q_{F,aM}$	Average monthly infiltration flow	l/s
$Q_{S,aM}$	Average monthly wastewater flow	l/s
Rtc	Real-time control	
Scada	Supervisory control and data acquisition	
Sso	Sanitary sewer overflows	
StDev	Standard deviation	
TKN	Total kjeldahl nitrogen	
TSS	Total suspended solids	
V	Volume	m^3
Wwtp	Wastewater treatment plant	
$\eta_{V,i}$	Storage utilisation ratio of catchment i	%

1 Introduction

In settlement areas domestic and industrial wastewater as well as, depending on the surface impermeability, significant quantities of rainwater accrue. Since the middle of the seventies real time control of urban drainage systems has been applied chiefly in the USA, later on in Europe too. The objective is to manage systematically existing drainage facilities and thus to utilize the capacity of the formerly static system as extensively as possible. The development of integrated control of sewage network and wastewater treatment plants has progressed during the last 10 years. Nevertheless, an operational implementation of the concepts for huge, complex systems has hardly been realised. This was an obvious reason to initiate the project "Integrated Sewage Management" in Berlin.

The ISM (Integrated Sewage Management) project aims at the development of strategies for an integrated management of the Berlin sewage system.

1.1 Project agreement

The initial agreement between Berliner Wasserbetriebe (BWB) and Veolia Water (formerly Vivendi Water) to establish a project called Integrated Sewage Management (ISM) was already declared in April 2000. The main initiators were Mr. Laurent Phan from Anjou Recherche, Dieter Jacobi and Norbert Engel from BWB. The aim of the ISM project was the optimisation of the sewage system of Berlin: sewerage network, storing assets, pumping stations, pressurised network and wastewater treatment plants. Based on general studies and on modelling the definition and design of an operation policy should be derived. The realisation of this project was intended to provide a good demonstration of the technological advance and know-how of both BWB and Veolia Water. A contract between Compagnie Générale des Eaux and the Berliner Wasser Betriebe to implement the ISM project was signed in November 2000. The parties jointly agreed on the way to incorporate the project within the structures to be created in relation to the Centre of Competence in Berlin.

From the beginning the project was subdivided into four phases:
Phase I – State of the Art study of the existing tools and methods and the existing management system
Phase II – Transposition and analysis of used tools and methods
Phase III – Application of combined methods to improve design and operation of a part of the Berlin sewage system (Pilot stage)
Phase IV – General study and design of a management policy on the whole Berlin system. Application.

The first contract extended from 2000 to the end of 2002 and included phase I and phase II. The results of the phases I and II were summarised in the final report ISM Phase 1 -2 in September 2001 (Gommery, 2001). This report is a compendium of the main stock data and characteristics of all components, which represent the Berlin sewage system.

In 2002 an analysis of comparative calculations for two catchment areas in Berlin-Köpenick (Germany) and Grand Couronne (France) and an evaluation on the basis of measurements were made (bpi, 2003).
In 2001 and 2002 measuring campaigns in two combined systems were carried out.

With the beginning of 2003 the project was integrated as a flagship project in the Berlin Centre of Competence for Water (KWB). The project partners remained BWB and Veolia Water in cooperation with Anjou Recherche. The main research topics at the KWB are sustainable management of water resources, technical innovations in drinking water management and wastewater treatment. On the wastewater field the ISM-project has a significant relevance on the development of stormwater management strategies in urban areas.

The new contract contained phases III and IV and ended in December 2005. During this period the model buildup and elaborate calibrations were performed for 18 combined and 29 separate sewer systems. Those catchments have been chosen that have a significant quantity of wastewater and are connected to the three main wastewater treatment plants of Berlin (Ruhleben, Waßmannsdorf and Schönerlinde). A measurement campaign in a seperate system was carried out to quantify the amount of stormwater fraction coming from misconnected areas.
The main emphasis was placed on the design and analysis of the management policy for the catchment area of wastewater treatment plant Ruhleben. This catchment area is composed of 13 combined sewer systems and 3 separate sewer systems. To complete the study, sewage transport in the network of attached pressure mains and the processes on the wastewater treatment plant Ruhleben were included into the development and design of the integrated management strategy.
Finally, the benefit of an application of the developed concept was pointed up. Due to the complexity of such a process and the necessary coordination with the system operator this incurs, a follow-up project (EVA – Entscheidungshilfesystem zur Verbundsteuerung von Abwasserpumpwerken / Decision support system for global control of sewage pump stations) was stipulated to apply the concept on the Berlin system.

1.2 Outline of the report

Chapter 2 of this report will give an overview of the Berlin sewage system covering the drainage networks, pump stations, pressure pipes and wastewater treatment plants as well as the current scada (supervisory control and data acquisition) system. This compendium is taken from the ISM Phase 1 -2 report (Gommery, 2001) and updated.

Chapter 3 will describe the methodology of model buildup and the final model that has been used in the framework of the ISM project. After a summary of the state of the art of integrated modelling and a description of general objectives, criteria and measures, the models for the Berlin subsystems (collection system, pressure pipes and wastewater treatment plant) are introduced. Furthermore, details of model calibration and the coupling of the sub models are illustrated.

Chapter 4 will have a focus on the development and evaluation of control strategies for the Berlin sewage system. Foremost, a screening test according to the recommendations of DWA-workgroup ES 2.4 “Real time control of sewer systems” (DWA, 2005) is carried out to assess the control potential of the system. After rating the subsystems and the entire system a local control strategy and a global control strategy are analysed and evaluated. Furthermore, the benefit from the currently realised combined sewer rehabilitation program and the influence of uneven rainfall distribution are examined.

Chapter 5 will describe the application of the ISM model to assess the impact of the new pump automatic (**N**eue **P**umpen **A**utomatik, NPA) on wastewater treatment plant Schönerlinde. And finally, the project is summarised in chapter 6 and an outlook is given.

2 Description of the Berlin sewage system

The Berliner Wasser Betriebe (BWB) are the largest water supply and wastewater disposal company in Germany. The task of the Berliner Wasser Betriebe (BWB) does not only include supplying water to the 3.4 million inhabitants of Berlin and around 600,000 inhabitants in the surrounding region but also carrying away and cleaning the wastewater produced. The BWB are also per procurationem responsible for the planning and design, construction and operation of the surface water drainage of the roads and therefore also for the stormwater treatment installations in Berlin.

In Berlin, the pumping of drinking water has historically been developed almost exclusively within the city boundaries. At the same time, wastewater disposal has to be managed within the same municipal area. The close spatial interlock between drinking water supply, wastewater disposal and water use conceals a high potential conflict between competing uses, which in the long-term can only be lastingly solved through the joint efforts of all concerned.

In the densely settled catchment areas of Berlin, significant quantities of domestic and trade wastewater as well as rainwater are harmlessly discharged while a great operational reliability is maintained. The domestic and industrial wastewaters as well as an increasing amount of stormwater are fed into a treatment to avoid adverse effects on the natural water cycle.

Around three quarters of the area of Berlin are drained via the separate system, whereas in the inner city, around a quarter of the total area drains into the combined system. Berlin’s drainage consists of 4,000 km sanitary sewers in separate systems and 1,900 km combined wastewater sewers. The wastewater produced is fed through 147 pump stations whereof 66 pump stations lead the wastewater over 1,000 km of pressure pipelines to the six Berlin wastewater treatment works for cleaning. Each larger pump station has at least two pressure pipes so that one of the two can always be operated as a reserve pipe. Appendix 1 shows a schematic drawing of the drainage situation in Berlin. The total area of Berlin is 891 square kilometres whereas the paved area connected to a sewer system amounts to 150 square kilometres, one third of it connected to the combined system. On average, a total of approx. 630,000 cubic metres of wastewater are cleaned at the attached six wwtps per day. In addition a mean volume of 7 million cubic metres of combined wastewater (coming from cso and stormwater tanks) and 37 million cubic metres of stormwater are discharged into the watercourses per year by more than 900 outlet structures.

The river Spree enters Berlin in the southeast and flows from east to west through the city, to then flow into the Havel. Several navigable canals branch off from the Spree within the city boundaries. The outward flow of all discharges flowing into and originating from Berlin takes place in the southwest via the Havel.

The particular requirements of the strain for improvement to the quality of Berlin’s watercourses result from the fact that the natural catchment areas of the Havel and Spree rivers are very small, at approx. 13,500 km^2 in total and therefore only low runoff occurs. A comparison of the characteristic water management figures is given in table 2.1.

	Size of catchment area (km^2)	**Average run-off MQ (m^3/s)**
Havel (at Borgsdorf)	3,476	14
Spree (Sophienwerder, 1996 - 2000)	10,104	23
Elbe (at Neu-Darchau)	131,950	714
Rhein (up to the Rees)	159,300	2280

Table 2.1: Comparison of characteristic water management figures of different river basins (SenStadtentwicklung, 2001)

The average low water run-off (MNQ) of the Spree is only 5.8 m^3/s, the MNQ of the Havel just before reaching Berlin is even as low as 3.9 m^3/s. Due to the decline of lignite mining in the Lausitz region and the associated reduction in discharges into the Spree, the low water run-off of the river will continue to fall in future. In the Havel catchment area the climatic and morphologic situation leads to reduced natural run-off rates and low flood runoff in the watercourse. The discharge balance (discharge = precipitation – evaporation) reaches from 60 to 200 mm in the Havel drainage basin. Due to the high proportion of paved area the mean discharge balance of the urban area of Berlin amounts to 190 mm per year (SenStadtentwicklung, 2005).

The Havel and Spree have the typical characteristics of lowland rivers. On the one hand, they are characterised by very low run-off fluctuations, i.e. the differences between MNQ and HQ are low compared to other rivers, and flooding problems are virtually unheard of in Berlin’s main flowing waters. On the other hand, they have extremely low flow velocities and therefore very high retention periods due to the very flat gradient of approx. 0.1 % for the Spree and approx. 0.012 % only for the Havel. During dry periods like in summer 2003 the flow of the Spree at the entrance to Berlin may decrease to zero.

Due to the low flow velocities and the resulting low self-purification property of the watercourses, they are particularly at risk from pollutant inputs, especially from nutrients. During low water periods and due to backwater accumulation caused by storage level regulation, the rivers even represent a transition stage between flowing waters and stagnant waters (lakes) from a limnological point of view, which leads to massive algae formation in summer. During heavy rainfall, the discharges from the Berlin sewer system are a multiple of the average run-off. Because Spree and Havel are heavily influenced by discharges from stormwater and combined sewer overflows the risk of low oxygen concentrations and high oxygen consumption can lead to hazardous conditions during rainfall. In this case the water authority applies an oxygenation of the affected watercourses by a ship, which was equipped for this purpose.

2.1 The wastewater treatment plants of Berlin

The sewage system includes six modern wastewater treatment works that are equipped with updated process technology for the removal of phosphates and nitrogen. All of these factors contribute to the safe disposal of wastewater and thus to the protection of Berlin/Brandenburg's numerous lakes and rivers. In 2004 232 million cubic metres of wastewater coming from within Berlin and the surrounding area were treated.

All of the six wastewater treatment works are equipped with biological treatment stages that include the removal of nutrients. Wastewater flows through a primary treatment stage, which includes screening, grit chambers and primary sedimentation tanks. After physical treatment, it moves on to the biological treatment stage, which includes aeration tanks and also anaerobic and anoxic zones for the biological removal of phosphates and the process of denitrification. Finally, the treated water is discharged into the area's receiving waters.

The following table specifies the dry weather capacities of the six wwtp of Berlin and the surrounding region. The capacity of the wwtp during storm weather conditions raises to 1,8 times the dry weather peak flow. The mean dry weather flow of the whole sewage system of Berlin accumulates to 6.3 m³/s.

Waste water treatment plant	**Mean dry weather inflow from Berlin [m³/d]**	**Mean dry weather inflow from surrounding region [m³/d]**
Ruhleben	222,000	0
Schönerlinde	75,000	11,000
Wassmannsdorf	192,000	13,000
Münchehofe	13,000	18,500
Stahnsdorf	27,000	20,000
Wansdorf	23,000	17,000
Sum	**552,000**	**79,000**

Table 2.2 Dry weather capacities of the six wwtps of Berliner Wasserbetriebe

Sludge is treated either by means of incineration, which includes waste heat re-utilisation and flue gas cleaning or by means of digestion, which includes biogas re-utilisation and gasification of biosolids for the generation of synthetic gas.

The wastewater treatment plant's effluent and the quality thereof are constantly monitored by Berliner Wasserbetriebe's own laboratories. Tests show that the control values stipulated by municipal regulations are consistently met.

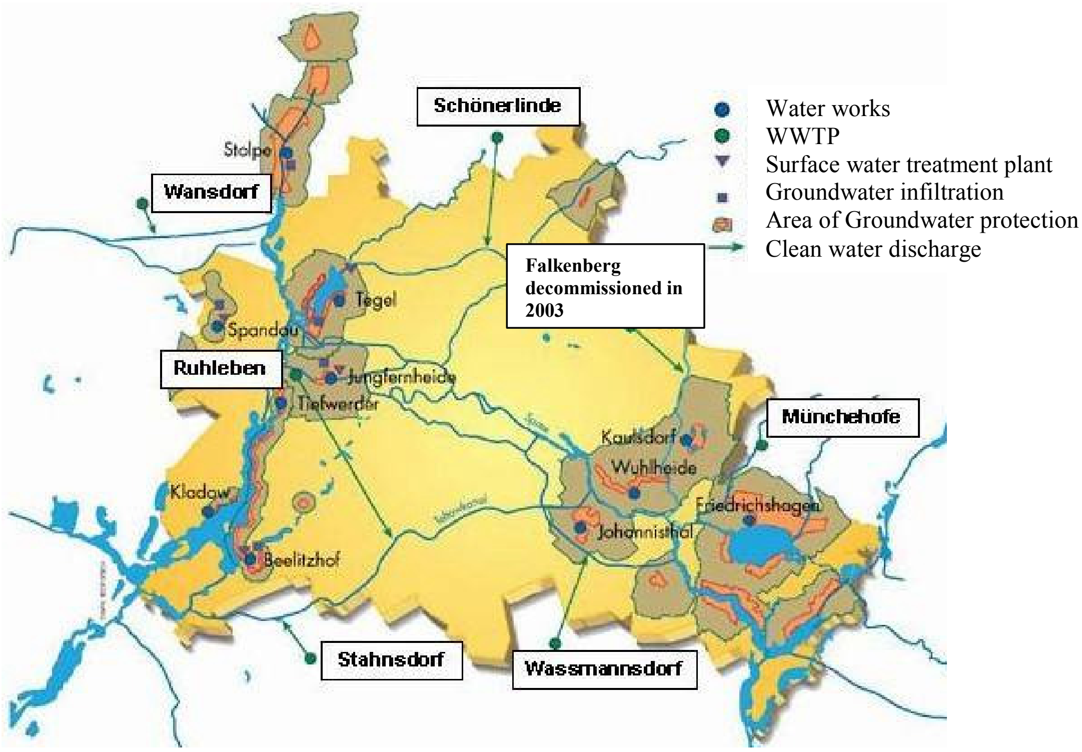


Figure 2.1 Location of wastewater treatment plants and clean water discharge

The following section will describe the properties of wwtp Ruhleben more detailed since this plant has been modelled in the frame of the ISM studies.

Wwtp Ruhleben is equipped with a mechanical and a biological treatment including biological phosphorus removal, pre-denitrification and nitrification. The mixed sludge is dewatered by centrifuges and incinerated in fluidised bed ovens. The biological treatment is separated into 3 blocks with a total of 16 primary settlement and aeration tanks and 54 final treatment tanks. Figure 2.2 gives a schematic overview of the plant.

Table 2.3 summarises some of the technical data of wwtp Ruhleben.

	Block A	Block B	Block C	Total
Total volume primary treatment				18,480 m³
Total volume anaerobic tanks (bio-P)	10,500 m³	16,800 m³	12,400 m³	39,700 m³
Total volume denitrification	15,750 m³	25,200 m³	18,600 m³	59,550 m³
Total volume aerated zone	24,150 m³	39,760 m³	28,692 m³	92,602 m³
Total volume degassing zone	2,100 m³	2,240 m³	2,308 m³	6,648 m³
Total surface final settlement tanks	2,844 m²	11,736 m²	6,360 m²	20,940 m²
Depth of final settlement tanks	15 m	6 m	8.3 m	

Table 2.3 Technical data of wwtp Ruhleben (in 2005)

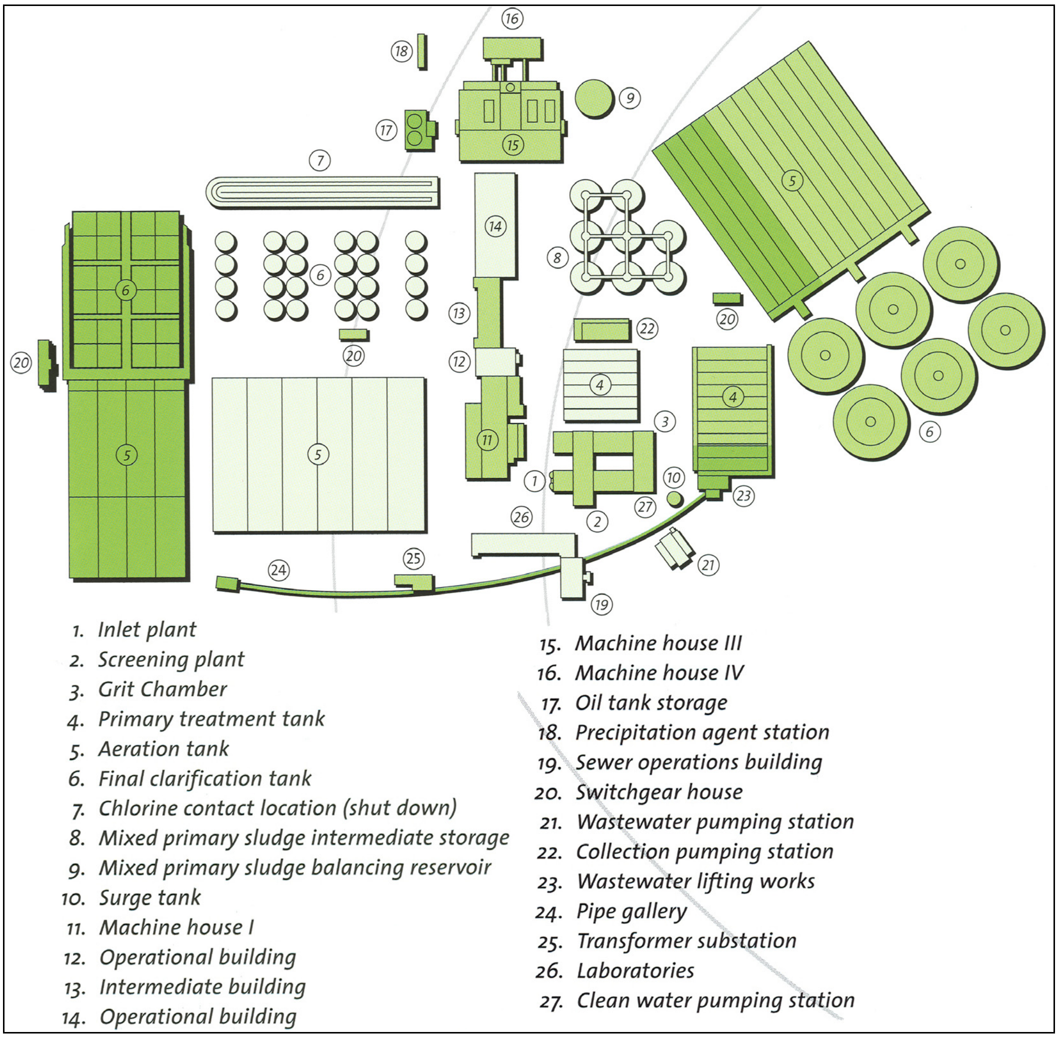


Figure 2.2 Overview of wwtp Ruhleben

2.1.1 Control concepts of wwtp Ruhleben

On average, the 3.5-fold of the dry weather inflow to the biological treatment is returned via recirculation into the anoxic zone. Surplus sludge and the effluent from sludge treatment are returned to the plant's inlet. Here, surplus and primary sludge are extracted as mixed sludge from the primary settlement tanks and are conveyed to the sludge treatment. On average, the return rate is 0.8.

The setpoint for oxygen control is around 2 mg/l. Dry matter contents within the activated sludge tanks is regulated to meet values between 3 and 6 g/l according to the season of the year.

2.1.2 Inflow characteristic of wwtp Ruhleben

The dry weather capacity of wwtp Ruhleben is 240,000 m³/d. During rain situation a maximum of 6,700 l/s can be treated. In 2004 the average concentration of sewage at the inflow to the plant was:

- COD = 922 mg/l
- N_{org}=30 mg/l
- NH_4 = 47 mg/l

2.2 The city of Berlin’s sewer network

The sewerage system of the city of Berlin is divided into 66 subcatchment areas of wastewater pump stations, which are connected with the surrounding wastewater treatment works via a networked pressure main system. The catchment areas of the pump stations in the central inner-city area and parts of the Spandau district drain into a combined water system. The pump station catchment areas, which lie outside of this central area, drain into the separate system. Lower-lying areas and island locations are connected to the nearest sewer network via booster pump stations for overcoming the geographic height differences or obstacles. There are 56 booster pump stations and 25 specific pump station at stormwater facilities within the city of Berlin. A further 23 booster pump stations convey wastewater from small catchment areas in the area surrounding Berlin into the wastewater sewerage system of the nearby Berlin catchment areas.
The location of the pump stations and the boundaries of the pump station catchment areas are shown in the appended layout plan (Appendix 2).

A restructuring process in the operation strategy of the wastewater pump stations is actually performed at BWB, called LISA project. At the beginning of the ISM-project there had been 15 pump stations manned with an operation staff team, which remotely monitored and controlled the associated group of pump stations. Six of those pump stations were coordinating the distribution of wastewater to the associated wwtps. The coordination required a highly trained staff, which had to deal with always changing conditions under limiting constraints during stormwater and damage situations. The priority objective of the project LISA is to reduce the manned pump stations down to one central pump station until 2008. At a number of 43 pump stations the equipment of pumps will be changed from a stepwise pumping regime with fixed pumps to a constant level regime by installing variable speed pumps. The degree of automation will increase while manual intervention into the control process will be reduced.

2.2.1 The Berlin separate system

48 catchment areas are drained by a separate system. The attached population amounts from 1,200 to 180,000. The mean dry weather discharge ranges from 1,000 to 36,000 cubic metres. The population allocated to the separate system sums up to 1.8 million. In the annual statistic 100 million cubic metres of sanitary wastewater and 3.3 million cubic metres of parasite stormwater are discharged by the separate system of Berlin to the wwtps.

The high fraction of stormwater coming from sanitary systems plays an important role at the Berlin sewage system. The mean amount of parasite water in sanitary sewers from all separate systems of Berlin is 3.3 Mio m^3 per year in contrast to 14.8 Mio m^3 stormwater coming from combined systems. The mean amount of stormwater at the pump stations of the separate system (catchment area > 100 ha), delivered to the wastewater treatment plants, reaches from 4,000 to 360,000 cubic metres per year. At Wittenau the large amount of stormwater results from the high number of stormwater retention basins, which are emptied into the sanitary sewer system. Due to high safety requirements in regard to the risk of sanitary sewer overflows (sso) the pump stations of separate systems are demanded to operate at full capacity, which can lead to a high raise of flow in combination with high raise of load at the inlet of the wwtps. The delivery rate of pumpage can reach quadruple of the dry weather flow at a single pump station. By this operation the occurrence of ssos is reduced to only rare catastrophic rain events.

Several wastewater catchment areas have been extended in the last years to include those areas that didn't have sewers up to then (so-called old settlement areas). This primarily concerns the pump station catchment areas of Karow, Spandau V, Rudow, Grünau, Altglienicke, Hirschgarten, Biesdorf, Buchholz, Blankenburg, Mahlsdorf and Malchow. Since the stormwater sewer systems haven't been enlarged in those regions, the problem of parasite water increased.

The occurrence of sewer infiltration and parasite water in the individual wastewater catchment areas is part of a project involving planning and operation departments of BWB. The results of the first phase of collecting the existing data showed that the proportions of sewer infiltration water contributing to dry weather flow in Berlin are negligibly small. However, there is a significant proportion of parasite water in several catchment areas during storms. Since it is a long-term challenge to detect and eliminate the misconnections to the wastewater sewerage the building of storage tanks with volumes from 20,000 up to 50,000 cubic metres at the three main wwtps was deducted from the project's results. During the coming years, investigations into the causes have to be carried out in the sewer network and at the surface of those catchment areas with the largest proportion of sewer infiltration water by analysing flow quantities.

2.2.2 The Berlin combined system

18 catchment areas are drained by a combined system. The attached population amounts from 14,000 to 260,000. The population allocated to the combined system sums up to 1.5 million. The mean dry weather discharge of the combined pump stations ranges from 6,000 to 42,000 cubic metres per day. In the annual statistic 95 million cubic metres of sanitary wastewater and 14.8 million cubic metres of stormwater are discharged by the combined system to the wwtps. Due to the building of several storage facilities within the combined sewer system in compliance with a program of rehabilitation until the year 2020 the stormwater volume will increase to 3 million cubic metres per year.

During storm weather conditions the discharge rate at the combined systems has to be increased to twice the dry weather peak flow (and 1.3 times the dry weather peak flow for the fraction coming from separate sewer systems). The only exception is Berlin VIII, Tiergarten, where the discharge raises to the triple of the dry weather peak flow.

Large proportions of the catchment areas of the combined wastewater pump stations at Wilmersdorf, Ruhleben, Spandau I, Charlottenburg III and Neukölln II have separate sewers, which are connected to the combined wastewater catchment area via gravity sewers. In Wilmersdorf, Charlottenburg III and Spandau I several overflow structures are located closely downstream to the confluence of those separate sewers into the combined wastewater catchment area. Therefore, a large storage volume is required to rehabilitate these combined wastewater areas. In Wilmersdorf this has resulted in a stormwater tank with overflow at the pump station. In the areas of Charlottenburg III and Spandau I these conditions will be met by the creation of additional storage volume in the existing combined wastewater networks. Wastewater catchment areas, which are connected to the combined wastewater catchment areas via booster pump stations, are located in the catchment areas of Spandau I and Berlin XII, Friedrichshain. The wastewater of the booster pump stations of the Kladow and Gatow districts are pumped directly into the sump well of the main pump station Spandau I.

The following changes in the sewage system since the first ISM report of phase I have to be mentioned. The wastewater from the separate system Berlin XIa is latterly discharged by gravity into the pump well of Berlin XI, Prenzlauer Berg. The stormwater of Berlin XIa is still discharging into the combined system of Berlin XI. This inflow structure will be converted to a direct discharge into a stormwater sewer in 2006. A catchment area of 313 ha with a separate system, which used to deliver into the combined system of Berlin XII, Friedrichshain now drains into the separate system of Lichtenberg in order to reduce the load emissions by cso in the combined system of Berlin XII.
A stormwater tank with a volume of 2,000 cubic metres and two flap weirs at Berlin IX, Wedding have been constructed. A stormwater tank with a volume of 3,500 cubic metres has been built at Wilmersdorf, near the pump station. A large weir at the end of a combined overflow sewer has been built to activate more than 10,000 cubic metres storage volume in the catchment area of Berlin V, Mitte.

Those rehabilitation structures with the aim of expanding the storage volume within the combined sewerage system are partial stages derived from the general water authority permit for the combined sewer system in 1998. According to this permit all combined wastewater catchment areas must be brought to the condition that the overflow quantities fall below 25 % of the mean annual rainwater flow and the $BOD_{5,}$ COD and TSS loads reach only 20 % of the average annual load of the stormwater flow. Verification must be provided by using pollution load calculation methods with long-term simulation over a 20-year period. The pollution load calculation has been commissioned for all combined wastewater catchment areas. The survey of the existing data of all combined wastewater networks is completed (see appendix 3). The rehabilitation concepts for the verification of the limiting values are available for all (18) combined catchment areas. Until 2005 the storage volume of the sewerage system including stormwater tanks with overflow amounts to 150,000 cubic metres. This volume will be duplicated by the compliance of all required measures stipulated by the water authority’s permit.

3 Methodology of model buildup and model description

The first objective of the ISM project was to build up a model of the Berlin sewage system described under chapter 2. The model should be able to represent the decisive processes of the system in order to support its integrated planning and operation.

Below, the state of the art of integrated modelling and a general methodology of building integrated models are outlined (chapters 3.1 and 3.2). Further on, available model approaches are discussed and the chosen approaches are described (chapters 3.3). The integrated model for the catchment of wwtp Ruhleben as used for the scenario study (chapter 4) is introduced.

A full description of the built model for the Berlin drainage system can be found under chapter 3.4.

3.1 State of the art in integrated modelling

In urban water management the last decade showed an increased awareness of the necessity and advantages of integrated system analysis and evaluation. Currently, for example in urban drainage planning and management an integration of the two subcomponents collection system and wastewater treatment plant (wwtp) can be observed (Scheer and Nusch, 2002; ATV-DVWK, 2003; van Mameren, 2003; Duong *et al.*, 2005; Nielsen and Nielsen, 2005). In parallel, the use of numerical models has become state of the art in analysing the water cycle and in particular in planning and designing the diverse components of the urban sewage and drainage system. The applied models are focusing in detail on different phenomena according to the individual objectives and needs.

To evaluate the functioning of a complete system and to study the interaction of its subsystems integrated models can be used. Different descriptions of the term “integrated modelling” can be found in literature (Erbe *et al.*, 2002; Leinweber, 2002; Rauch *et al.*, 2002; Schütze and Alex, 2004). Summarised, integrated modelling can be defined as modelling of two or more physical systems having different governing equations and at least one common interface leading to interaction. Scale, both temporal and spatial, and complexity of the model are depending on the objectives of the study. The model may cover the catchment area, the sewerage and the wwtp when looking at emissions (Simon *et al.*, 2004; Wiese, 2004). Moreover, receiving water (Grüning, 2002; Meirlaen, 2002; Seggelke, 2002) and also the groundwater body (Monninkhoff, 2004) may be incorporated if the study is immission or receiving water quality oriented. Schmitt and Huber (2005) demand that in the future integrated modelling should cover the full urban water cycle.

The buildup of an integrated model is a complex task and it is linked to a high number of requirements. The system processes to be modeled, the adequate model approaches and their coupling have to be syntonised to the objectives that have been identified and the dependant problem-oriented criteria. Moreover, the scale of the model should be adapted according to the given requirements. Therefore, the need for a methodical approach to integrated modelling is obvious.

The next chapter will introduce a structured, problem-oriented methodology for the setup of integrated models. An emphasis is placed on the necessity for the selection of adequate model components. In Berlin this aspect is of particular importance for the modelling of wastewater transport through pressure mains that is governed predominantly by pump stations.
The benefit of integrated modelling concerning the assessment of total system performance and the interaction of the subcomponents is underlined when applying the ISM model to evaluate concepts of system management in chapter 4.

3.2 Methodology of model buildup

As described above the use of numerical models has become state of the art in planning, designing and analysing the urban sewage system. Over the last years different guidelines have been formulated to support the work with models and the realisation of simulation studies. These guidelines concentrate on the individual subcomponents of the sewage system like wwtp (Hulsbeek *et al.*, 2002; Vanrolleghem *et al.*, 2003; WERF, 2003; Langergraber *et al.*, 2004) or sewer system (ATV, 1992; WaPUG, 2002; ATV-DVWK, 2004). Furthermore, Schütze (1998) and, based thereon, Erbe (2004) formulated requirements for an ideal model platform suitable for integrated simulation. However, a general guideline for integrated simulation studies is lacking. The following methodical approach to integrated modelling of the urban wastewater system has been set up as the basis for the work on the ISM model.

Figure 3.1 outlines the basic work sequence towards the buildup of an integrated model. The guiding idea is to optimally adapt the model to the given problem in consideration of the available data and model approaches. In the words of Rauch *et al.* (2002), pragmatism is required to avoid unnecessary complexity.

The **motivation** for modelling studies usually originates from either the realisation of acute or long-term deficiencies of the wastewater system or the desire for system optimisation (technical and/or economical). A rather academic reason for modelling and simulation is the wish to acquire a better system understanding. The **objectives** of the study are directly derived from the motivation. They can be related to either one or more subcomponents of the system. For the evaluation of the simulation results significant **criteria** have to be derived from the objectives. Concerning ecological objectives it is differentiated between emission- and immission-based criteria. In parallel, one has to compile a catalogue of **measures** for the scenario analysis. On the one hand only measures with an effect on the defined criteria have to be considered on the other hand the feasibility of the measures in the real system has to be guaranteed. Possibly, some measures may only be found during the phase of simulation and analysis.

Further on, those **subsystems** and **system processes** have to be identified that will be affected by the chosen measures and have a significant (direct or indirect) influence on the defined criteria. The system boundary and the **interaction** of the subcomponents and processes have to be formulated. At this point the question arises if the study necessarily has to be carried out on the basis of an integrated model. Possibly, individual models will be sufficient to evaluate the chosen measures. In case of integrated modelling the decision between a sequential or parallel simulation has to be made.

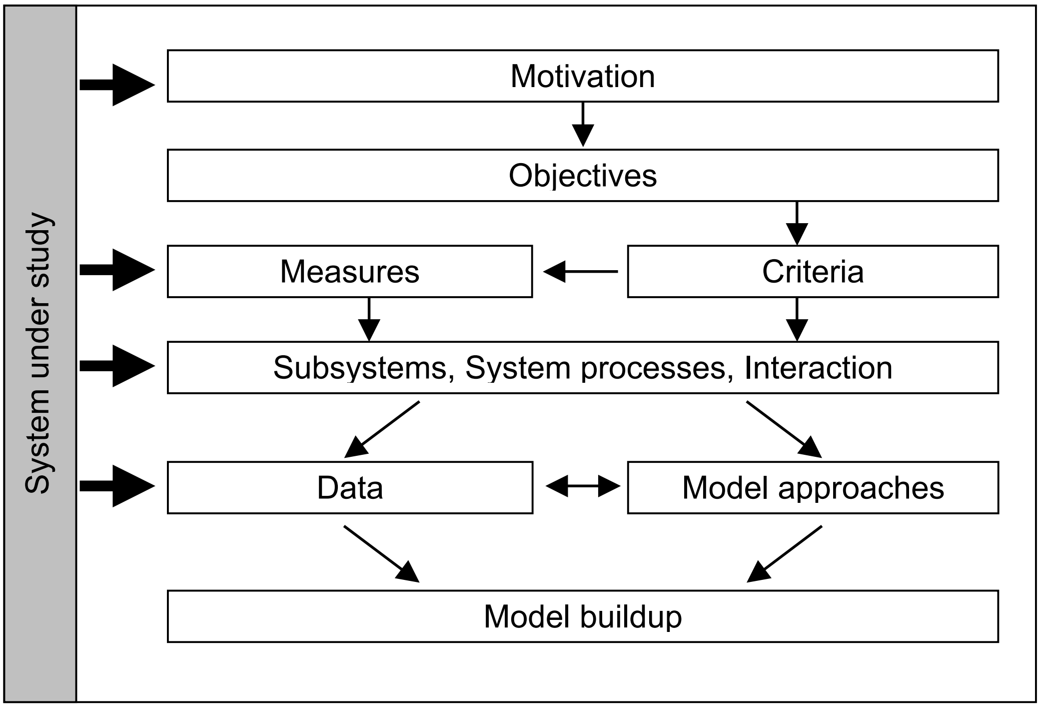


Figure 3.1 Outline of the proposed methodical approach to integrated modelling

After the predefinition of system boundary, system processes and their interaction adequate **model approaches** have to be selected. If necessary available approaches have to be adapted or new modules have to be developed. To apply these model approaches a sufficient set of **data** concerning model structure and parameters is required. On the one hand the chosen models will determine the collection of data (type and extent), on the other hand may a lack of data lead to limitations concerning model selection. This interrelation between models and data can significantly influence the buildup of an integrated model as described by Schütze and Alex (2004).

Finally, the integrated **model** is **built up** on the basis of the selected model approaches and the collected data. When defining interfaces between the submodels high attention has to be paid to the selection of suitable parameters, their fractionation (q.v. Bornemann *et al.* (1998)) and the adequate temporal scale. Furthermore, one should mind to reduce the complexity and spatial scale of the model as far as possible.

Before applying the model within a scenario analysis, further steps have to be carried out like data quality assurance, additional data collection (measurement campaign), model analysis, calibration, validation and the definition of the timeframe to be analysed.

3.3 Model approaches

This chapter will illustrate the above-introduced methodology on the basis of the model setup for the Berlin-Ruhleben sewage system. A special focus is placed on the characteristics of the drainage system and the adequate model adaptation. The following aspects summarise the situation of the Berlin drainage system and point out the boundary conditions that have to be taken into account in planning and operation of the system as well as in modelling.

- Due to low runoff rates and velocities the situation of the receiving waters Spree and Havel is very sensitive with an increased risk of eutrophication. Today, approximately 25 % of the phosphorus input to the receiving waters in the centre of Berlin originates from combined sewer overflows (CSO). Assuming an area-wide upgrade of rainwater treatment at the separate sewer system and an upgrade of the wwtps (P_{tot} effluent concentration: 30 µg/l) this fraction may increase up to 50 % in the future (Pawlowski, 2005).
- The combined sewer system in the centre of the city (1800 km, 6400 ha imp) shows predominantly low gradients and partly high inline sewer capacities.
- A historically founded system of around 150 pump stations is used for the delivery and distribution of combined water and wastewater from the collection systems via long pressure pipes (1000 km) to six wwtps. Simultaneously, in case of rainfall events the pumps act as variable throttles on the outflow of the combined sewerage and activate the inline sewer capacities.

3.3.1 Motivation, Objectives, Measures and Criteria

Currently, the deficiencies of the Berlin combined sewer system are being removed by either building additional retention volume or by applying measures of local real-time control (Engel, 1998; Schroeder and Pawlowsky-Reusing, 2004). The aim is to meet the legal requirements for combined sewer overflows. During this process, the potential of a global control of wastewater pump stations has been recognised. The objective is to use this potential, improve the systems performance and through this prepare the system for future regulatory requirements. Besides total emissions a focus is laid on the emissions from csos. The evaluation criteria concerning cso are overflow volume, load, duration and frequency.

3.3.2 Subsystems, System processes and Interaction

The subsystems and processes to be modelled are derived from the measure under study and the defined criteria. To enable an evaluation of total emissions it is necessary to incorporate catchment area (wastewater collection, rainfall-runoff-process, pollution accumulation and washoff), collection system (flow, pollutant transport, storage, csos) and wwtp (biological conversion processes, clarification). Further on, the Berlin specific transport of wastewater through pressure mains has to be considered. In case of a rain event the increase of pumpage immediately leads to an increased inflow and load at the wwtp. During the period of high pumpage the inflow load will stay high until the lower concentrated combined water will reach the plant (after hours). Both, advective pollutant transport and the limiting pressure situation have to be taken into account. Concerning the interaction of the subsystems, the pumps play the prominent role. As described above, the pumps influence both, the flow through the pressure pipes and the storage of combined water within the main collectors. In contrast, the interface between pressure main and wwtp is unidirectional and as long as there is no integrated control there will be no feedback from the plant.

3.3.3 Model approaches and Data

The processes that are of particular importance for the control concepts or have a significant influence on the criteria (objectives) have to be simulated adequately. Hence, for the Berlin model the main attention was paid to an accurate reproduction of in-pipe storage activation and the transport of wastewater through the pressure pipes. A sufficient set of data was available to model the system structure. For process parameter estimation the necessary information was taken from the operational SCADA system. Some gaps in the data could be closed by additional measurement campaigns.

To take into account reverse flow and the activation of in-pipe storage a dynamic flow routing model had to be incorporated. The model had to be capable of simulating pollutant transport and carrying out long-term simulations. Furthermore, a module for real-time control was indispensable.

To accurately simulate the transport of wastewater through pressure mains, for this subsystem it was necessary to turn away from the dynamic flow routing model. The simulations of pressure conditions that were based on the Preissmann slot (Cunge and Wegner, 1964) lead to retention effects within the pressure mains and thus, to unreasonable results. On the other hand a conceptual approach on the basis of completely stirred tank reactors would not have been able to reproduce the pressure conditions that are of high importance for the evaluation of operational scenarios. A suitable approach to pressure main simulation seemed to be based on the solution of flow continuity and headloss equations under steady state conditions leading to stable and fast calculations.

The software SIMBA® 5 of ifak System GmbH has been used to simulate the dynamic treatment processes. For the activated sludge conversion part the Activated Sludge Model No. 1 (ASM 1) has been used (Henze et al., 1986).

The three models have been coupled in sequence on the basis of simple input and output files.

3.3.3.1 Collection system

At BWB the model Hystem-Extran is used for hydrodynamic simulations of sewer networks. As consultancy bpi-Hannover had calculated flow and pollution loads for all combined catchment areas of Berlin to derive sanitation concepts to reach the requirements of the water authority. Anjou Recherche (Veolia Water) had great experiences in using InfoWorks for hydrodynamic and pollution simulations of sewage systems. To evaluate the reliability of the results of InfoWorks a comparison of the hydrodynamic and the pollution load module of the programs used by the cooperation partners was made.

To assess the reliability of the hydrodynamic calculation of the used models InfoWorks and Hystem-Extran a measurement campaign in a small storm water catchment area was performed. In figure 3.2 a map of the catchment area at Berlin-Köpenick and the storm water network is shown. The connected area adds up to 11.4 ha with a mean runoff value of 77%.

As a first step the hydrographs at different measuring points for a synthetic rainfall were compared. Figure 3.3 shows the results of this calculation.

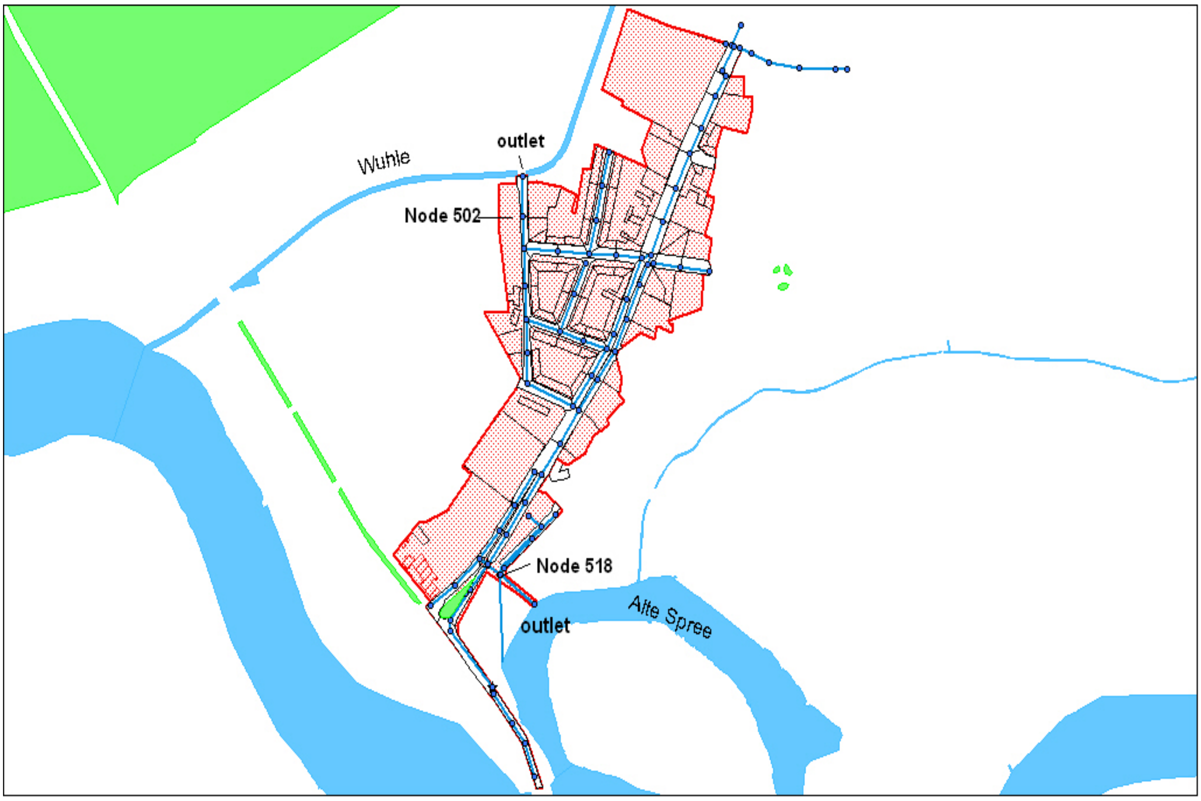


Figure 3.2 Storm water catchment area at Köpenick pointing out measuring points 502 and 518

One difference in the two software products is the way of solving the differential equations (InfoWorks: implicitly, Hystem-Extran: explicitly). This has to be considered on the choice of calculation timesteps or minimum conduit length in the model. Another difference is the way of connecting contributing area to the sewer section resulting in a difference between the peak flows as can be seen in figure 3.3. Hystem-Extran offers the facility of partitioning the contributing area proportionally to the upstream and downstream node, whereas InfoWorks attaches the catchment area entirely to a defined node (usually, the upstream node is used). This has to be considered, when a sewer network is skeletonised and large subcatchments have to be connected adequately. Concerning the Berlin combined sewer network there are only a few links with an appended catchment area in the sewer model, which are longer than 300 metres. The InfoWorks model configuration at a combined sewer overflow demands special attention on the disposition of the impervious contributing areas, if the links upstream or downstream are long.

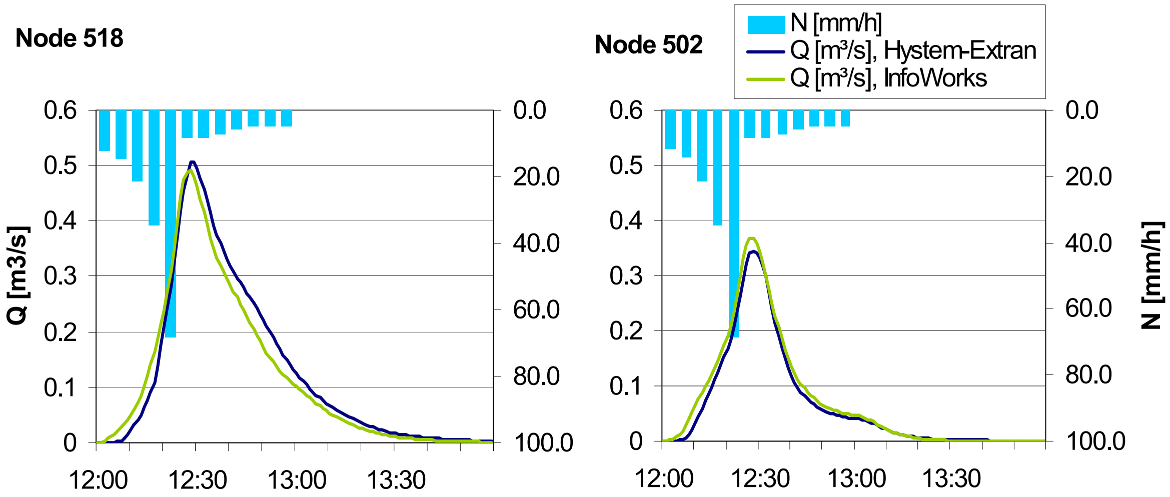


Figure 3.3 Comparison of the hydrographs from the calculation with a synthetic rainfall at nodes 502 and 518

Yet another difference between the two model approaches in terms of runoff routing can be observed in the form of different starts of rising of the hydrographs. This results from the different approaches for the initial losses in the phase of flow formation for impermeable areas. Hystem-Extran provides a continuous boundary-value-method to determine the effective rainfall (after filling of sprinkle loss logarithmic increase of runoff value with filling of depression storage). Whereas InfoWorks applies a constant runoff routing value after sprinkle loss and depression storage are covered. While calibrations were carried out in the ISM project, this constant approach had an adverse effect on the results of the hydrographs in the starting phase.

The results shown in Figure 3.3 differ in terms of runoff volume from the total area by 0,2%. The discharged volumes at each outlet differ from 7% to 11%. This derives from a difference of the peak flow at a connection link between two subsystems.

To compare calculated hydrographs with measured data, flow measurements at nodes 502 and 518 at the Köpenick catchment were carried out. As an example figure 3.4 shows a period within this measurement campaign.

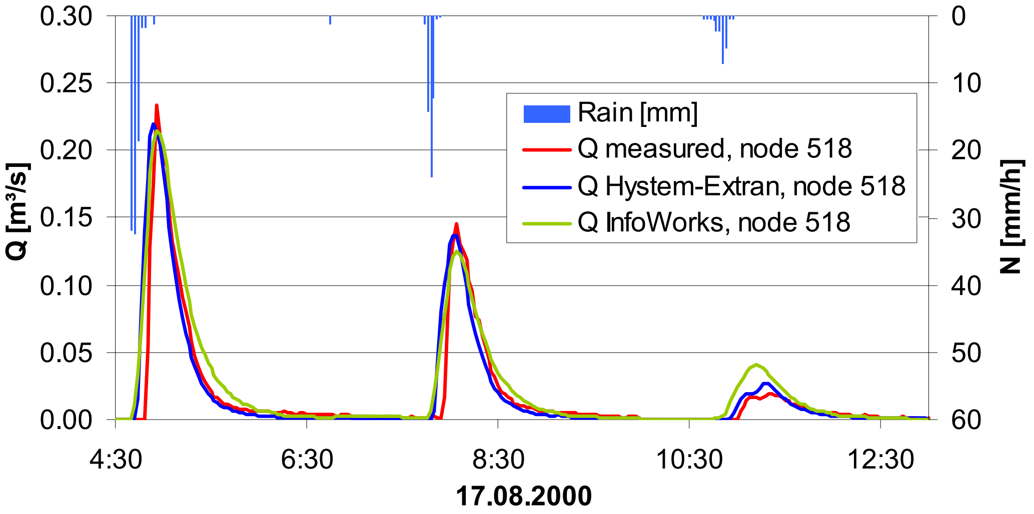


Figure 3.4 Comparison of hydrographs from calculation with a measured flow at node 518

The results of the calculated flow compared with a measurement campaign during one month are satisfactory regarding the comparability of the two simulation types as illustrated in figure 3.4. The differences between calculated runoff volume and measured volume differ between 3% at node 518 and 25% at node 502. The rain height for this event was 13.6 mm. Another rain event with 19.5 mm over a period of 8 hours showed deviations between 24% at node 518 and 50% at node 502 from the measurement. These simulations were carried out with a fixed parameter set for the whole period of one month, which was derived from calibrations with single events. Due to the different characteristic of the runoff routing process at rain events with high and mean intensities the discrepancy varies with the rain intensity.
One reason for this originates from the simulation approach, which doesn't define runoff from impervious areas. In the measuring and calibration process in separate systems, where the proportion of imperviousness is low in residential areas with less population density, this runoff caused by intensive rainfall could become relevant. Due to the extraordinary expense to quantify the accordant runoff parameters in terms of storm water entering wastewater sewers it was neglected in the ISM-model.

More significant effects on the model accuracy come from imprecise boundary conditions, which are difficult to quantify such as missing information about the non-uniform rain distribution over the catchment, changing water level at the outlet (which occurred at the Wuhle) and unavailable information about retention facilities on private properties.

A further comparison was drawn between InfoWorks (actually, the former version called Hydroworks was used) and the simulation software HHK of the consultancy bpi-Hannover, which carried out the pollution load simulations of all combined sewer systems of Berlin and derived the sanitation concept regarding the postulations of the water authority.
The calculations were made for the catchment area of Grand Couronne, near Rouen in France (bpi, 2003). The total area amounts to 152.0 ha with only 26.3 ha of paved

area. 94.0 ha are drained by a combined system. Directly in front of the wwtp there is an inline storm water tank with 1400 m³. The overflow from the tank is the only discharge from the combined sewer system into the receiving water (Seine). From the tank the sewage is pumped continuously into the treatment plant.

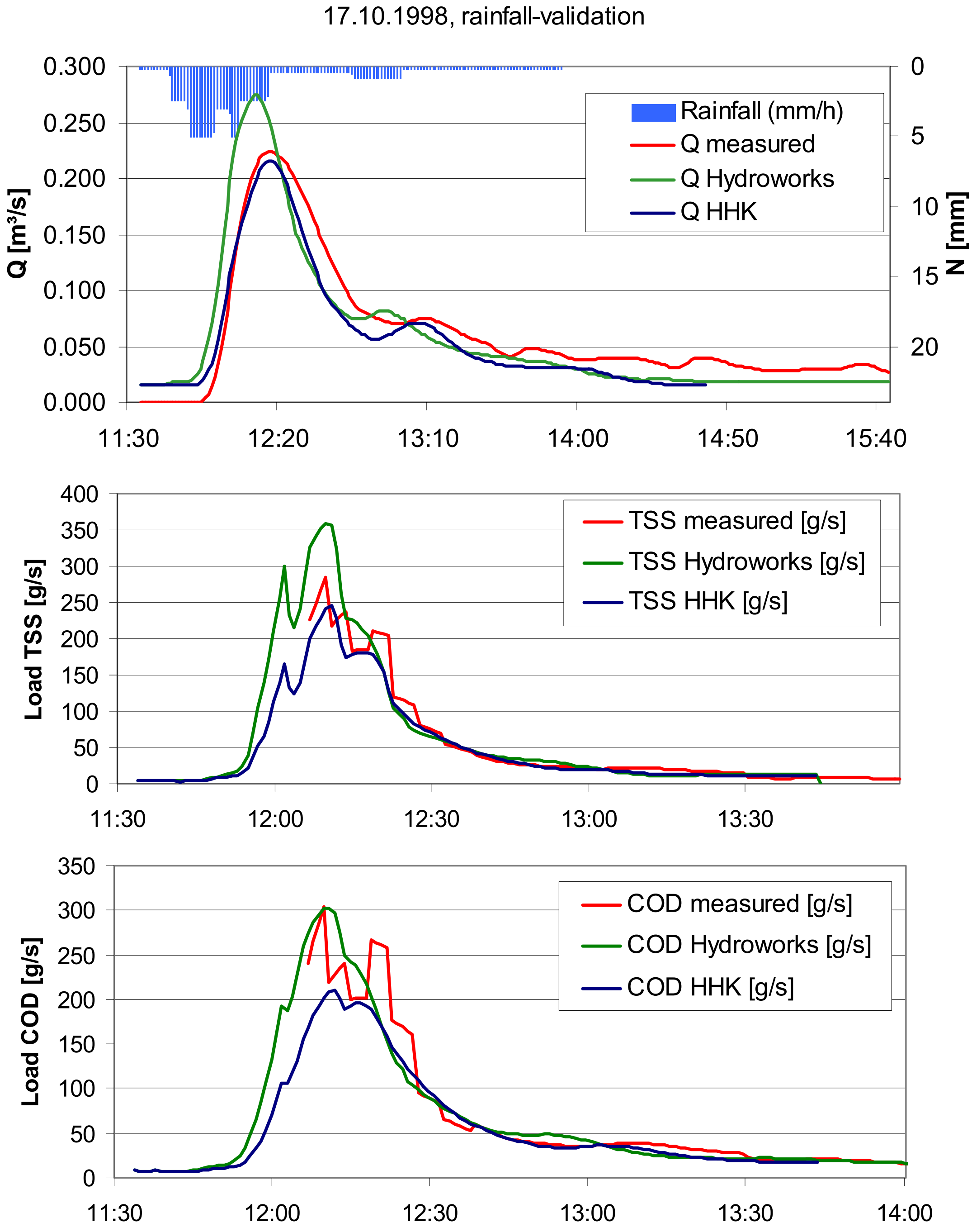


Figure 3.5 Comparison of measured and simulated hydrographs and pollutographs from the Grand Couronne catchment

The simulated data were compared with measurements of flow (7 events and one long time series of 1 month) and pollutant loads (4 events). The results show that

both models are able to reproduce measured pollutographs (see figure 3.5). Deviations in load are mainly influenced by inaccuracies in the underlying hydraulic simulation. To calibrate the HHK model and to adapt the simulated pollutographs to the measurements, the surface mass (TSS potential) had to be varied from 37.0 kg/ha to 53.0 kg/ha for the different rain events.
With both models the fitting of the pollutant curves was carried out successfully. Nevertheless, due to the high slope of the catchment, sedimentation and remobilisation within the conduits played a negligible role, making the pollutant transport process easy to describe. Unfortunately, only for one rain event samples could be taken over the full duration of the event. Most of the samples were taken with delay. Consequently, the effect of a first flush could not be examined.

The general uncertainty that is inherent to the InfoWorks model and parameters has been studied by Gogien and Zug (2004). On the basis of a set of measurements over 2 years from the “Marais” catchment (Paris) the InfoWorks software has been tested concerning reproducibility of flow and pollutant phenomena.
The results show that the model uncertainty is lower than that uncertainty inherent to the measurement of accordant process data (flow, massflow). According to this, error values of 10 % for hydraulic and 30 % for pollution are classically considered as the limits under which the model is well calibrated. Gogien and Zug (2004) achieved mean errors of 8 % in volume, 22 % for TSS mass and 19 % for COD mass for a series of 31 rain events. As an indication, the mean errors on maximum values are 12 % for flow, 30 % for TSS massflow and 32 % for COD massflow, respectively.

Finally, for modelling the sewers and pump stations the dynamic flow routing model InfoWorks CS of Wallingford Software Limited was chosen due to its user-friendliness (window navigation, GIS) and comprehensiveness (pollutant load calculation, long-time simulation, spatial rainfall distribution, rtc module).
The network has been built up in a skeletonised form, nevertheless accounting for the total available storage capacity. Storm water tanks and combined sewer overflows as well as actuators for real-time control have been considered in detail.

There are three sources of sewage entering the collection system. First, the more or less continuous inflow from households, trade and industry is simulated. The inflow has a diurnal pattern; furthermore, this pattern is different for weekdays and weekends, basing on the population’s behaviour. The pollutants concentration, too, has an accordant fluctuation.
Further on, the infiltration of groundwater into the collectors is modelled by a constant base flow with zero-pollutant-concentrations. The infiltration rate is determined by the “night-minimum method” according to BWB (2002) and ATV-DVWK (2004), respectively.
The adaptation of the model to this dry weather characteristic is carried out on the basis of measurements (dry weather calibration). Table 3.1 gives the average dry weather concentrations that have been observed during the measurement campaign at catchment Bln X (2002) and that are used as the general set of parameters throughout the entire model. TSS has to be used since any particulate pollutant is simulated as attached and related to this parameter. COD, TKN and NH_4-N are used

because they represent the basic parameters that have to be taken into account for the simulation of the wwtp (see chapter 3.3.3.3).

Parameter	TSS	COD	BOD	TKN	NH_4-N	Ptot
Concentration [mg/l]	426.0	996.0	391.4	79.9	57.0	10.7
Used in model	yes	yes	no	yes	yes	no

Table 3.1 Average dry weather pollutant concentrations observed in 2002 at catchment Bln X

The last source of sewage inflow is rainfall. Rainfall runoff is simulation by the fixed runoff method (after initial losses) for runoff formation and a linear reservoir model (Desbordes model) for runoff concentration.

Runoff from pervious surfaces is not regarded. At the separate system misconnections to the wastewater sewers are taken into account as impervious areas with a fixed runoff coefficient of 1.00 (= 100 %). The accordant parameters that have been found by calibration for the different catchments of wwtp Ruhleben are stated in table 3.2. An overview of the defined landuse IDs and the accordant wastewater profiles and surface IDs is given in appendix 4.

Runoff Surface ID	Description	Runoff Routing Value	Initial Loss Type	Initial Loss Value	Fixed Runoff Coefficient
1	undurchlässig Bln1	0.80	Slope	0.000060	0.80
10	undurchlässig Bln10.süd	0.60	Slope	0.000070	0.51
13	undurchlässig Wilm	0.90	Slope	0.000042	0.53
14	undurchlässig Chb1	1.00	Slope	0.000030	0.62
15	undurchlässig Chb3	0.60	Slope	0.000040	0.61
16	undurchlässig Ruh.west	2.10	Slope	0.000100	0.60
17	undurchlässig Spa1	2.30	Slope	0.000050	0.95
2	undurchlässig Bln2.nord	2.20	Slope	0.000072	0.95
21	durchlässig	1.00	Abs	0.001000	0.00
25	fehlangeschlossen Trenngebiete	0.50	Abs	0.001000	1.00
26	fehlangeschlossen Hlg	0.35	Abs	0.001000	1.00
3	undurchlässig Bln3	2.20	Slope	0.000016	0.65
4	undurchlässig Bln4	1.40	Slope	0.000070	0.91
7	undurchlässig Bln7	0.90	Slope	0.000071	0.60
8	undurchlässig Bln8	0.60	Slope	0.000070	0.60
9	undurchlässig Bln9	0.70	Slope	0.000040	0.90
92	fehlangeschlossen Spa1	1.00	Abs	0.001000	1.00
96	undurchlässig Ruh.ost	1.60	Slope	0.000100	0.59
97	undurchlässig Bln2.süd	1.10	Slope	0.000072	0.95
98	undurchlässig Bln10.mitte	0.70	Slope	0.000070	0.57
99	undurchlässig Bln10.nord	0.59	Slope	0.000070	0.48

Table 3.2 InfoWorks parameters for rainfall runoff simulation after model calibration for the catchments of wwtp Ruhleben

An objective way to verify the results of the simulation over this one-year period is to compare them with operational data. The operation department AE of BWB edits monthly the statistical data of the delivery at every pump station, subdivided into a wastewater (respective dry weather flow) and a rainwater fraction. These data were compared with the monthly pumpage rates of the simulation. For this comparison the data of the sewer network model and the pump control strategy had to be adapted to the current state (so called *local 2004*). Further on, rain distribution was estimated as uniform. The results are shown in figure 3.6. At most of the catchment areas the simulation has overestimated the dry weather flow. The main reason for this deviation results from the decrease of domestic sewage amount since the calibrations had been carried out. At catchment Wittenau the disconnection of pump stations Waidmannslust and Tegel (now directly connected to pressure pipe) has not yet been regarded in the simulation.

The difference in the dry weather fraction causes simultaneously a slight miscalculation and underestimation of the pumped rainwater volume in those cases where cso discharge occurs. The deviation in rainwater derives also from the difference in actual and estimated rainfall runoff that was derived from a uniformly distributed rain. For further research, detailed calibrations with current data for wastewater production should be made at the combined sewer catchments Bln VII, Bln VIII, Bln X and Wilmersdorf.

At the separate system of Wittenau the inflow and filling degree of storm water basins has not been regarded. Consequently, the discharge from the emptying process into the wastewater sewers has not been taken into account.

A further reason for the deviation of over 100 % up to 400 % in rain fraction (e.g. catchment Ruhleben) is the exceeding of the defined maximum pumpage of the wastewater pump stations to avoid high water levels in the sewer networks (not regarded by simulation). In the case of rainfall runoff from pervious surfaces, these areas should be taken into account in future calculations, if there is a considerable amount of misconnected areas to the wastewater system.

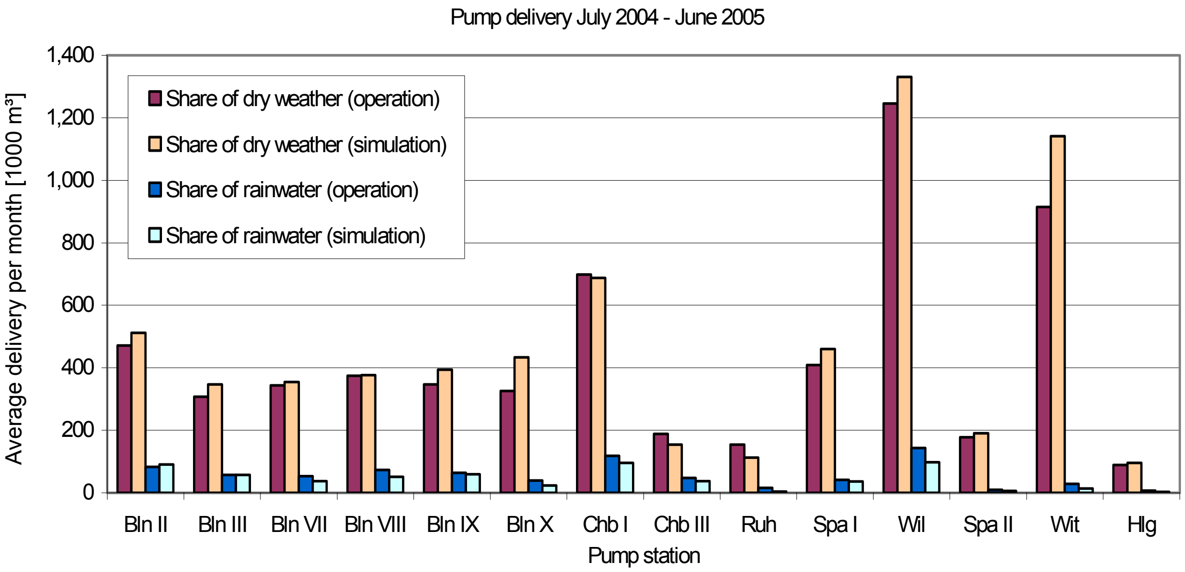


Figure 3.6 Comparison of measured and simulated pumpages concerning mean dry weather and rainwater fractions over the simulated period

InfoWork's quality simulation is based on the accumulation and washoff of particulate pollutants on the surface and the gully pot model for dissolved pollutants. The maximum surface mass (TSS potential) used is 75.0 kg/ha, the buildup factor is 6.0 kg/(ha*d) and the decay factor is 0.08 d^{-1}. These values are the default settings.

For the description of runoff within the conduits the governing model equations are the Saint-Venant equations (Yen, 1973). The fully dynamic wave equations are used. The conveyance function is based on the Colebrook-White expressions. At the upstream and the downstream end of each conduit it is possible to define local headlosses to take into account flow conditions at the nodes.
The Preissmann 4-point scheme (Preissmann, 1961) is used to approximate the Saint-Venant equations, in which functions and derivatives are replaced by weighted averages over the four corners of a box in (x,t) space. The implicit nature of the scheme removes any restrictions on the timestep.

Quality simulation is based on advective pollutant transport. The dispersion coefficient is set to 0, so that dispersion of pollutants is not taken into account. Nevertheless, numerical dispersion can be observed (Bouteligier et al., 2005). Biological conversion processes within the gravity sewers are neglected.

The Velikanov model is used for sediment behaviour within the conduits (Wiuff, 1985, Zug et al., 1998). The erosion and deposition calculations are made at the end of every water quality timestep after the advection equations have been solved. The use of the Velikanov model is a departure from the default model approach used by InfoWorks, the Ackers-White equation (Ackers, 1991).
This change became necessary since the Ackers-White approach lead to unreasonable results concerning the transport and discharge of sediments. At each computational point along each pipe a non-dimensional carrying capacity is calculated that represents the maximum concentration of a given sediment fraction that can be held within the flow. Among others the carrying capacity depends on the local flow velocity (m/s). Due to the hydraulic conditions within the Berlin combined sewers the flow velocity is very low leading to extreme sedimentation when using the Ackers-White model. These deposits are discharged during combined sewer overflow. The simulated mass of sediments being discharged could not be verified.

After changing the model approach and using the Velikanov equation the simulation results represent reasonably the mass of pollutants being discharges by cso. Figure 3.7 shows the simulated average discharge concentration of different pollutants (simulation period see chapter 4) in comparison to statistical values compiled by Brombach and Fuchs (2003).

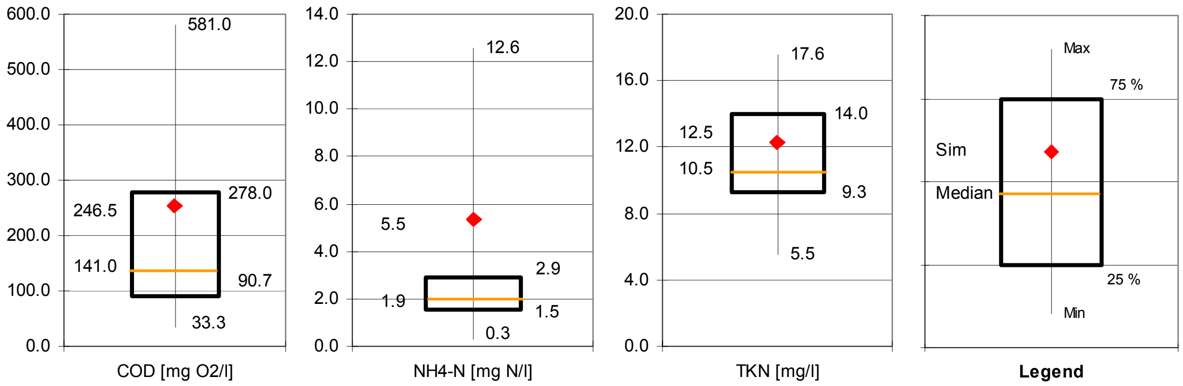


Figure 3.7 Comparison of simulated average discharge concentrations with statistical values from the DWA database

3.3.3.2 Pressure network

Wastewater transport through pressurised mains is modelled by EPANET 2 of the U.S. Environmental Protection Agency (EPA, 2000). Flow continuity and headloss equations are solved under steady state conditions using the so-called “Gradient Method” (Todini and Pilati, 1987). The governing equations for the quality solver are based on the principles of conservation of mass simulating advective transport within the pipes and complete and instantaneous mixing at the pipe junctions. Biological conversion processes within the pressurised pipes are neglected.

The network data for the Ruhleben catchment have been adopted from the SIR-3S model used by BWB, department AE (3Sconsult, 2002). Table 3.3 gives an overview of the objects and object properties that have been imported. Redundant pipes have not been modelled. The statuses of the valves (open/close) and reductions of pipe diameters due to incrustations have been set according to the information and assumptions given by Buchholz (2004).

Object type	**Junctions**	**Pipes**	**Valves**
property_1	X coordinates	length	diameter
property_2	Y coordinates	diameter	type
property_3	geodetic elevation (Z)	roughness	local loss coefficient
property_4		local loss coefficient	status (open/close)
number of objects modelled (catchment Ruh)	325	218	113

Table 3.3 Object properties and number of objects that have been used for the EPANET model of the sewage pressure network, catchment Ruhleben

Figure 3.8 shows a comparison between simulated and measured NH_4-N concentrations at the inflow to wwtp Schönerlinde following a rain event. Concerning the simulation of dissolved pollutants like NH_4-N a sufficient accuracy is achieved. The simulation of the transport of particulate pollutants, on the other hand, underlies higher uncertainties. The processes of sedimentation and remobilisation within the pressure mains are not yet known in detail. Consequently, EPANET doesn’t simulate these processes at all but calculates advective pollutant transport assuming a sufficient accuracy in terms of the defined criteria.

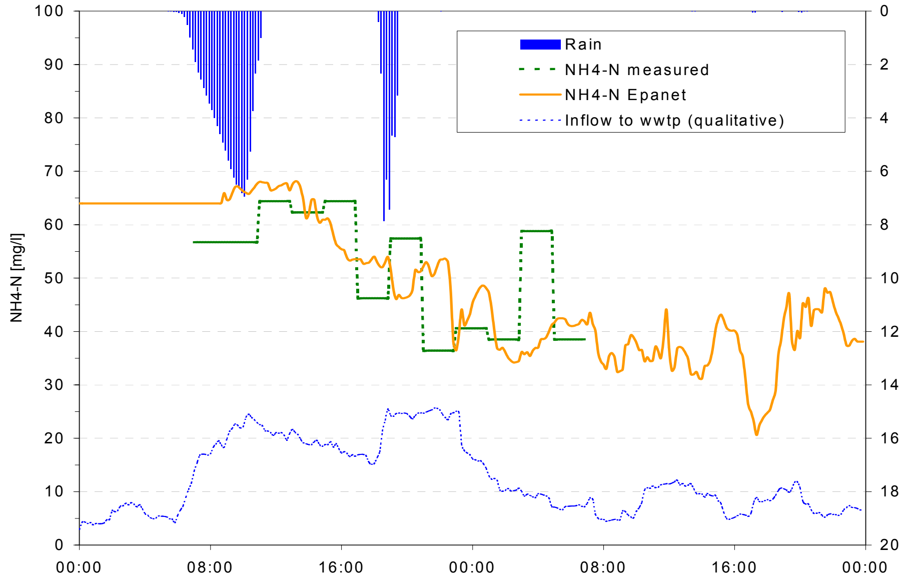


Figure 3.8 Comparison between simulated and measured NH_4-N concentrations at the inflow to wwtp Schönerlinde following a rain event

3.3.3.3 Wastewater treatment plant

The modular program SIMBA® 5 of ifak System GmbH is used to simulate the dynamic treatment processes under varying load conditions. For the activated sludge conversion part an extended version of the Activated Sludge Model No. 1 (ASM 1) is used (Henze et al., 1986).

Due to the difference in model structure, pollutant data generated by the runoff routing model InfoWorks and passed on by EPANET have to be adapted to the fractions used for the simulation of the wwtp. Usually, the fractionation is carried out according to Bornemann et al. (1998) as illustrated in figure 3.9. Dissolved fractions are indicated by the character S (solved) and particulate fractions are indicated by the character X.

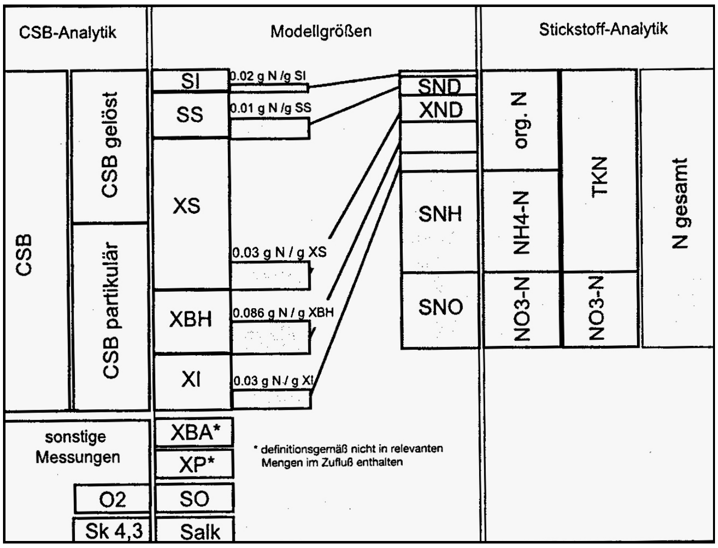


Figure 3.9 Fractionation of wwtp inflow for the use of ASM 1 according to Bornemann et al. (1998)

The standard SIMBA fractionation block uses the parameter COD_{tot} to derive the carbon fractions as well as X_{ND} and S_{ND}. Assuming variations of the relation between dissolved and particulate fractions this approach will lead to imprecise parameter estimation. In consequence of first flush phenomena for example particulate COD will escalate, whereas concentrations of dissolved carbon and nitrogen fractions will decrease. To reproduce this behaviour a more detailed approach was chosen taking into account dissolved as well as particulate COD and moreover NH_4-N and N_{org} during runoff simulation.
Table 3.4 shows the fractions used for the simulation of the wwtp and their calculation based on inflow parameters.

Abbr.	Parameter	Calculation from inflow values	Unit
S_I	Soluble inert organic matter	$0{,}1 \cdot COD_S$	$\frac{g_{COD}}{m^3}$
S_S	Readily biodegradable substrate	$0{,}6 \cdot COD_S$	$\frac{g_{COD}}{m^3}$
X_I	Particulate inert organic matter	$0{,}166 \cdot COD_X$	$\frac{g_{COD}}{m^3}$
X_S	Slowly biodegradable substrate	$COD_{tot} - S_I - S_S - X_I - X_{BH}$	$\frac{g_{COD}}{m^3}$
X_{BH}	Active heterotrophic biomass	$0{,}3 \cdot COD_X$	$\frac{g_{COD}}{m^3}$
X_{BA}	Active autotrophic biomass	0,001	$\frac{g_{COD}}{m^3}$
X_P	Particulate products arising from biomass decay	0	$\frac{g_{COD}}{m^3}$
S_O	Oxygen	0,1	$\frac{-g_{COD}}{m^3}$
S_{NO}	Nitrate and nitrite nitrogen	0	$\frac{g_N}{m^3}$
S_{NH}	NH_4 and NH_3 nitrogen	NH_4	$\frac{g_N}{m^3}$
S_{ND}	Soluble biodegradable organic nitrogen	$0{,}77 \cdot \begin{pmatrix} N_{org} - 0{,}02 \cdot S_I - \\ 0{,}03 \cdot X_I - 0{,}086 \cdot X_{BH} \end{pmatrix}$	$\frac{g_N}{m^3}$
X_{ND}	Particulate biodegradable organic nitrogen	$\frac{23}{77} \cdot S_{ND}$	$\frac{g_N}{m^3}$
S_{ALK}	Alkalinity	8	$\frac{mol}{m^3}$

Table 3.4 Fractions of the ASM 1 used for the simulation of the wwtp and their calculation based on inflow parameters

Model structure

Each block of wwtp Ruhleben including the final clarification tanks is modeled as one line. Only the primary clarifiers are merged to one tank. Below, the specific approaches of model implementation are outlined.

The model of Otterpohl et al. (1994) is used to simulate the primary clarification. The separation rate of COD is calculated depending on the retention time in the tank. The separation rate is adjusted to the relation between particulate COD and soluble COD and applied to the particulate fractions. The original model of Otterpohl does not consider a dynamic relation between particulate and soluble COD. Therefore, a modified model approach, provided by ifak System GmbH, has been applied taking into account the relation between particulate COD and total COD and using it as an input parameter.
The wwtp model realises a separate extraction of primary sludge and surplus activated sludge from final sedimentation. Extraction of primary sludge is simulated with a constant rate of 2,200 m^3/d.

For the activated sludge conversion part an extended version of the Activated Sludge Model No. 1 (ASM 1) is used (Henze et al., 1986). To reproduce roughly plug flow within the longitudinal aeration tanks the volume of the aerobic zones has been modelled by three tanks in series, respectively. Anaerobic and anoxic zones have been regarded as completely stirred tank reactors.

For the simulation of the final clarification the 10-layer-model of Otterpohl and Freund (1992) is used. With this approach it is possible to reproduce sufficiently the process of clarification under dry weather and storm weather conditions. Nevertheless, during peak load situations sludge washout cannot be represented reliably by this model approach. CFD (computational fluid dynamics) simulations, which are beyond the scope of the ISM project, would be necessary.

Operational parameters

The final clarification capacity of block A of wwtp Ruhleben is lower than that of block B and C. Consequently, the charging of block A with combined water is lower than the volumes of the aeration tanks indicate.
Hence, during simulation an optimal utilisation of the aeration tanks cannot be achieved. However, during peak load situations an overloading of the clarifiers and sludge washout will appear later and more uniformly over the three blocks. This implementation is a simplification of the real operation regime at wwtp Ruhleben, however leading to sufficient results.
The distribution of aeration tank volumes and flows as implemented in the model is illustrated in figure 3.10.

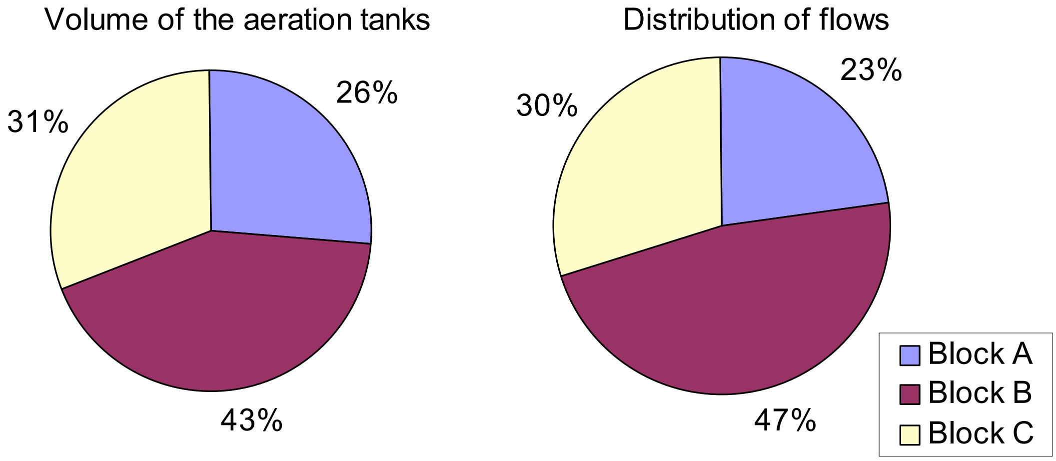


Figure 3.10 Distribution of aeration tank volumes and flows as implemented in the model of wwtp Ruhleben

The temperature within the activated sludge tanks plays a decisive role concerning growth and metabolic rate of the microorganisms. For the simulation the temperature is set according to an empiric curve generated from measured process data. During winter the degradation performance of the microorganisms is diminished due to the low temperature. Consequently, the activated sludge process is pursued with an increased quantity of microorganisms, i.e. dry matter contents. Refeeding a portion of the surplus sludge from final clarification into the anaerobic tank regulates the dry matter content. Analogue to the temperature, the setpoint of dry matter contents is given by an empirically derived annual curve (see figure 3.11).

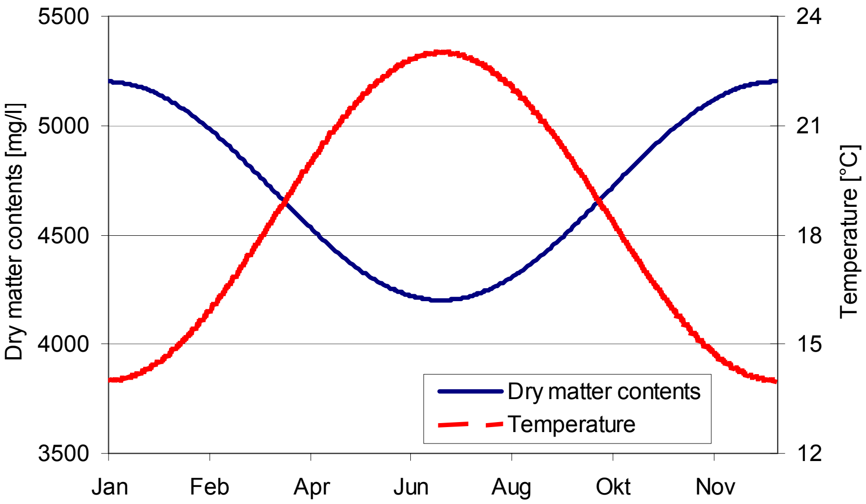


Figure 3.11 Empirical annual curves derived from process measurements used for the simulation of the activated sludge process

The operation mode of the wwtp has been implemented into the model with constant flows of recirculation and sludge extraction. A portion of the sludge extracted from final clarification is returned into the anaerobic tank in order to regulate the dry matter contents. The remaining flow is extracted as surplus sludge.

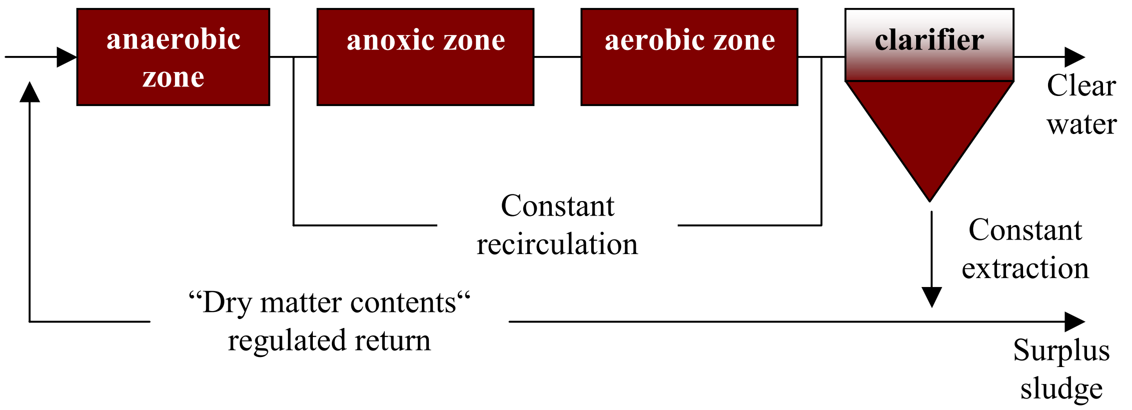


Figure 3.12 Schematic overview of the model configuration of wwtp Ruhleben for return sludge and recirculation

In contrast to this, in reality the surplus sludge is not separated from the return current but extracted as mixed sludge (primary and surplus sludge) from the primary settlement tanks. Figure 3.12 gives a schematic overview of the model configuration for return sludge and recirculation. Table 3.5 shows the accordant flows.
Further on, the setpoint for oxygen within the aeration tanks has been fixed to 2 mg/l within the model.

	Recirculation	**Recirculation factor (Dry weather average)**	**Sludge extraction from final clarifier**
Block A	177,100 m³/d	2.8	40,480 m³/d
Block B	379,456 m³/d	3.7	87,333 m³/d
Block C	213,444 m³/d	2.8	48,787 m³/d

Table 3.5 Values of recirculation and surplus sludge extraction from model simulation

Inflow characteristic

The inflow to the wwtp varies according to the diurnal and yearly profile of wastewater production and groundwater infiltration and the impact from rainwater (volume, duration, dynamic).
To compare the inflow characteristic of the different simulation scenarios among each other and with the real conditions, 2h-averages of the inflow volume have been calculated and divided into classes. The different scenarios are described in detail in chapter 4. What can be seen in table 3.6 (scenario global_b) is that the maximum capacity of the wwtp is not exceeded during simulation. There is an accumulation of inflow rates between 2500 l/s and 3500 l/s that can be explained by the functioning of the applied control concept. What is not regarded in simulation is the minimum acceptable inflow to the plant. The table shows simulated values between 500 l/s and 1000 l/s that cannot be found in the measurement data. In reality those inflows

are avoided due to plant-specific constraints. However, this deviation in simulation does not have an influence on the results.

Classes [l/s]	Measurements from 2004	Simulation scenario global_b
0 - 500	0	0
500 - 1000	0	424
1000 - 1500	132	342
1500 - 2000	877	569
2000 - 2500	959	205
2500 - 3000	700	932
3000 - 3500	685	957
3500 - 4000	614	610
4000 - 4500	154	72
4500 - 5000	68	58
5000 - 5500	46	39
5500 - 6000	46	50
6000 - 6700	73	118
6700 - 7000	26	4
7000 - 7650	0	0
7650 - 8000	0	0

Table 3.6 Classes of 2h-average inflow volumes to wwtp Ruhleben for simulation scenario global_b and measurements

Calibration

The calibration of the model for wwtp Ruhleben is based on the set of data from the standard sampling procedure carried out at the plant (24-h composite samples every second day). Different parameters of the ASM 1 and of the fractionation have been calibrated statically (see table 3.7).

	Parameter	**Standard value**	**Calibrated value**
aSI	Fraction of S_I in total COD	0.07	0.05
aSS	Fraction of S_S in total COD	0.2	0.3
aXI	Fraction of X_I in total COD	0.1	0.08
μ_H	Maximum growth rate of heterotrophic biomass [1/d]	6.0	2.0
μ_A	Maximum growth rate of autotrophic biomass [1/d]	0.8	2.6

Table 3.7 Calibrated parameters of the ASM 1

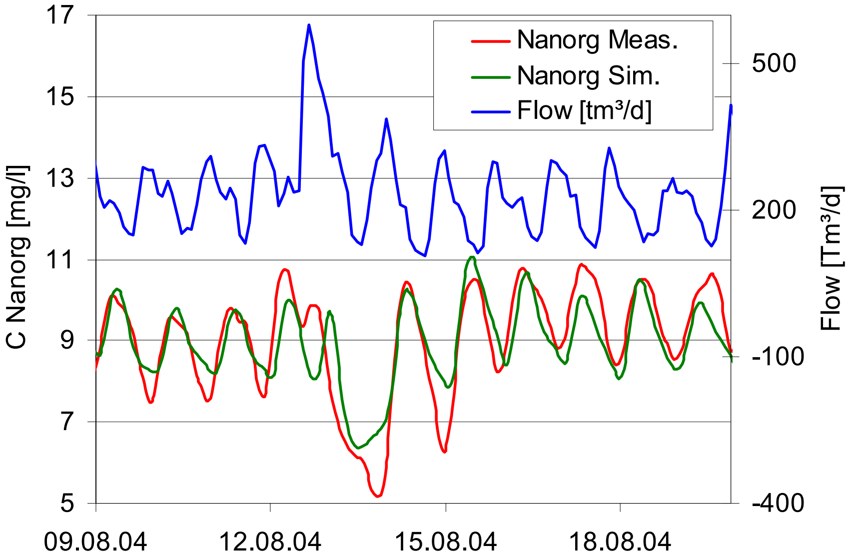


Figure 3.13 Measured and calibrated N_{anorg} concentration for a rain event from 13.08.2004.

Additionally, online effluent measurements of N_{anorg} and flow have been used. Figure 3.13 gives an impression of the calibrated effluent concentrations. For a rain event from 13.08.2004 the measured and calibrated N_{anorg} concentration and the measured flow are shown.

Furthermore, a comparison of measured and simulated average effluent concentrations from 2004 is given in table 3.8.

Parameter		**Measurement 2004**	**Simulation 2004**
COD	Min	31.0	24.0
	Average	42.7	35.0
	Max	70.0	45.0
NH_4	Min	0.1	0.3
	Average	0.6	1.6
	Max	9.9	7.0
N_{org}	Min	1.3	0.7
	Average	3.1	1.0
	Max	13.3	1.5
N_{anorg}	Min	4.5	5.8
	Average	8.4	9.1
	Max	14.4	13.0

Table 3.8 Comparison of measured and simulated average effluent concentrations from 2004

3.4 Description of the model for the drainage system

This chapter gives a full description of the InfoWorks model for the Berlin drainage system. All catchments that are supplying the three main wastewater treatment plants (Ruhleben, Waßmannsdorf and Schönerlinde) and have a significant impact on the system ($Q_{rain,max}$ > 100 l/s) have been taken into account (see appendix 5). That means, 100 % of the combined sewer systems (18 catchments) and 63 % of the wastewater systems (29 from 46 catchments) have been modeled. Since there is no impact from storm water collectors on the treatment plants these sewer networks have been neglected.

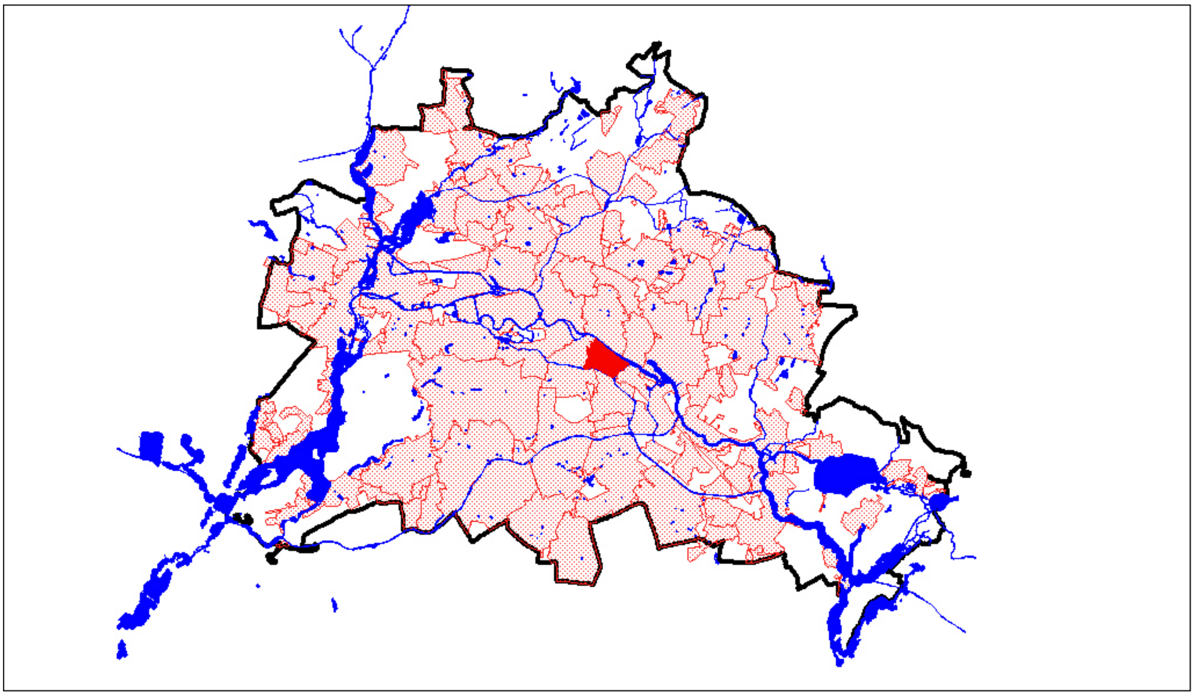
The following list will give a detailed description of the sub models for any of these combined and wastewater catchments. The list covers a catchment overview and characteristic data of the sub model concerning conduits, nodes, pump stations, combined sewer overflows and storm water storage tanks. A focus is given to the reproduction of sewer storage capacities illustrated by accordant storage characteristic curves. Furthermore, examples from model calibration are shown.

Combined system		Separate system	
Catchment	**Page**	**Catchment**	**Page**
Bln I	34	Altgl	162
Bln II	40	Bie I	167
Bln III	46	Bri	172
Bln IV	52	Buh	177
Bln V	58	Grü	182
Bln VII	64	Hlg	187
Bln VIII	78	Hdf	201
Bln IX	84	Joh	206
Bln X	90	Kht I	211
Bln XI	108	Kar	216
Bln XII	114	Lbg	212
Nkn I	120	Lrd	226
Nkn II	126	Mal	231
Spa I	132	Mdf	236
Wilm	138	Mfd I	241
Chb I	144	Mar I	246
Chb III	150	Mar II	251
Ruh	156	Nsch	256
		Ros	261
		Rud	266
		Spa II	271
		Stg	276
		Thf	281
		Wit	286

Table 3.9 Contents of the subcatchment model description

3.4.1 APw Berlin I

Subcatchment:	Berlin I	
Contributing Area:	300 ha	
Population:	55617 Inh.	
WWTP:	dry weather:	Ruhleben
	storm weather:	Waßmannsdorf



Location of subcatchment Berlin I

Model characteristics Berlin I

System type:	Combined
Length of modelled pipes	
Combined:	16.033 km
Waste water:	-
Storm water:	-
Other:	2.529 km
Number of Nodes	125
Number of Pump Stations	1
Pump Station:	APw Berlin I, Paul-Lincke-Ufer
US Node ID:	14175006
Average dry weather flow:	135.60 l/s
Maximum Capacity	
local:	0.360 m^3/s
global:	-
Destination	
dry weather:	Ruhleben
storm weather:	Waßmannsdorf

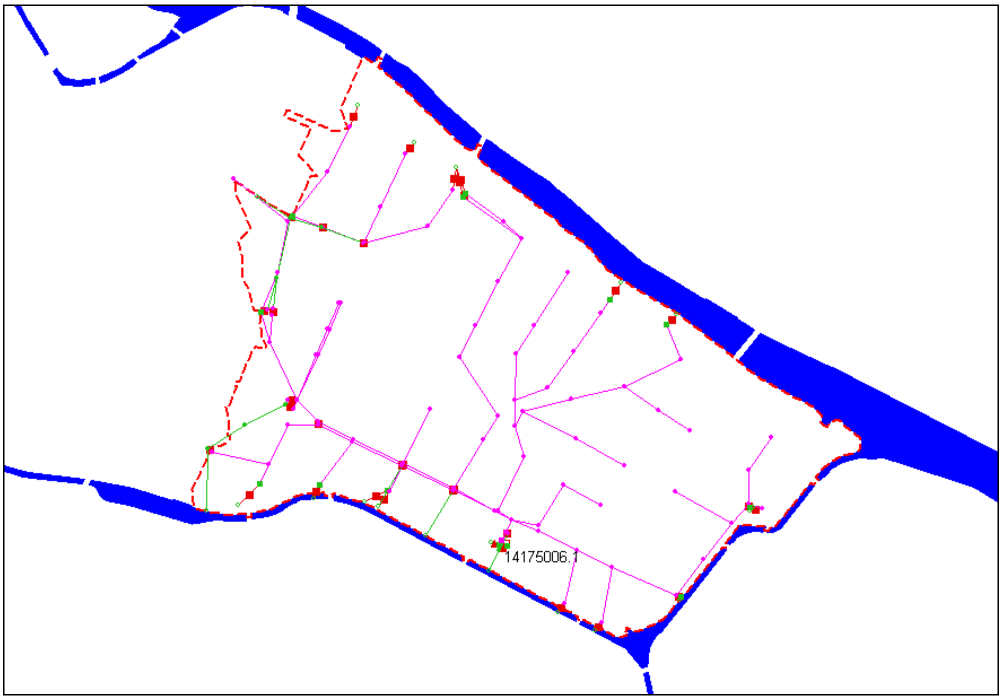
Number of storage tanks and storage sewers: 1

Description: Combined water tank with overflow
Node ID: 14175951
Asset ID:
Asset name : RÜB, Paul-Lincke-Ufer
Volume: 2170 m³
Filling: Pump (1200 l/s)

Number of combined sewer overflows: 27

Additional assets:

Inline storage capacity: 5008 m³
Maximum storage level: 32.20 maD

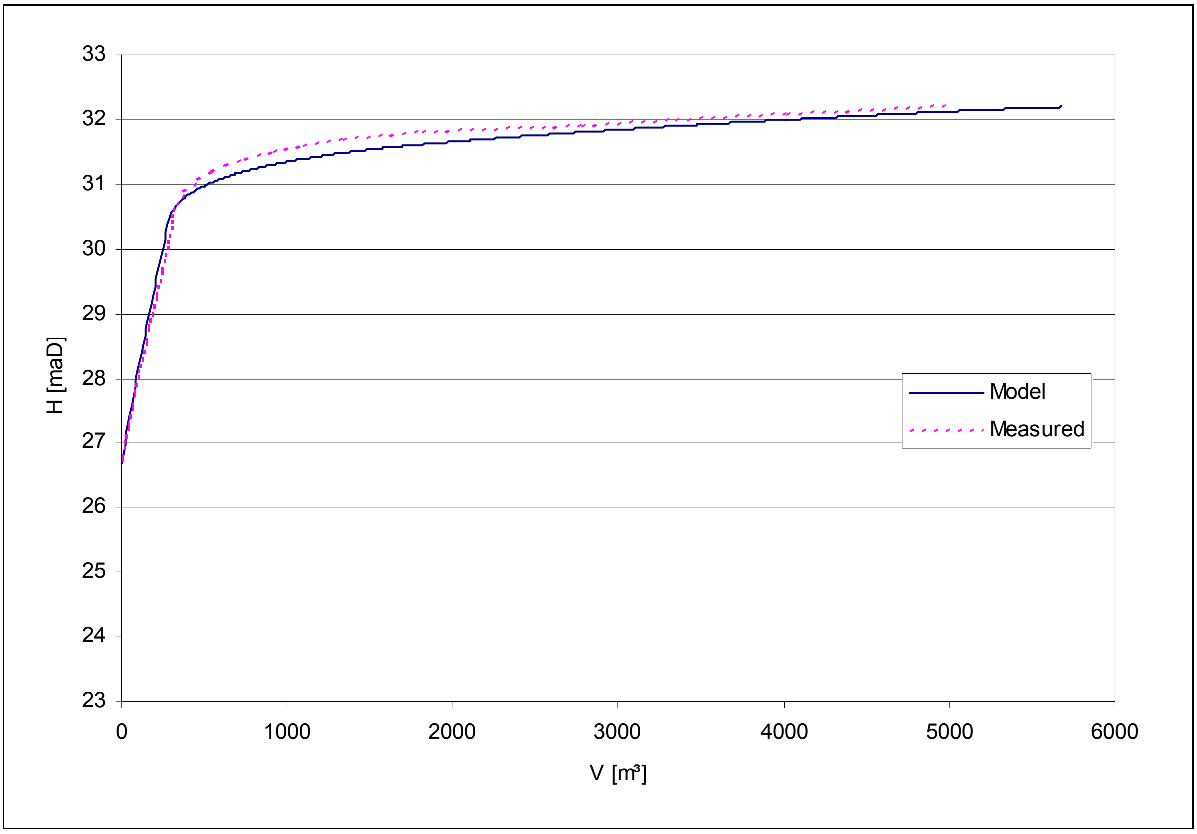


Network model of subcatchment Berlin I

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	5670	5008
storage level [maD]:	32.20	32.20
lowest crest level of cso [maD]:	32.38	

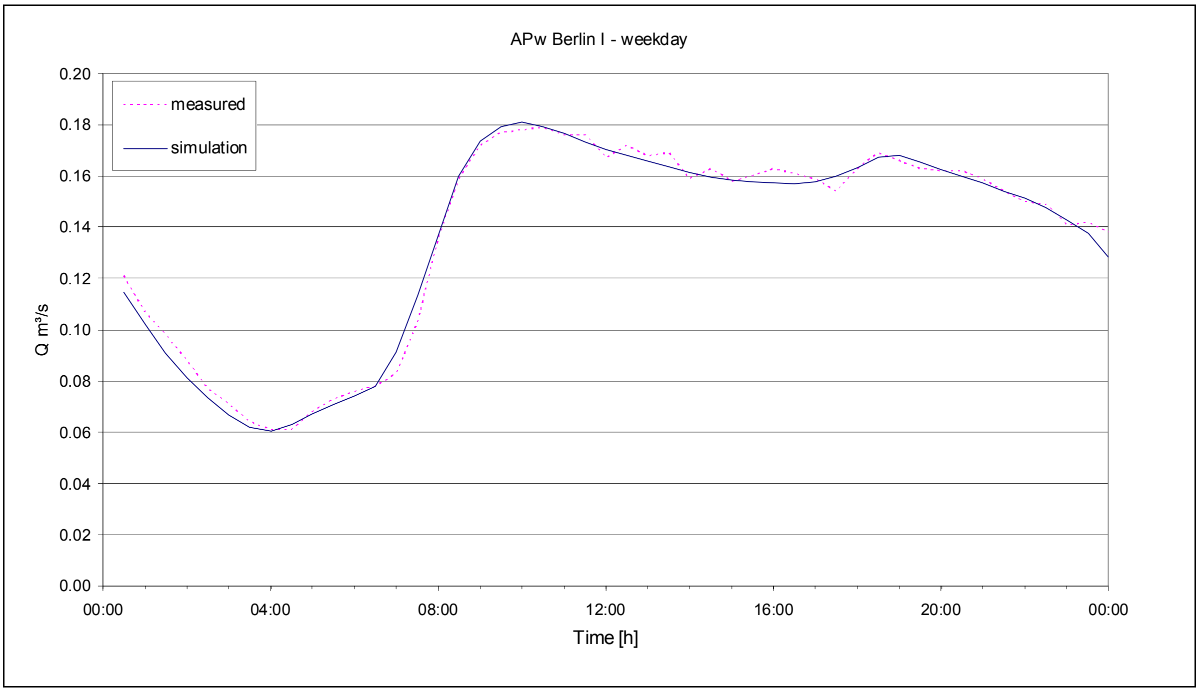
APw Bln I



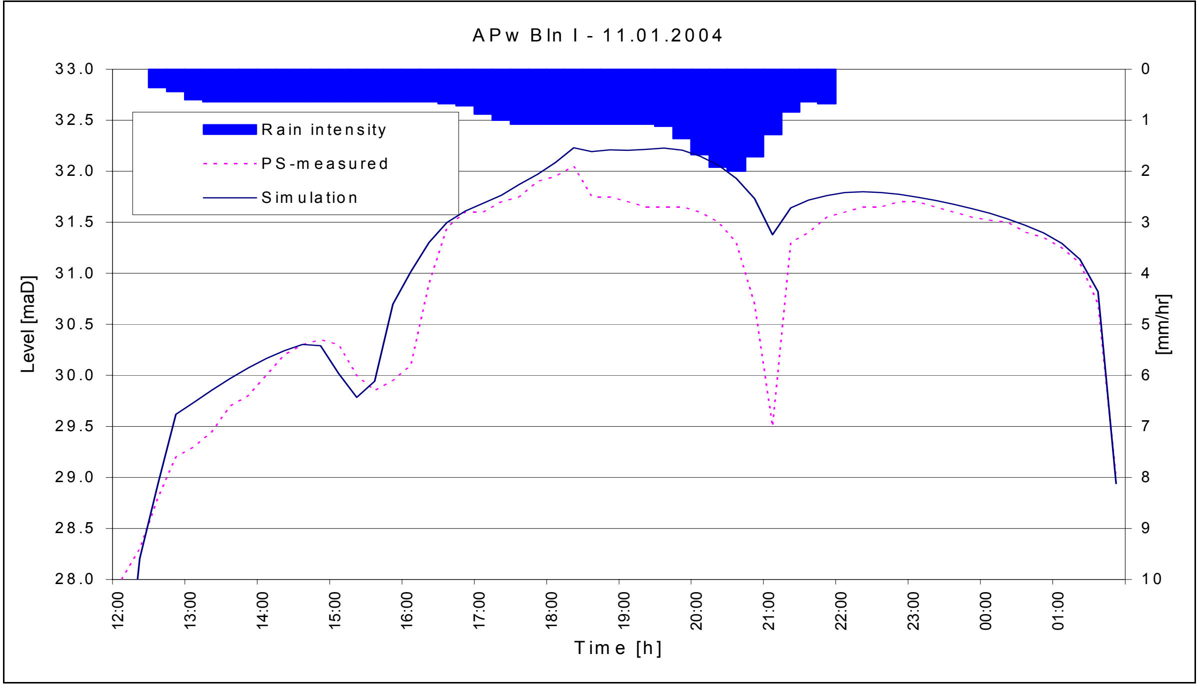
Storage characteristic of sewer network Berlin I

Calibration

Dry Weather: Flow at Pump station Bln I
min flow: 0.060 m³/s
max flow: 0.181 m³/s



Storm Weather: Level at Pump station Bln I

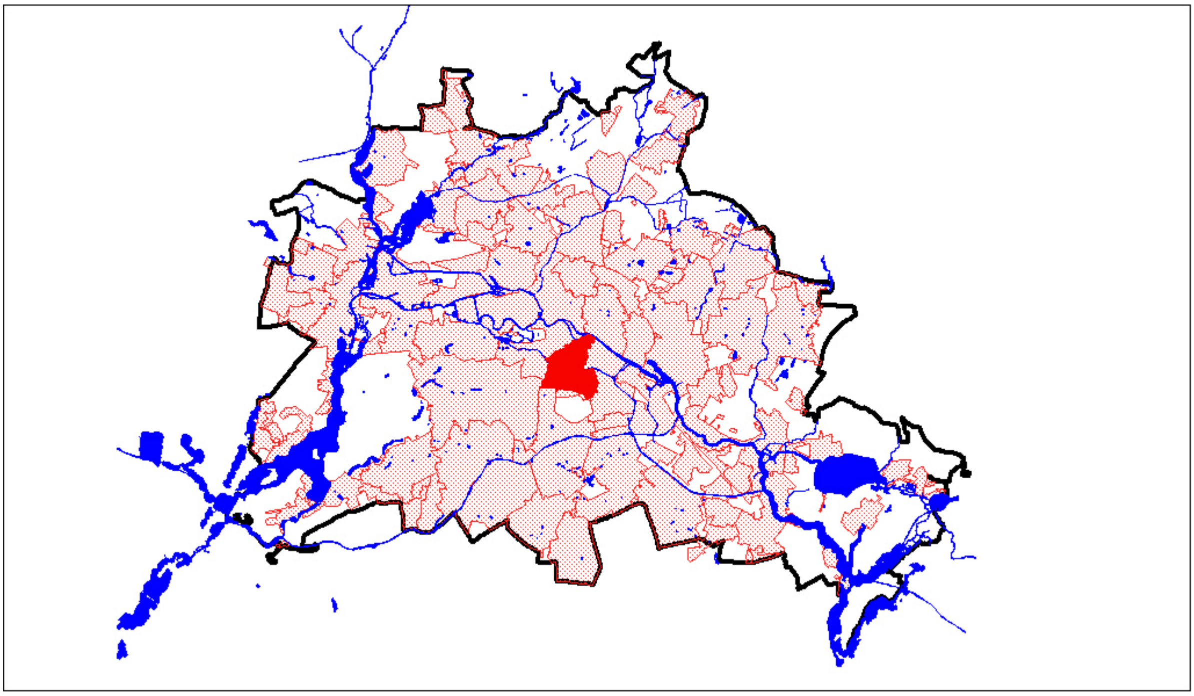


Specifics

- The sewer network is linked with catchment Bln II at node (15181004).
- Except for the heightening of the weir crests measures of rehabilitation have not yet been modeled (network Ruhleben_2010).

3.4.2 HPw Berlin II

Subcatchment:	Berlin II	
Contributing Area:	623 ha	
Population:	96304 Inh.	
WWTP:	dry weather:	Waßmannsdorf
	storm weather:	Ruhleben



Location of subcatchment Berlin II

Model characteristics Berlin II

System type: Combined

Length of modelled pipes

- **Combined:** 30.197 km
- **Waste water:** -
- **Storm water:** 0.571 km
- **Other:** 11.209 km

Number of Nodes 556

Number of Pump Stations 1

- **Pump Station:** HPw Berlin II, Gitschiner Str.
- **US Node ID:** 15206005
- **Average dry weather flow:** 202.30 l/s
- **Maximum Capacity**
  - **local:** 0.570 m^3/s
  - **global:** 0.700 m^3/s
- **Destination**
  - **dry weather:** Waßmannsdorf
  - **storm weather:** Ruhleben

Number of storage tanks and storage sewers: 2

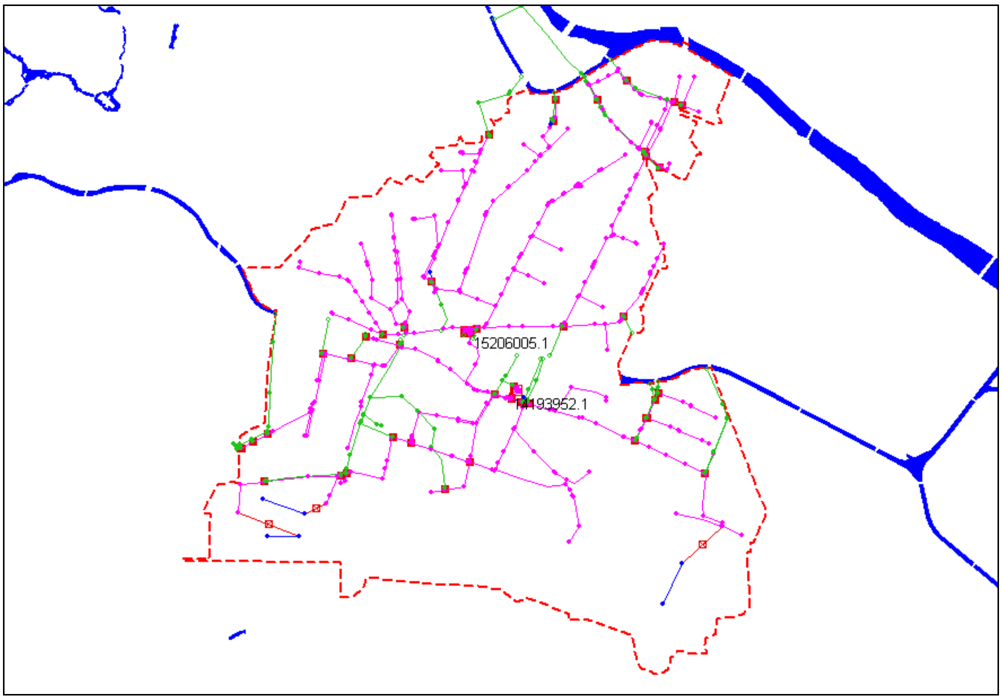
Description: Combined water tank with overflow
Node ID: 15206951
Asset ID:
Asset name : Bln II, RÜB Gitschiner Str.
Volume: 2700 m³
Filling: Gravity

Description: Combined water tank with overflow
Node ID: 14193952
Asset ID:
Asset name : Bln VI, RÜB Urbanstr.
Volume: 3300 m³
Filling: Gravity

Number of combined sewer overflows: 40

Additional assets:

Inline storage capacity: 8582 m³
Maximum storage level: 32.10 maD

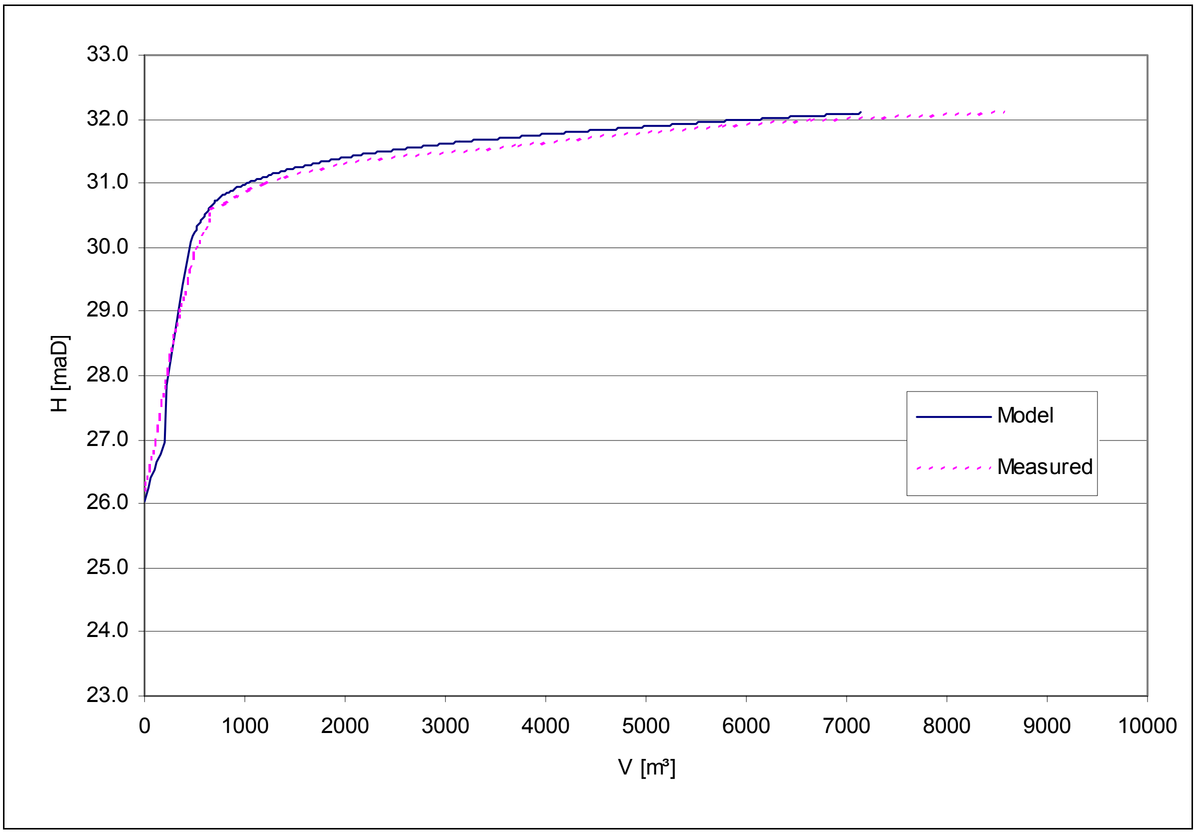


Network model of subcatchment Berlin II

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	7132	8582
storage level [maD]:	32.10	32.10
lowest crest level of cso [maD]:	32.36	

HPw Bln II

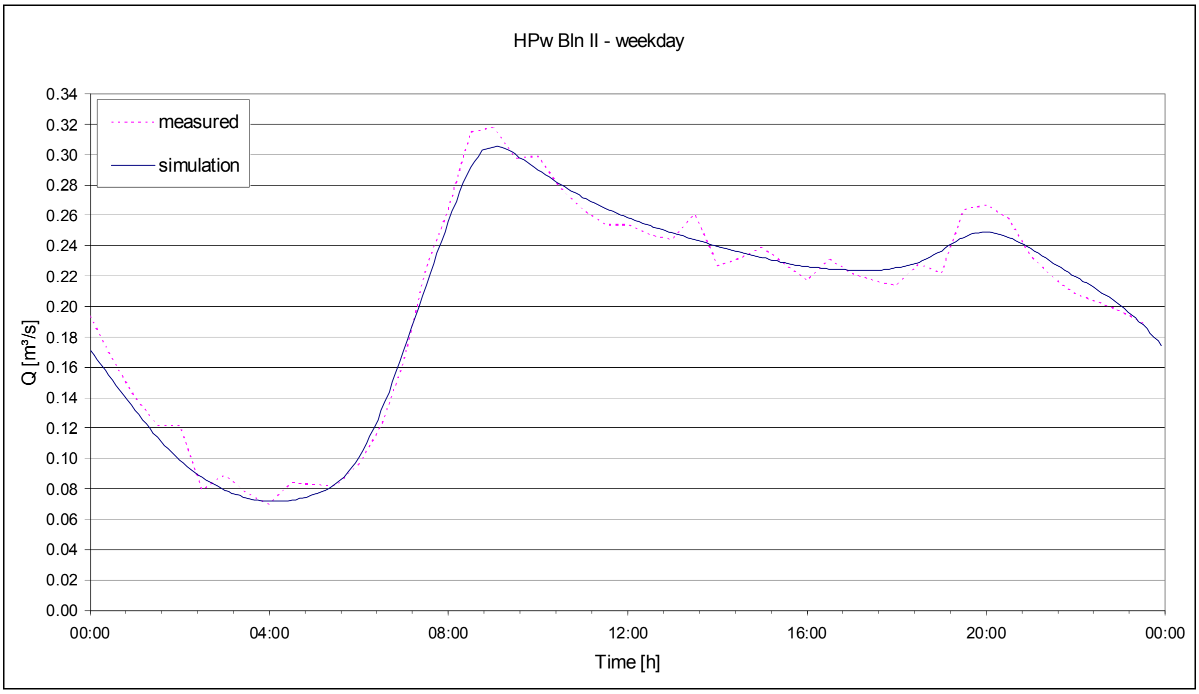


Storage characteristic of sewer network Berlin II

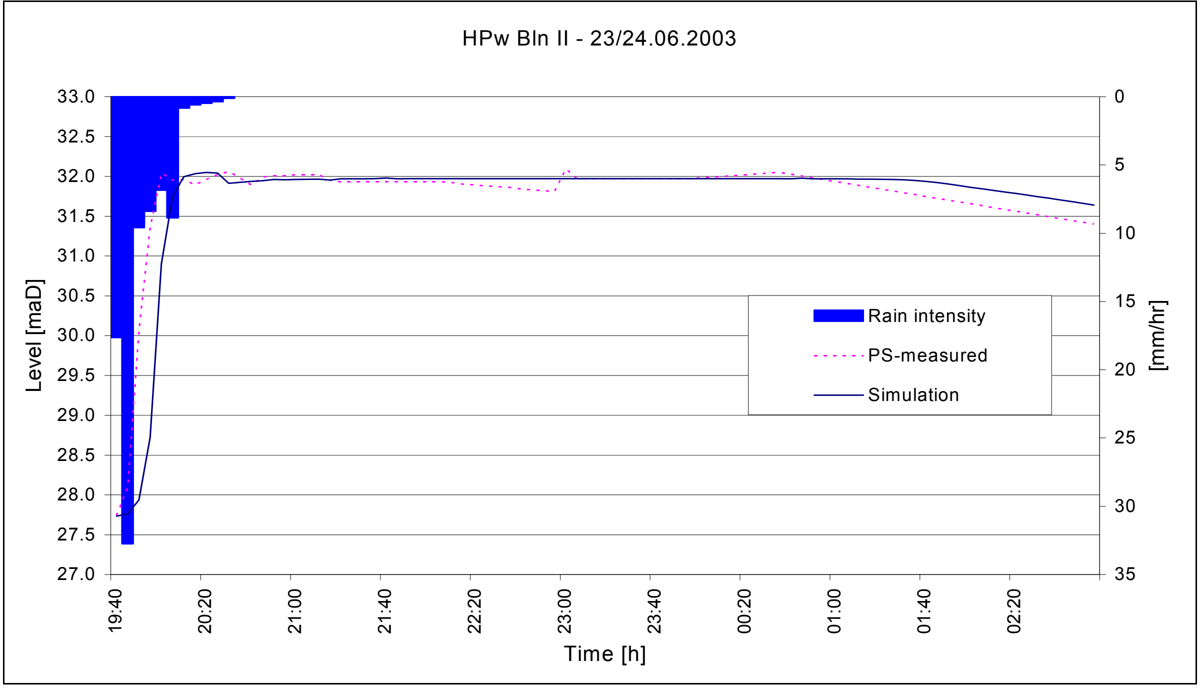
Calibration

Dry Weather: Flow at Pump station Bln II

min flow: 0.072 m³/s
max flow: 0.305 m³/s



Storm Weather: Level at Pump station Bln II

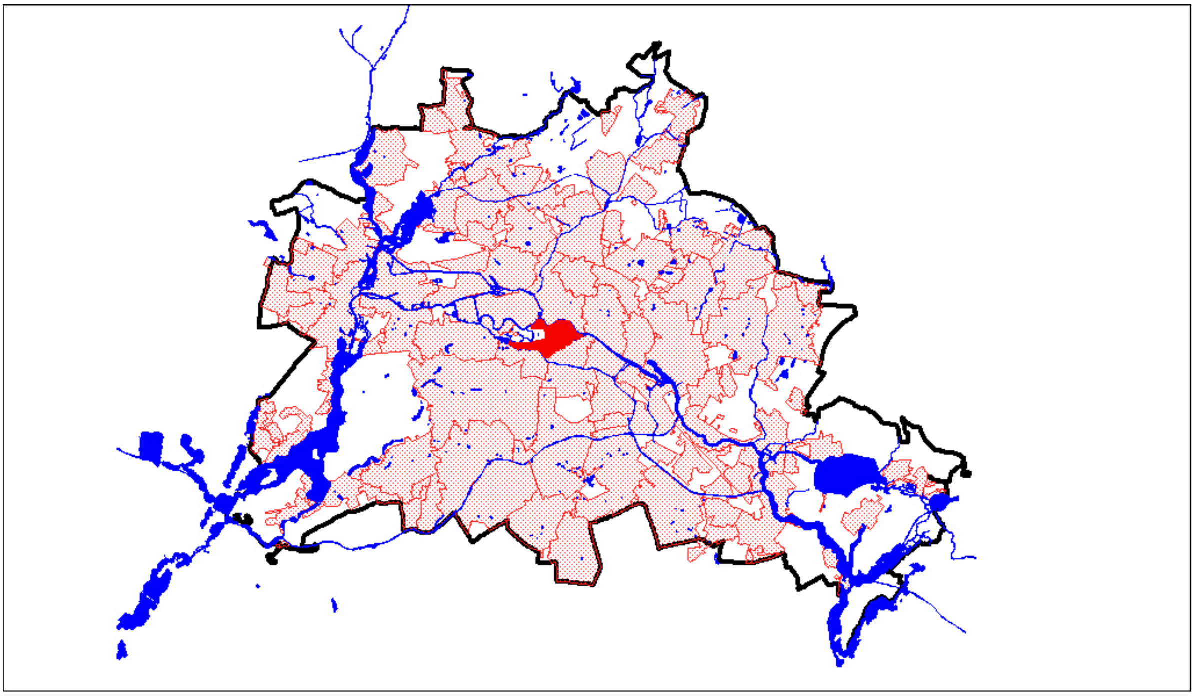


Specifics

- The subcatchment Bln II is built from 2 former subcatchments (Bln II and Bln VI). The sewer networks are linked by only one conduit.
- The sewer network is linked with catchment Bln I at node (15181004).
- The tanks and the pump station inflow are managed by a complex rtc strategy. Rtc file 2010 represents the rehabilitated state according to the recommendations of bpi Hannover. The control concept for the pump station that is based on a flow measurement cannot be realised until the installation of an accordant measurement device.

3.4.3 APw Berlin III

Subcatchment:	Berlin III	
Contributing Area:	398 ha	
Population:	26201 Inh.	
WWTP:	dry weather:	Ruhleben
	storm weather:	Ruhleben



Location of subcatchment Berlin III

Model characteristics Berlin III

System type:	combined
Length of modelled pipes	
Combined:	30.084 km
Waste water:	-
Storm water:	0.335 km
Other:	7.699 km
Number of Nodes	259
Number of Pump Stations	2
Pump Station:	APw Berlin III, Schöneberger Str.
US Node ID:	15211002
Average dry weather flow:	129.10 l/s
Maximum Capacity	
local:	0.400 m^3/s
global:	0.500 m^3/s
Destination	
dry weather:	Ruhleben
storm weather:	Ruhleben
Booster Station:	ÜPw Berlin IIIa, Breite Straße
US Node ID:	18206001
Maximum capacity:	75 l/s
Destination:	Sewer network Berlin III
Node ID	18206345

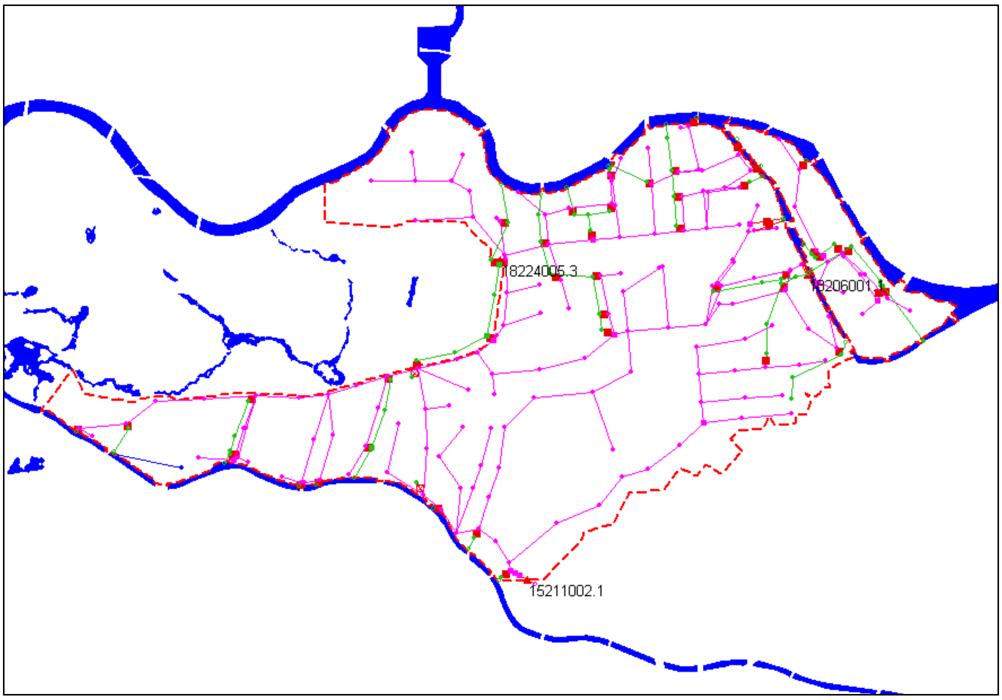
Number of storage tanks and storage sewers: 1

Description: Storage sewer
Node ID: 18224005
Asset ID:
Asset name : SK Ebertstraße
Volume: 2190 m³
Filling: Gravity

Number of combined sewer overflows: 46

Additional assets:

Inline storage capacity: 12560 m³
Maximum storage level: 32.01 maD

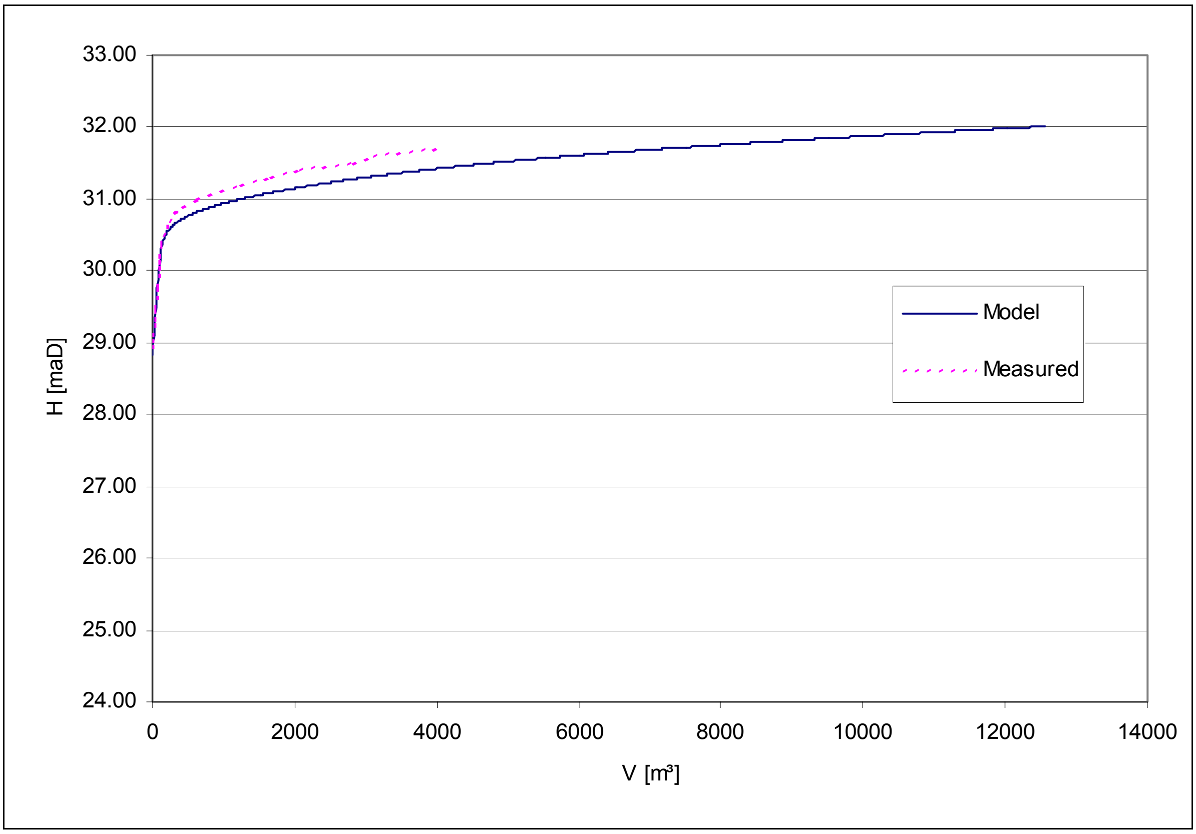


Network model of subcatchment Berlin III

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	12560	4094
storage level [maD]:	32.01	31.70
lowest crest level of cso [maD]:	32.01	

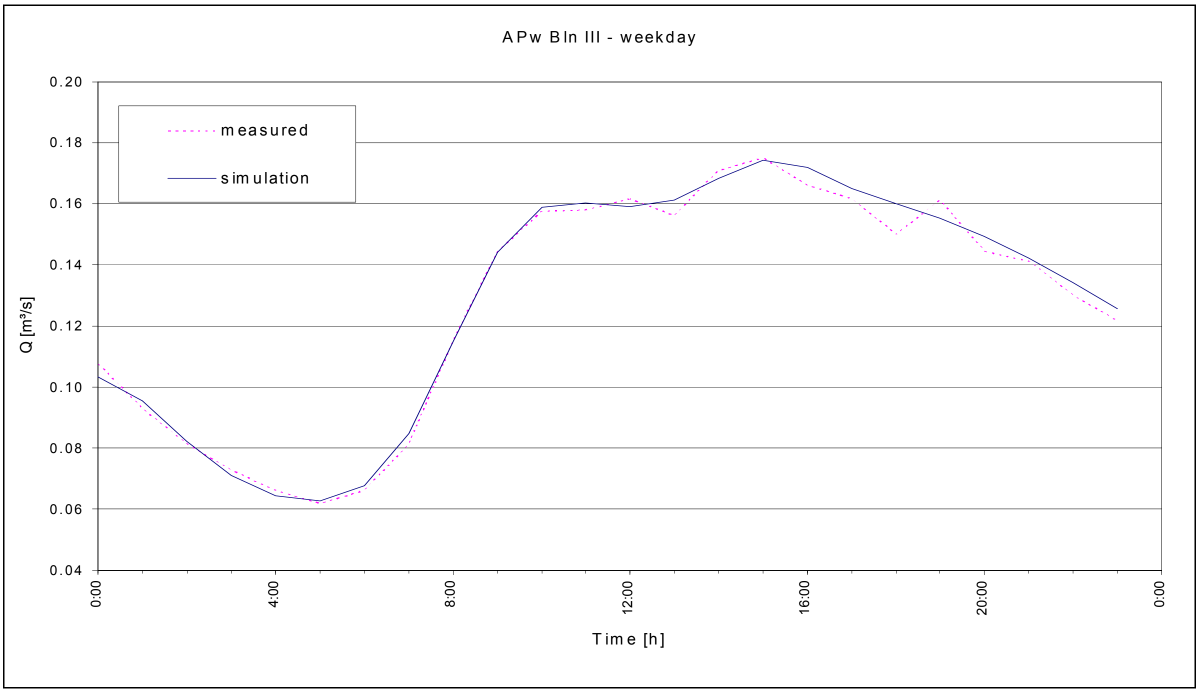
APw Bln III



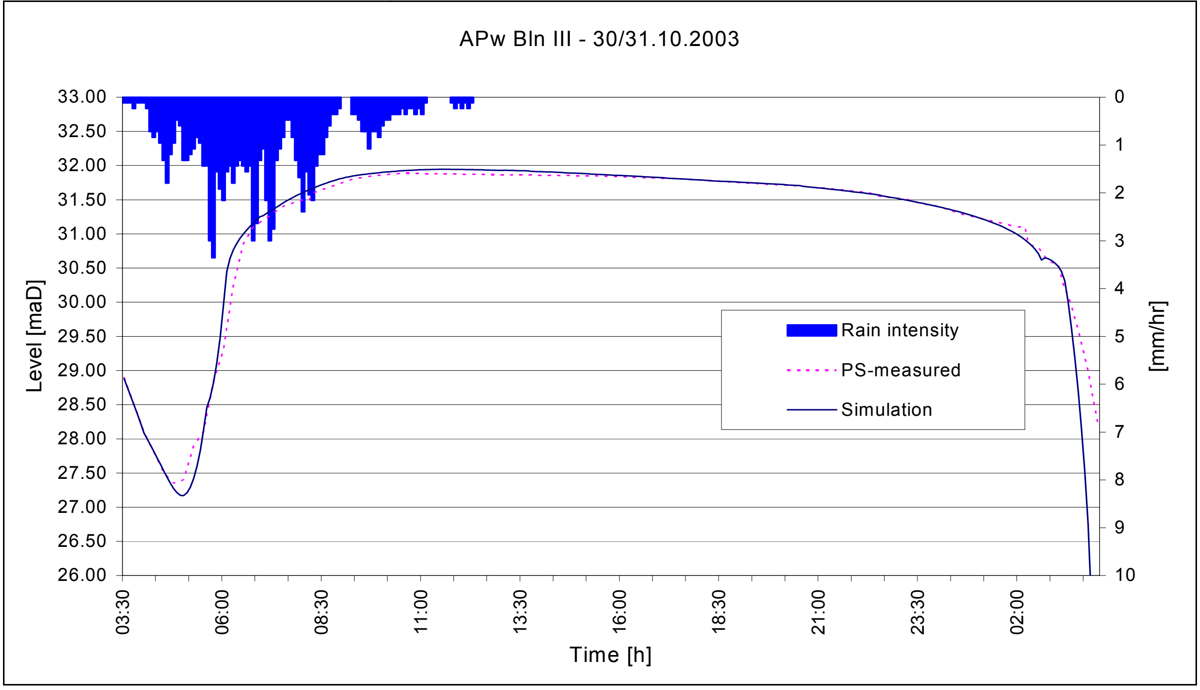
Storage characteristic of sewer network Berlin III

Calibration

Dry Weather: Flow at Pump station Bln III
min flow: 0.062 m³/s
max flow: 0.175 m³/s



Storm Weather: Level at Pump station Bln III



Specifics

- The catchment is characterised by low gradient and in part a low depth of coverage.
- In catchment Bln III rehabilitation and restructuring of the sewer network is still proceeding.
- The dry weather flow (influenced by groundwater input from construction sites) as well as the percentage of impermeable area will have to be adjusted when constructing has stopped.

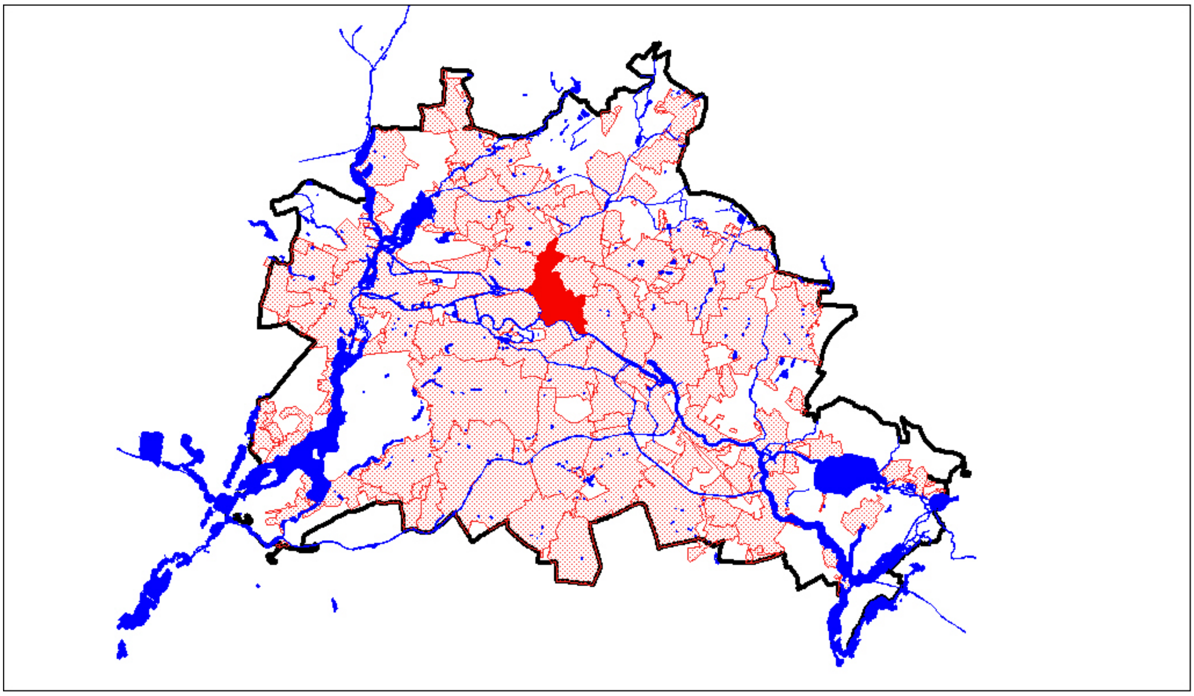
3.4.4 APw Berlin IV

Subcatchment: Berlin IV

Contributing Area: 726 ha

Population: 96880 Inh.

WWTP: dry weather: Ruhleben
storm weather: Ruhleben / Schönerlinde



Location of subcatchment Berlin IV

Model characteristics Berlin IV

System type: Combined

Length of modelled pipes

- **Combined:** 42.304 km
- **Waste water:** -
- **Storm water:** 0.2 km
- **Other:** 14.238 km

Number of Nodes 382

Number of Pump Stations 1

- **Pump Station:** APw Berlin IV, Scharnhorststr.
- **US Node ID:** saugraum_bln4
- **Average dry weather flow:** 224.90 l/s
- **Maximum Capacity**
  - **local:** 0.800 m^3/s
  - **global:** 1.000 m^3/s
- **Destination**
  - **dry weather:** Ruhleben
  - **storm weather:** Ruhleben / Schönerlinde

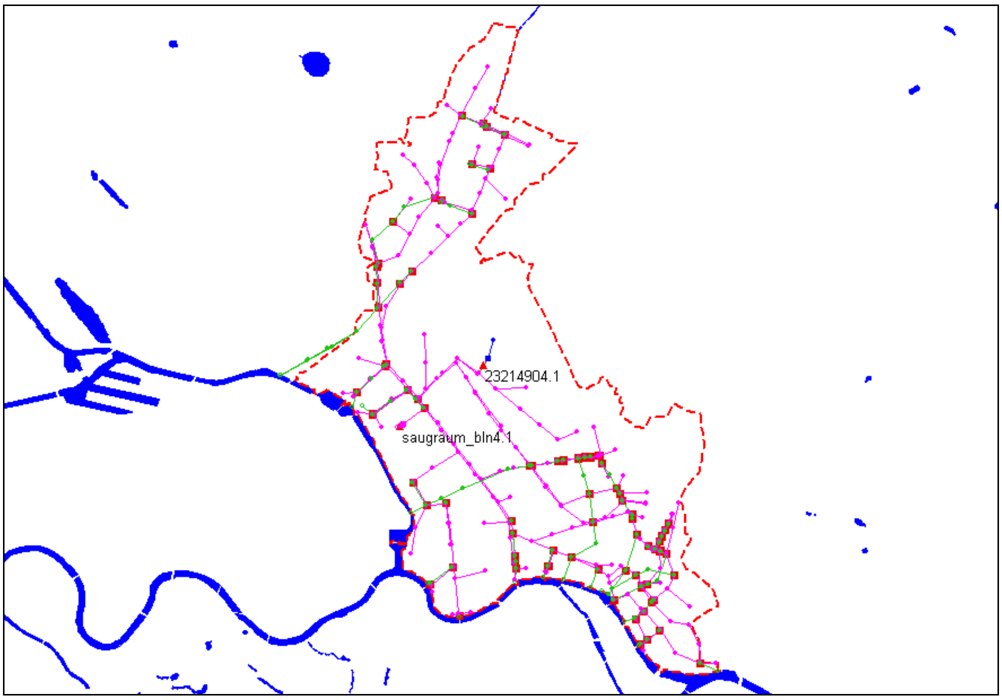
Number of storage tanks and storage sewers: -

Description:
Node ID:
Asset ID:
Volume:

Number of combined sewer overflows: 101

Additional assets:

Inline storage capacity: 2902 m³
Maximum storage level: 31.31 maD

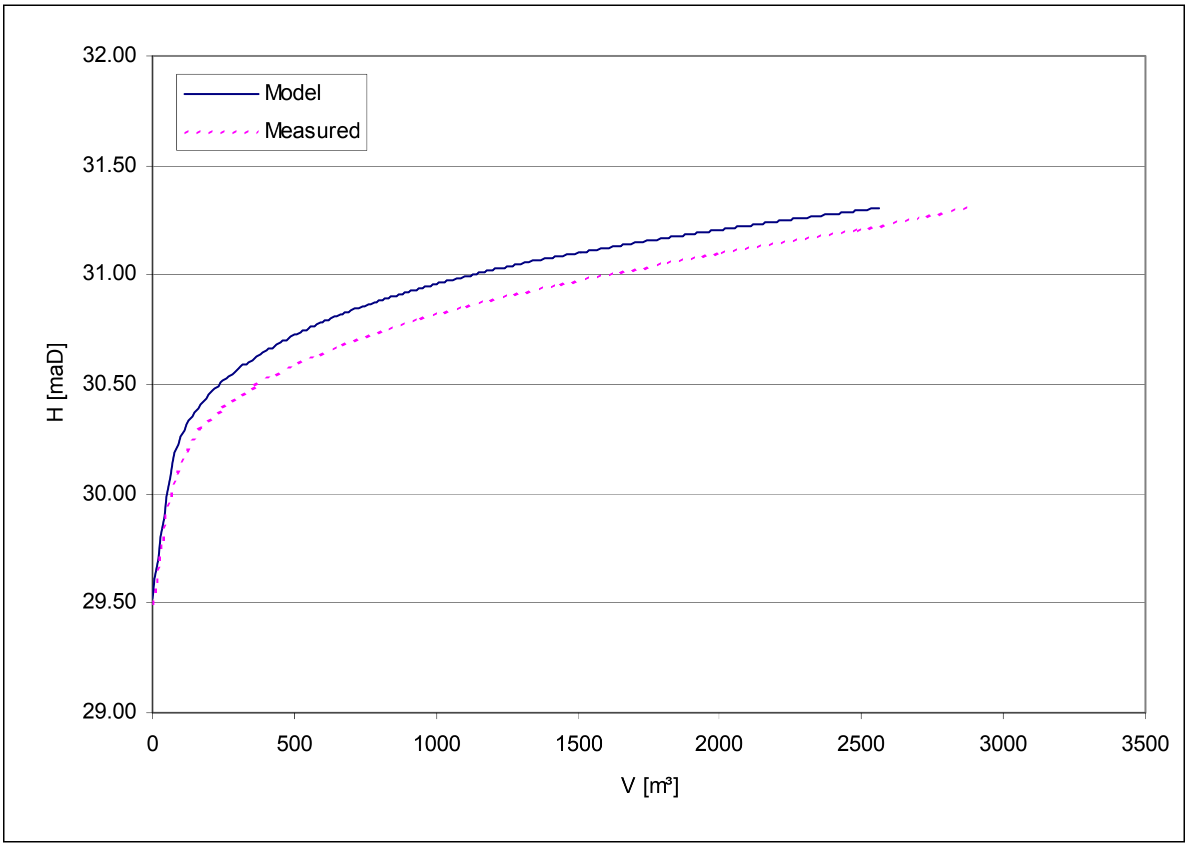


Network model of subcatchment Berlin IV

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	2560	2902
storage level [maD]:	31.31	31.31
lowest crest level of cso [maD]:	31.31	

APw Bln IV

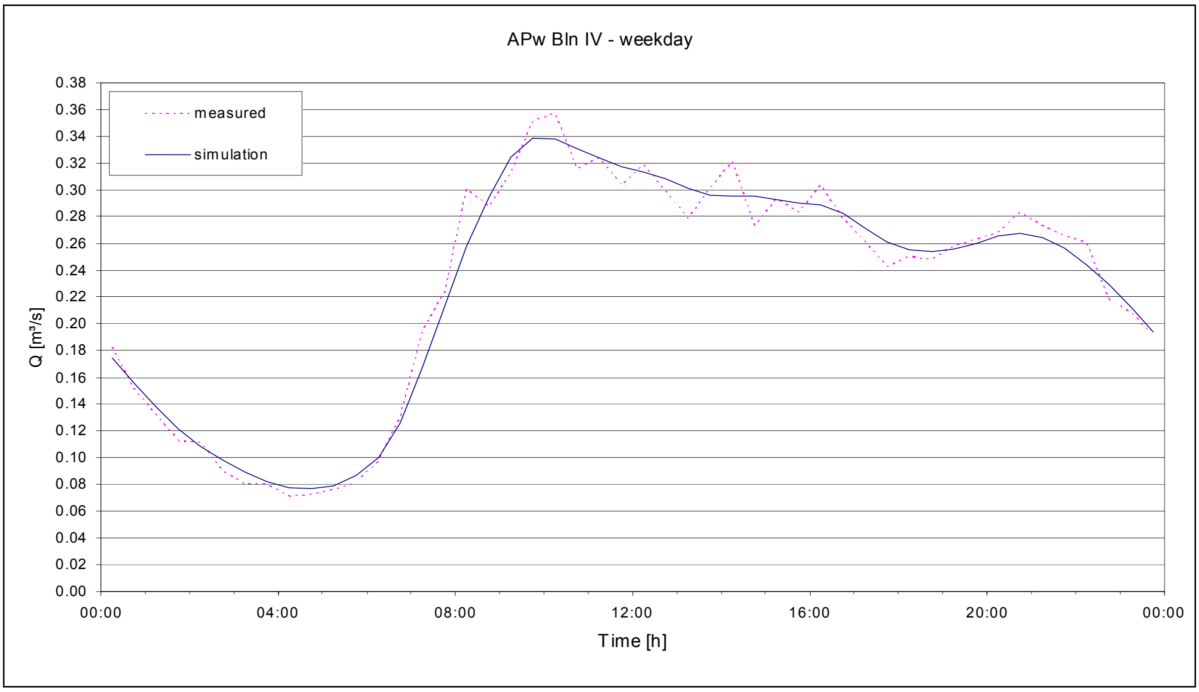


Storage characteristic of sewer network Berlin IV

Calibration

Dry Weather: Flow at Pump station Bln IV

min flow:	0.076 m³/s
max flow:	0.339 m³/s



Storm Weather:

Due to a lack of data a storm weather calibration could not be carried out.

Specifics

- At catchment Bln IV there is a significant need for rehabilitation. Except for the heightening of the weir crests those measures of rehabilitation (e.g. storm water tank of 16.000 m³) have not yet been modelled (network Ruhleben_2010).

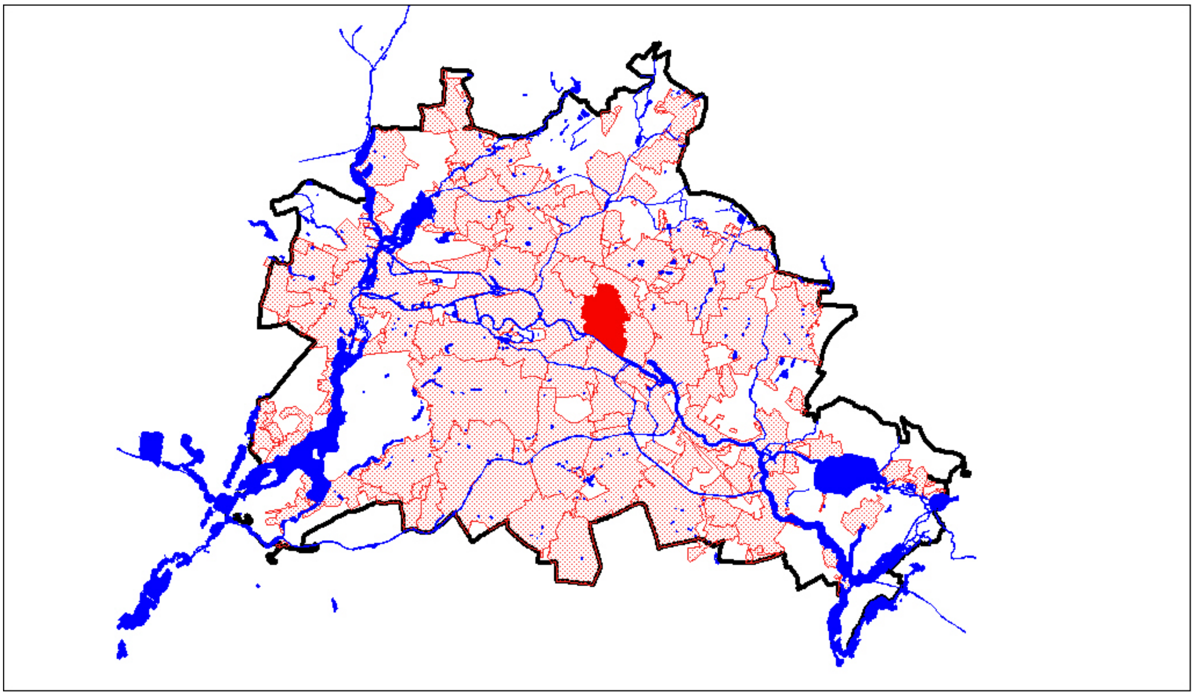
3.4.5 HPw Berlin V

Subcatchment: Berlin V

Contributing Area: 675 ha

Population: 88964 Inh.

WWTP: dry weather: Schönerlinde
storm weather: Schönerlinde



Location of subcatchment Berlin V

Model characteristics Berlin V

System type:	Combined
Length of modelled pipes	
Combined:	27.177 km
Waste water:	-
Storm water:	-
Other:	7.758 km
Number of Nodes:	185
Number of Pump Stations	1
Pump Station:	HPw Berlin V, Holzmarktstr.
US Node ID:	Saugraum_Bln_V
Average dry weather flow:	171.30 l/s
Maximum Capacity	
local:	0.560 m^3/s
global:	0.700 m^3/s
Destination	
dry weather:	Schönerlinde
storm weather:	Schönerlinde

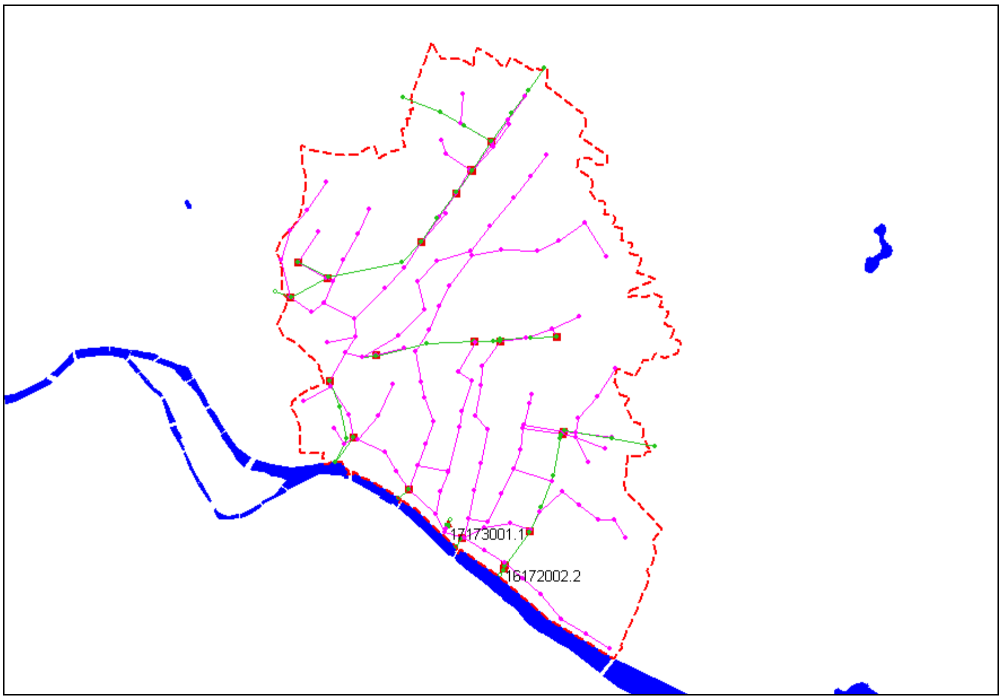
Number of storage tanks and storage sewers: 1

Description: Storage sewer
Node ID: 16172002
Asset ID:
Asset name : SK Straße der Pariser Kommune
Volume: 6200 m³
Filling: Gravity

Number of combined sewer overflows: 18

Additional assets:

Inline storage capacity: 14330 m³
Maximum storage level: 32.69 maD

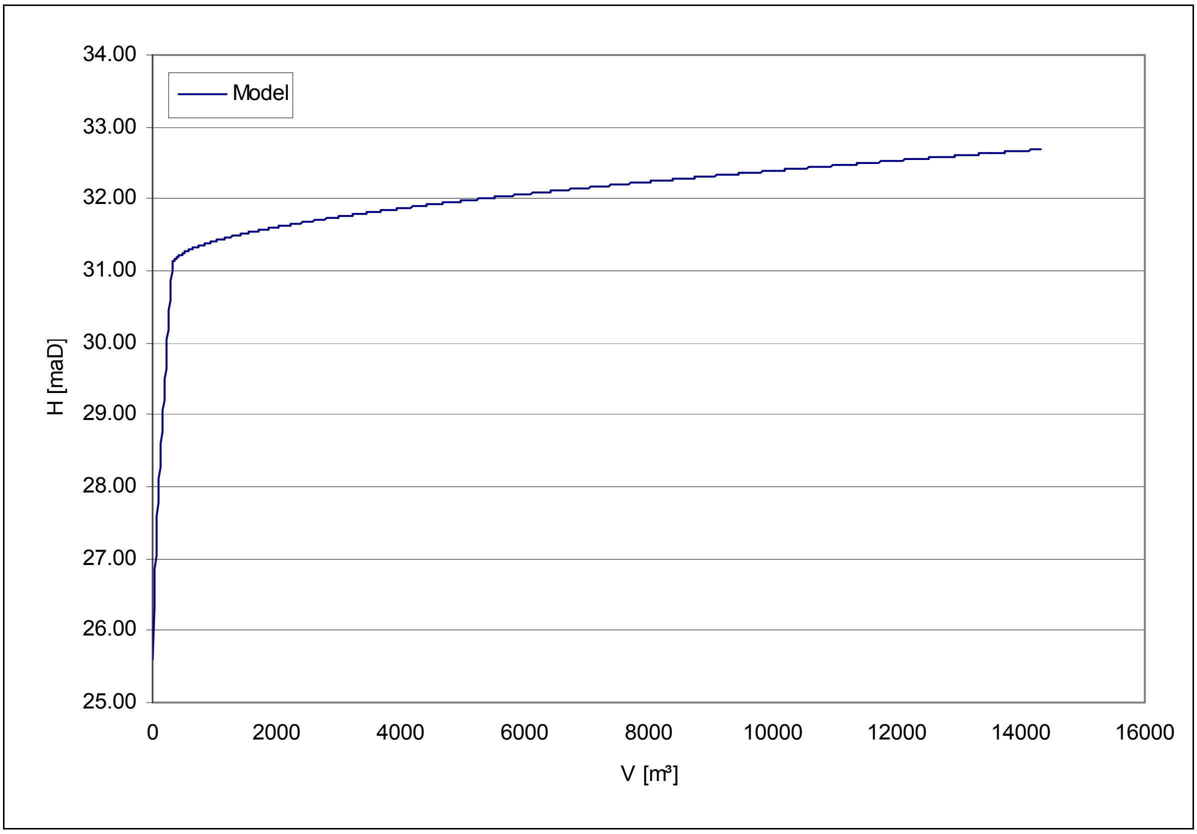


Network model of subcatchment Berlin V

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	14330	-
storage level [maD]:	32.69	-
lowest crest level of cso [maD]:	32.69	

HPw Bln V

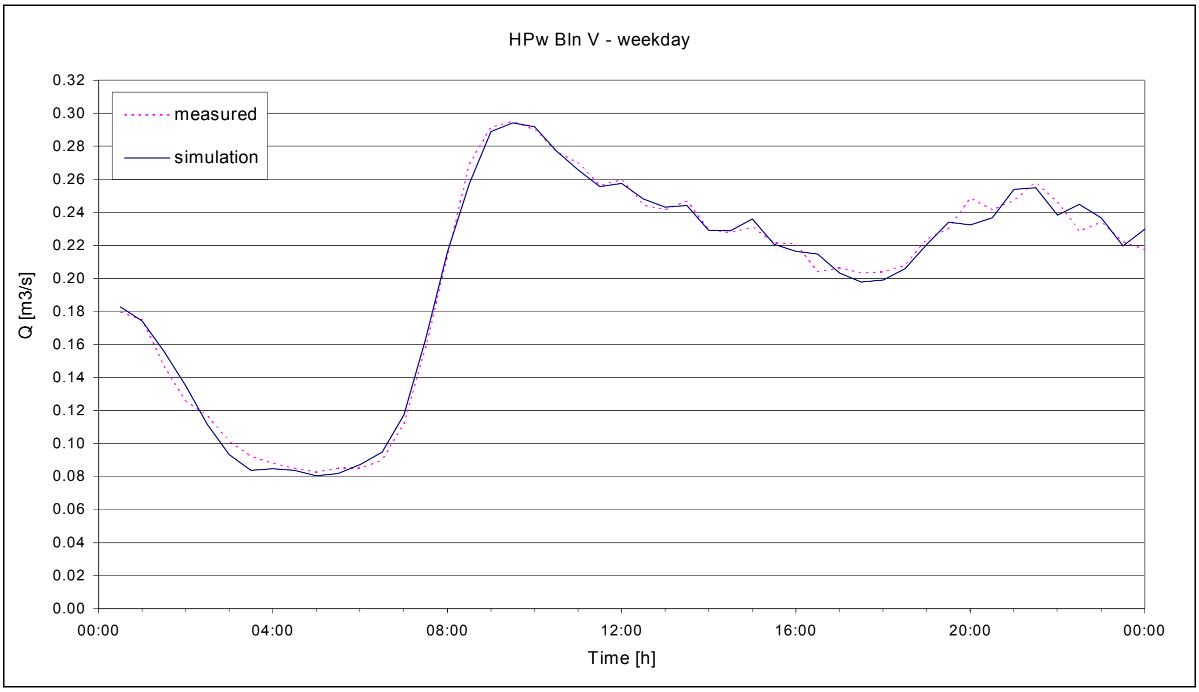


Storage characteristic of sewer network Berlin V

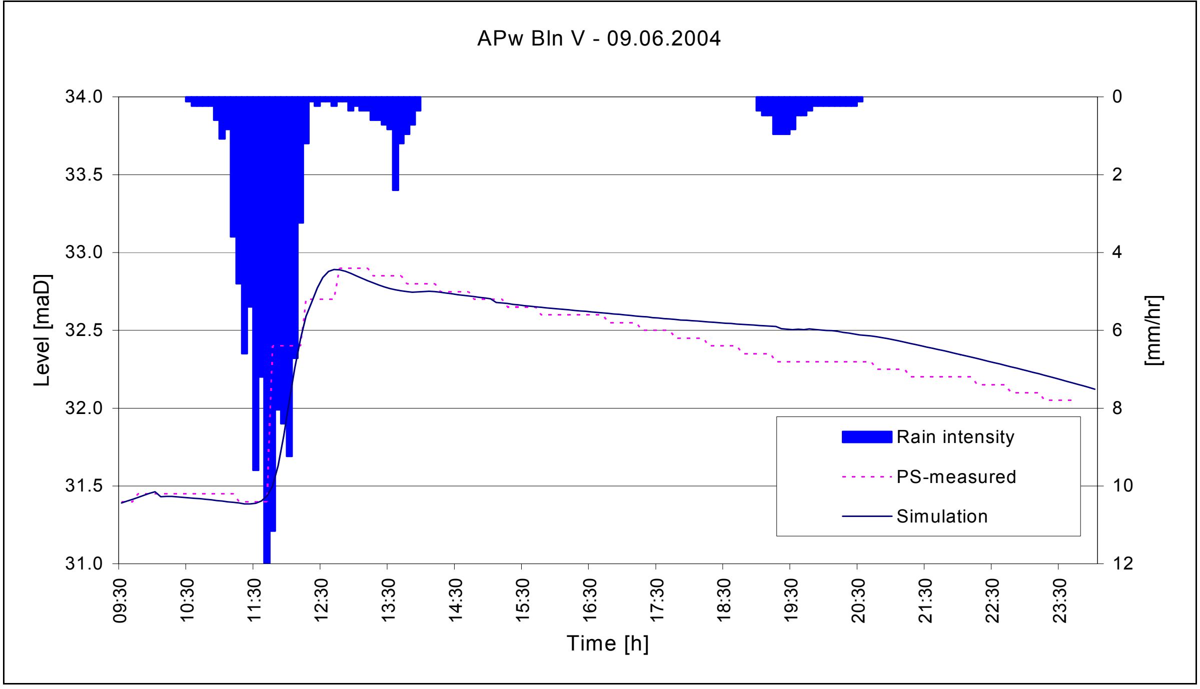
Calibration

Dry Weather: Flow at Pump station Bln V

min flow:	0.080 m³/s
max flow:	0.294 m³/s



Storm Weather: Level at Pump station Bln V



Specifics

- Future measures of rehabilitation (e.g. Alexanderstr.) have not yet been modelled.

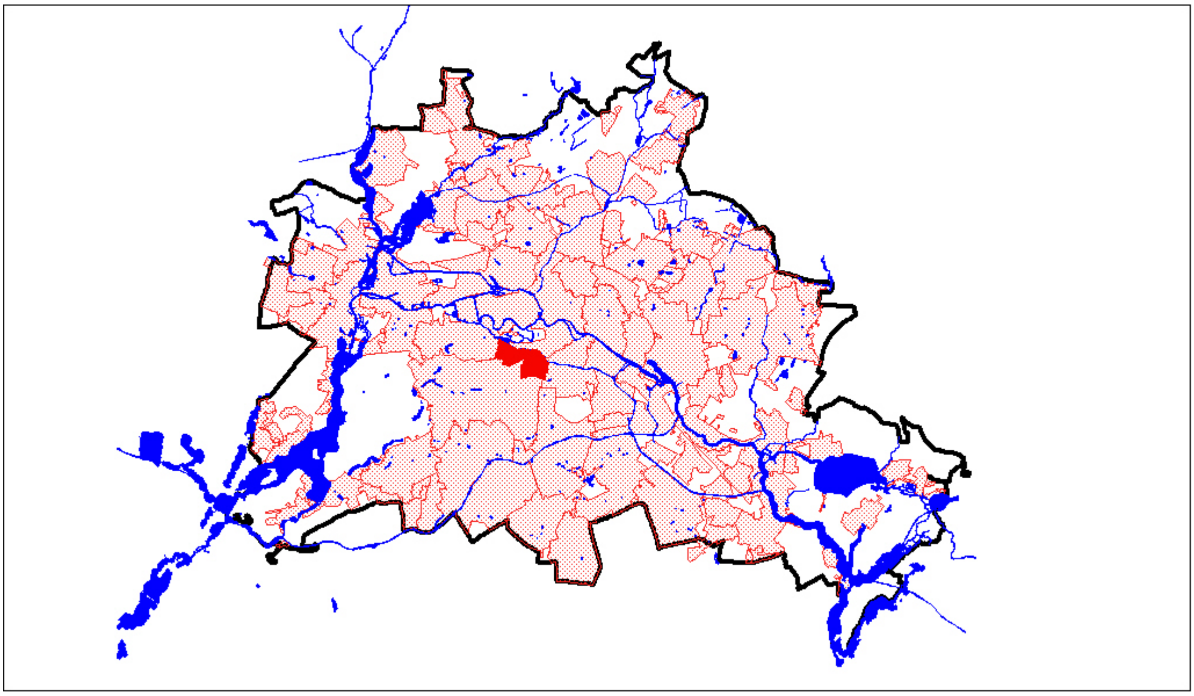
3.4.6 APw Berlin VII

Subcatchment: Berlin VII

Contributing Area: 311 ha

Population: 41935 Inh.

WWTP: dry weather: Ruhleben
storm weather: Ruhleben

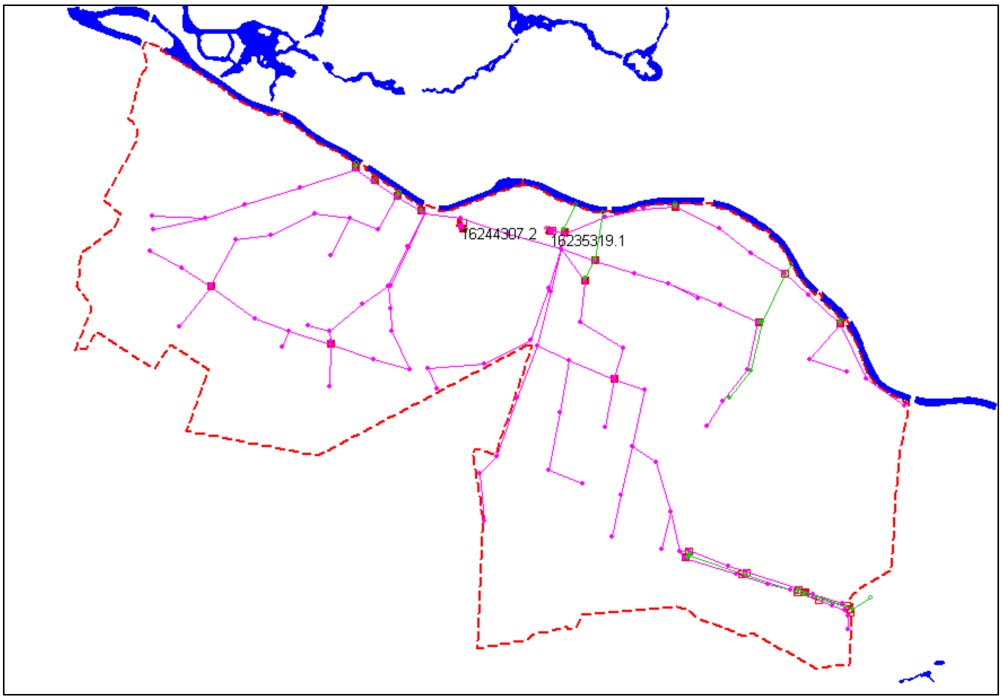


Location of subcatchment Berlin VII

Model characteristics Berlin VII

System type:	Combined
Length of modelled pipes	
Combined:	16.796 km
Waste water:	-
Storm water:	-
Other:	2.124 km
Number of Nodes	142
Number of Pump Stations	1
Pump Station:	APw Berlin VII, Genthiner Str.
US Node ID:	16235319
Average dry weather flow:	138.30 l/s
Maximum Capacity	
local:	0.420 m^3/s
global:	0.500 m^3/s
Destination	
dry weather:	Ruhleben
storm weather:	Ruhleben

Number of storage tanks and storage sewers:	1
Description:	Combined water tank with overflow
Node ID:	16244950
Asset ID:	RUEB LÜTZOWPLATZ
Asset name :	RÜB Lützowplatz
Volume:	1000 m³
Filling:	Pump (833 l/s)
Number of combined sewer overflows:	12
Additional assets:	
Inline storage capacity:	11760 m³
Maximum storage level:	32.16 maD

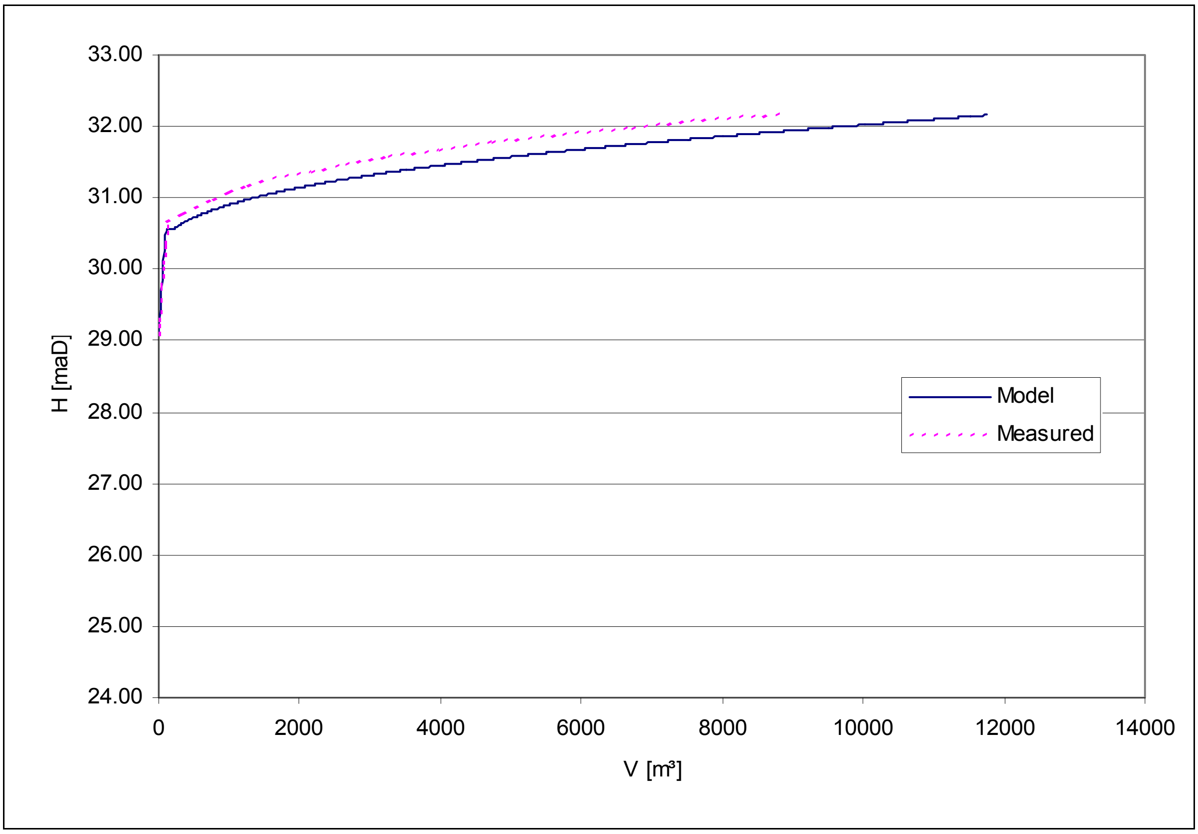


Network model of subcatchment Berlin VII

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	11760	8812
storage level [maD]:	32.16	32.18
lowest crest level of cso [maD]:	32.16	

APw Bln VII



Storage characteristic of sewer network Berlin VII

Measurement Campaign

Measurement points: 3

Name: PS

Location: Pump station Bln VII, Genthiner Str.

Measurements: Flow, water level

Analyzed parameters: TSS, COD, COD_{filtr}, BOD_5, N_{org}, NH_4-N, TKN, P_{tot}

Measurement period: 21/06/2001 – 27/09/2001

Remark: Measurement within and in front of the pump station
Controlled sampling at the inflow to the pump station

Measurement point PS, Bln VII

Name:	M1
Location:	Lützowstr.
Measurements:	Flow, water level
Analyzed parameters:	No sampling
Measurement period:	03/08/2001 – 25/09/2001
Remark:	Only temporary measurements due to low runoff

Measurement point M1, Bln VII

Name: M2

Location: Courbièrestr.

Measurements: Flow, water level

Analyzed parameters: TSS, COD, COD_{filtr}, BOD_5, N_{org}, NH_4-N, TKN, P_{tot}

Measurement period: 06/08/2001 – 30/09/2001

Remark: Good and consistent set of data

Measurement point M2, Bln VII

Name: R1

Location: Zoo

Measurements: Rainfall

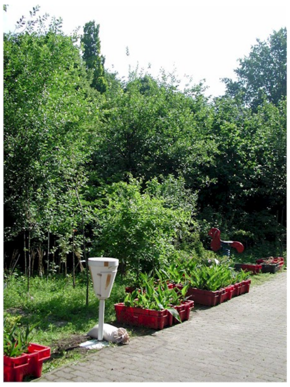
Measurement period: 01/08/2001 – 30/09/2001

Name: R2

Location: Kleistpark

Measurements: Rainfall

Measurement period: 01/08/2001 – 30/09/2001



Measured dry weather events

PS

Date	V [m³]	Q_{mean} [m³/s]	TSS [mg/l]	COD [mg/l]	BOD [mg/l]	Norg [mg/l]	NH4 [mg/l]	Ptot [mg/l]
01.08.2001	12669	0,147	783,04	1377,39	316,52	30,09	34,26	9,86
22.08.2001	13223	0,153	452,50	925,00	275,00	21,58	38,79	9,58
26.08.2001	11586	0,134	450,83	960,83	280,83	22,10	35,15	8,51

M2

Date	V [m³]	Q_{mean} [m³/s]	TSS [mg/l]	COD [mg/l]	BOD [mg/l]	Norg [mg/l]	NH4 [mg/l]	Ptot [mg/l]
01.08.2001	1820	0,021	312,73	787,73	328,18	17,27	44,18	9,93
22.08.2001	2643	0,031	302,73	789,09	371,82	19,45	43,64	9,31
26.08.2001	2062	0,024	267,27	671,82	262,73	17,18	39,36	8,35

Measured storm weather events

PS

Date	V [m³]	Q_{mean} [m³/s]	TSS [mg/l]	COD [mg/l]	BOD [mg/l]	Norg [mg/l]	NH4 [mg/l]	Ptot [mg/l]
4.8.2001	9748	0.271	131.55	209.82	60.68	6.45	11.55	2.80
8.9.2001	18249	0.255	260.83	518.75	156.67	15.58	17.46	5.30
18.9.2001	15125	0.300	270.92	426.67	-	13.43	12.61	4.73

M2

Date	V [m³]	Q_{mean} [m³/s]	TSS [mg/l]	COD [mg/l]	BOD [mg/l]	Norg [mg/l]	NH4 [mg/l]	Ptot [mg/l]
8.9.2001	3310	0.077	74.00	220.42	49.17	6.86	12.43	5.07
18.9.2001	5727	0.114	246.50	550.42	-	13.49	9.13	4.91

Calibration

Event Identification

Date	Start	End	Rain Duration	Rain Height	Rain I_{max}
Dry Weather, Hydraulic					
14.8.2001	00:00	00:00	-	-	-
29.8.2001	00:00	00:00	-	-	-
1.9.2001	00:00	00:00	-	-	-
2.9.2001	00:00	00:00	-	-	-
Storm Weather, Hydraulic					
4.8.2001	18:00	06:00	00:45 h	3.9 mm	51.0 mm/h
13.8.2001	04:30	20:45	06:39 h	7.9 mm	5.3 mm/h
7.9.2001	19:20	16:20	10:07 h	9.5 mm	7.0 mm/h
Dry Weather, Quality					
26.8.2001	00:00	00:00	-	-	-
Storm Weather, Quality					
4.8.2001	18:30	06:00	00:45 h	3.9 mm	51.0 mm/h

Comparison Measurement – Simulation

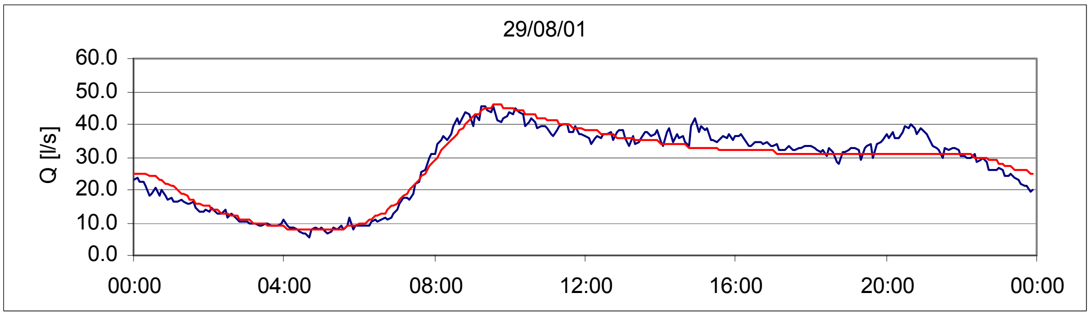
Hydraulic

Date	V_{meas} [m³]	V_{sim} [m³]	$Qmax_{meas}$ [m³/s]	$Qmax_{sim}$ [m³/s]	$Qmin_{meas}$ [m³/s]	$Qmin_{sim}$ [m³/s]
Dry Weather						
14.8.2001	2116	2036	0.044	0.035	0.002	0.009
29.8.2001	2398	2377	0.046	0.046	0.006	0.008
1.9.2001	2556	2189	0.050	0.038	0.010	0.009
2.9.2001	2265	2192	0.040	0.038	0.005	0.009
Storm Weather						
4.8.2001	10814	10808	0.467	0.404	0.104	0.100
13.8.2001	3845	3595	0.178	0.180	0.002	0.007
7.9.2001	4795	3823	0.185	0.180	0.039	0.018

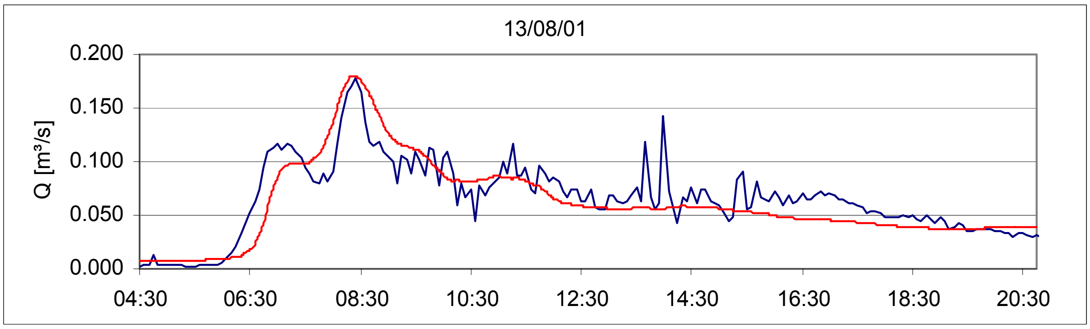
Quality [NH4-N at PS]

Date	M_{meas} [kg]	M_{sim} [kg]	$Cmax_{meas}$ [mg/l]	$Cmax_{sim}$ [mg/l]	$Cmin_{meas}$ [mg/l]	$Cmin_{sim}$ [mg/l]
Dry Weather						
22.8.2001	492.4	491.5	45.0	43.0	31.0	28.9
Storm Weather						
4.8.2001	95.5	103.2	33.0	35.1	4.4	5.6

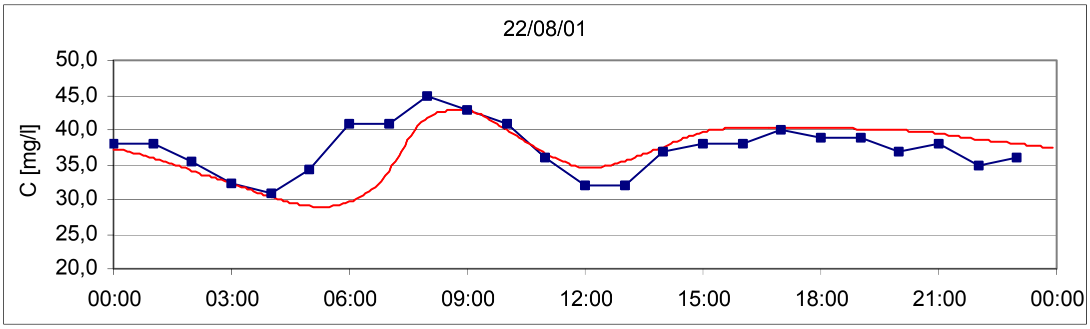
Dry Weather: Flow at M2



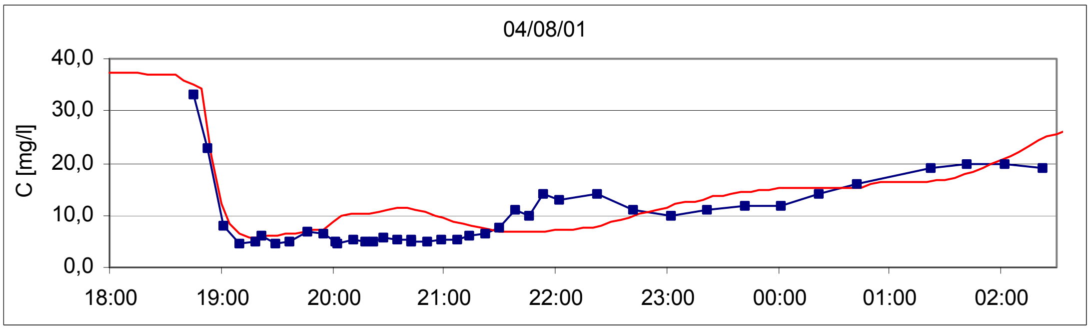
Storm Weather: Flow at M2



Dry Weather: NH4-N Concentration at PS



Storm Weather: NH4-N Concentration at PS



Validation

Event Identification

Date	Start	End	Rain Duration	Rain Height	Rain I_{max}
Dry Weather, Hydraulic					
15.8.2001	00:00	00:00	-	-	-
16.8.2001	00:00	00:00	-	-	-
25.8.2001	00:00	00:00	-	-	-
26.8.2001	00:00	00:00	-	-	-
30.8.2001	00:00	00:00	-	-	-
Storm Weather, Hydraulic					
6.8.2001	17:36	05:15	00:29 h	1.2 mm	51.0 mm/h
13.9.2001	10:30	22:45	09:52 h	4.4 mm	4.2 mm/h
18.9.2001	08:00	06:00	10:20 h	22.87 mm	29.0 mm/h
Dry Weather, Quality					
26.8.2001	00:00	00:00	-	-	-
Storm Weather, Quality					
7.9.2001	19:20	16:20	10:07 h	9.5 mm	7.0 mm/h
18.9.2001	08:00	06:00	10:20 h	22.87 mm	29.0 mm/h

Comparison Measurement – Simulation

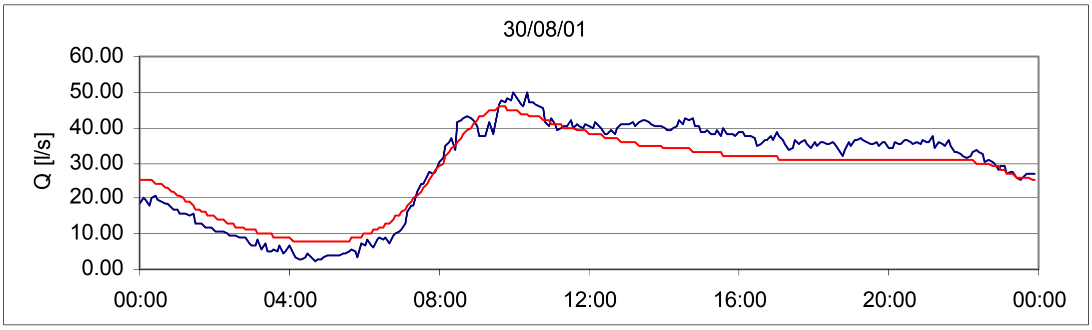
Hydraulic

Date	V_{meas} [m³]	V_{sim} [m³]	$Qmax_{meas}$ [m³/s]	$Qmax_{sim}$ [m³/s]	$Qmin_{meas}$ [m³/s]	$Qmin_{sim}$ [m³/s]
Dry Weather						
15.8.2001	2178	2036	0.040	0.035	0.002	0.009
16.8.2001	2339	2036	0.042	0.035	0.004	0.009
25.8.2001	2370	2189	0.044	0.038	0.004	0.009
26.8.2001	1955	2192	0.037	0.038	0.004	0.009
30.8.2001	2472	2377	0.050	0.046	0.003	0.008
Storm Weather						
6.8.2001	606	744	0.138	0.156	0.027	0.034
13.9.2001	1446	1428	0.106	0.104	0.034	0.030
18.9.2001	6500	7477	0.247	0.245	0.004	0.007

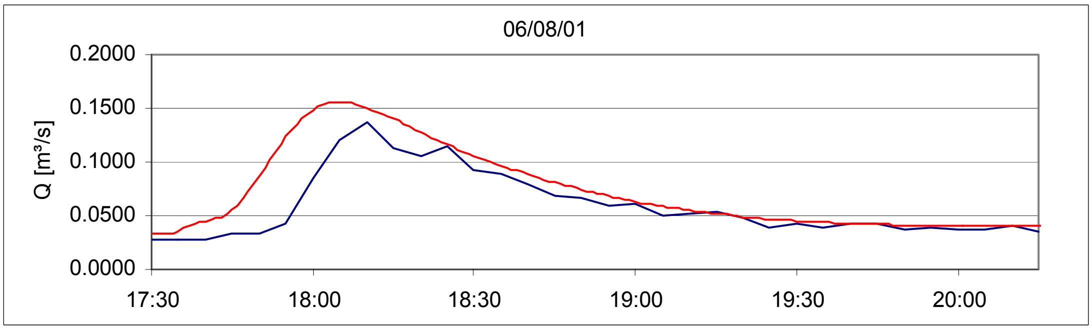
Quality [NH4-N at PS]

Date	M_{meas} [kg]	M_{sim} [kg]	$Cmax_{meas}$ [mg/l]	$Cmax_{sim}$ [mg/l]	$Cmin_{meas}$ [mg/l]	$Cmin_{sim}$ [mg/l]
Dry Weather						
26.8.2001	435.4	417.7	51.0	52.5	22.0	21.7
Storm Weather						
7.9.2001	62.0	60.9	27.0	36.0	6.9	4.7
18.9.2001	67.0	51.1	39.0	37.3	5.2	4.7

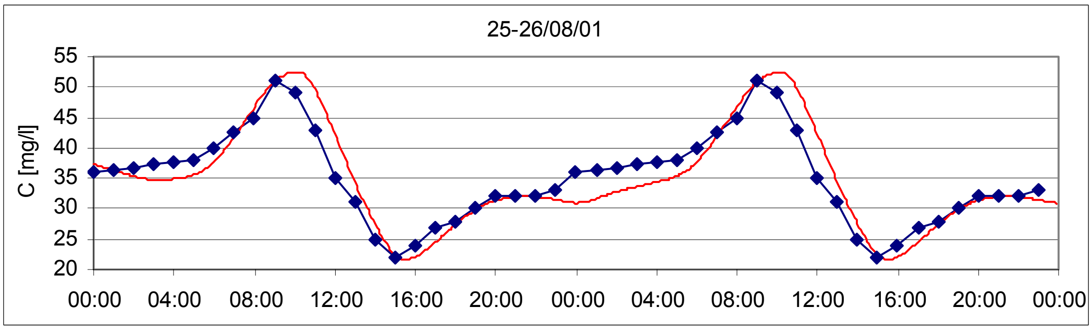
Dry Weather: Flow at M2



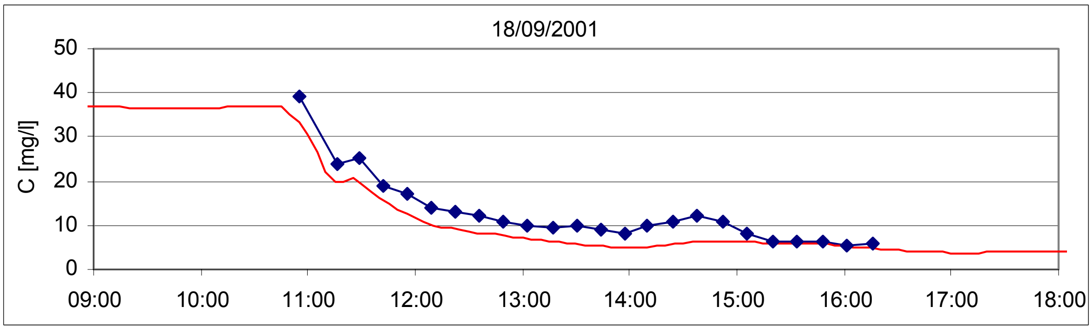
Storm Weather: Flow at M2



Dry Weather: NH4-N Concentration at PS



Storm Weather: NH4-N Concentration at PS

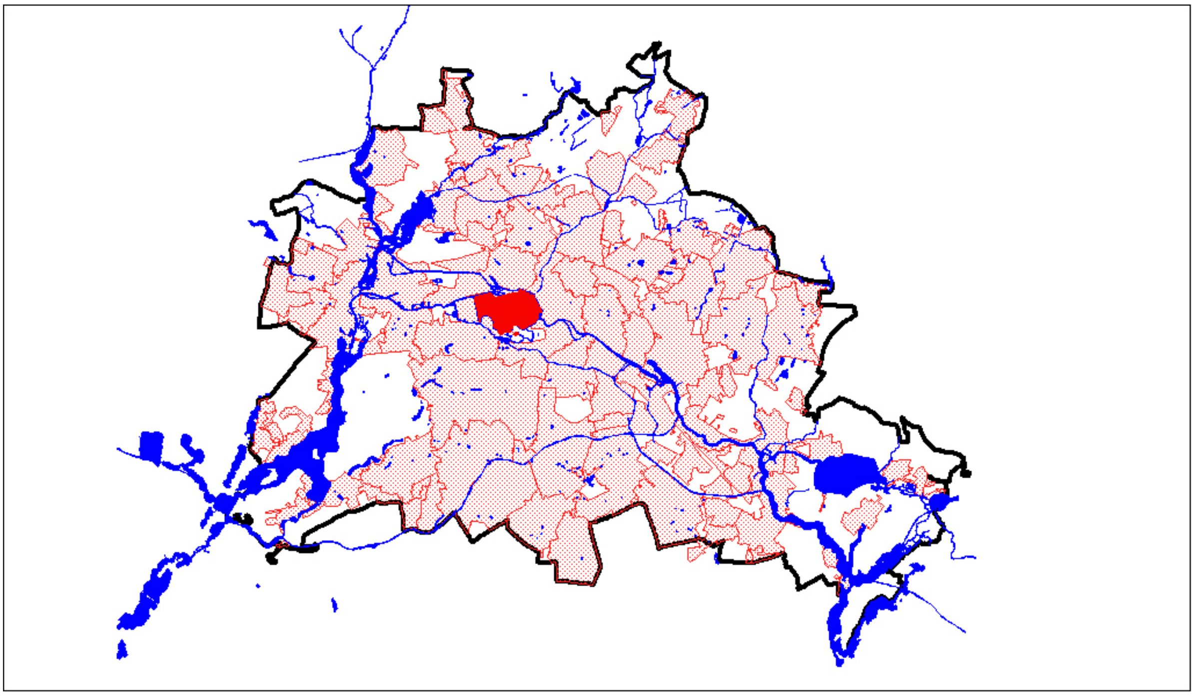


Specifics

- Special observations on catchment Bln VII are the very low gradient and the extreme backwater effect during rain events leading to high accumulation of sediments within the sewerage, especially in front of the pump station.
- High peaks of TSS (and attached pollutants) concentration and massflow due to these conditions.
- The extreme processes of sedimentation and remobilisation cannot be reproduced by the model.

3.4.7 APw Berlin VIII

Subcatchment:	Berlin VIII	
Contributing Area:	516 ha	
Population:	79114 Inh.	
WWTP:	dry weather:	Ruhleben
	storm weather:	Ruhleben



Location of subcatchment Berlin VIII

Model characteristics Berlin VIII

System type:	Combined
Length of modelled pipes	
Combined:	22.292 km
Waste water:	-
Storm water:	-
Other:	2.910 km
Number of Nodes	157
Number of Pump Stations	1
Pump Station:	APw Berlin VIII, Alt Moabit
US Node ID:	saugraum_Bln8
Average dry weather flow:	143.10 l/s
Maximum Capacity	
local:	0.690 m^3/s
global:	1.000 m^3/s
Destination	
dry weather:	Ruhleben
storm weather:	Ruhleben

Number of storage tanks and storage sewers: 1

Description: Combined water tank with overflow
Node ID: Rub_Bln8
Asset ID: RUEB Alt-Moabit
Asset name : RÜB Alt-Moabit
Volume: 1500 m³
Filling: Pump (1050 l/s)

Number of combined sewer overflows: 19

Additional assets:

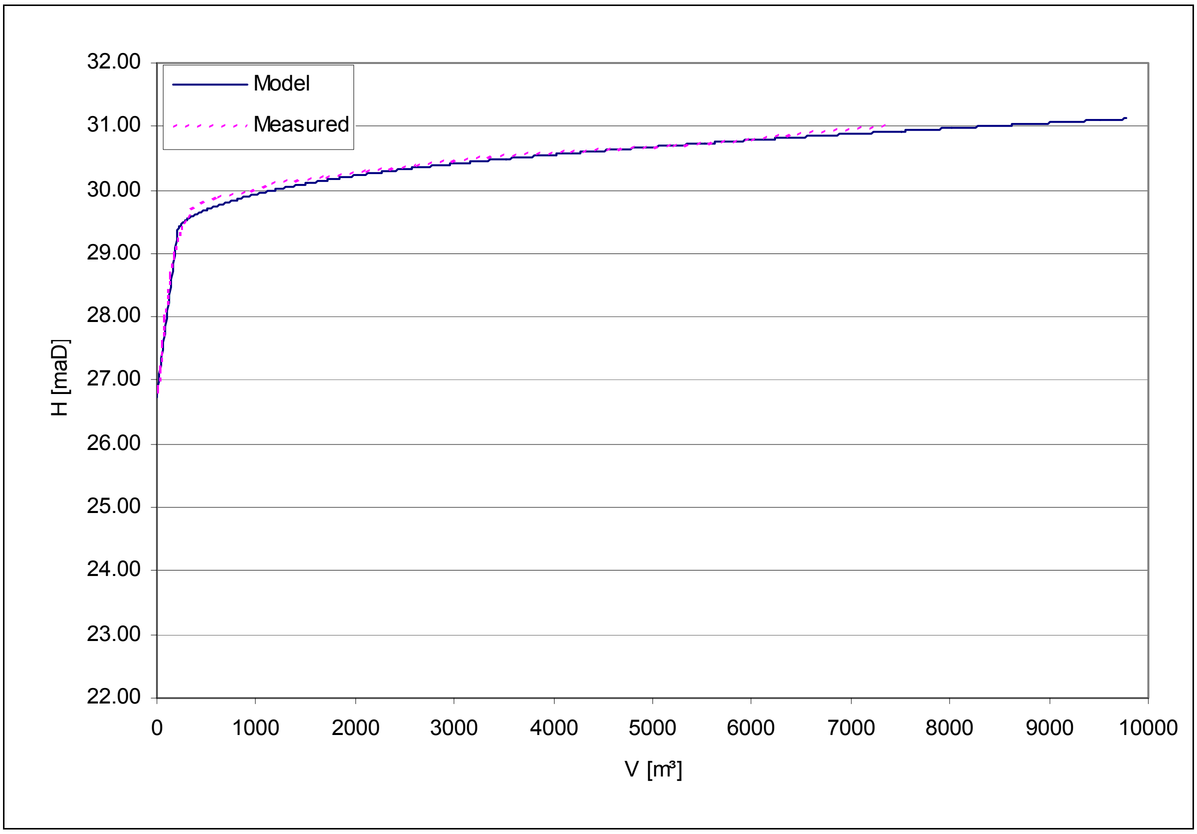
Inline storage capacity: 9770 m³
Maximum storage level: 31.12 maD

Network model of subcatchment Berlin VIII

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	9770	7388
storage level [maD]:	31.12	31.00
lowest crest level of cso [maD]:	31.12	

APw Bln VIII

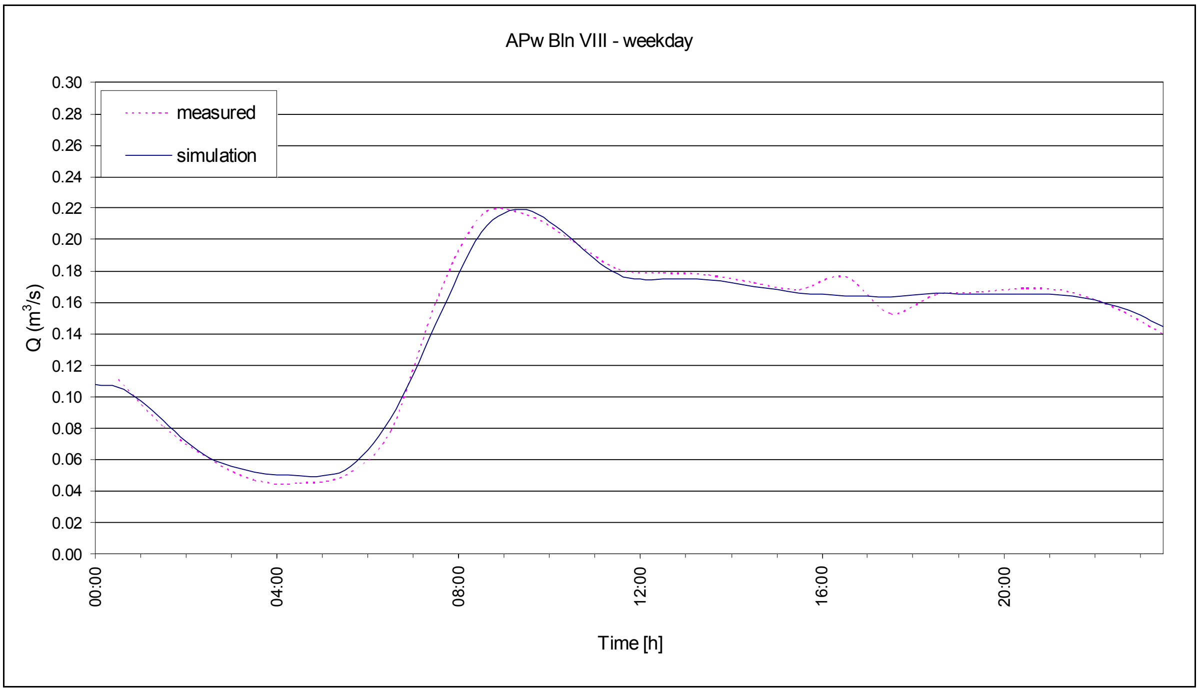


Storage characteristic of sewer network Berlin VIII

Calibration

Dry Weather: Flow at Pump station Bln VIII

min flow:	0.050 m³/s
max flow:	0.219 m³/s



Storm Weather:

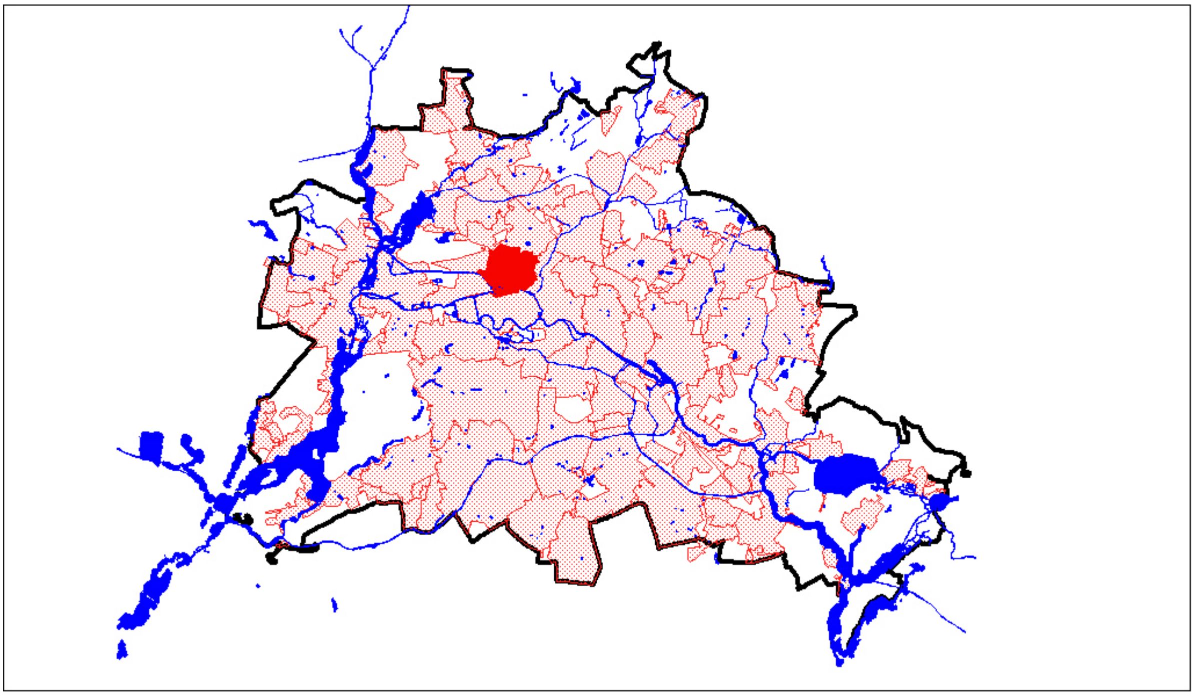
Due to a lack of data a storm weather calibration could not be carried out.

Specifics

- At catchment Bln VIII there will be a new situation concerning wastewater inflow due to the commissioning of the new railway station “Berliner Hauptbahnhof”.
- Furthermore, significant rehabilitations of hydraulic bottlenecks will be realised in the future.
- The model will have to be adapted to these changes.

3.4.8 APw Berlin IX

Subcatchment:	Berlin IX	
Contributing Area:	478 ha	
Population:	70874 Inh.	
WWTP:	dry weather:	Ruhleben
	storm weather:	Ruhleben



Location of subcatchment Berlin IX

Model characteristics Berlin IX

System type:	Combined
Length of modelled pipes	
Combined:	17.328 km
Waste water:	-
Storm water:	-
Other:	0.772 km
Number of Nodes:	109
Number of Pump Stations	1
Pump Station:	APw Berlin IX, Seestr.
US Node ID:	saugraum
Average dry weather flow:	152.20 l/s
Maximum Capacity	
local:	0.450 m^3/s
global:	0.600 m^3/s
Destination	
dry weather:	Ruhleben
storm weather:	Ruhleben

Number of storage tanks and storage sewers: 2

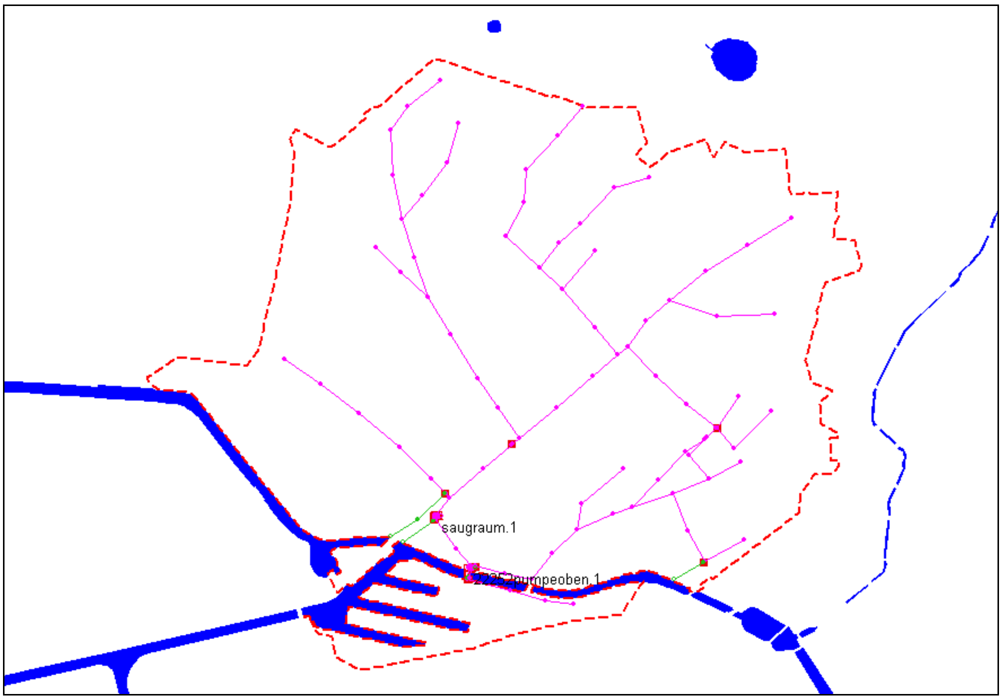
Description: Main sewer with dynamic weir
Node ID: weir_us
Asset ID:
Asset name : Mischkanal Seestr./Afrikanische Str.
Volume: 3600 m³

Description: Combined water tank with overflow
Node ID: 23256rueb
Asset ID:
Asset name : RÜB Seestr.
Volume: 2000 m³
Filling: Gravity

Number of combined sewer overflows: 5

Additional assets:

Inline storage capacity: 5880 m³
Maximum storage level: 31.30 maD

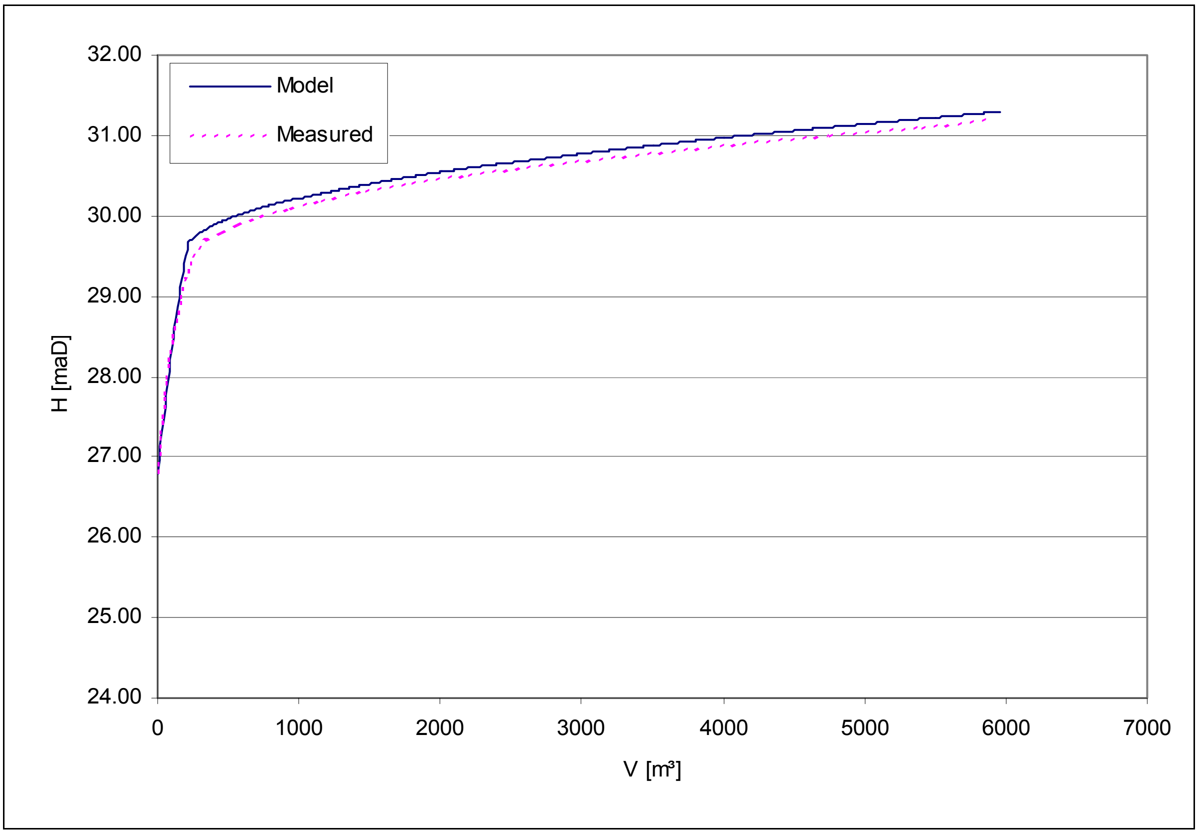


Network model of subcatchment Berlin IX

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	5960	5880
storage level [maD]:	31.30	31.30
lowest crest level of cso [maD]:	31.30	

APw Bln IX



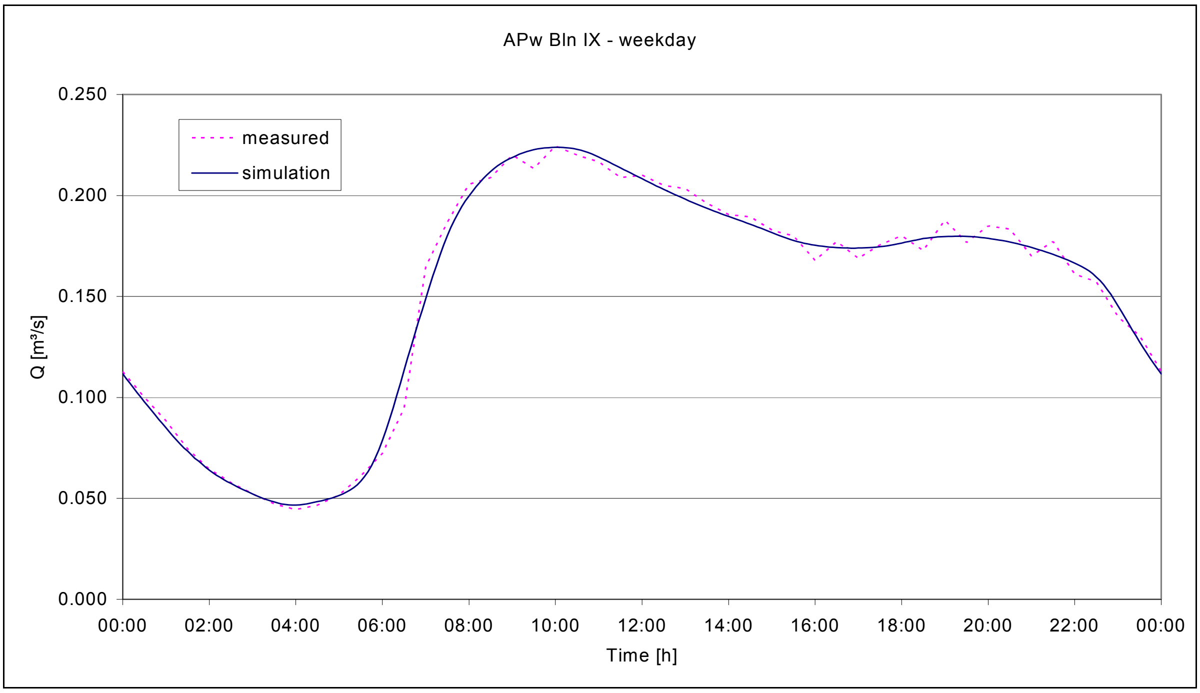
Storage characteristic of sewer network Berlin IX

Calibration

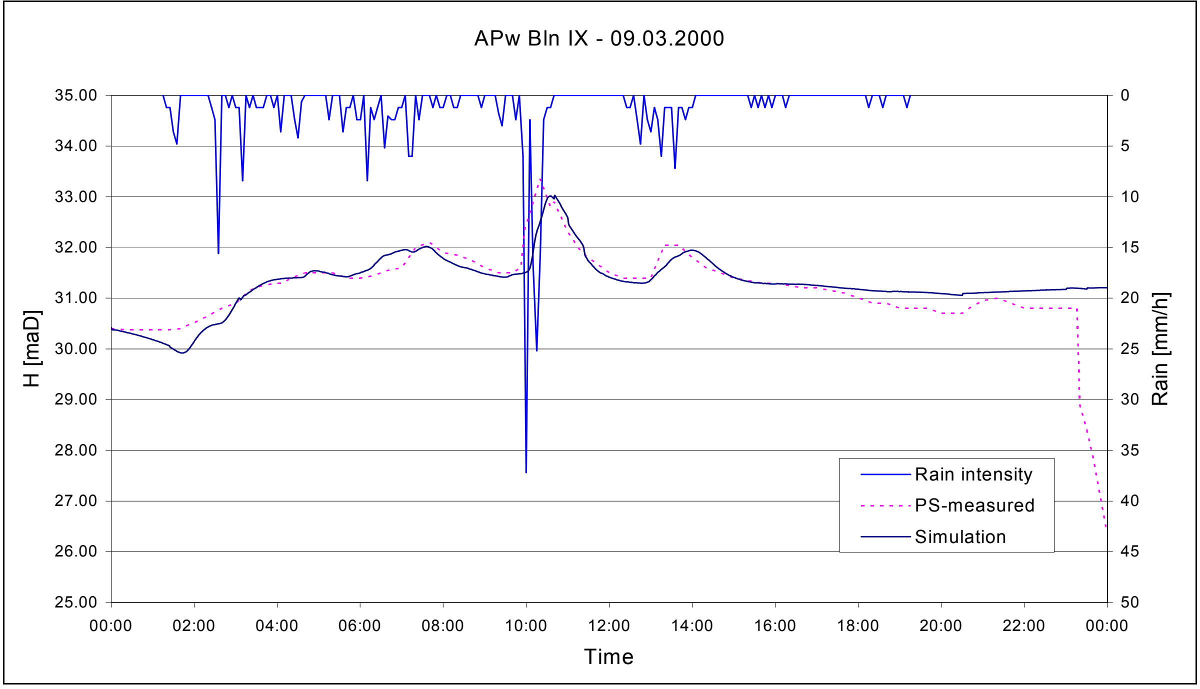
Dry Weather: Flow at Pump station Bln IX

min flow: 0.047 m³/s

max flow: 0.224 m³/s



Storm Weather: Level at Pump station Bln IX

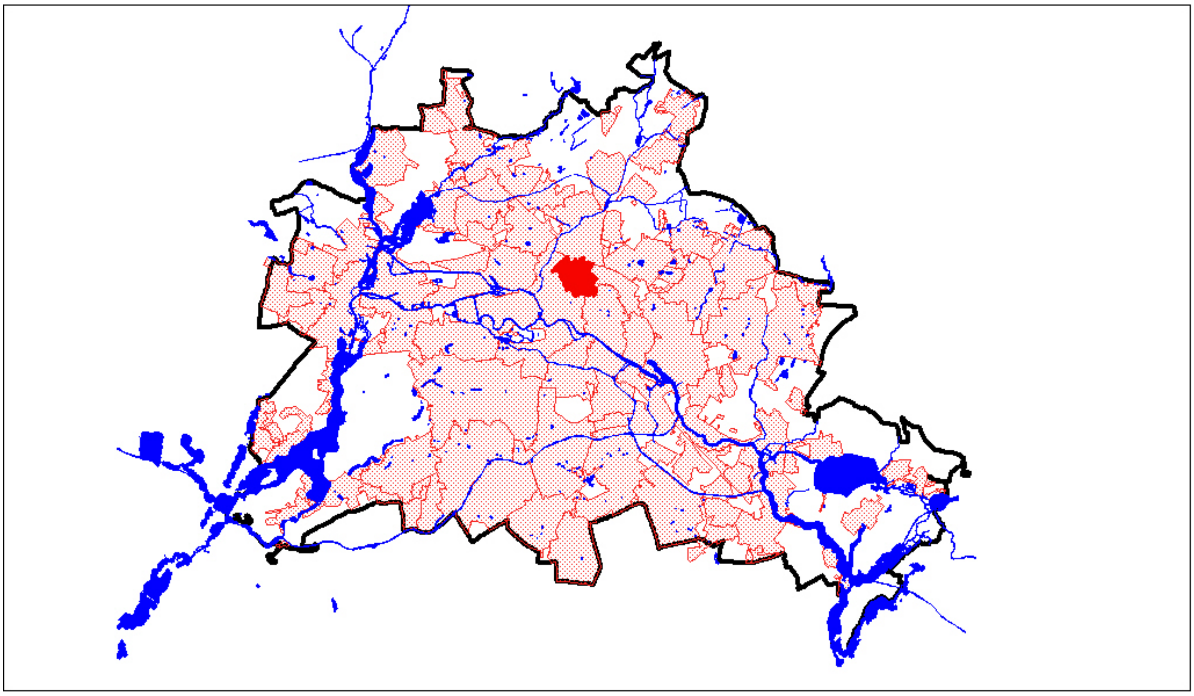


Specifics

- At catchment Bln IX there is a high number of local regulators that have been modelled in detail.
- The state of full rehabilitation has been modelled (network Ruhleben_2010).
- Several times during pollutant simulation numerical instabilities have been observed near pump station Bln IX. These may come from the topology of the network closing a circle between pump station and storm water tank. Thereupon, the model has been modified by reproducing the emptying of the tank by a pump. Nevertheless, attention should be paid to future simulation results at Bln IX.

3.4.9 APw Berlin X

Subcatchment:	Berlin X	
Contributing Area:	359 ha	
Population:	68577 Inh.	
WWTP:	dry weather:	Ruhleben
	storm weather:	Ruhleben



Location of subcatchment Berlin X

Model characteristics Berlin X

System type:	Combined
Length of modelled pipes	
Combined:	12.270 km
Waste water:	-
Storm water:	0.40 km
Other:	6.830 km
Number of Nodes	223
Number of Pump Stations	1
Pump Station:	APw Berlin X, Bellermannstr.
US Node ID:	25214002
Average dry weather flow:	122.80 l/s
Maximum Capacity	
local:	0.370 m^3/s
global:	0.600 m^3/s
Destination	
dry weather:	Ruhleben
storm weather:	Ruhleben

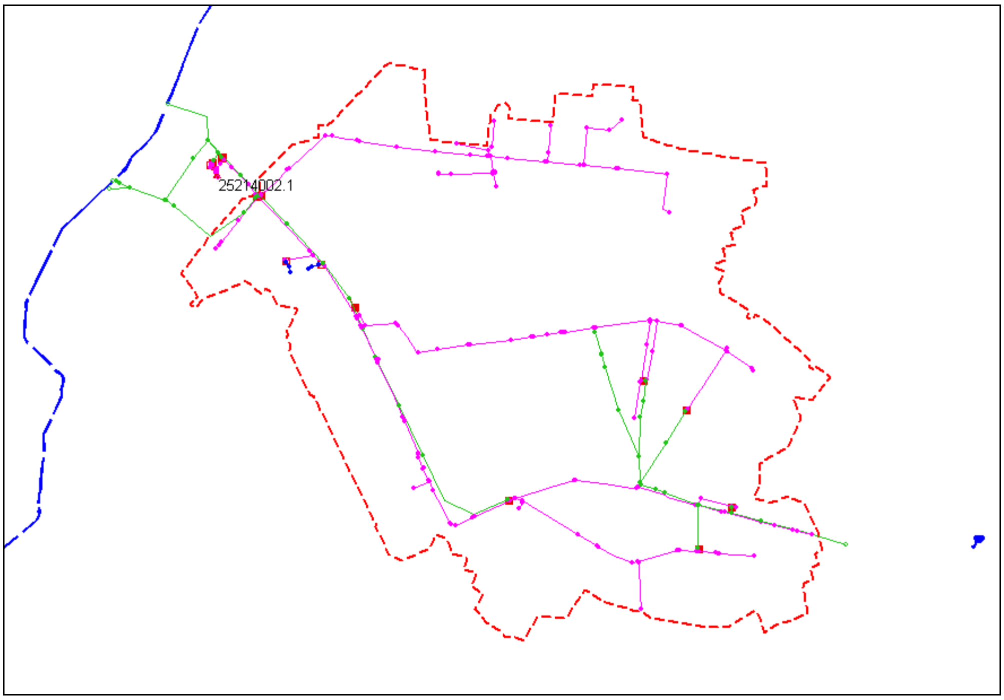
Number of storage tanks and storage sewers: 1

Description: Combined water tank with overflow
Node ID: 25214952
Asset ID:
Asset name : RÜB Bellermannstr.
Volume: 1500 m³
Filling: Pump (1100 l/s)

Number of combined sewer overflows: 14

Additional assets:

Inline storage capacity: 1620 m³
Maximum storage level: 37.86 maD

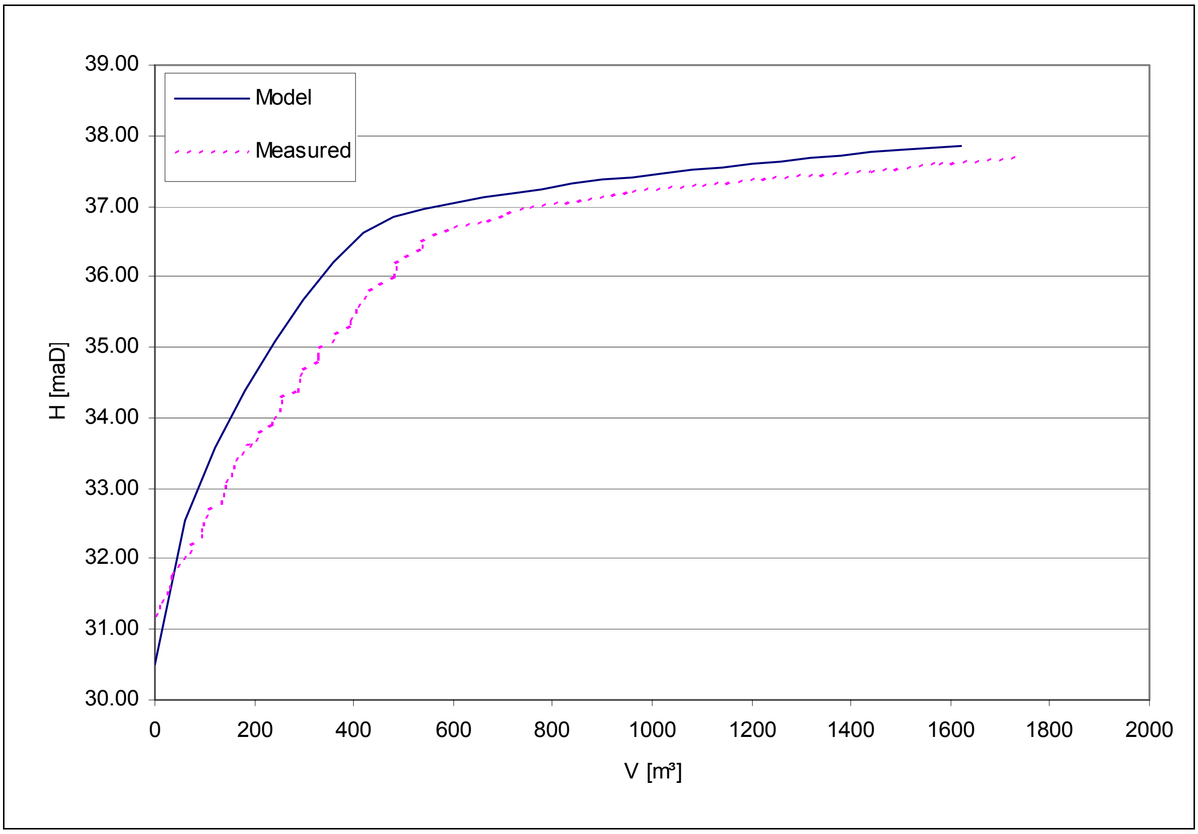


Network model of subcatchment Berlin X

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	1620	1742
Storage level [maD]:	37.86	37.70
lowest crest level of cso [maD]:	37.86	

APw Bln X



Storage characteristic of sewer network Berlin X

Measurement Campaign

Measurement points: 7

Name: PS

Location: Pump station Bln X, Bellermannstr.

Measurements: Flow, water level

Analyzed parameters: No sampling

Measurement period: 16/07/2002 – 03/11/2002

Remark: Measurement within and in front of the pump station

Name:	RT
Location:	RÜB Bellermannstr.
Measurements:	Water level
Analyzed parameters:	TSS, COD, COD_{filtr}, BOD_5, N_{org}, NH_4-N, TKN, P_{tot}
Measurement period:	16/07/2002 – 03/11/2002
Remark:	Level controlled automatic sampling

Name: M3

Location: Bellermannstr.

Measurements: Flow, water level

Analyzed parameters: TSS, COD, COD_{filtr}, BOD_5, N_{org}, NH_4-N, TKN, P_{tot}

Measurement period: 27/06/2002 – 31/10/2002

Remark: Good and consistent set of data
Volume proportional sampling controlled by flow meter

Name: M5

Location: Grüntaler Str.

Measurements: Flow, water level

Analyzed parameters: No sampling

Measurement period: 17/06/2002 – 31/10/2002

Remark: Good set of data
Few fallouts due to battery problems

Name: SO

Location: RÜ Grüntaler Str.

Measurements: Water level

Analyzed parameters: No sampling

Measurement period: 08/08/2002 – 31/10/2002

Remark: Only few discharge events could by measured

Name: M12

Location: Swinemünder Brücke

Measurements: Flow, Water level

Analyzed parameters: No sampling

Measurement period: 16/09/2002 – 31/10/2002

Remark: Only few rain events could by measured

Name: M14

Location: Graunstr.

Measurements: Water level

Analyzed parameters: No sampling

Measurement period: 10/07/2002 – 31/10/2002

Remark: -

Name:	R1
Location:	Pump station Bln X, Bellermannstr.
Measurements:	Rainfall
Measurement period:	02/07/2002 – 31/10/2002

Name:	R2
Location:	Max-Schmeling-Halle
Measurements:	Rainfall
Measurement period:	12/06/2002 – 31/10/2002

Measured dry weather events

M3

Date	V [m³]	Q_{mean} [m³/s]	TSS [mg/l]	COD [mg/l]	BOD [mg/l]	Norg [mg/l]	NH4 [mg/l]	Ptot [mg/l]
28.7.2002	10070	0.117	210.50	702.10	276.50	22.72	55.20	9.93
15.8.2002	12026	0.139	354.58	893.96	329.58	22.88	54.29	9.56
20.8.2002	13818	0.160	408.33	985.00	366.25	21.75	57.46	10.36
28.8.2002	16968	0.196	454.17	1022.08	384.17	23.67	54.04	10.59
9.9.2002	14086	0.163	415.42	980.83	423.75	23.42	59.46	11.27

Measured storm weather events

M3

Date	V [m³]	Q_{mean} [m³/s]	TSS [mg/l]	COD [mg/l]	BOD [mg/l]	Norg [mg/l]	NH4 [mg/l]	Ptot [mg/l]
8.8.2002	6478	0.322	129.08	191.77	59.23	8.67	7.28	2.36
26.9.2002	3484	0.211	343.85	827.69	384.62	18.54	45.08	9.35
21.10.2002	8439	0.281	367.92	777.50	318.33	18.73	33.57	8.48
23.10.2002	10966	0.335	222.61	484.35	163.70	13.50	24.77	5.45

RT

Date	V [m³]	Q_{mean} [m³/s]	TSS [mg/l]	COD [mg/l]	BOD [mg/l]	Norg [mg/l]	NH4 [mg/l]	Ptot [mg/l]
18.10.2002	3696	1.100	100.00	230.00	100.00	8.70	8.10	3.08

Calibration

Event Identification M3

Date	Start	End	Rain Duration	Rain Height	Rain I_{max}
Dry Weather, Hydraulic					
20.08.2002	00:00	00:00	-	-	-
09.09.2002	00:00	00:00	-	-	-
Storm Weather, Hydraulic					
25.07.2002	12:40	18:25	05:45 h	2.9 mm	10.8 mm/h
08.08.2002	00:50	04:30	03:40 h	6.6 mm	28.8 mm/h
Dry Weather, Quality					
20.08.2002	08:00	08:00	-	-	-
Storm Weather, Quality					
26.09.2002	12:00	23:50	11:50 h	0.7 mm	2.4 mm/h
21.10.2002	08:25	12:30	04:05 h	2.2 mm	4.8 mm/h

Comparison Measurement – Simulation M3

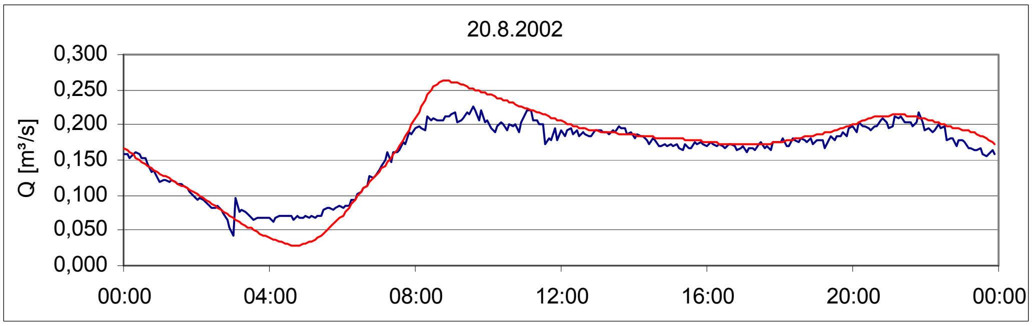
Hydraulic

Date	V_{meas} [m^3]	V_{sim} [m^3]	$Qmax_{meas}$ [m^3/s]	$Qmax_{sim}$ [m^3/s]	$Qmin_{meas}$ [m^3/s]	$Qmin_{sim}$ [m^3/s]
Dry Weather						
20.08.2002	13771	14308	0,226	0,263	0,044	0,029
09.09.2002	13675	14308	0,241	0,263	0,037	0,029
Storm Weather						
25.07.2002	7268	7187	0,757	0,774	0,122	0,096
08.08.2002	6534	6092	1,530	1,666	0,059	0,069

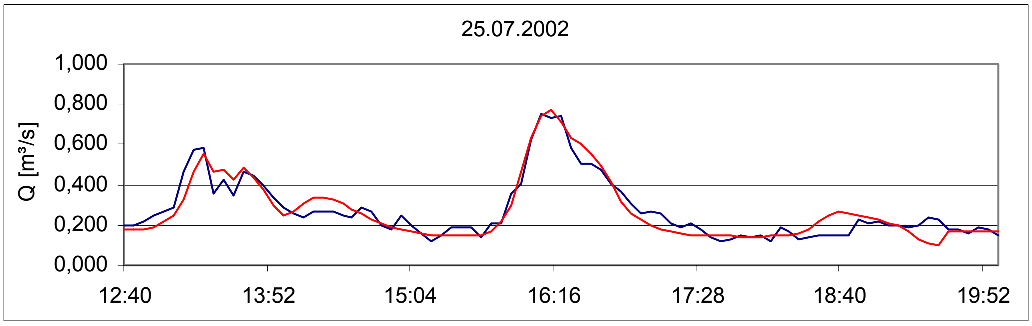
Quality [NH4-N]

Date	M_{meas} [kg]	M_{sim} [kg]	$Cmax_{meas}$ [mg/l]	$Cmax_{sim}$ [mg/l]	$Cmin_{meas}$ [mg/l]	$Cmin_{sim}$ [mg/l]
Dry Weather						
20.08.2002	774,9	788,4	94,0	96,1	40,0	41,17
Storm Weather						
26.09.2002	139,7	149,8	51,0	55,0	33,0	41,5
21.10.2002	266,0	290,2	83,0	83,3	15,0	17,0

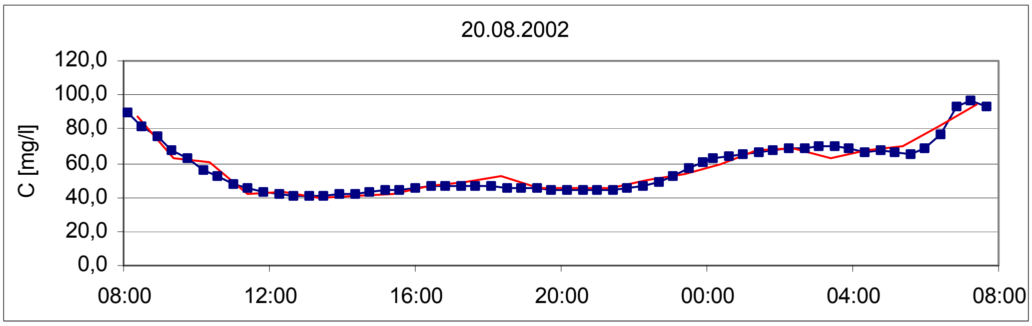
Dry Weather: Flow at M3



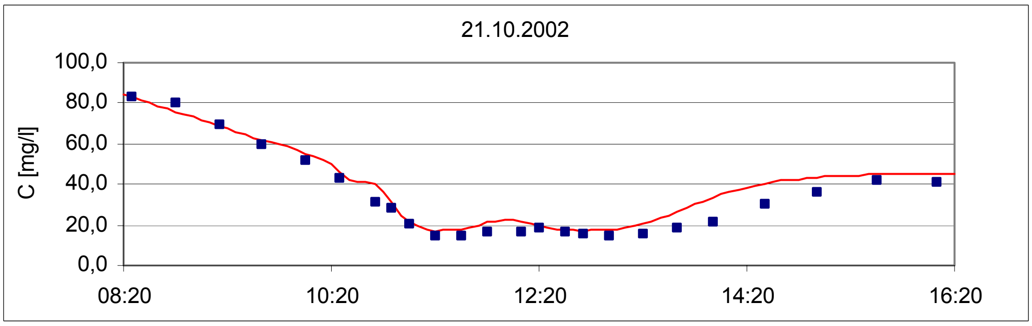
Storm Weather: Flow at M3



Dry Weather: NH4-N Concentration at M3



Storm Weather: NH4-N Concentration at M3



Validation

Event Identification M3

Date	Start	End	Rain Duration	Rain Height	Rain I_{max}
Dry Weather, Hydraulic					
21.08.02	00:00	00:00	-	-	-
10.09.02	00:00	00:00	-	-	-
Storm Weather, Hydraulic					
22.07.2002	09:50	14:05	04:15 h	8.9 mm	10.4 mm/h
02.08.2002	02:55	08:50	05:55 h	2.5 mm	4.0 mm/h
12.-13.08.2002	05:35	16:25	34:50 h	62.7 mm	19.2 mm/h
Dry Weather, Quality					
28.08.2002	08:00	08:00	-	-	-
09.09.2002	08:00	08:00	-	-	-
Storm Weather, Quality					
08.08.2002	00:50	04:30	03:40 h	6.6 mm	28.8 mm/h
23.10.2002	04:10	16:25	12:15 h	4.9 mm	9.6 mm/h

Comparison Measurement – Simulation M3

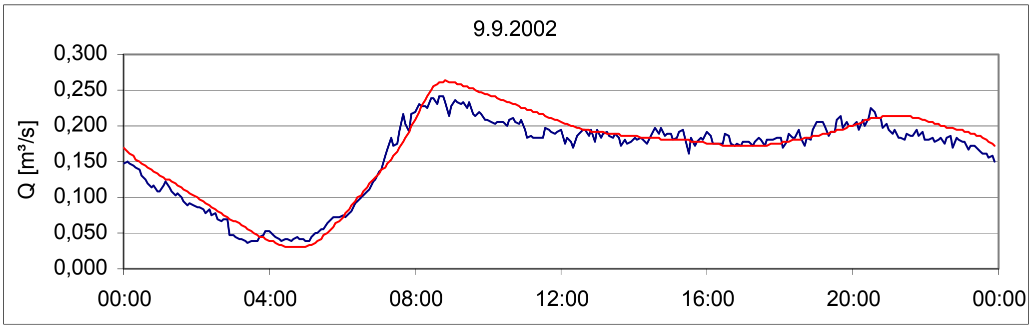
Hydraulic

Date	V_{meas} [m^3]	V_{sim} [m^3]	$Qmax_{meas}$ [m^3/s]	$Qmax_{sim}$ [m^3/s]	$Qmin_{meas}$ [m^3/s]	$Qmin_{sim}$ [m^3/s]
Dry Weather						
21.08.02	14117	14308	0,261	0,263	0,051	0,029
10.09.02	14342	14308	0,270	0,263	0,034	0,029
Storm Weather						
22.07.2002	14124	14522	1,853	1,851	0,222	0,178
02.08.2002	6456	6877	0,698	0,708	0,009	0,019
12.-13.08.2002	101219	103038	2,716	2,253	0,038	0,052

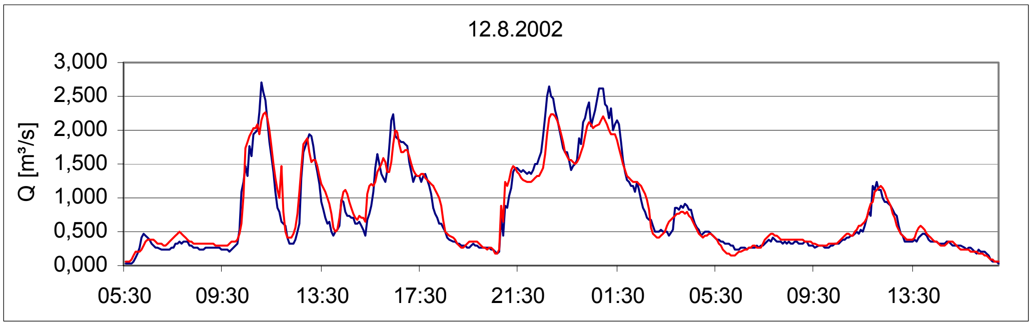
Quality [NH4-N]

Date	M_{meas} [kg]	M_{sim} [kg]	$Cmax_{meas}$ [mg/l]	$Cmax_{sim}$ [mg/l]	$Cmin_{meas}$ [mg/l]	$Cmin_{sim}$ [mg/l]
Dry Weather						
28.08.2002	867,9	788,4	97,0	96,1	38,0	41,2
09.09.2002	819,4	788,4	94,0	96,1	40,0	41,2
Storm Weather						
08.08.2002	23,4	21,1	13,0	15,2	4,4	1,1
23.10.2002	217,3	297,3	38,0	44,2	6,6	8,5

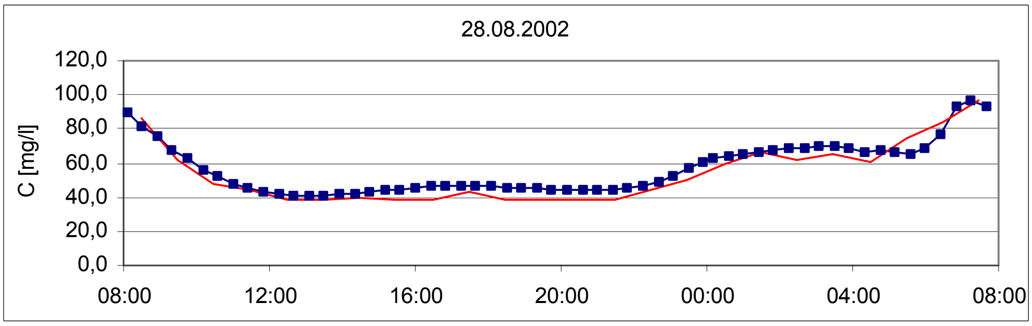
Dry Weather: Flow at M3



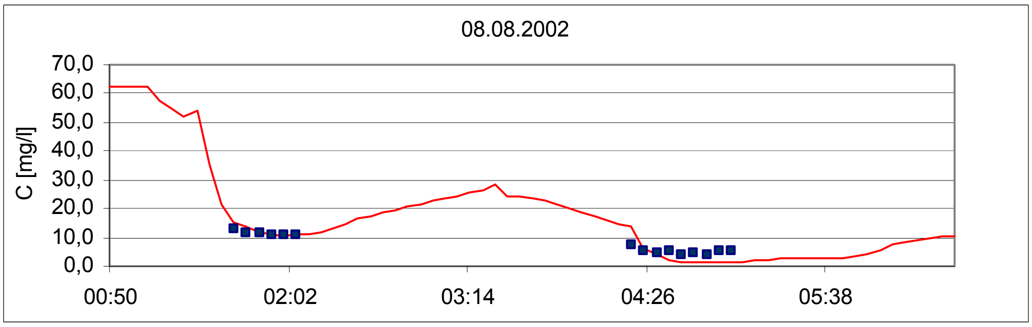
Storm Weather: Flow at M3



Dry Weather: NH4-N Concentration at M3



Storm Weather: NH4-N Concentration at M3

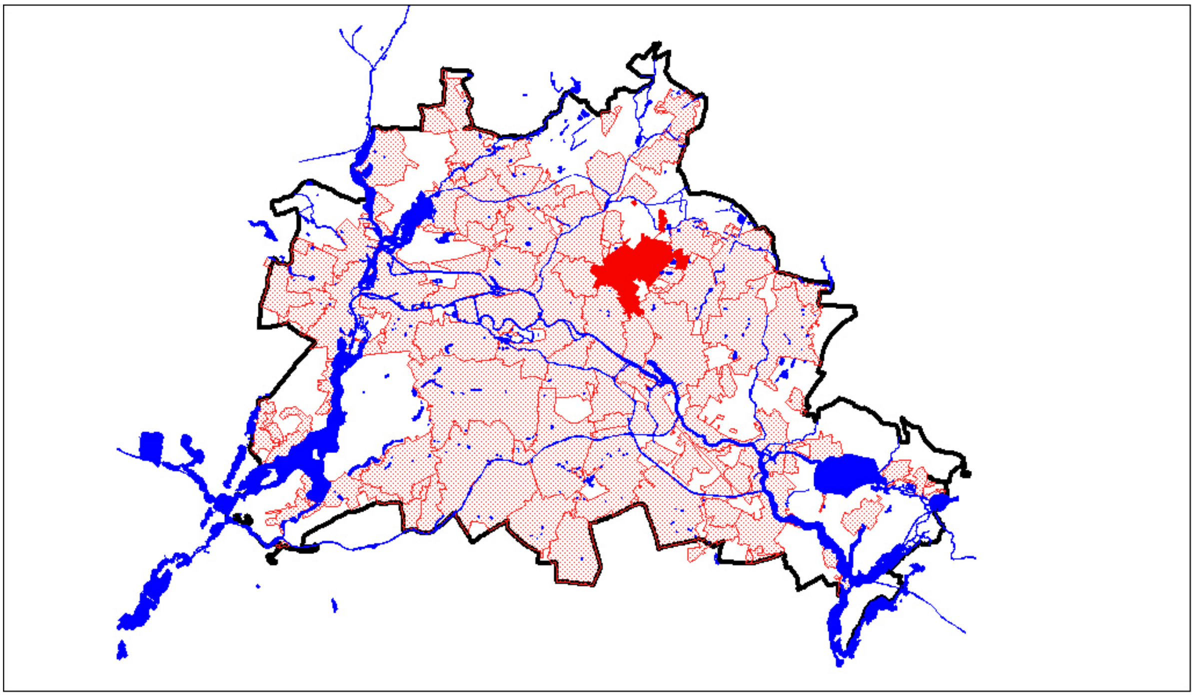


Specifics

- Special observations on catchment Bln X have been the high gradient of the sewers leading to only few deposits.
- Due to this condition the model for catchment Bln X could be calibrated with high accuracy.
- The model for the state 2010 (network Ruhleben_2010) reflects only some of the rehabilitation measures (Bornholmer Str., Bellermannstr.). The storage sewer at Mauerpark has not yet been modelled.

3.4.10 APw Berlin XI

Subcatchment:	Berlin XI (incl. XIa)	
Contributing Area:	1515 ha	
Population:	91052 Inh.	
WWTP:	dry weather:	Schönerlinde
	storm weather:	Schönerlinde



Location of subcatchment Berlin XI

Model characteristics Berlin XI

System type:

Bln XI Combined
Bln XIa Separate

Length of modelled pipes

Combined: 18.413 km
Waste water: 10.599 km
Storm water: 16.371 km
Other: 1.178 km

Number of Nodes 527

Number of Pump Stations 1

Pump Station: APw Berlin XI, Erich-Weinert-Straße
US Node ID: Saugraum_Bln_XI
Average dry weather flow: 156.50 l/s
Maximum Capacity
local: 0.500 m^3/s
global: 0.650 m^3/s
Destination
dry weather: Schönerlinde
storm weather: Schönerlinde

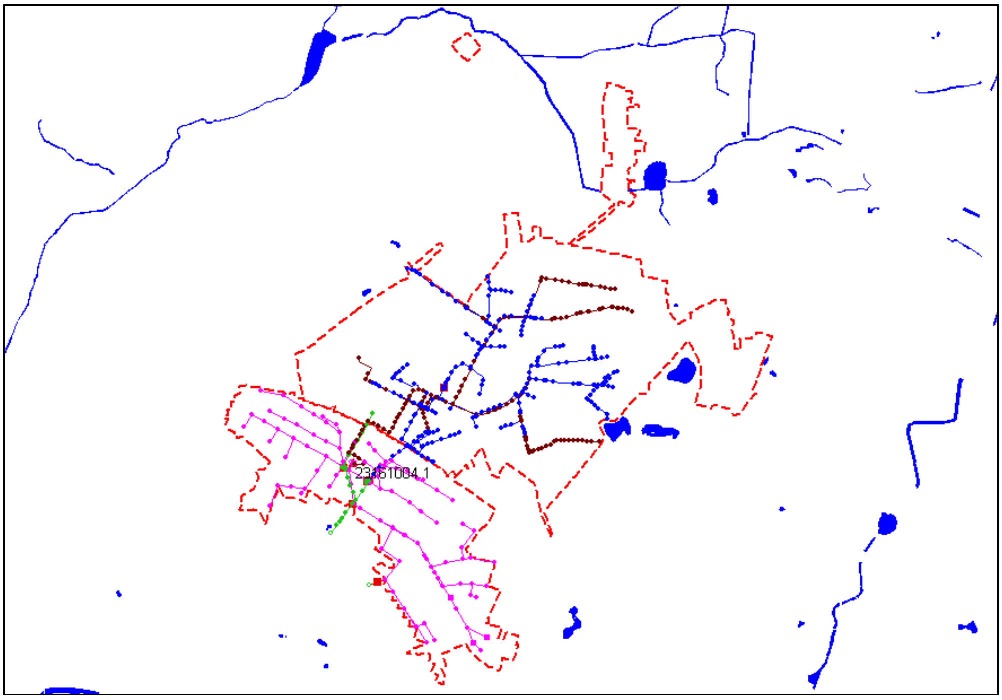
Number of storage tanks and storage sewers: -

Description:
Node ID:
Asset ID:
Volume:

Number of combined sewer overflows: 5

Additional assets:

Inline storage capacity: 5340
Maximum storage level: 42.38

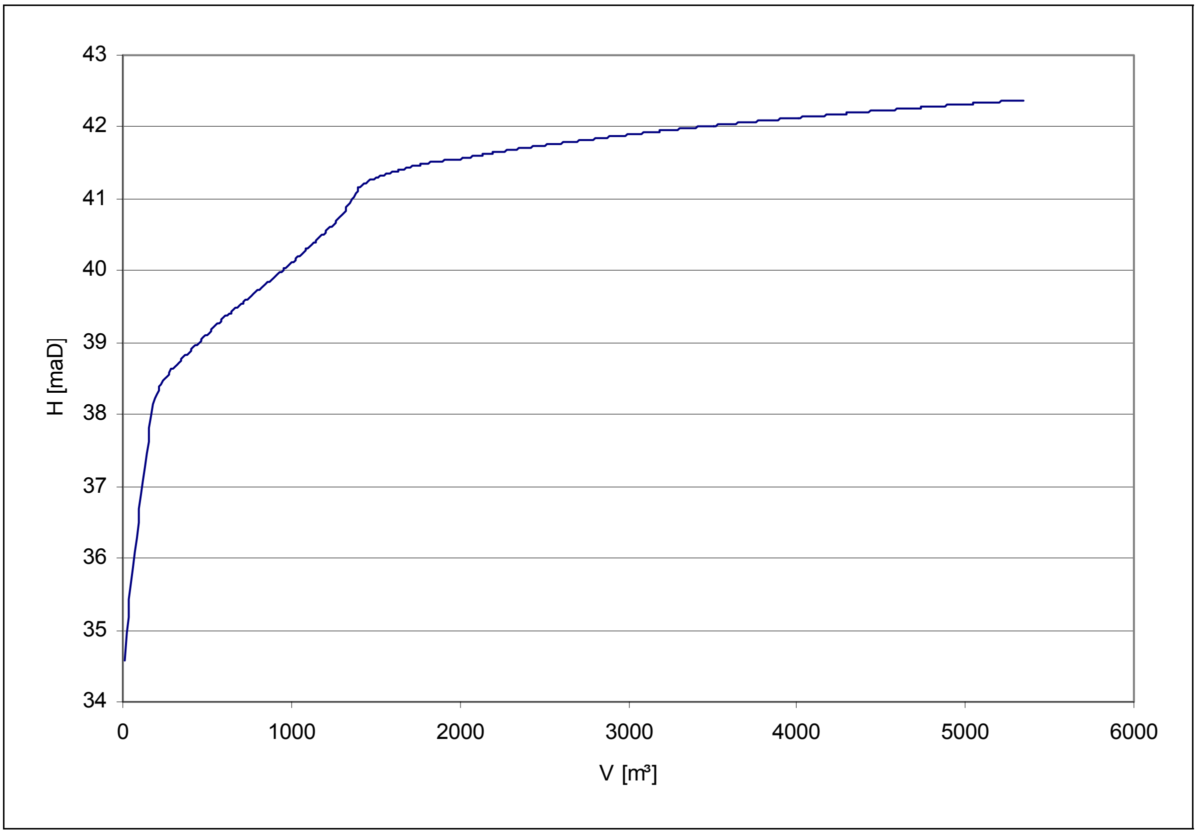


Network model of subcatchment Berlin XI

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	5340	-
storage level [maD]:	42.38	-
lowest crest level of cso [maD]:	42.38	

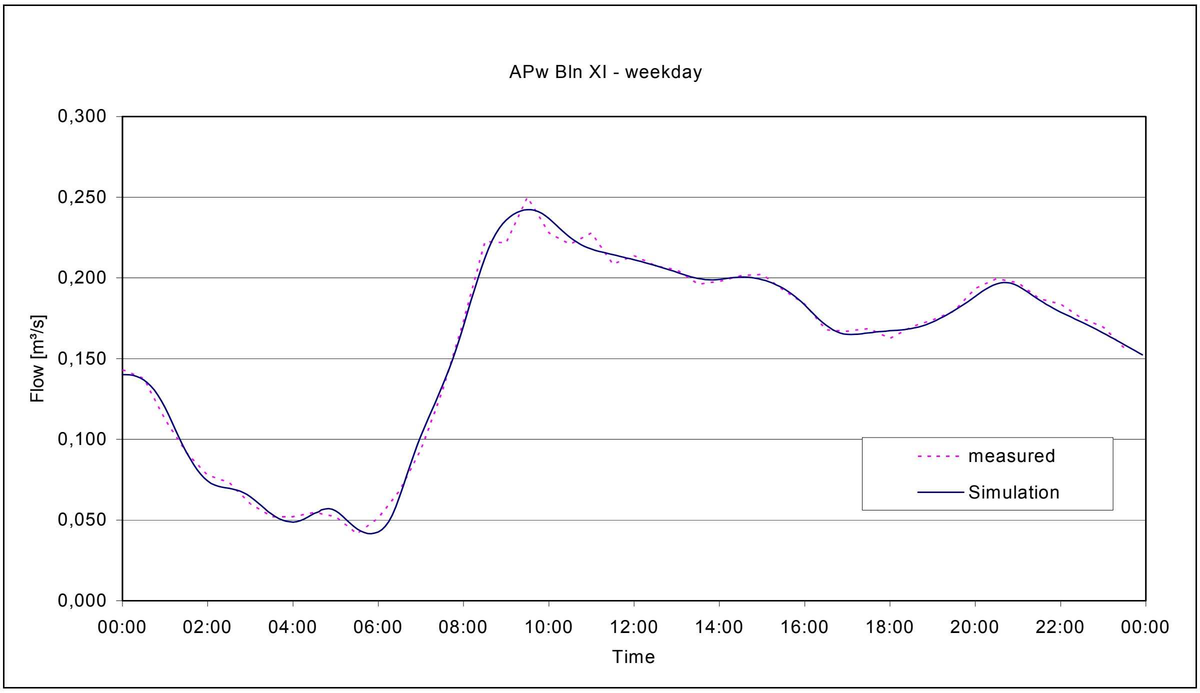
APw Bln XI



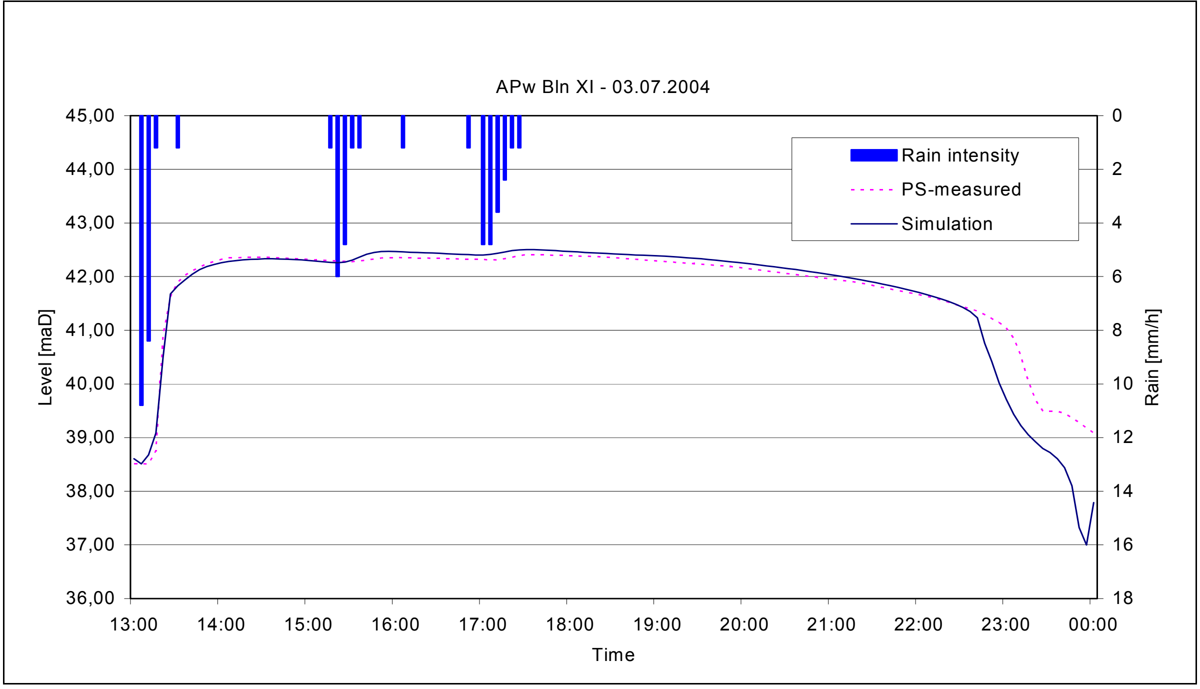
Storage characteristic of sewer network Berlin XI

Calibration

Dry Weather: Flow at Pump station Bln XI
min flow: 0.042 m³/s
max flow: 0.242 m³/s



Storm Weather: Level at Pump station Bln XI



Specifics

- The rainwater inflow from the northern part of the catchment is difficult to calibrate. Several retention reservoirs are located there having a significant influence on the runoff characteristic. This characteristic could only be included on the basis of extensive measurements.
- A new calibration has to be carried out after the connection of this northern catchment area to the overflow sewer (will be realised in the future).
- Measures of rehabilitation have not yet been modelled.

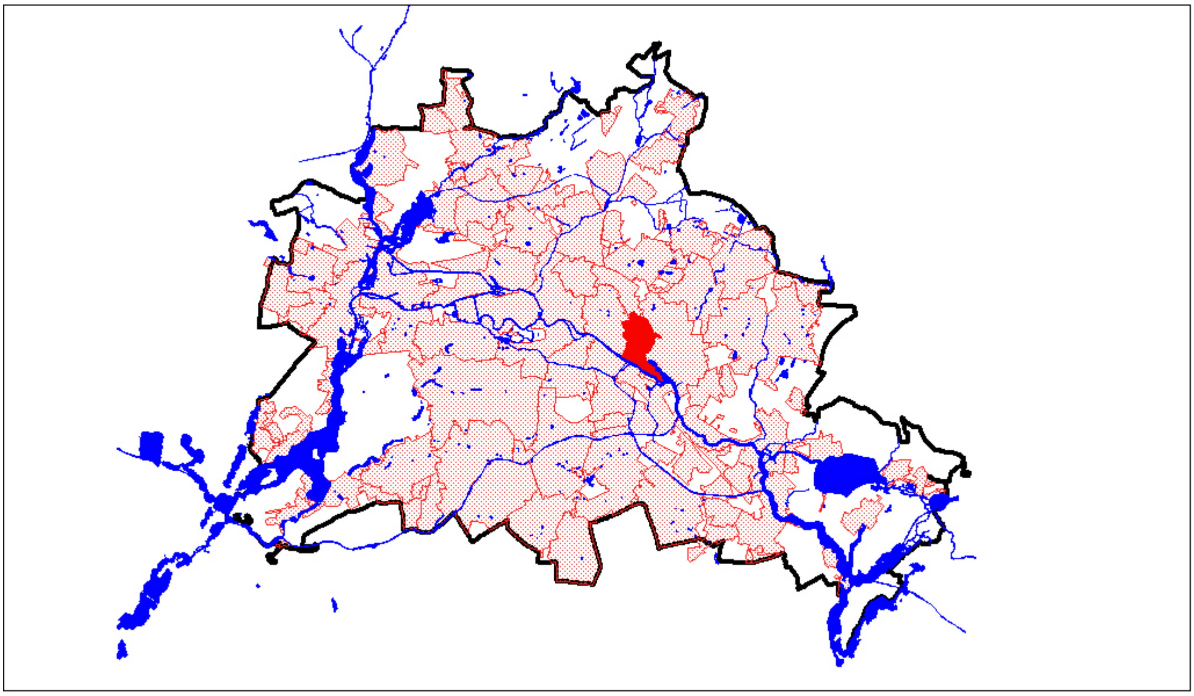
3.4.11 APw Berlin XII

Subcatchment: Berlin XII

Contributing Area: 418 ha

Population: 62693 Inh.

WWTP: dry weather: Schönerlinde
storm weather: Schönerlinde



Location of subcatchment Berlin XII

Model characteristics Berlin XII

System type: Combined

Length of modelled pipes

- **Combined:** 18.035 km
- **Waste water:** -
- **Storm water:** 0.220 km
- **Other:** 4.419 km

Number of Nodes 111

Number of Pump Stations 1

- **Pump Station:** APw Berlin XII, Rudolfstr.
- **US Node ID:** 16156003
- **Average dry weather flow:** 127.80 l/s
- **Maximum Capacity**
  - **local:** 0.250 m^3/s
  - **global:** 0.410 m^3/s
- **Destination**
  - **dry weather:** Schönerlinde
  - **storm weather:** Schönerlinde

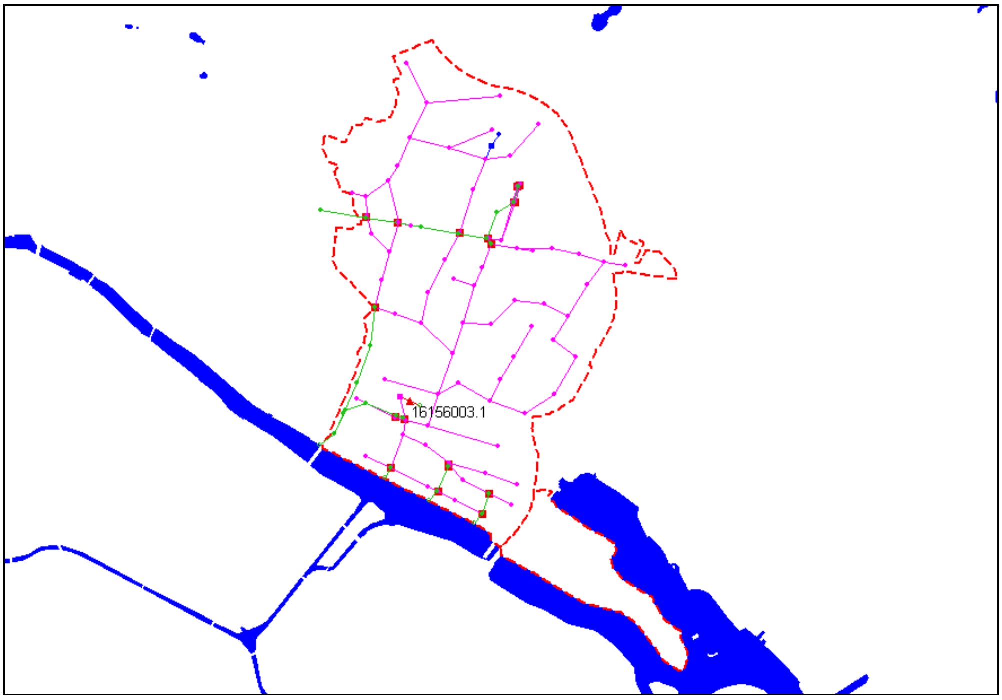
Number of storage tanks and storage sewers: 1

Description: Storage sewer Pariser Kommune
Node ID: 17182001
Asset ID:
Asset name : SK Straße der Pariser Kommune
Volume: 6200 m³
Filling: Gravity

Number of combined sewer overflows: 18

Additional assets:

Inline storage capacity: 5180 m³
Maximum storage level: 33.06 maD

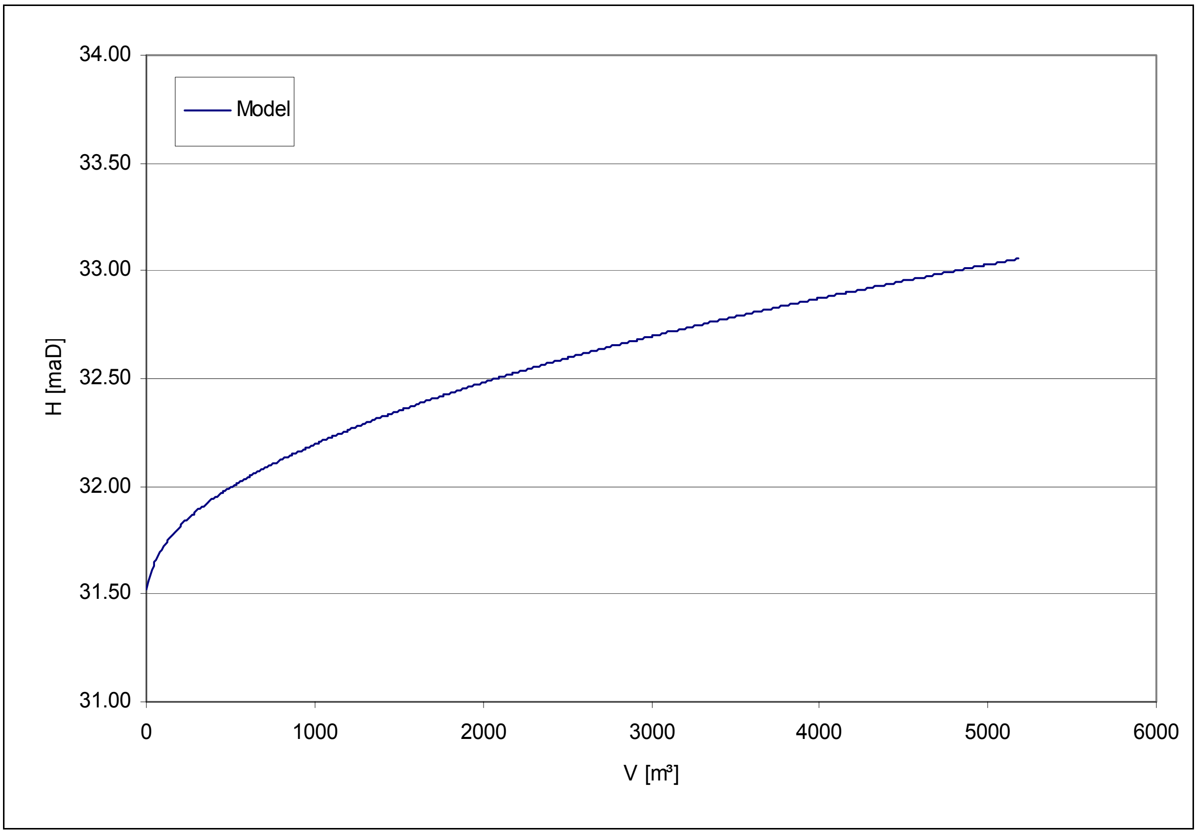


Network model of subcatchment Berlin XII

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	5180	1710
storage level [maD]:	33.06	32.40
lowest crest level of cso [maD]:	33.06	

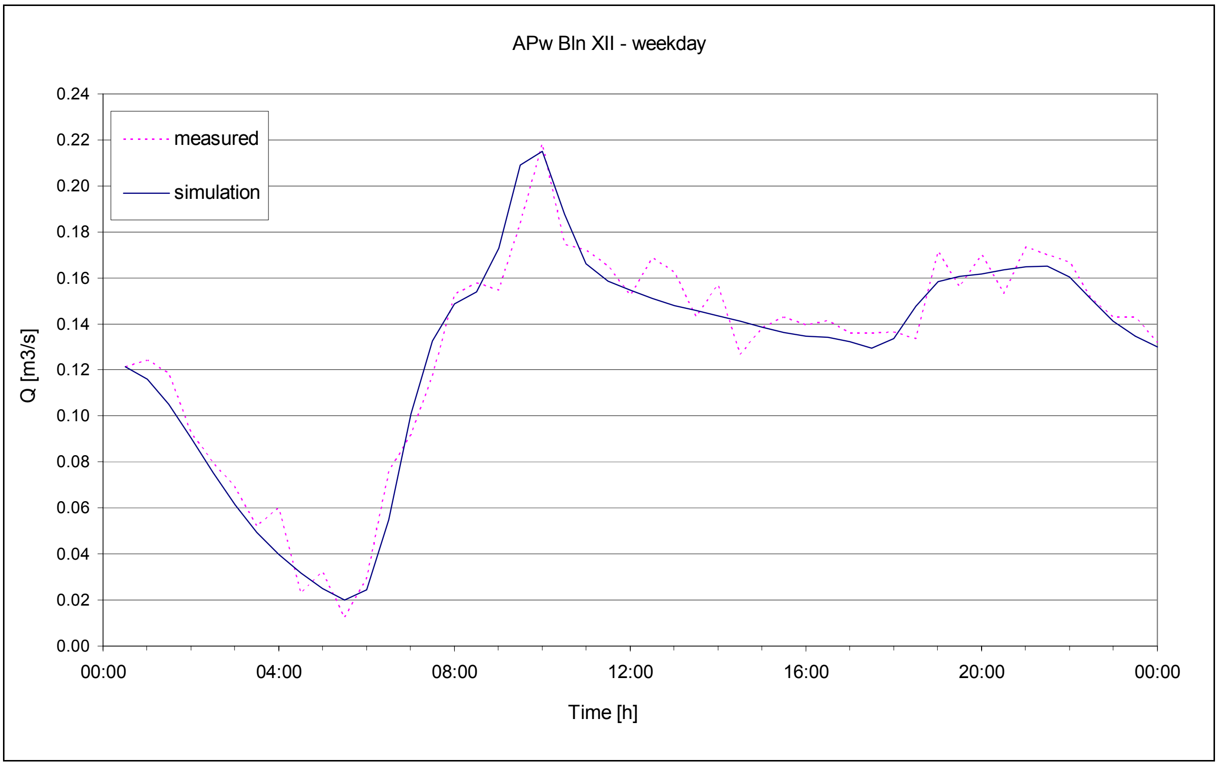
APw Bln XII



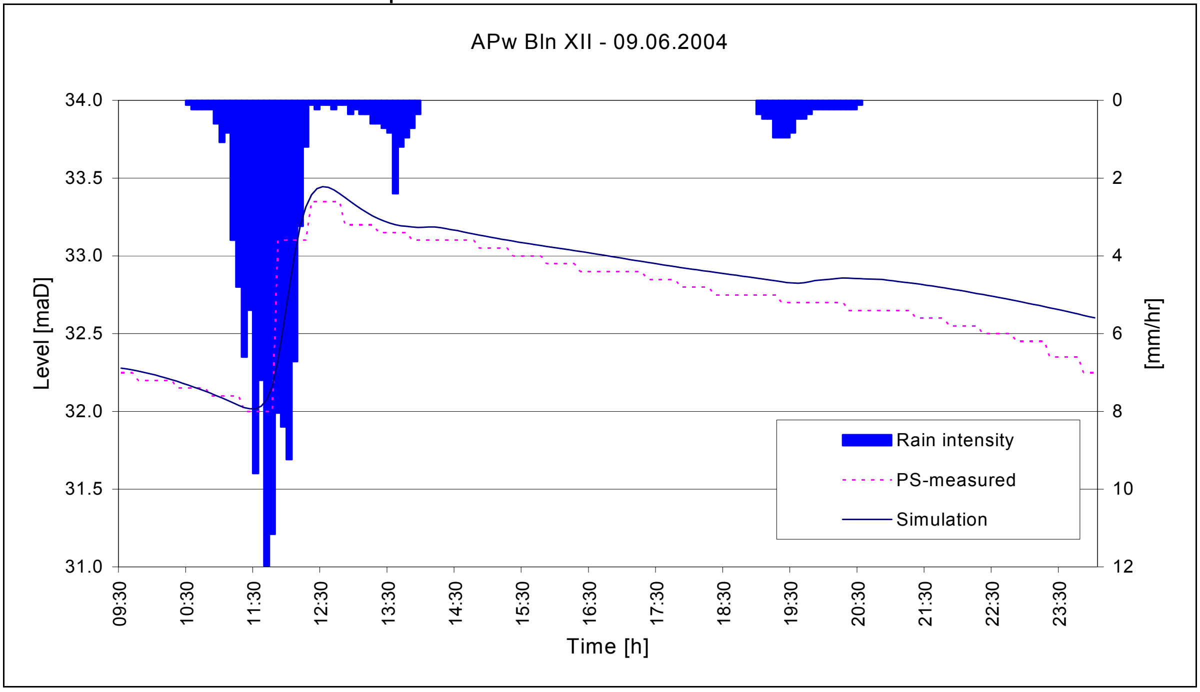
Storage characteristic of sewer network Berlin XII

Calibration

Dry Weather: Flow at Pump station Bln XII
min flow: 0.020 m³/s
max flow: 0.215 m³/s



Storm Weather: Level at Pump station Bln XII



Specifics

- The combined sewer overflows of the northern part of catchment Bln XII discharge into the storage sewer “Straße der Pariser Kommune”.
- Measures of rehabilitation have not yet been modelled.

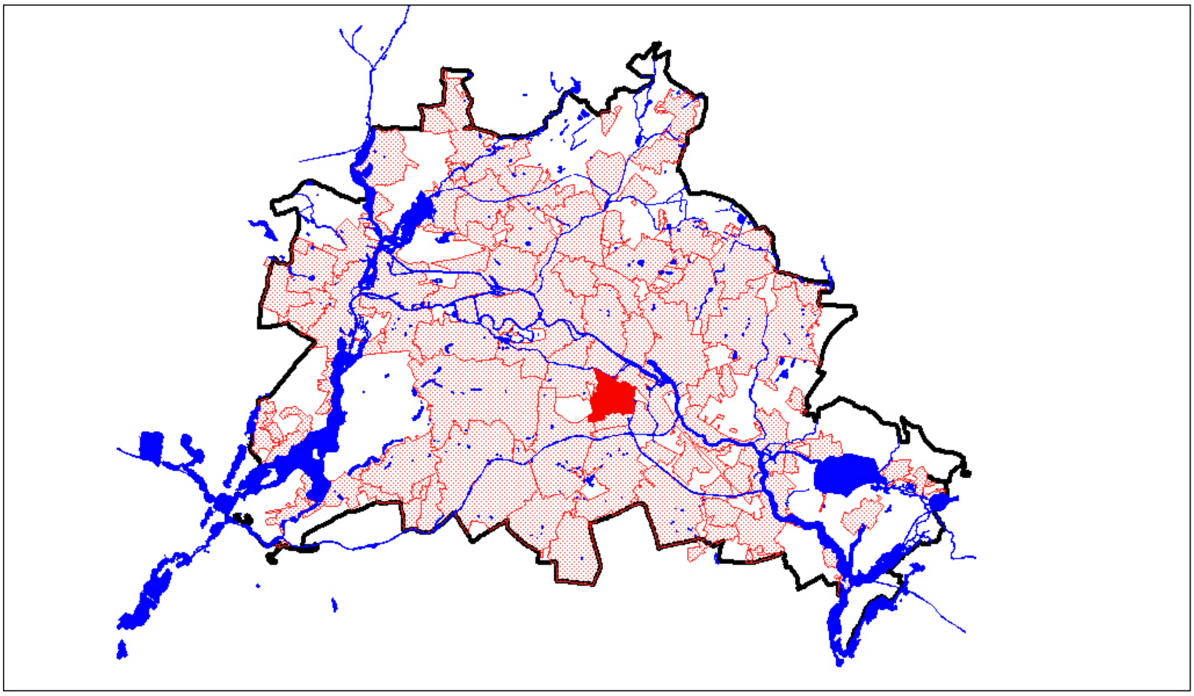
3.4.12 APw Neukölln I

Subcatchment: Neukölln I

Contributing Area: 486 ha

Population: 113866 Inh.

WWTP: dry weather: Waßmannsdorf
storm weather: Waßmannsdorf



Location of subcatchment Neukölln I

Model characteristics Neukölln I

System type:	Combined
Length of modelled pipes	
Combined:	14.799 km
Waste water:	-
Storm water:	0.130 km
Other:	3.498 km
Number of Nodes	130
Number of Pump Stations	1
Pump Station:	APw Neukölln I, Wildenbruchstr.
US Node ID:	12163951
Average dry weather flow:	198.60 l/s
Maximum Capacity	
local:	0.630 m^3/s
global:	-
Destination	
dry weather:	Waßmannsdorf
storm weather:	Waßmannsdorf

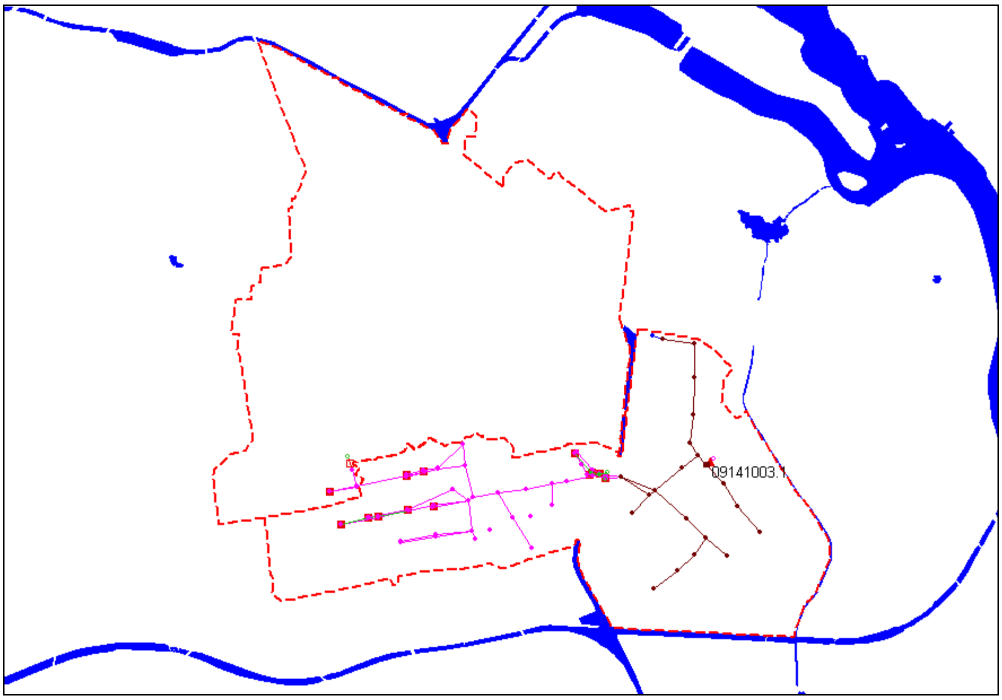
Number of storage tanks and storage sewers: 1

Description: Combined water tank with overflow
Node ID: 12163952
Asset ID:
Asset name : RÜB Wildenbruchstr.
Volume: 3600 m³
Filling: Gravity

Number of combined sewer overflows: 25

Additional assets:

Inline storage capacity: 7970 m³
Maximum storage level: 32.79 maD

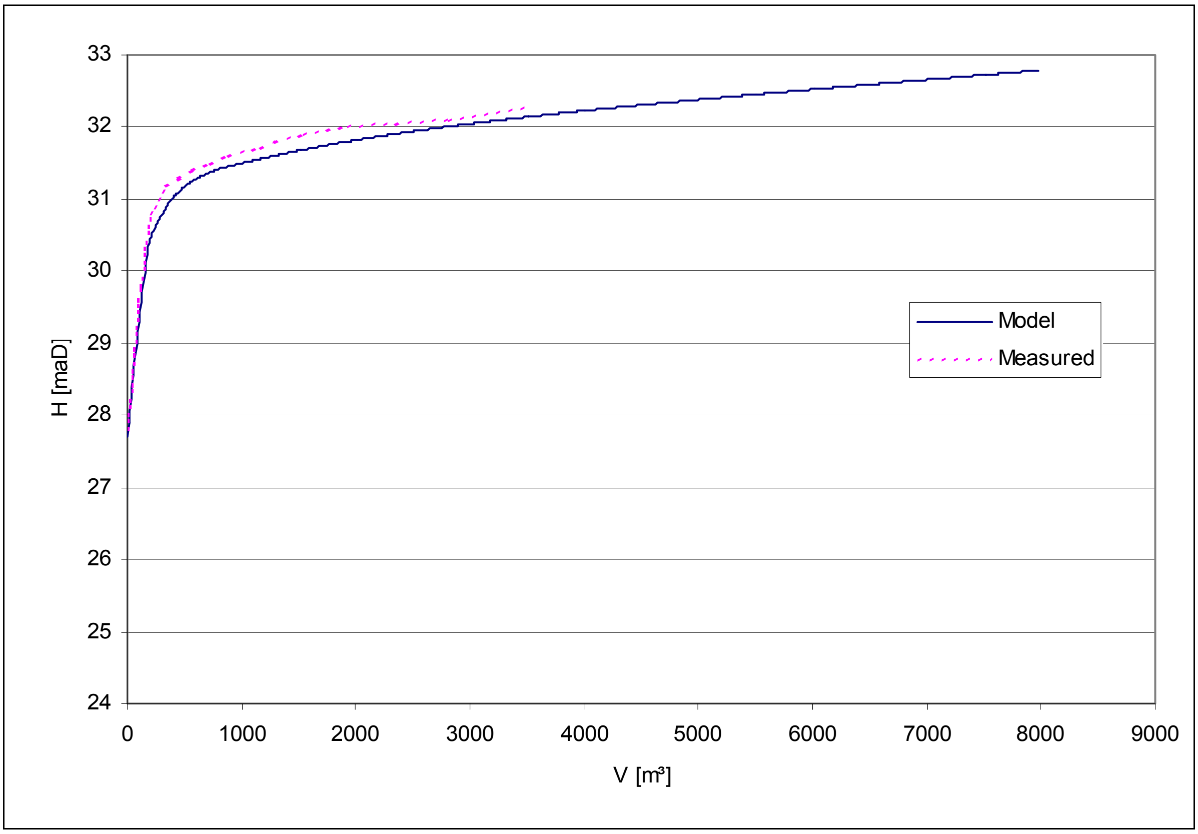


Network model of subcatchment Neukölln I

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	7970	3499
storage level [maD]:	32.79	32.25
lowest crest level of cso [maD]:	32.79	

APw Nkn I



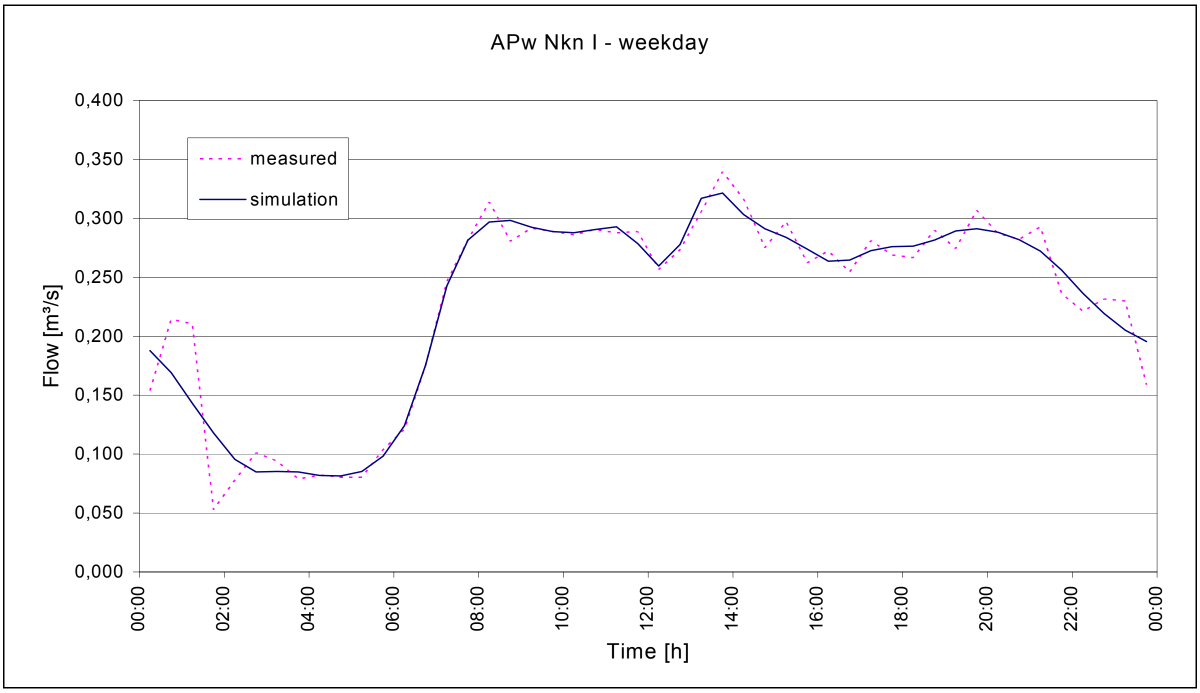
Storage characteristic of sewer network Neukölln I

Calibration

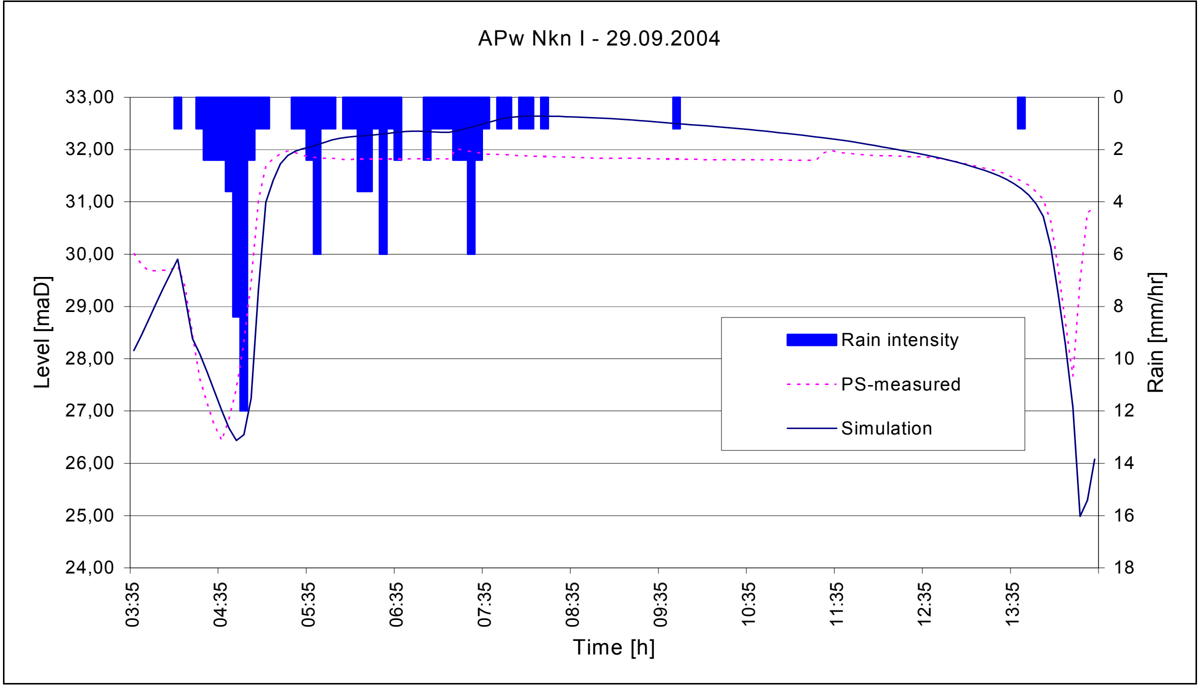
Dry Weather: Flow at Pump station Nkn I

min flow: 0.081 m³/s

max flow: 0.322 m³/s



Storm Weather: Level at Pump station Nkn I



Specifics

- There is an overlap of the catchments Nkn I and Nkn II. When coupling the sub models of these catchments to build a total model one has to treat this area carefully.
- Measures of rehabilitation have not yet been modelled.

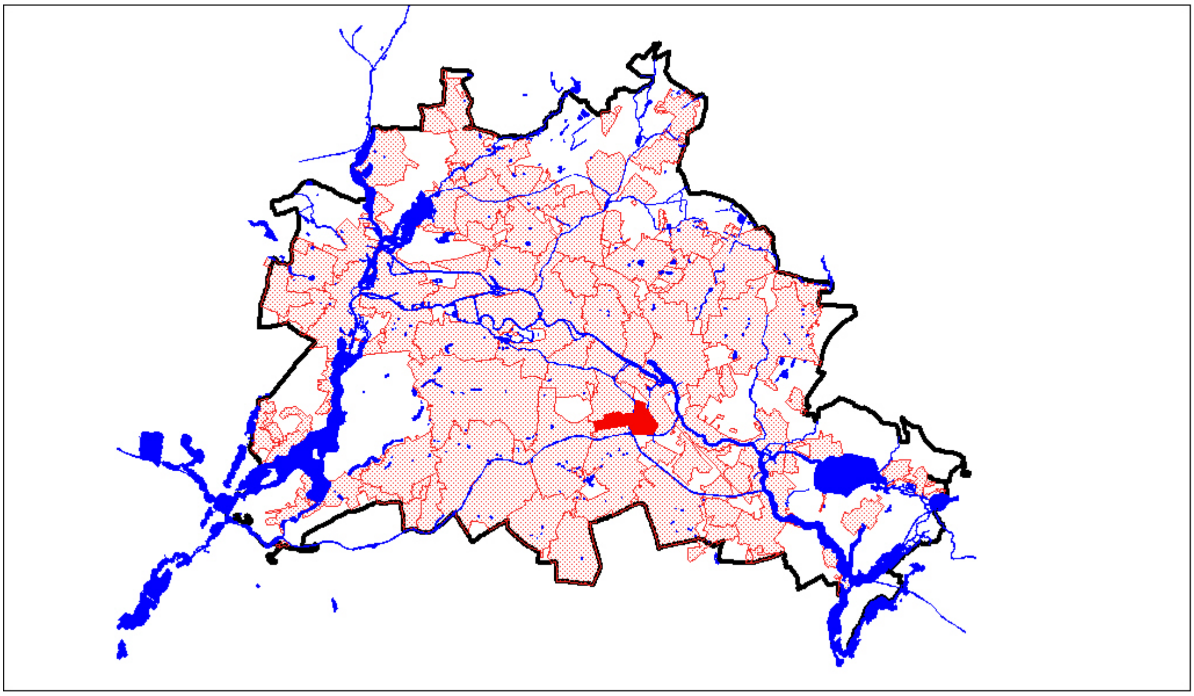
3.4.13 APw Neukölln II

Subcatchment: Neukölln II

Contributing Area: 320 ha

Population: 30344 Inh.

WWTP: dry weather: Waßmannsdorf
storm weather: Waßmannsdorf



Location of subcatchment Neukölln II

Model characteristics Neukölln II

System type:	Combined and separate
Length of modelled pipes	
Combined:	7.074 km
Waste water:	4.310 km
Storm water:	0.157 km
Other:	0.889 km
Number of Nodes	74
Number of Pump Stations	1
Pump Station:	APw Neukölln II, Dammweg
US Node ID:	09141003
Average dry weather flow:	69.10 l/s
Maximum Capacity	
local:	0.200 m^3/s
global:	-
Destination	
dry weather:	Waßmannsdorf
storm weather:	Waßmannsdorf

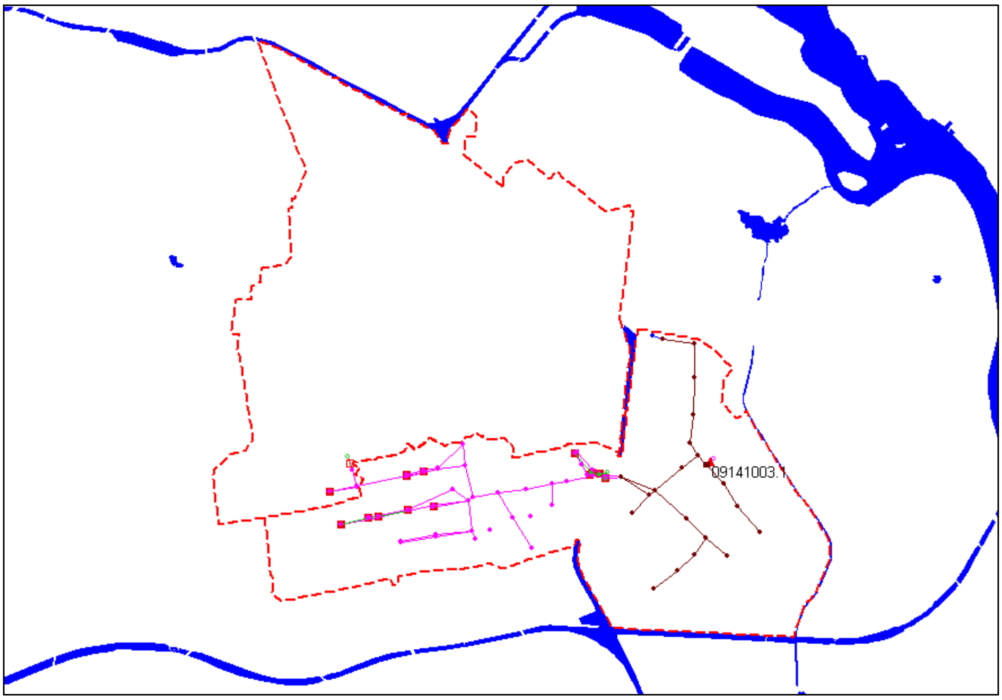
Number of storage tanks and storage sewers: -

Description:
Node ID:
Asset ID:
Volume:

Number of combined sewer overflows: 5

Additional assets:

Inline storage capacity: 2740 m³
Maximum storage level: 32.24 maD

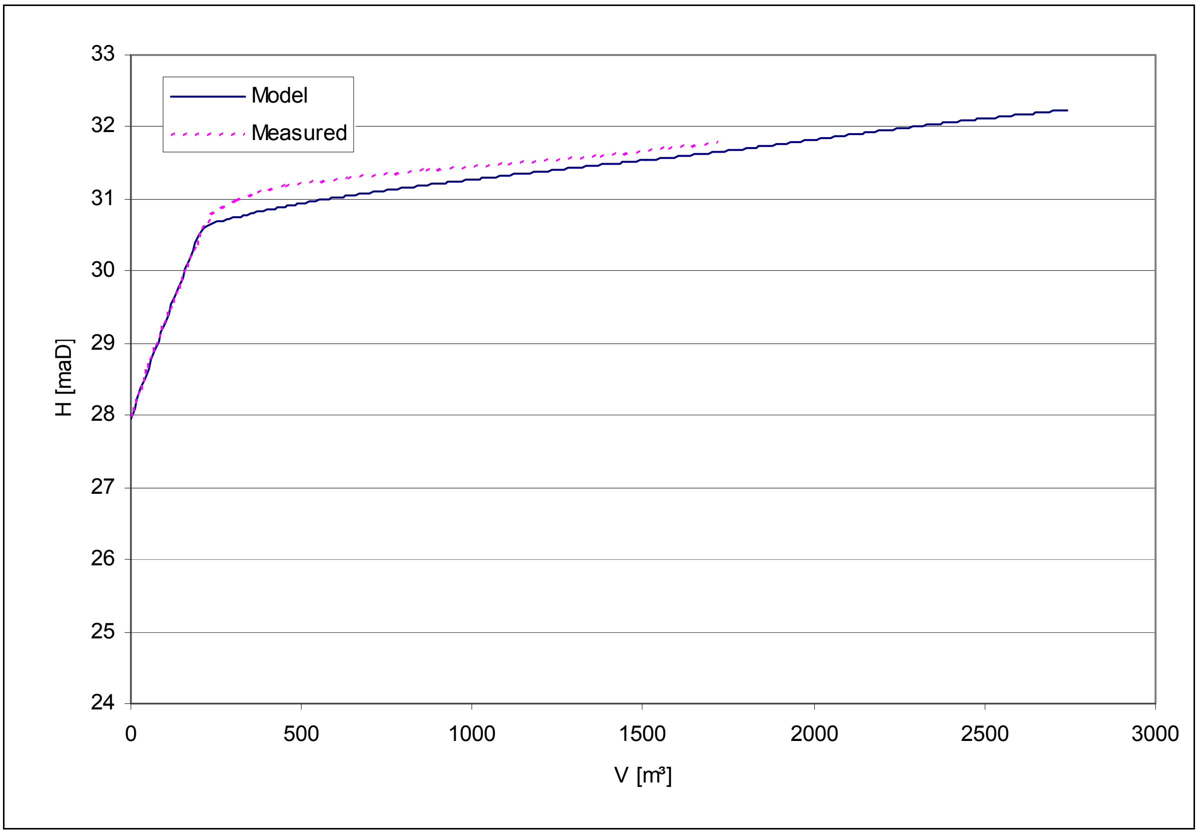


Network model of subcatchment Neukölln II

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	2740	1722
storage level [maD]:	32.24	31.80
lowest crest level of cso [maD]:	32.24	

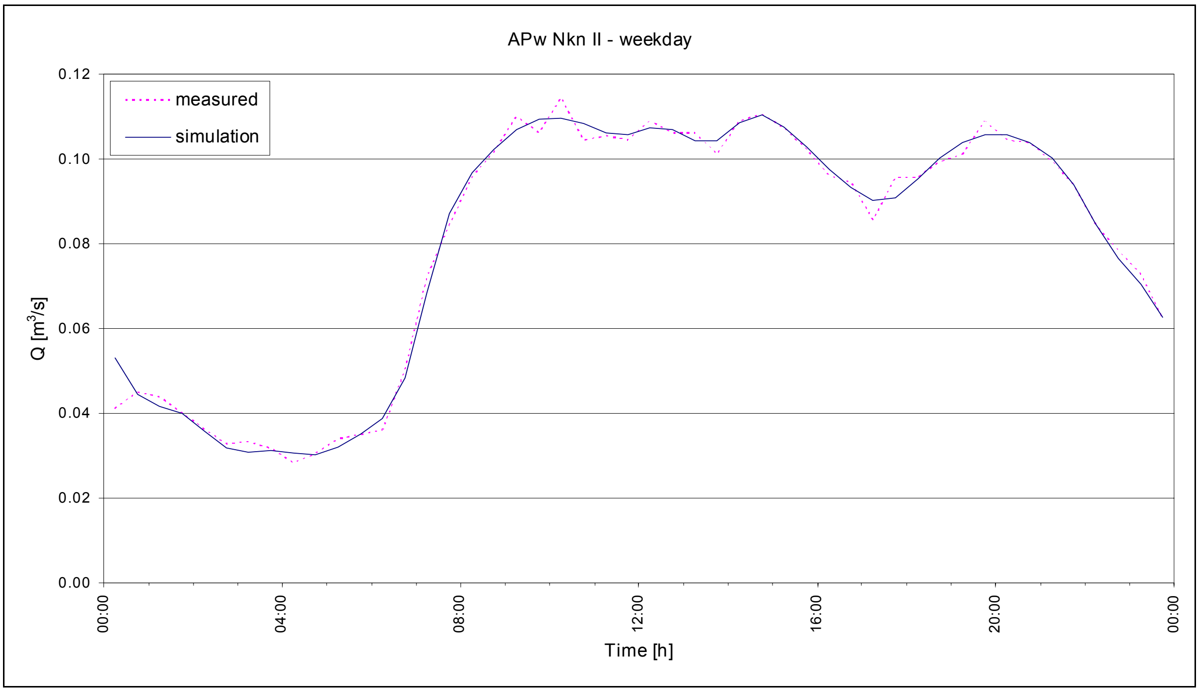
APw Nkn II



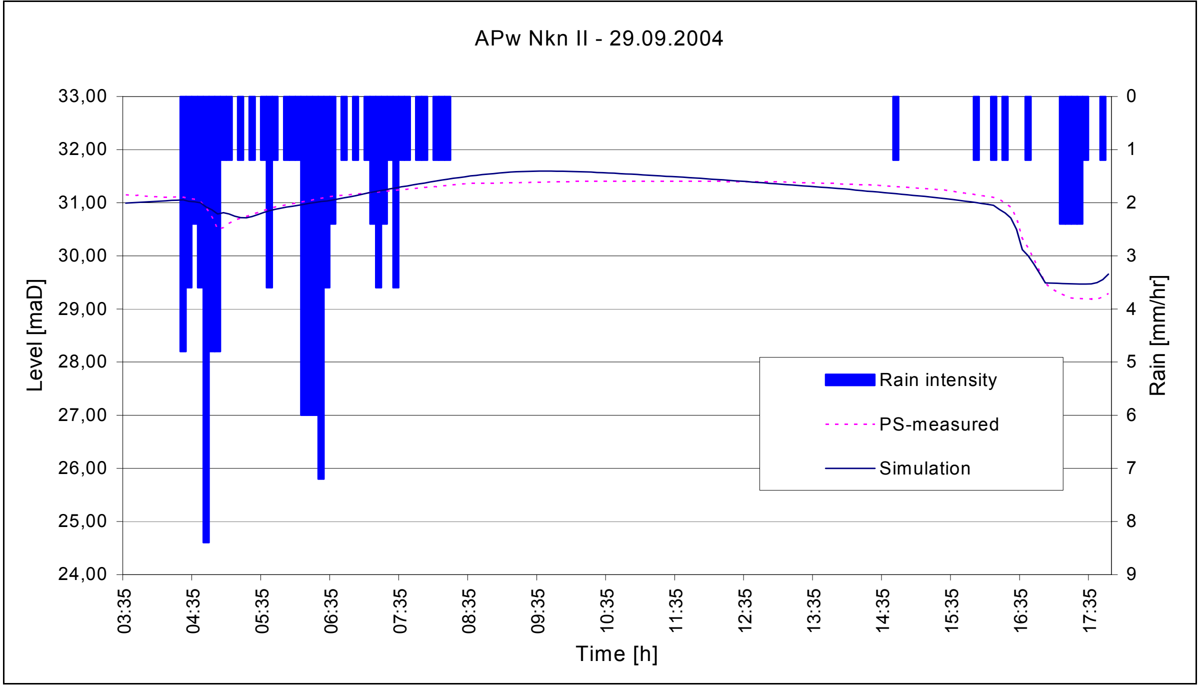
Storage characteristic of sewer network Neukölln II

Calibration

Dry Weather: Flow at Pump station Nkn II
min flow: 0.030 m³/s
max flow: 0.110 m³/s



Storm Weather: Level at Pump station Nkn II

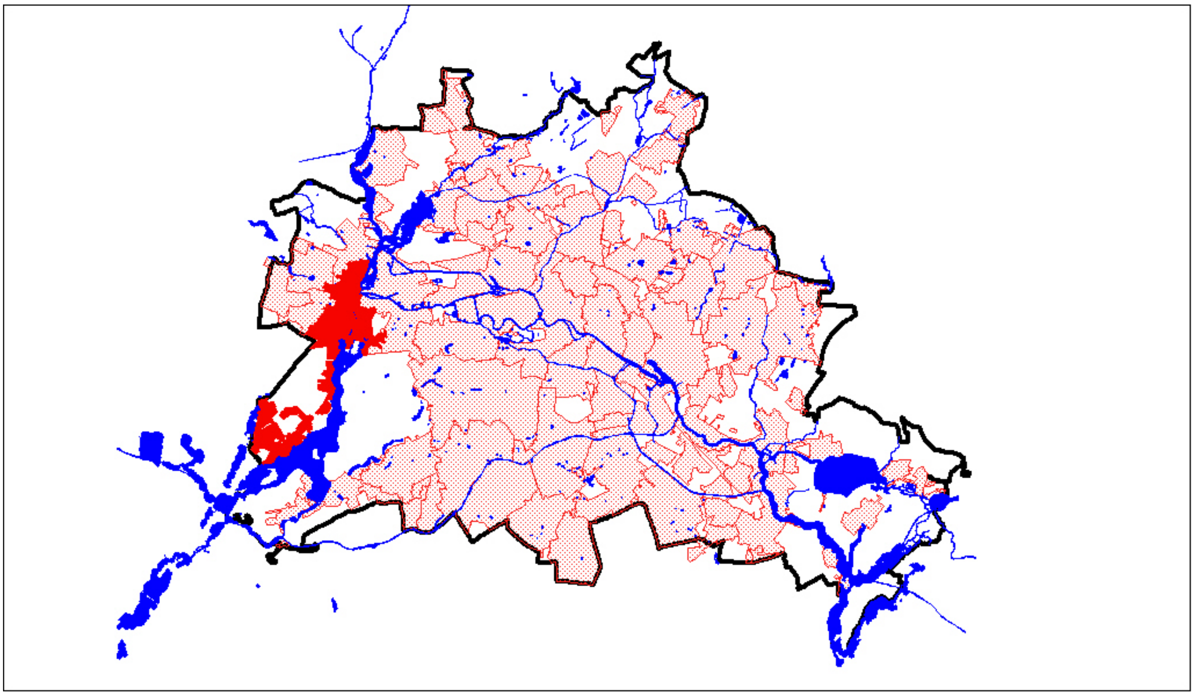


Specifics

- There is an overlap of the catchments Nkn I and Nkn II. When coupling the sub models of these catchments to build a total model one has to treat this area carefully.
- Measures of rehabilitation have not yet been modelled.
- Catchment Nkn II is divided into a separate (eastern part) and a combined (western part) system. The sewage from the combined system flows into the eastern wastewater system via an inverted siphon. Due to this hydraulic situation the assessment of cso activity by means of water level measurements at the pump station is hardly possible.

3.4.14 HPw Spandau I

Subcatchment:	Spandau I	
Contributing Area:	1431 ha	
Population:	91513 Inh.	
WWTP:	dry weather:	Ruhleben / Wansdorf
	storm weather:	Ruhleben / Wansdorf



Location of subcatchment Spandau I

Model characteristics Spandau I

System type:	Combined and separate
Length of modelled pipes	
Combined:	16.055 km
Waste water:	0.281 km
Storm water:	-
Other:	2.702 km
Number of Nodes	134
Number of Pump Stations	2
Pump Station:	HPw Spandau I, Betckestr.
US Node ID:	Saugraum_HPW_Spa1
Average dry weather flow:	163.70 l/s
Maximum Capacity	
local:	0.650 m^3/s
global:	1.000 m^3/s
Destination	
dry weather:	Ruhleben / Wansdorf
storm weather:	Ruhleben / Wansdorf
Booster Station:	ÜPw Spandau Ia
US Node ID:	ÜPW_Spa1a
Maximum capacity:	100 l/s
Destination:	Saugraum_HPW_Spa1

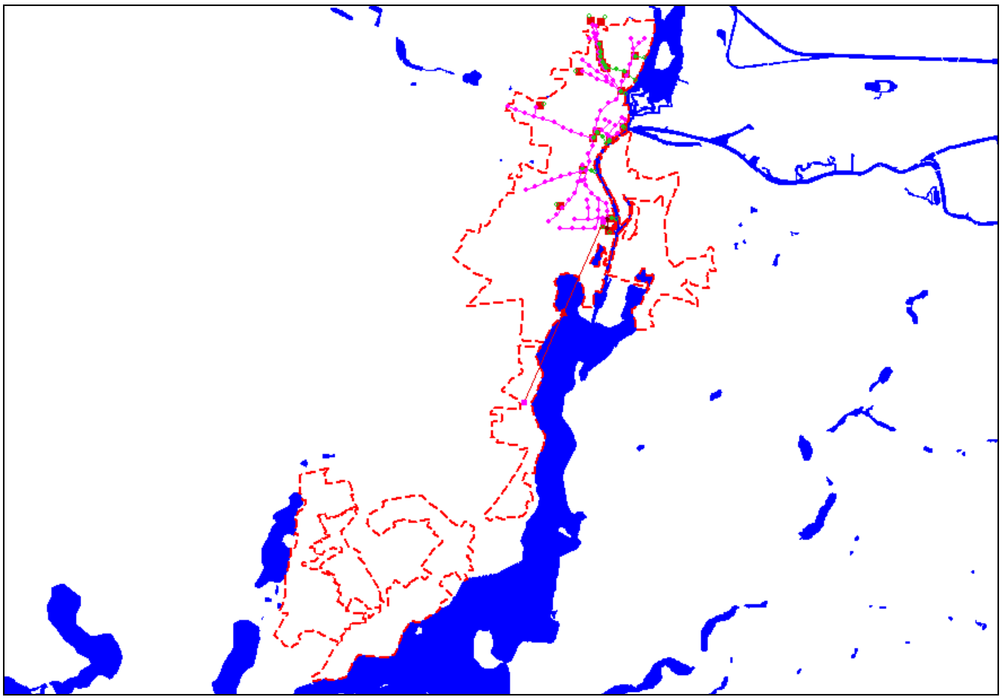
Number of storage tanks and storage sewers: -

Description:
Node ID:
Asset ID:
Volume:

Number of combined sewer overflows: 21

Additional assets:

Inline storage capacity: 5900 m³
Maximum storage level: 30.54 maD

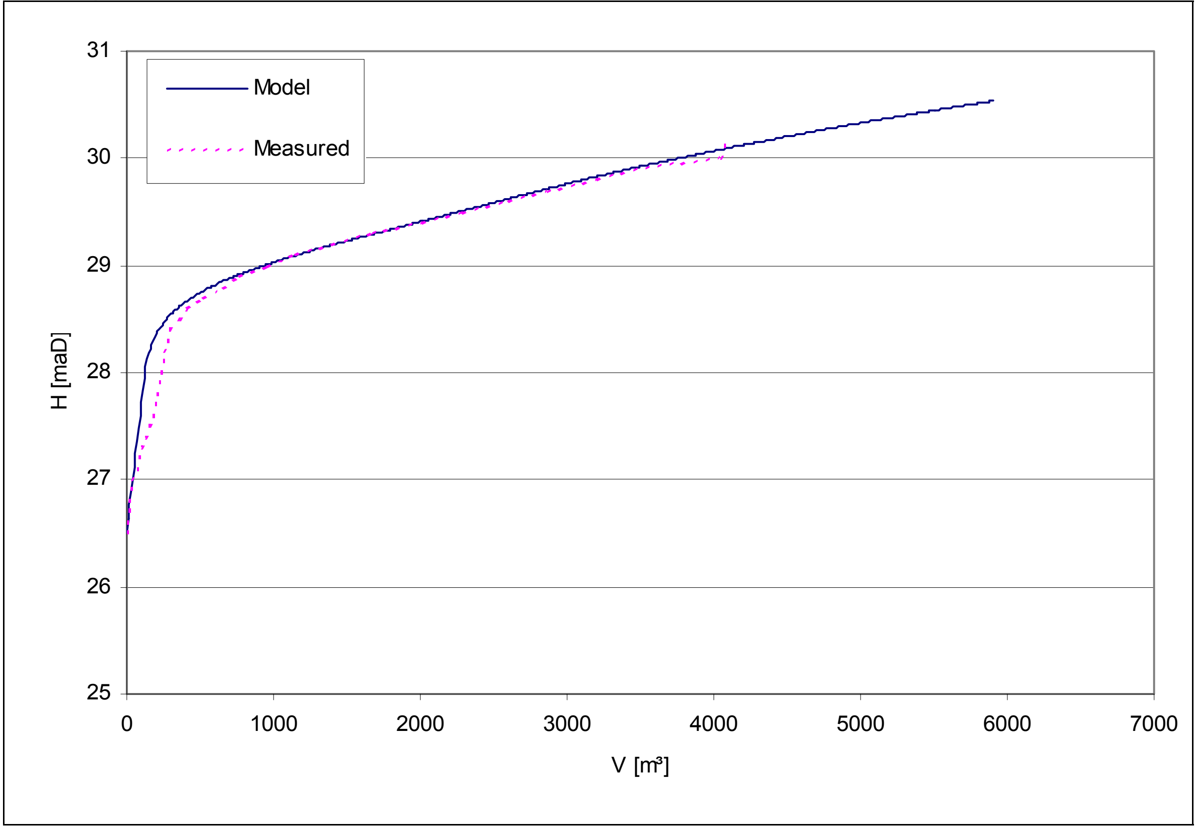


Network model of subcatchment Spandau I

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	5900	4069
storage level [maD]:	30.54	30.20
lowest crest level of cso [maD]:	30.54	

HPw Spa I

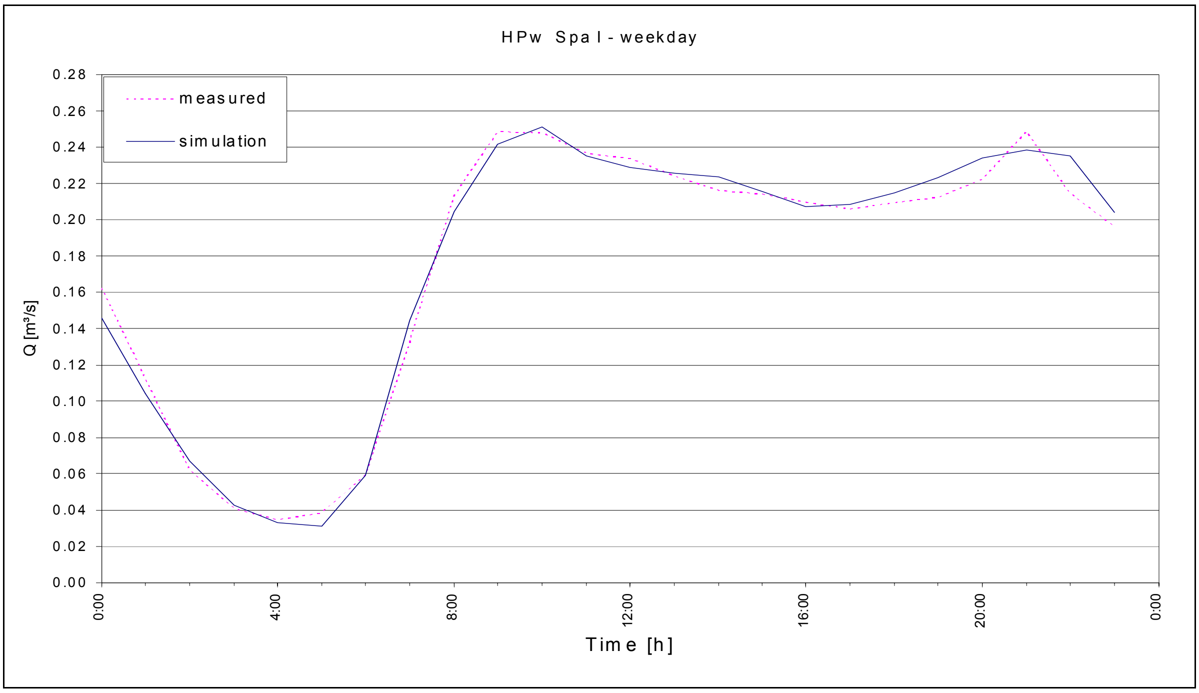


Storage characteristic of sewer network Spandau I

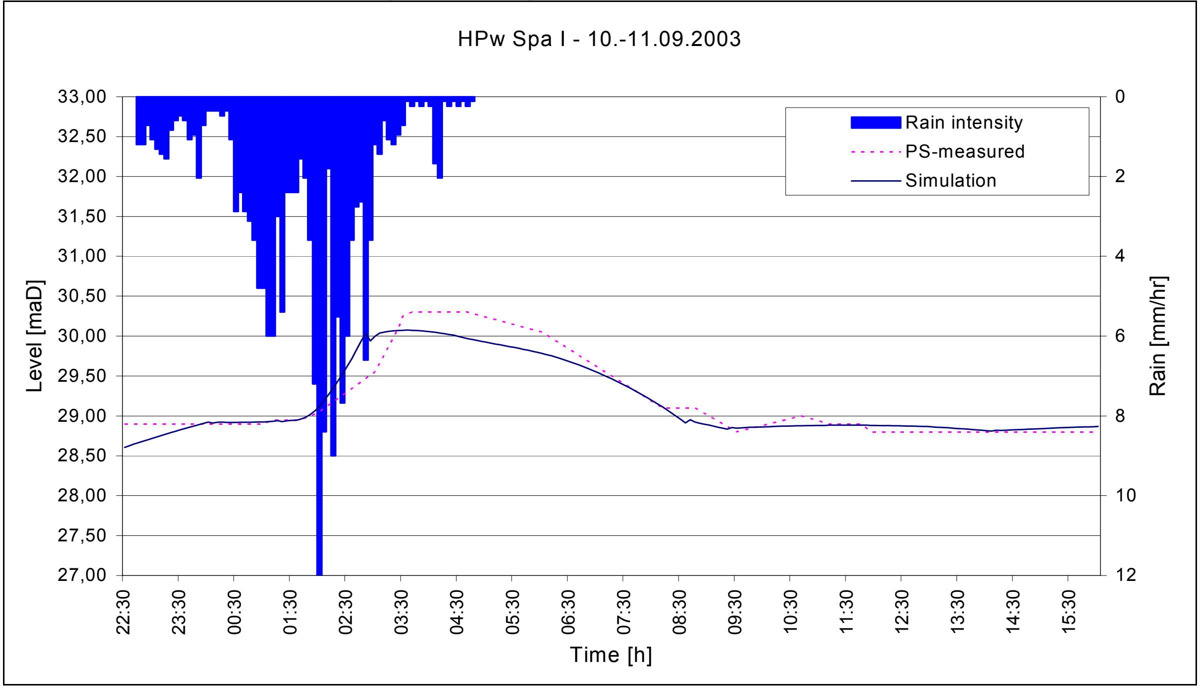
Calibration

Dry Weather: Flow at Pump station Spa I

min flow:	0.031 m³/s
max flow:	0.251 m³/s



Storm Weather: Level at Pump station Spa I

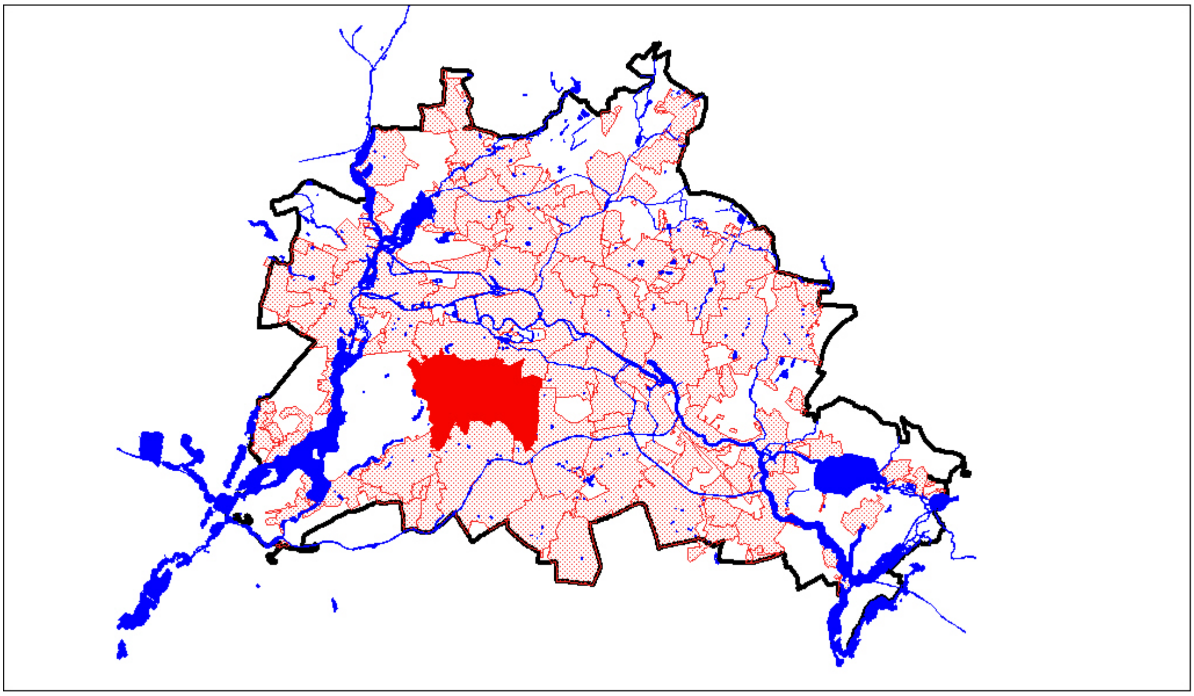


Specifics

- The system consists of various types of subcatchments. There is combined as well as separate system. Also, parts of the separate system lead into combined system again.
- It was necessary to take into account the inflow from misconnected areas in the separate system of Spandau Ia (including Gatow a - c) to assess the correct storm water impact on the system.
- The system was altered in March 2003. Former, the subcatchment of Berlin Spandau Ib used to be pumped into the sewer system of main pumping station Spandau I, Betckestr. Today, sewage of this subcatchment flows into the system of subcatchment Berlin Ruhleben (already modelled).

3.4.15 HPw Wilmersdorf

Subcatchment:	Wilmersdorf	
Contributing Area:	2087 ha	
Population:	267877 Inh.	
WWTP:	dry weather:	Ruhleben
	storm weather:	Ruhleben



Location of subcatchment Wilmersdorf

Model characteristics Wilmersdorf

System type:	Combined and separate
Length of modelled pipes	
Combined:	43.970 km
Waste water:	-
Storm water:	10.696 km
Other:	10.655 km
Number of Nodes	359
Number of Pump Stations	1
Pump Station:	HPw Wilmersdorf, Hohenzollerndamm
US Node ID:	14264009
Average dry weather flow:	525.20 l/s
Maximum Capacity	
local:	1.450 m^3/s
global:	1.700 m^3/s
Destination	
dry weather:	Ruhleben
storm weather:	Ruhleben

Number of storage tanks and storage sewers: 3

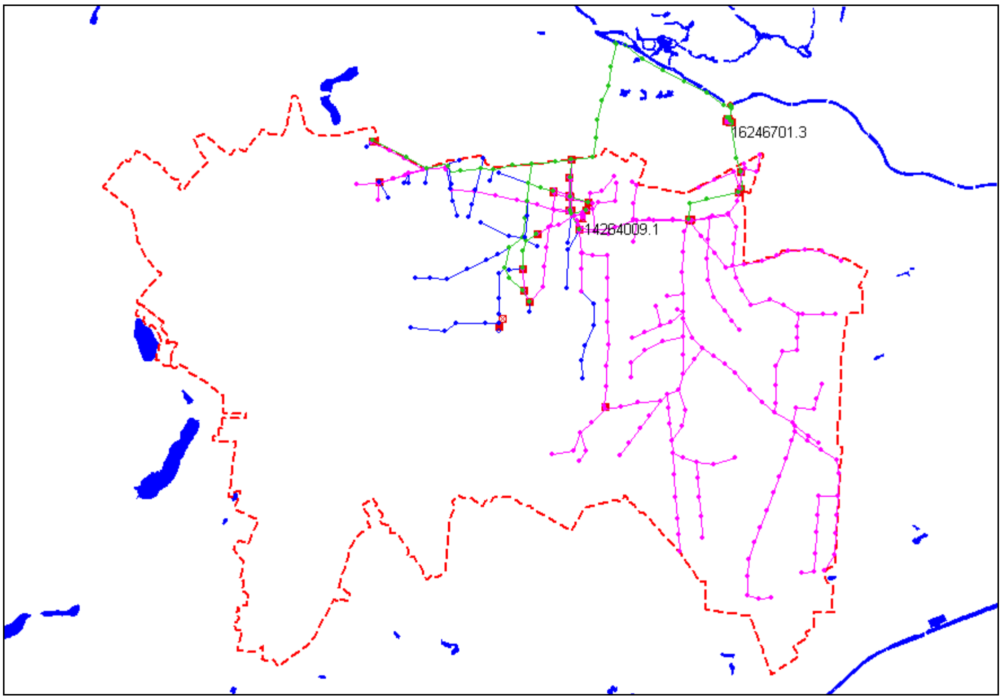
Description: Combined water tanks with overflow
Node ID: 16246T01, 16246T02
Asset ID:
Asset name : RÜB Lützowplatz
Volume: 2000 m³
Filling: Pumps (2 x 833 l/s)

Description: Storage sewer with overflow
Node ID: 16246701
Asset ID:
Asset name : Dammbalkenverschluss Lützowplatz
Volume: 4460 m³

Number of combined sewer overflows: 25

Additional assets:

Inline storage capacity: 5990 m³
Maximum storage level: 31.77 maD

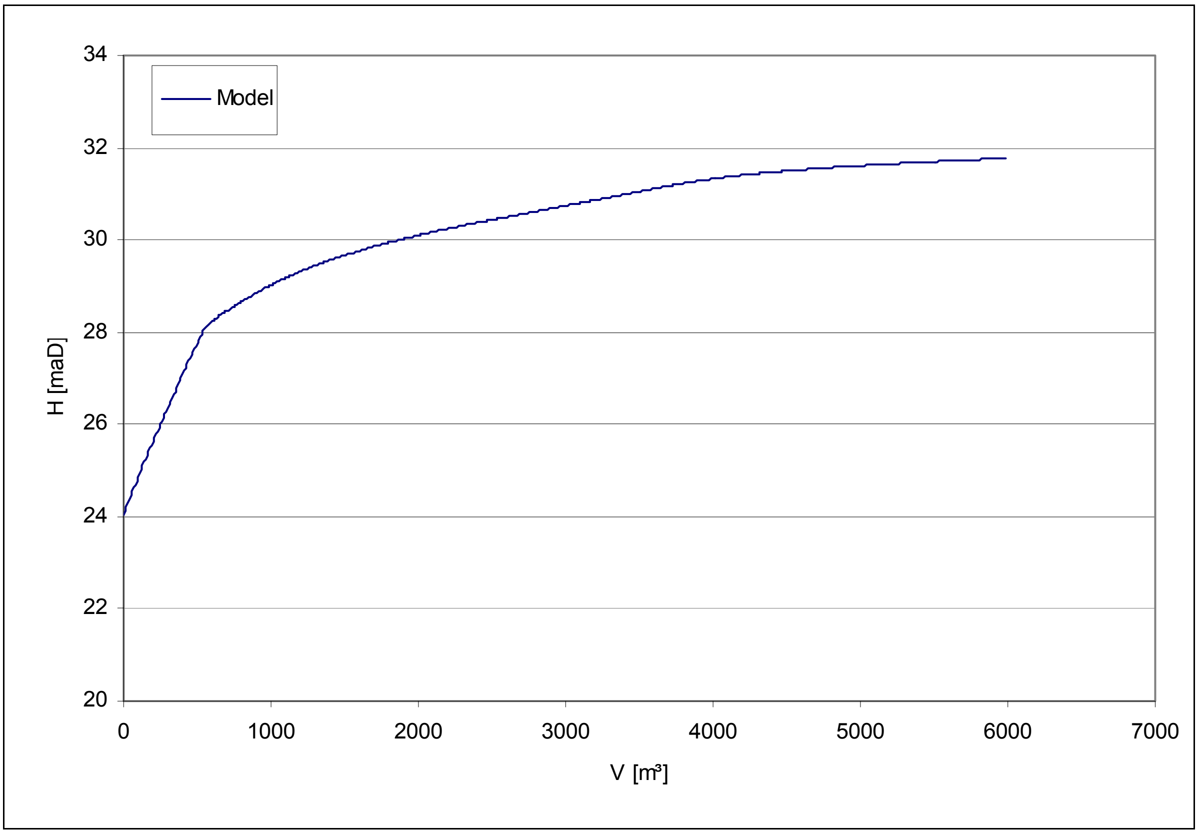


Network model of subcatchment Wilmersdorf

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	5990	-
storage level [maD]:	31,77	-
lowest crest level of cso [maD]:	31.77	

HPw Wil

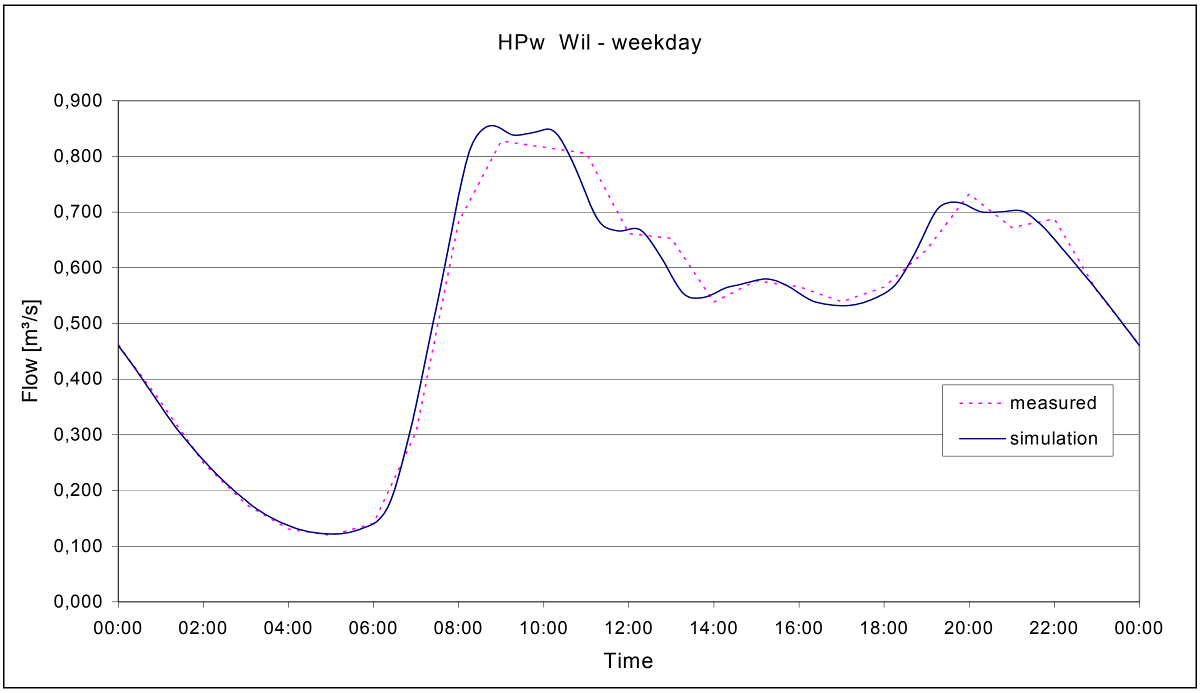


Storage characteristic of sewer network Wilmersdorf

Calibration

Dry Weather: Flow at Pump station Wil

min flow:	0.122 m³/s
max flow:	0.855 m³/s



Storm Weather:

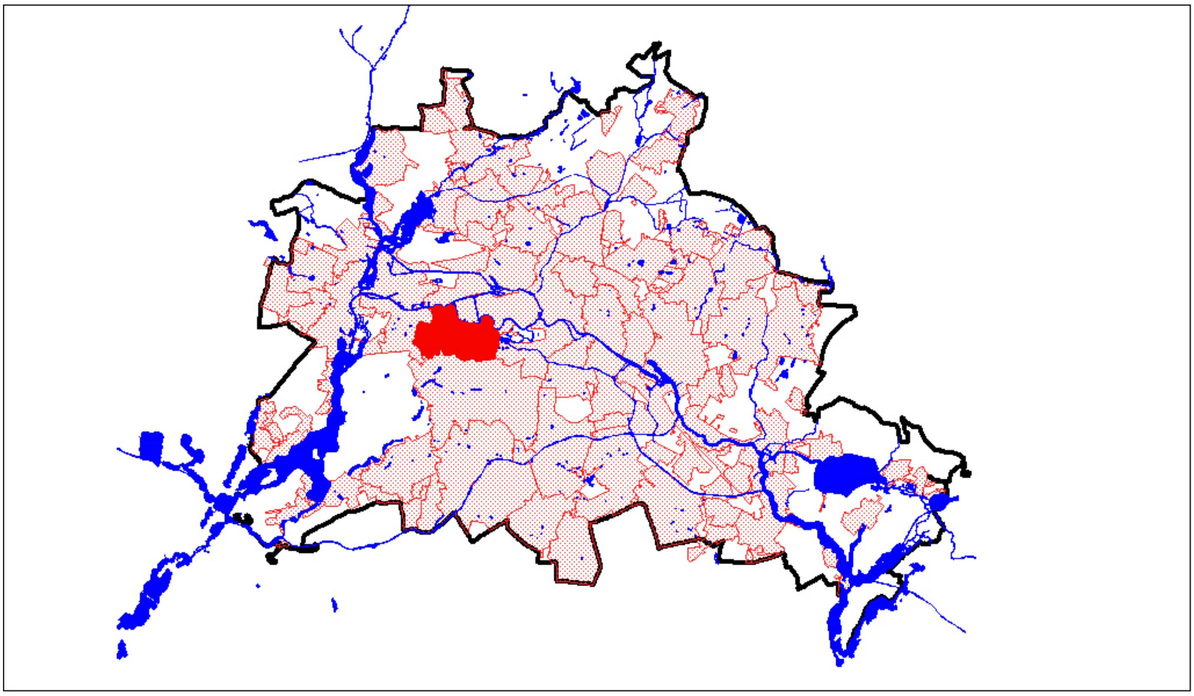
Due to the high variation in dry weather flow and a lack of data a storm weather calibration could not be carried out.

Specifics

- The sluice board (Hubschütz) at Lützowplatz is simplified in the model since the real control concept for this device could not be reproduced with InfoWorks. Now, the sluice board is modelled by a static weir with a crest length of 20 m.
- The “Wilmersdorf” part of the catchment is drained mainly by a separate sewer system. The “Schöneberg” part is drained by a combined system.
- After realisation of the measures of rehabilitation the Wilmersdorf model will have to be newly calibrated and the global control concept will have to be adapted to the new conditions.
- Occasionally, during pollutant simulation numerical instabilities have been observed at the storage sewer (Lützowplatz). Attention should be paid to future simulation results.

3.4.16 HPw Charlottenburg I

Subcatchment:	Charlottenburg I	
Contributing Area:	1069 ha	
Population:	141997 Inh.	
WWTP:	dry weather:	Ruhleben
	storm weather:	Ruhleben



Location of subcatchment Charlottenburg I

Model characteristics Charlottenburg I

System type: Combined

Length of modelled pipes

Combined: 37.204 km
Waste water: -
Storm water: 3.429 km
Other: 9.891 km

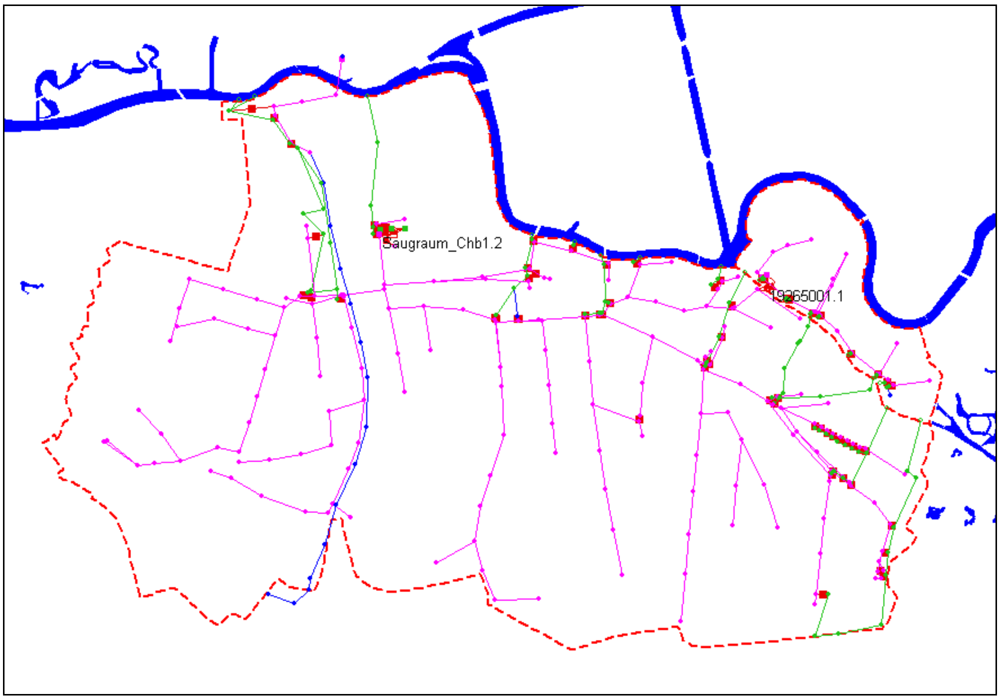
Number of Nodes 331

Number of Pump Stations 2

Pump Station: HPW Charlottenburg I, Sophie-Charlotten-Str.
US Node ID: Saugraum_Chb1
Average dry weather flow: 273.90 l/s
Maximum Capacity
local: 0.900 m^3/s
global: 1.100 m^3/s
Destination
dry weather: Ruhleben
storm weather: Ruhleben

Booster Station: ÜPw Charlottenburg Ia
US Node ID: 19265001
Maximum capacity: 280 l/s
Destination: Sewer network Charlottenburg I
Node ID 18261304

Number of storage tanks and storage sewers:	3
Description:	Combined water tanks with overflow
Node ID:	19293004, 19293006, 19293008
Asset ID:	
Asset name :	RÜB Mollwitzstr.
Volume:	3000 m³
Filling:	Pumps (3 x 833 l/s)
Number of combined sewer overflows:	57
Additional assets:	
Inline storage capacity:	8610 m³
Maximum storage level:	30.84 maD

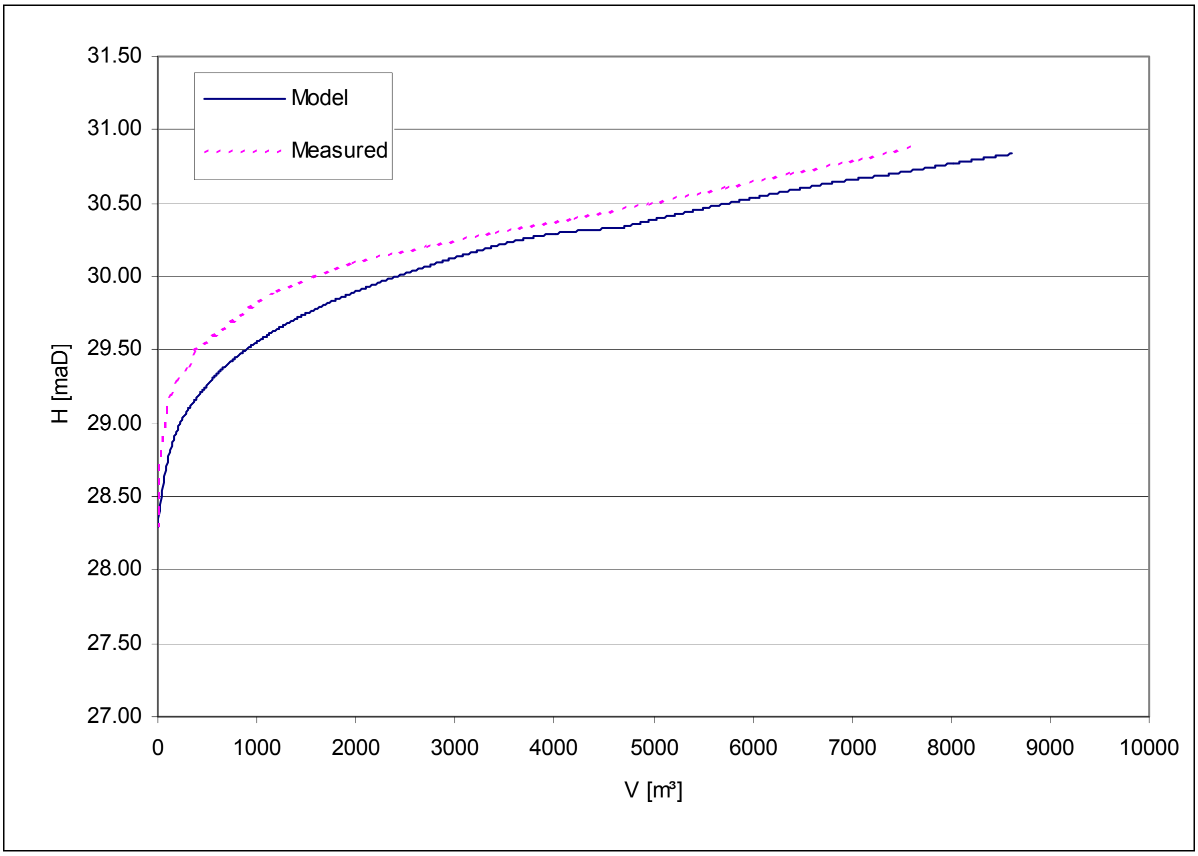


Network model of subcatchment Charlottenburg I

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	8610	7658
storage level [maD]:	30.84	30.90
lowest crest level of cso [maD]:	30.84	

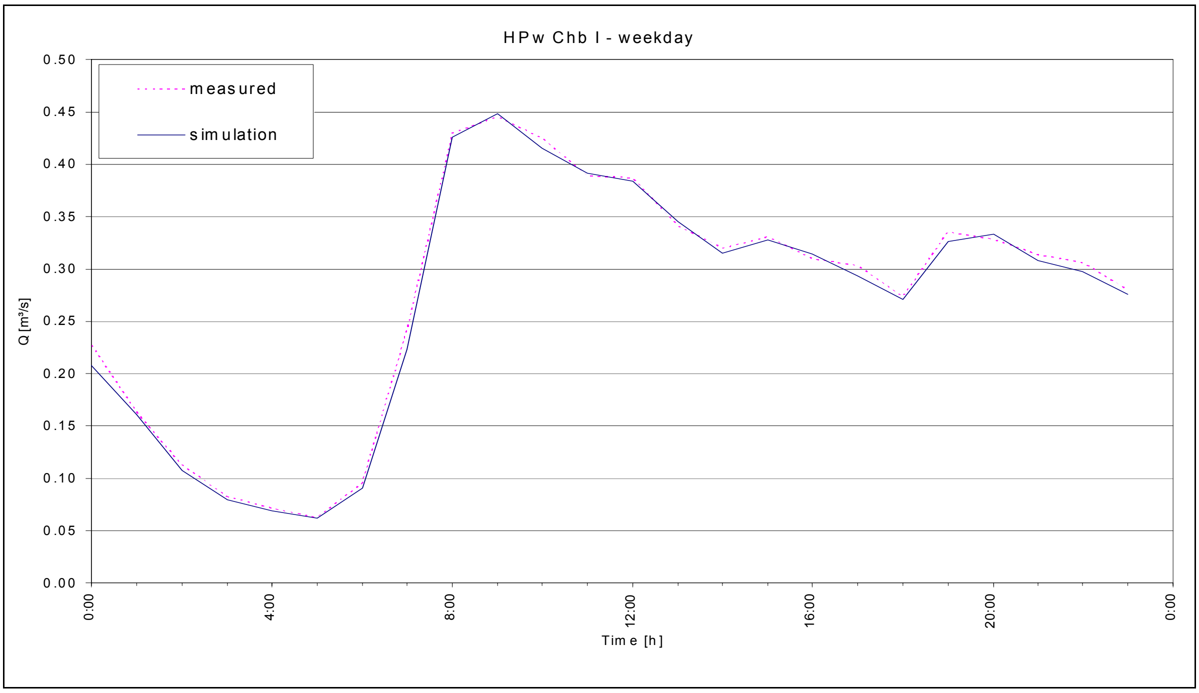
HPw Chb I



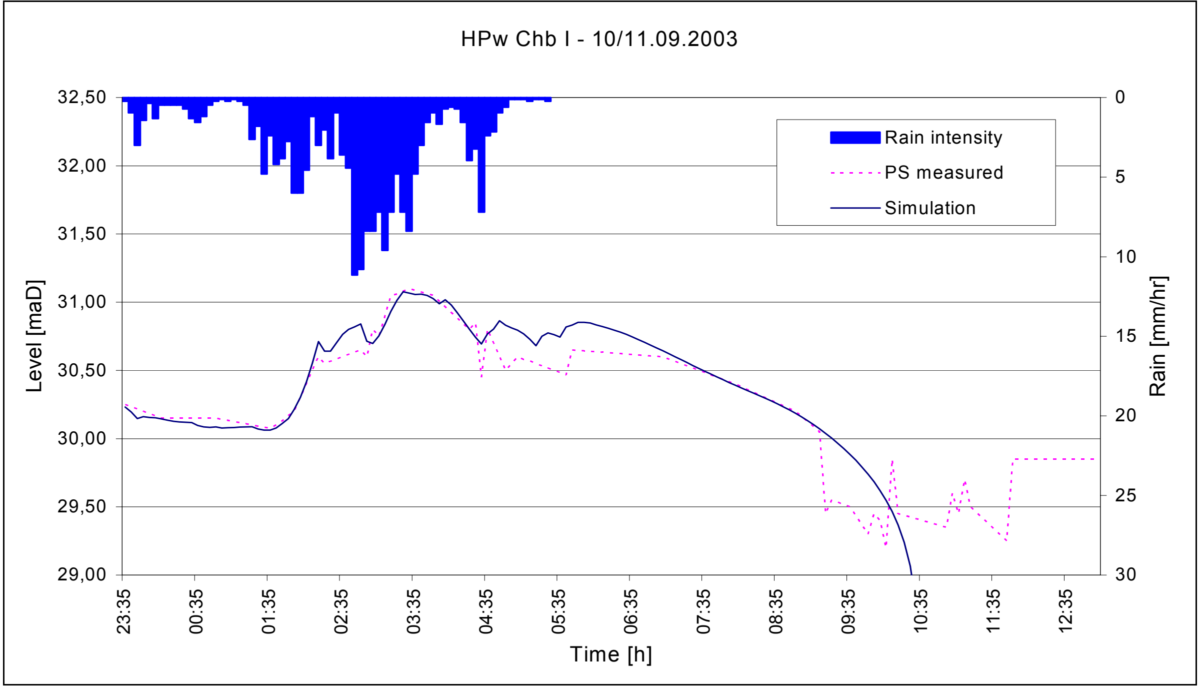
Storage characteristic of sewer network Charlottenburg I

Calibration

Dry Weather: Flow at Pump station Chb I
min flow: 0.062 m³/s
max flow: 0.448 m³/s



Storm Weather: Level at Pump station Chb I



Specifics

- Charlottenburg I and Charlottenburg III are connected by one link, which is a siphon under river Spree. Thus, parts of subcatchment Chb I discharge into subcatchment Chb III. This includes wastewater from a hospital in the very east of Chb I as well as combined sewer overflow and rain water from the BAB 100. The rest of catchment Chb I consists of combined system only.

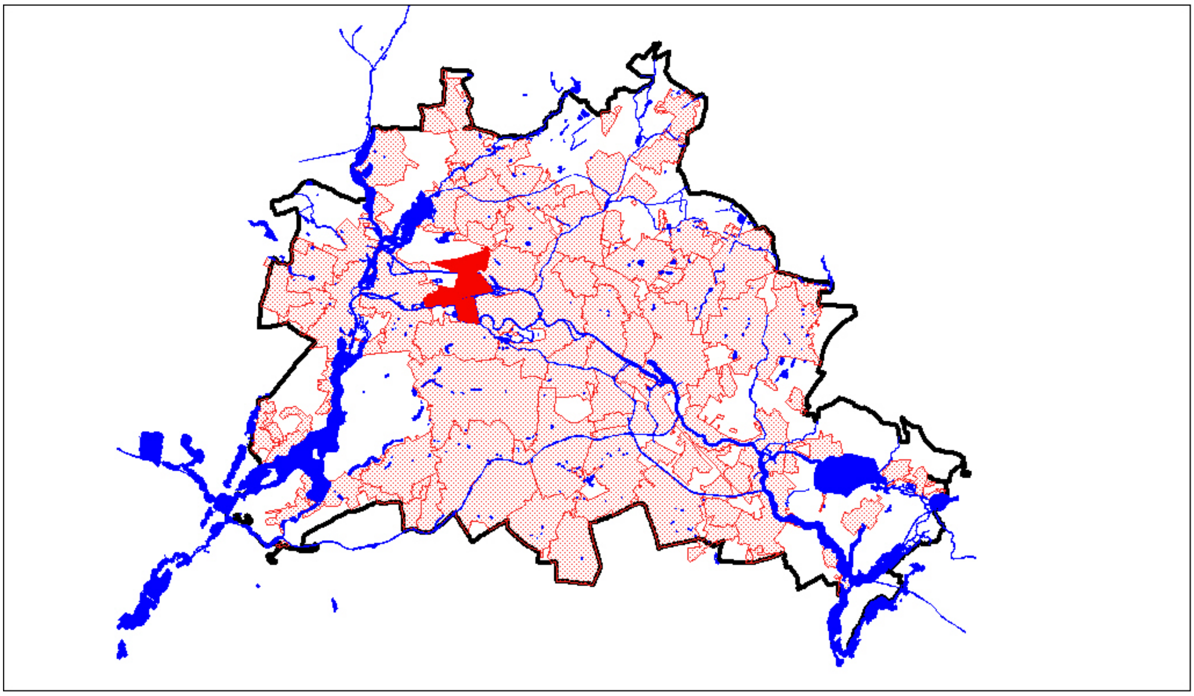
3.4.17 Charlottenburg III

Subcatchment: Charlottenburg III

Contributing Area: 508 ha

Population: 55245 Inh.

WWTP: dry weather: Ruhleben
storm weather: Ruhleben



Location of subcatchment Charlottenburg III

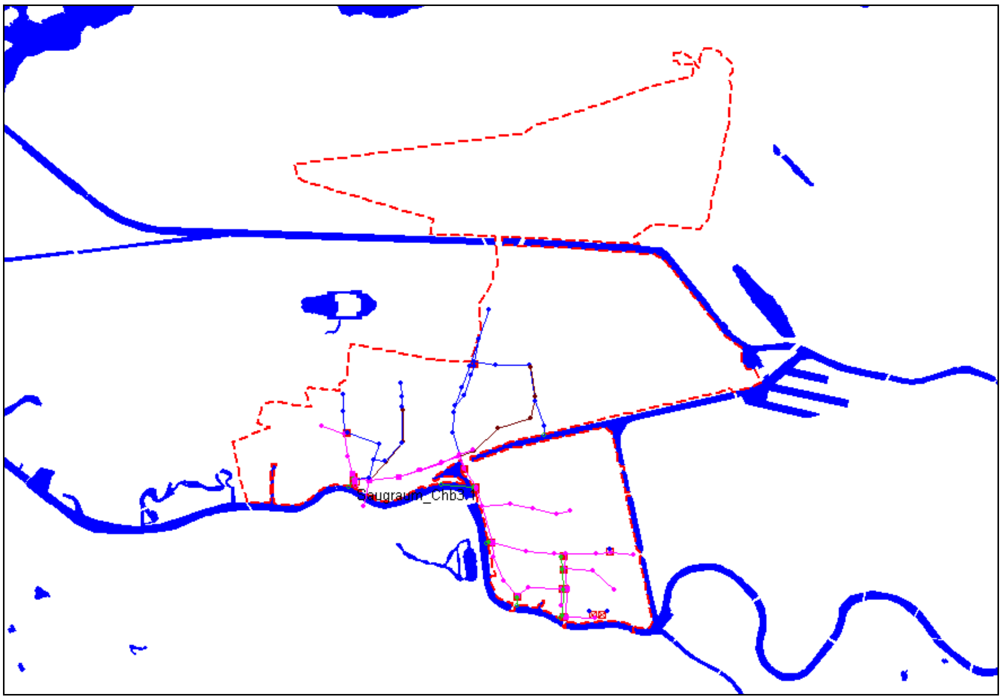
Model characteristics Charlottenburg III

System type:	Combined and separate
Length of modelled pipes	
Combined:	7.678 km
Waste water:	1.933 km
Storm water:	5.128 km
Other:	1.124 km
Number of Nodes	97
Number of Pump Stations	1
Pump Station:	APw Charlottenburg III, Nonnendamm
US Node ID:	Saugraum_Chb3
Average dry weather flow:	62.00 l/s
Maximum Capacity	
local:	0.200 m^3/s
global:	0.400 m^3/s
Destination	
dry weather:	Ruhleben
storm weather:	Ruhleben

Number of storage tanks and storage sewers:	-

Description:
Node ID:
Asset ID:
Volume:

Number of combined sewer overflows:	20
Additional assets:	
Inline storage capacity:	14600 m³
Maximum storage level:	30.36 maD

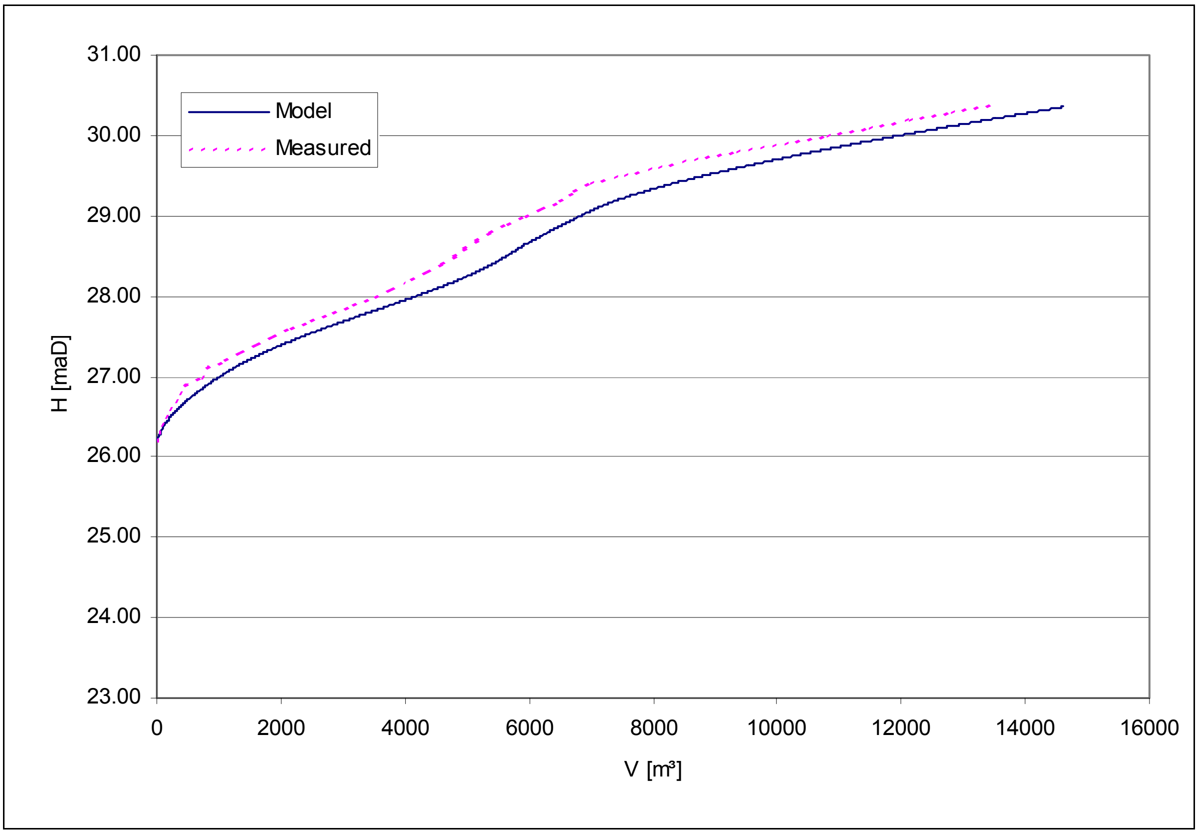


Network model of subcatchment Charlottenburg III

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	14600	13467
Storage level [maD]:	30.36	30.40
lowest crest level of cso [maD]:	30.36	

APw Chb III

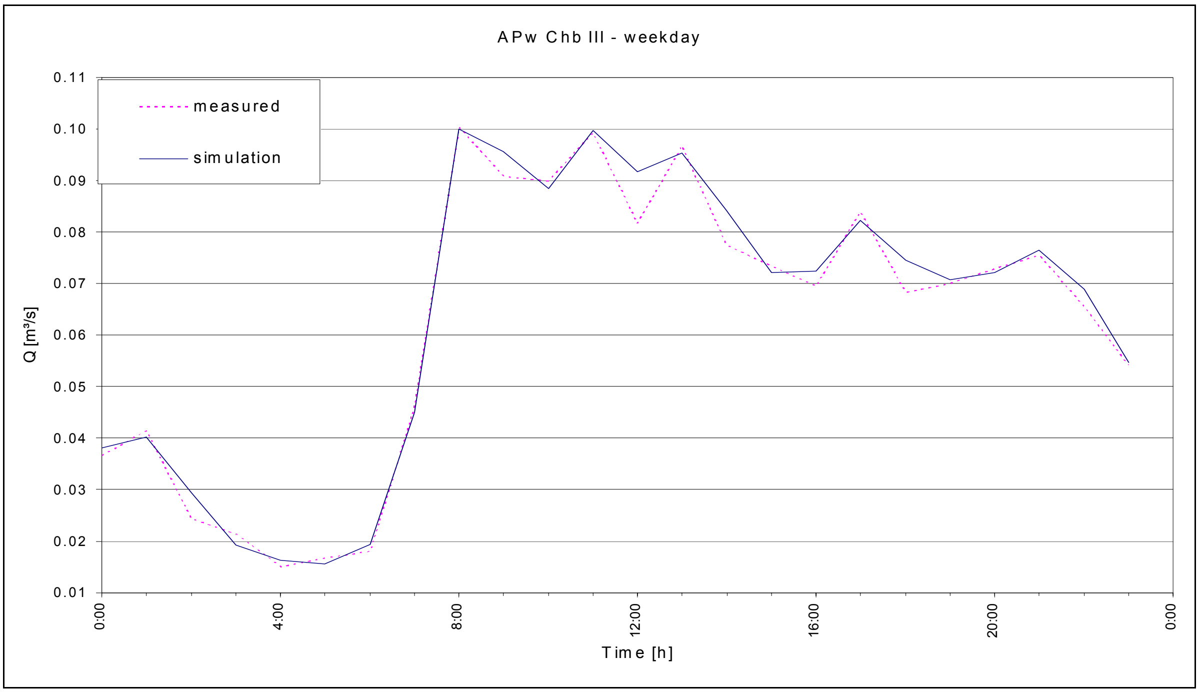


Storage characteristic of sewer network Charlottenburg III

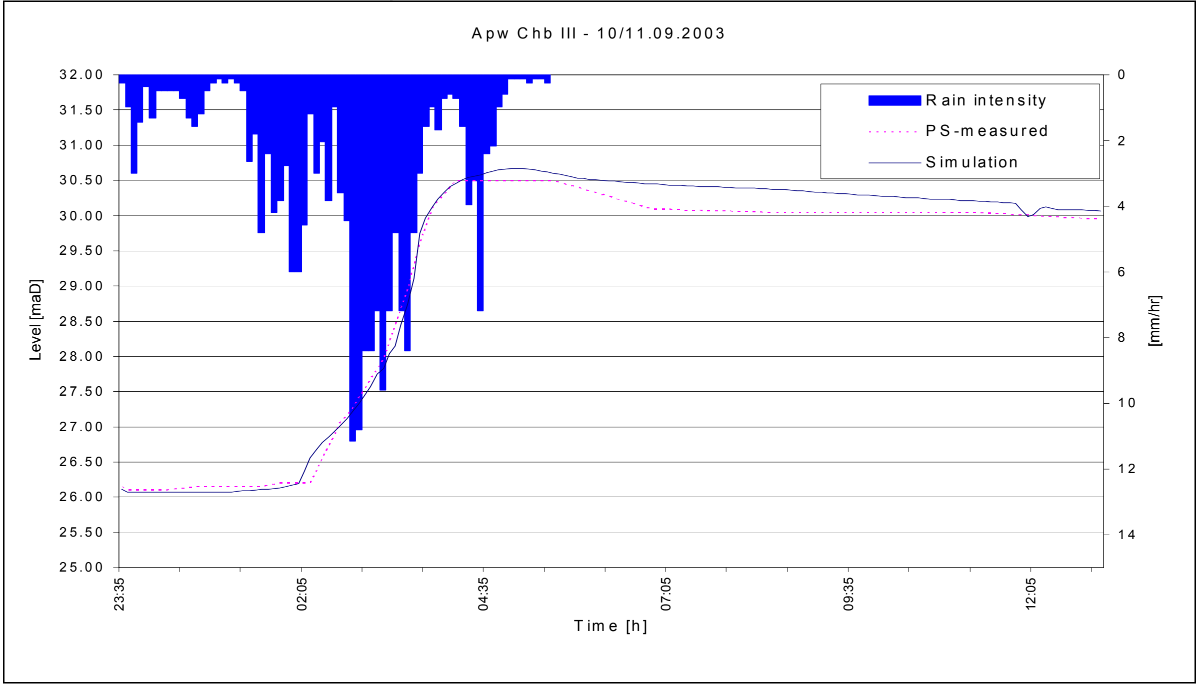
Calibration

Dry Weather: Flow at Pump station Chb III

min flow: 0.016 m³/s
max flow: 0.100 m³/s



Storm Weather: Level at Pump station Chb III



Specifics

- Chb III has separate system as well as combined system. There is rainwater inflow into some wastewater pipes of the separated system of Chb III. The influence of this inflow was researched by BWB 2002. For the model, this runoff area was included.
- Charlottenburg I and Charlottenburg III are connected by one link, which is a siphon under river Spree. Thus, parts of subcatchment Chb I discharge into subcatchment Chb III. This includes wastewater from a hospital in the very east of Chb I as well as combined sewer overflow and rain water from the BAB 100.

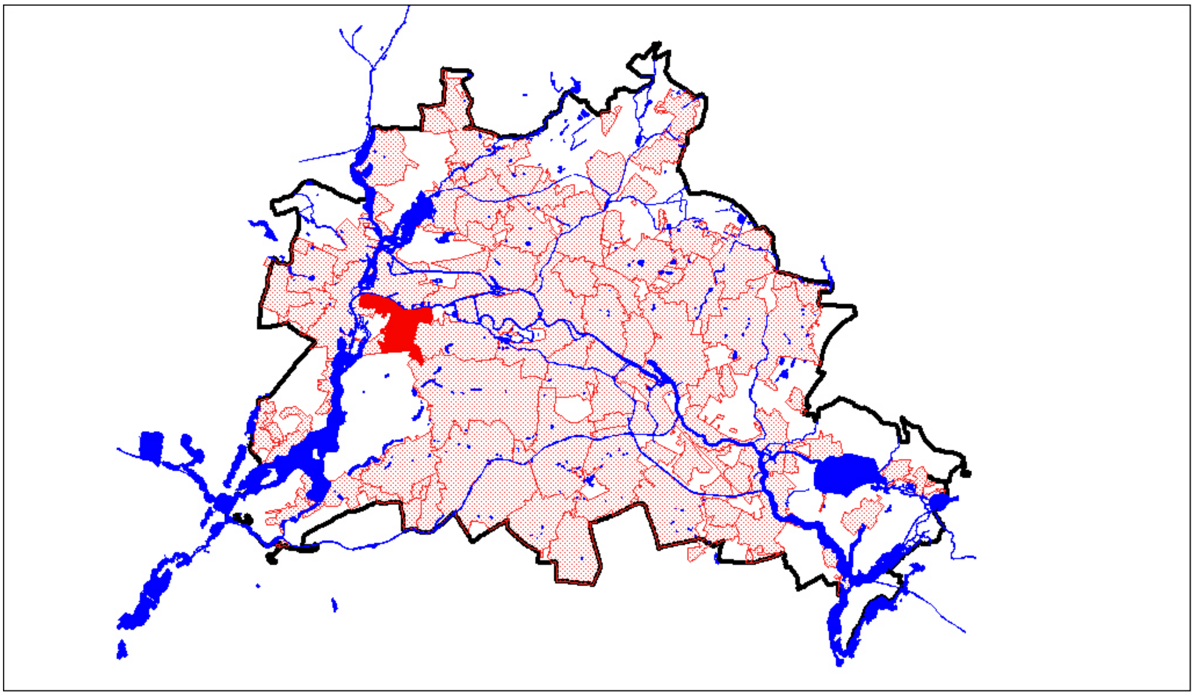
3.4.18 APw Ruhleben

Subcatchment: Ruhleben

Contributing Area: 621 ha

Population: 18520 Inh.

WWTP: dry weather: Ruhleben
storm weather: Ruhleben



Location of subcatchment Ruhleben

Model characteristics Ruhleben

System type: Combined and separated

Length of modelled pipes

Combined: 3.171 km
Waste water: 5.273 km
Storm water: -
Other: 0.636 km

Number of Nodes 92

Number of Pump Stations 1

Pump Station: APw Ruhleben, Freiheit
US Node ID: Saugraum_Ruh
Average dry weather flow: 68.30 l/s
Maximum Capacity
local: 0.200 m^3/s
global: 0.500 m^3/s
Destination
dry weather: Ruhleben
storm weather: Ruhleben

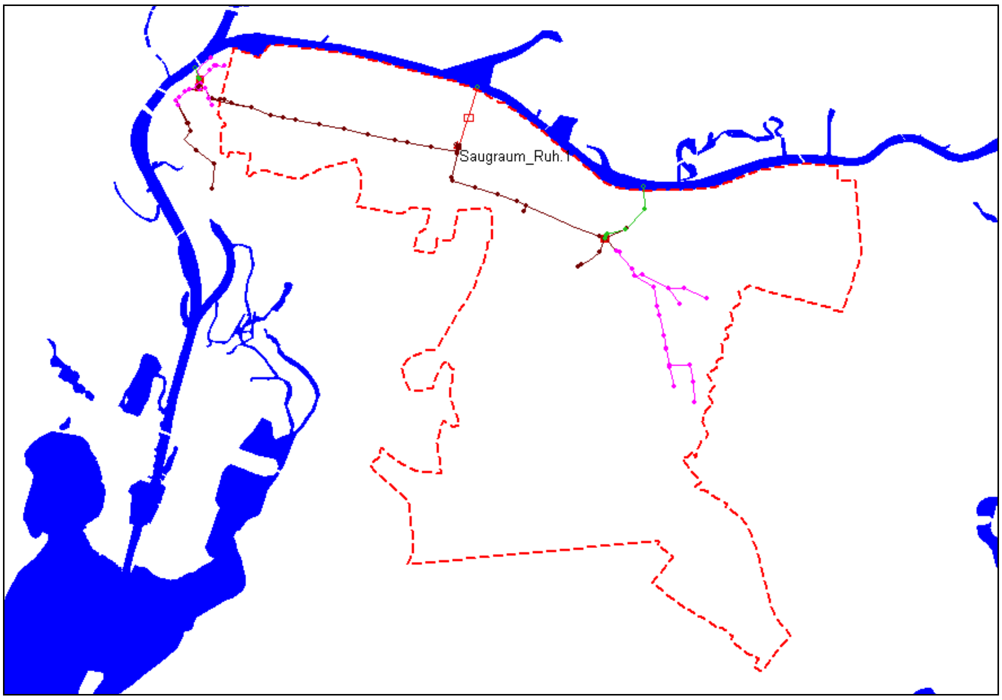
Number of storage tanks and storage sewers: -

Description:
Node ID:
Asset ID:
Volume:

Number of combined sewer overflows: 2

Additional assets:

Inline storage capacity: 1980 m³
Maximum storage level: 30.50 maD

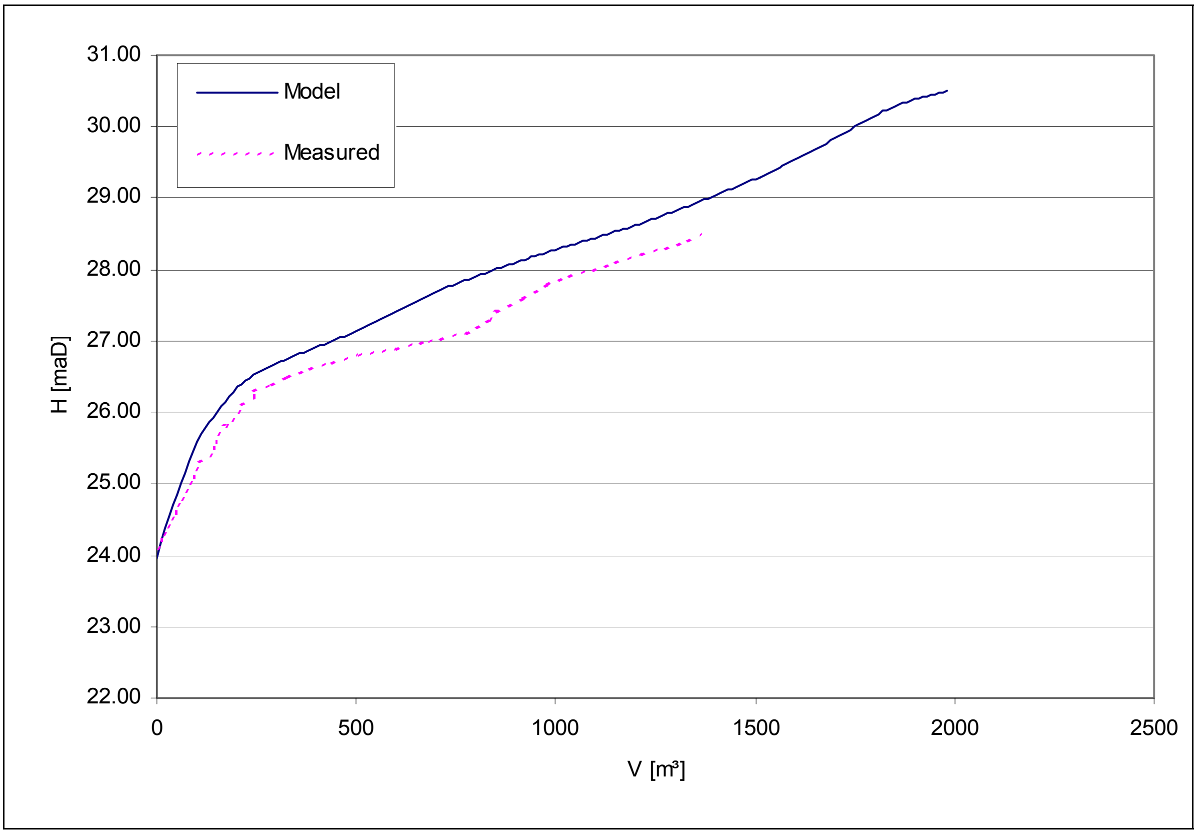


Network model of subcatchment Ruhleben

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	1980	1359
storage level [maD]:	30.50	28.50
lowest crest level of cso [maD]:	30.50	

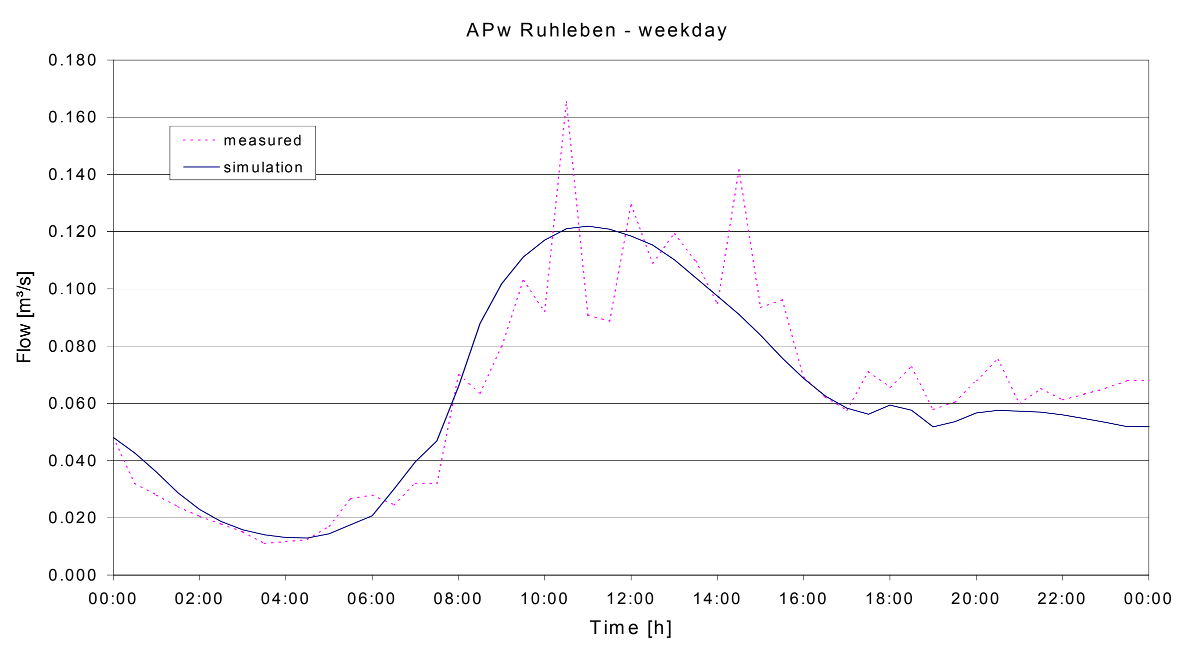
APw Ruh



Storage characteristic of sewer network Ruhleben

Calibration

Dry Weather: Flow at Pump station Ruh
min flow: 0.013 m³/s
max flow: 0.122 m³/s



Dry weather calibration has to be adapted anew, because the catchment of Spandau Ib is now connected to Ruhleben. This situation is not yet considered in our model.

Storm Weather:

Due to a lack of data a storm weather calibration could not be carried out.

Specifics

- Special observations on the catchment Ruhleben have been the high number of industrial inflows and an additional inflow of faeces at the pump station. Due to these conditions the calibration of the model involves high uncertainties.
- Further reconstructions of the network will be carried out in the near future. The complete reconstruction of RÜ “Spandauer Damm” will have a significant influence on the system behaviour and consequently on the global rtc (adaptation will be necessary).

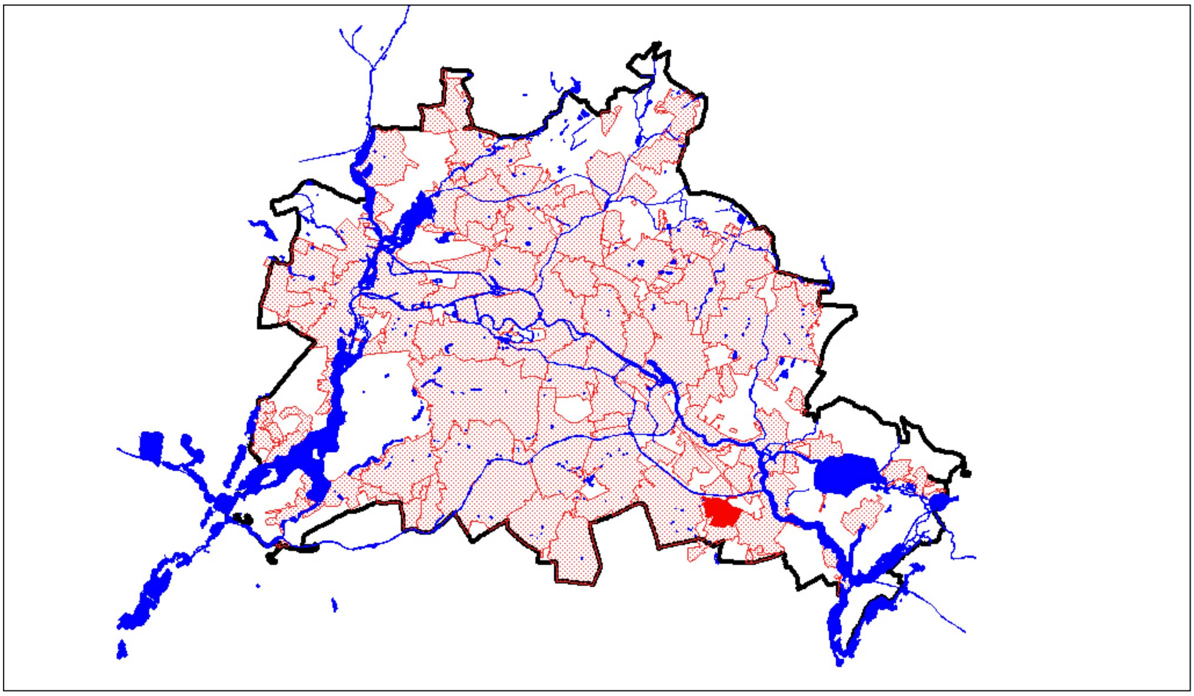
3.4.19 Altglienicke I

Subcatchment: Atlglienicke I

Total Area: 296 ha

Population: 8122 Inh.

WWTP: dry weather: Waßmannsdorf
rain weather: Waßmannsdorf



Location of subcatchment Altglienicke I

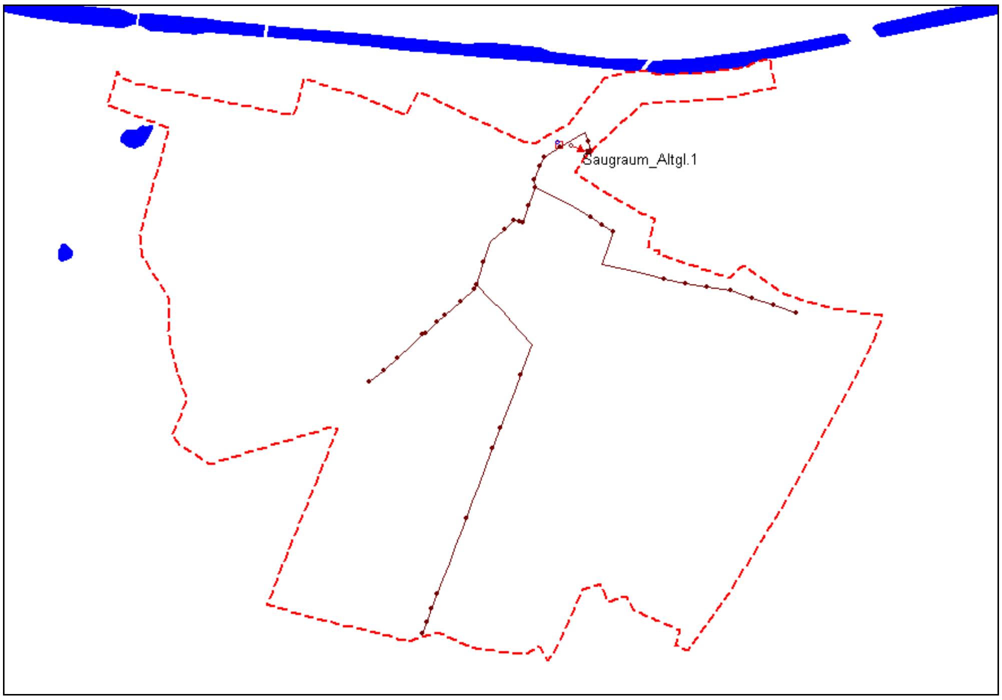
Model characteristics Altglienicke I

System type:	Separate
Length of modelled pipes	
Combined:	-
Waste water:	3.502 km
Storm water:	-
Other:	-
Number of Nodes	44
Number of Pump Stations	1
Pump Station:	APw Altglienicke I, Köpenicker Str.
Node ID:	Saugraum_Altgl
Average dry wheather flow:	9.20 l/s
Maximum Capacity	
local:	0.060 m^3/s
global:	-
Destination	
dry weather:	Waßmannsdorf
storm weather:	Waßmannsdorf

Number of emergency outlets: 1

Node ID: 01086001

invert level [maD]: 33.86

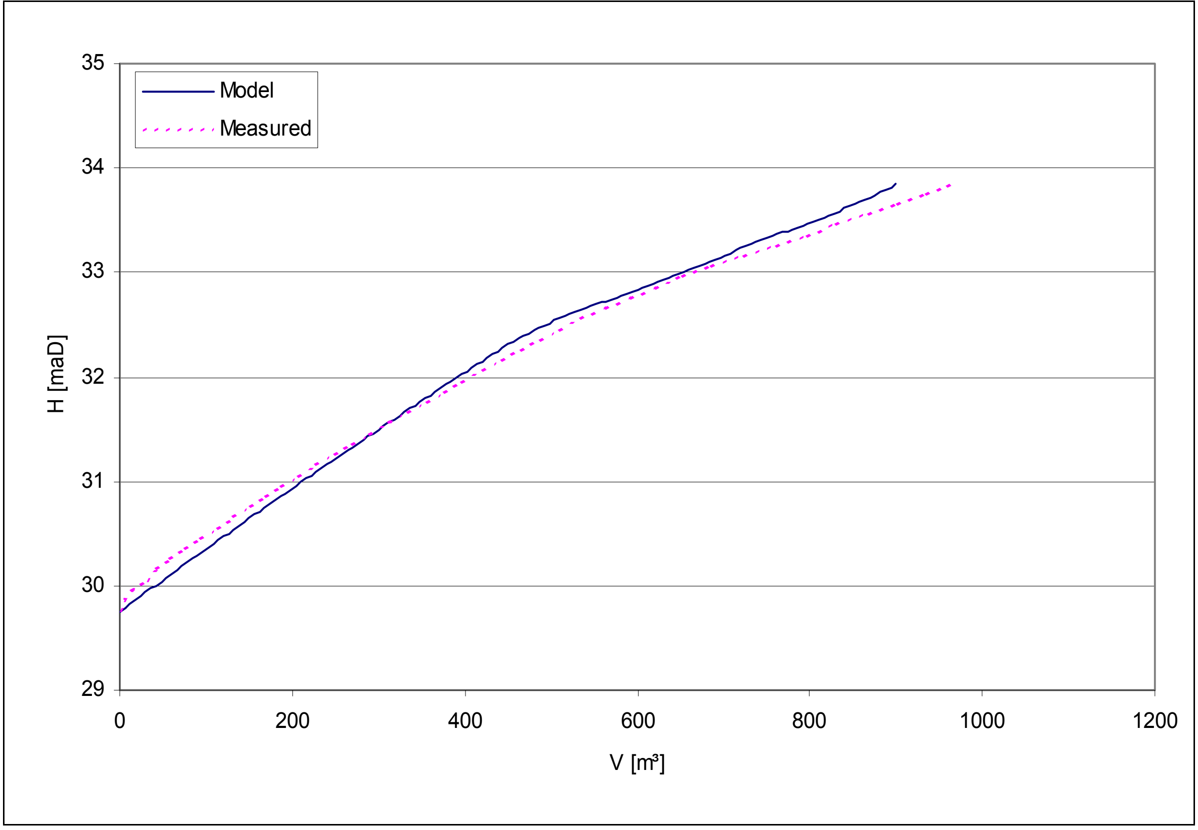


Network model of subcatchment Altglienicke I

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	900	971
storage level [maaD]:	33.86	33.86
invert level of emergency outlet [maD]:	33.86	

APw Altgl I



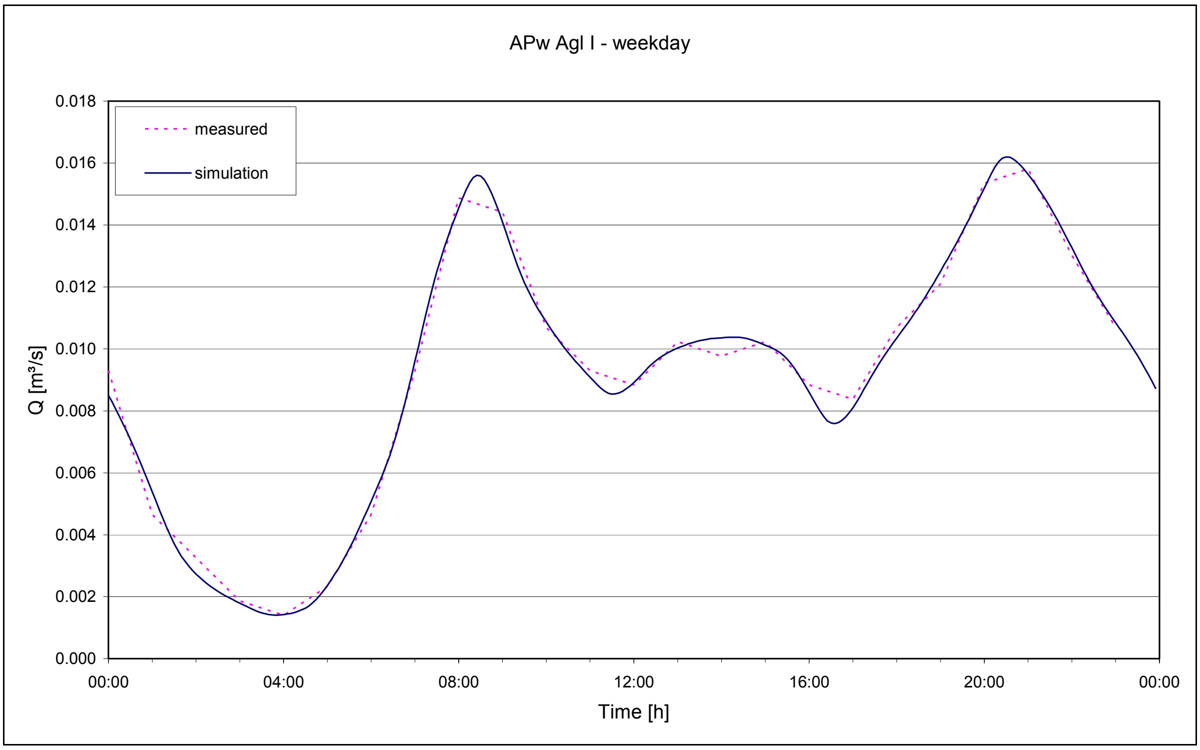
Storage characteristic of sewer network Altglienicke I

Calibration

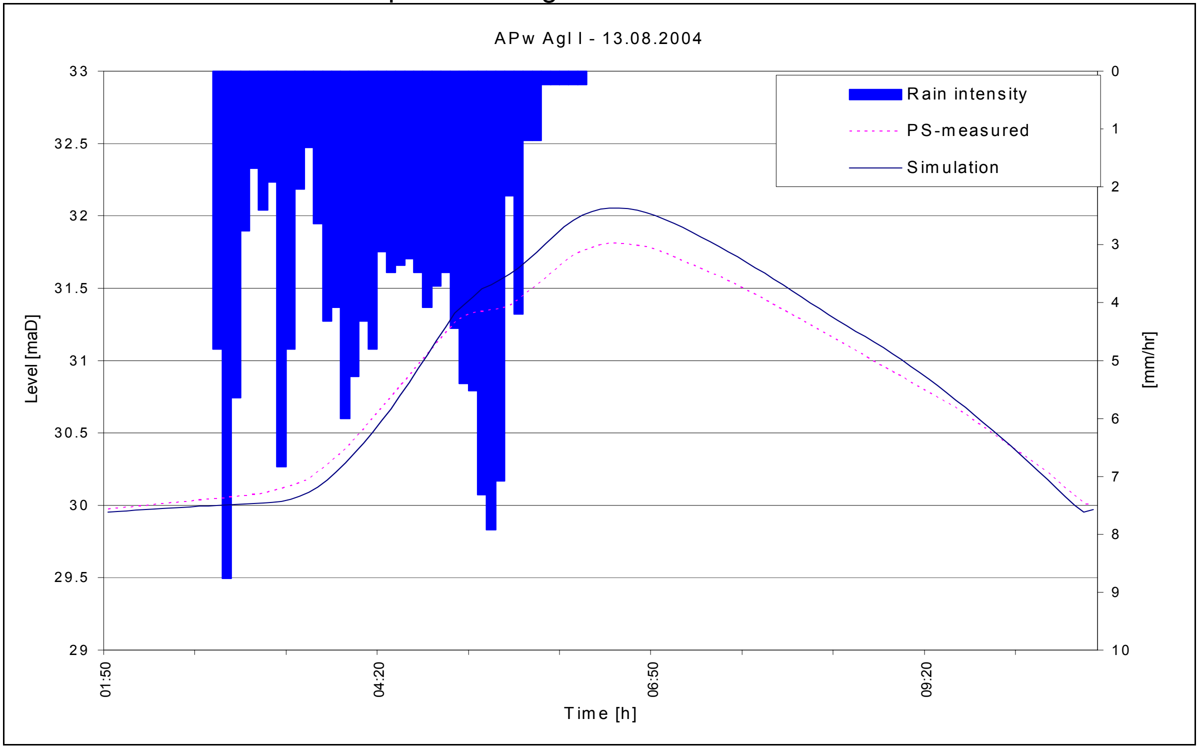
Dry Weather: Flow at Pump station Altgl I, 14.06.2000, adapted to data from 2004

min flow: 0.001 m³/s

max flow: 0.016 m³/s



Storm Weather: Level at Pump station Altgl I



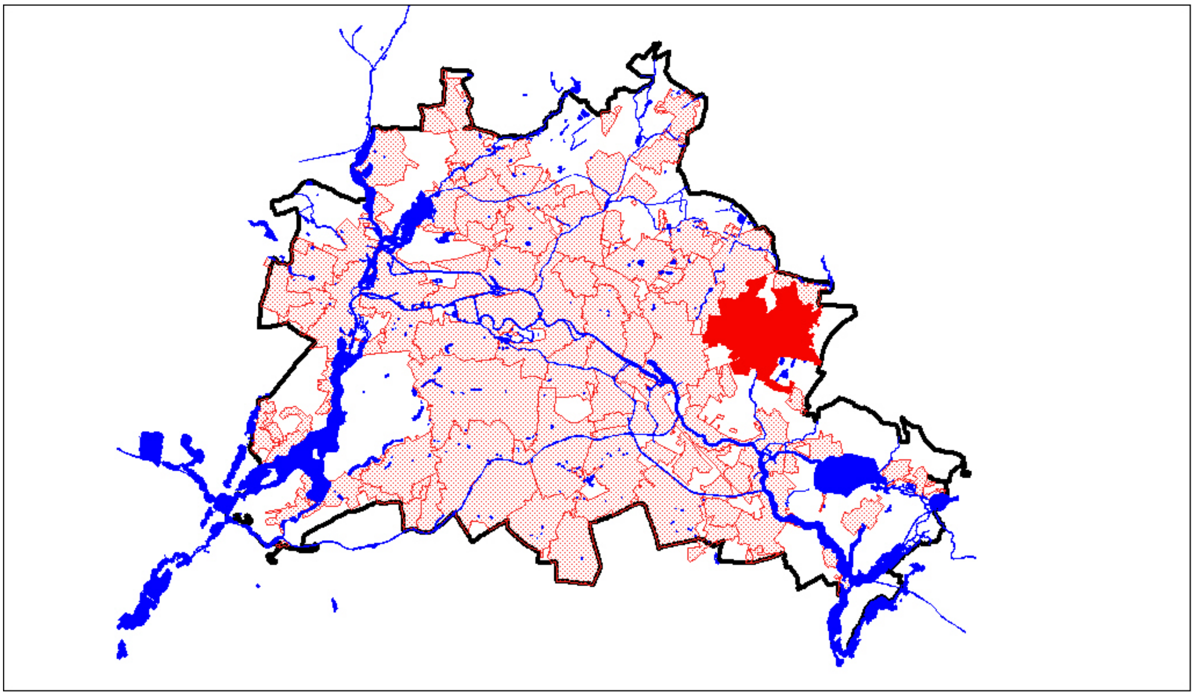
3.4.20 Biesdorf I

Subcatchment: Biesdorf I

Total Area: 2714 ha

Population: 115483 Inh.

WWTP: dry weather: Waßmannsdorf
rain weather: Waßmannsdorf/Münchehofe



Location of subcatchment Biesdorf I

Model characteristics Biesdorf I

System type: Separate

Length of modelled pipes

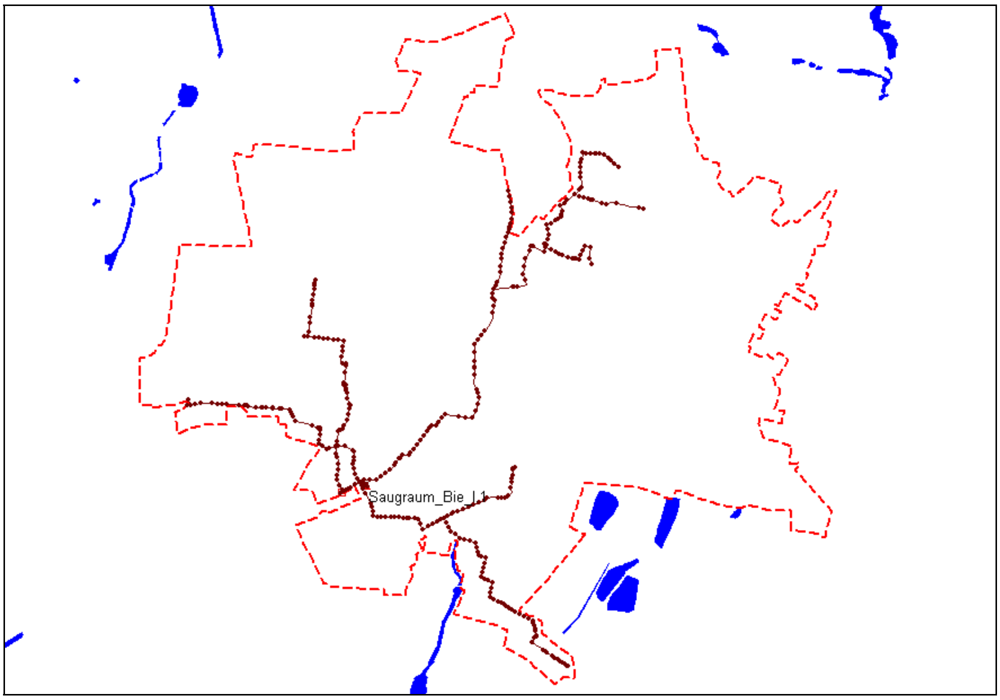
- **Combined:** -
- **Waste water:** 18.392 km
- **Storm water:** -
- **Other:** -

Number of Nodes 356

Number of Pump Stations 1

- **Pump Station:** APw Alt Biesdorf I, Grabensprung
- **Node ID:** Saugraum_Bie_I
- **Average dry wheather flow:** 173.20 l/s
- **Maximum Capacity**
    - **local:** 0.700 m^3/s
    - **global:** -
- **Destination**
    - **dry weather:** Waßmannsdorf
    - **storm weather:** Waßmannsdorf/Münchehofe

Number of emergency outlets: 1
Node ID: 15072001
invert level [maD]: 35.92

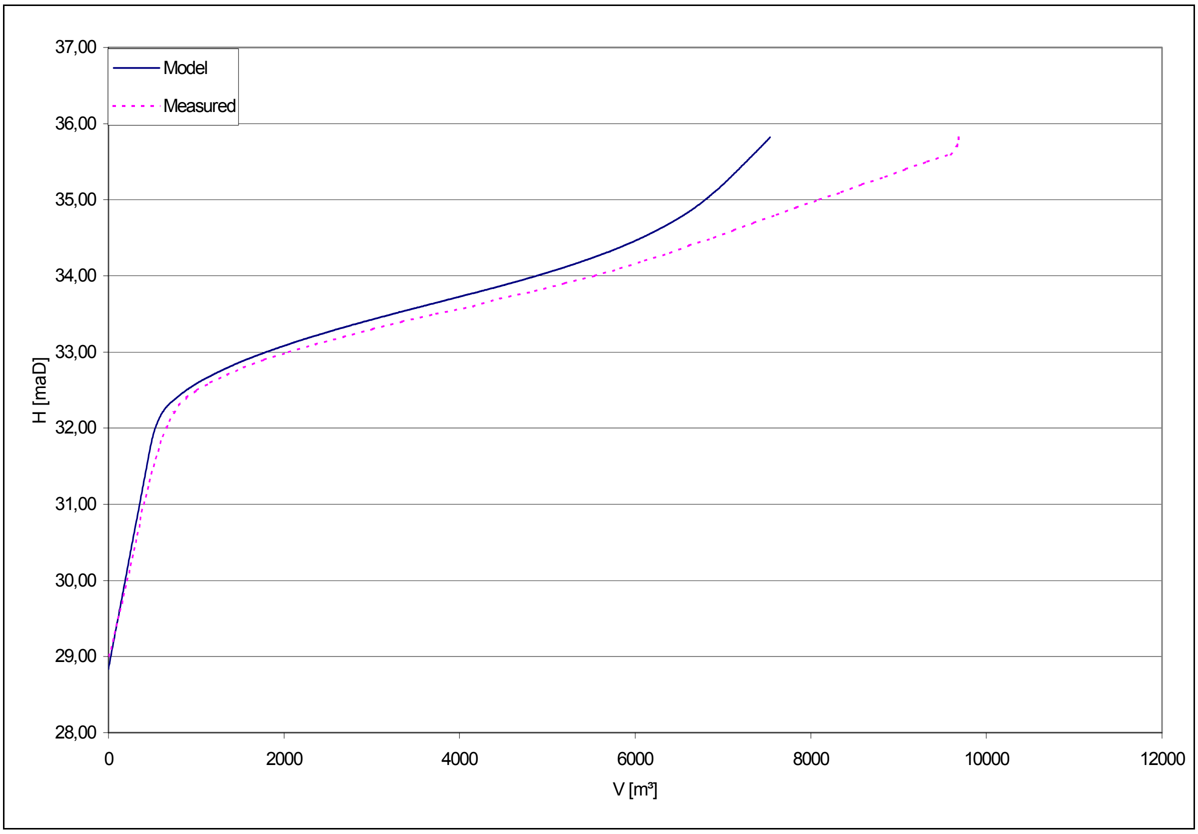


Network model of subcatchment Biesdorf I

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	7536	9680
storage level [maD]:	35.82	35.82
invert level of emergency outlet [maD]:	35.92	

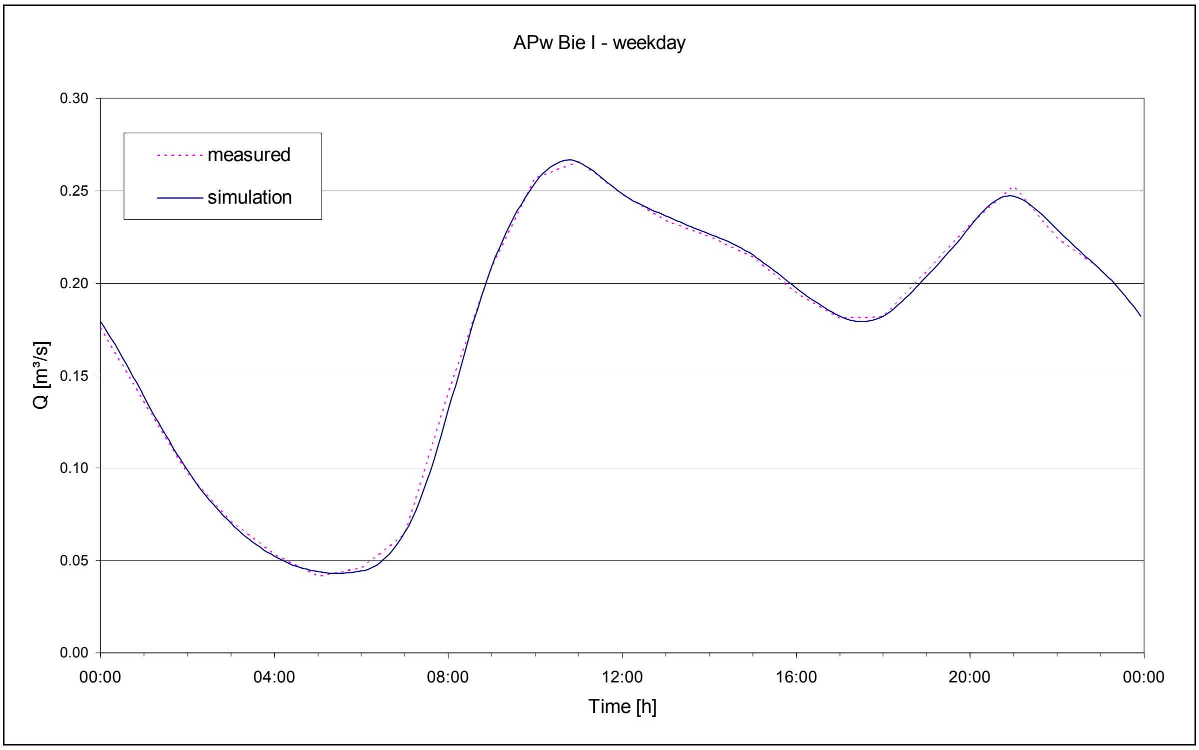
APw Bie I



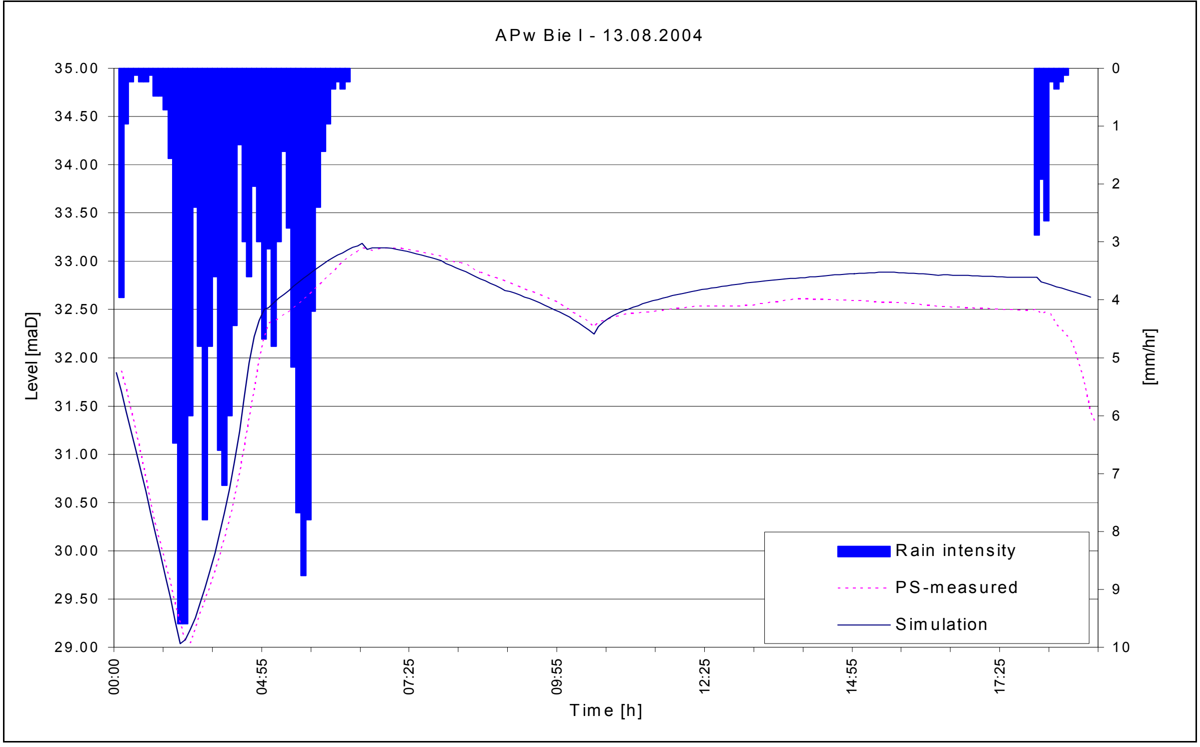
Storage characteristic of sewer network Biesdorf I

Calibration

Dry Weather: Flow at Pump station Bie I, 31.10.2000, adapted to data from 2004
min flow: 0.043 m³/s
max flow: 0.267 m³/s



Storm Weather: Level at Pump station Bie I



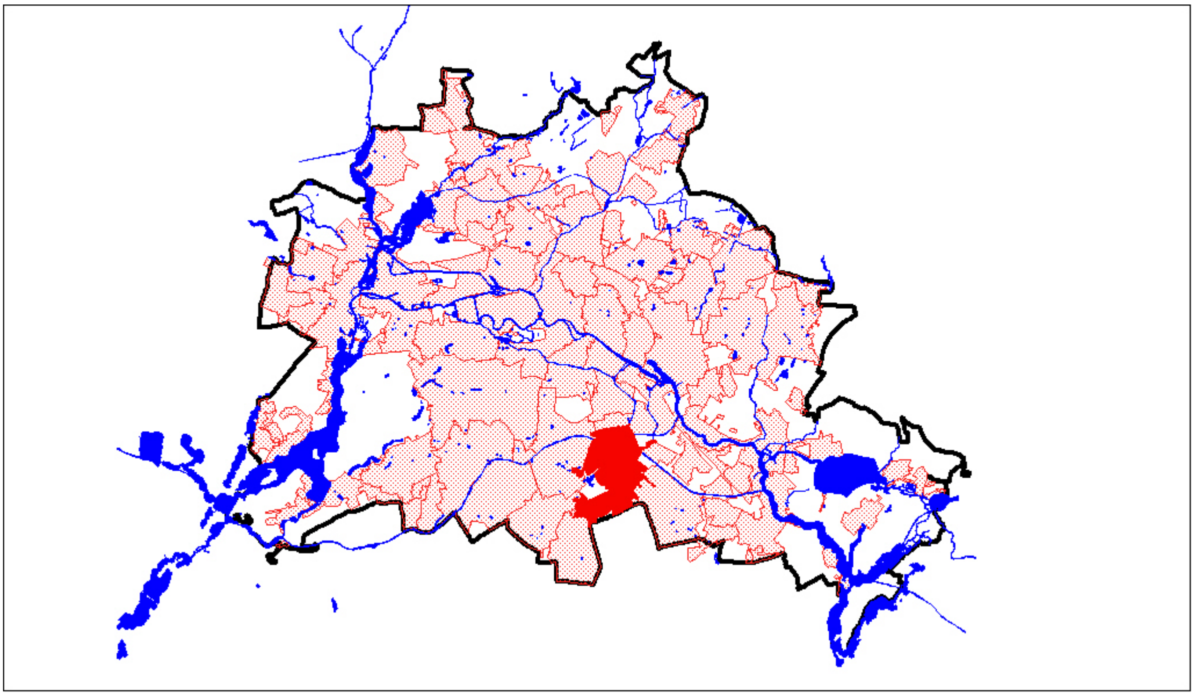
3.4.21 HPw Britz

Subcatchment: Britz

Total Area: 1634 ha

Population: 83418 Inh.

WWTP: dry weather: Waßmannsdorf
rain weather: Waßmannsdorf



Location of subcatchment Britz

Model characteristics Britz

System type: Separate

Length of modelled pipes

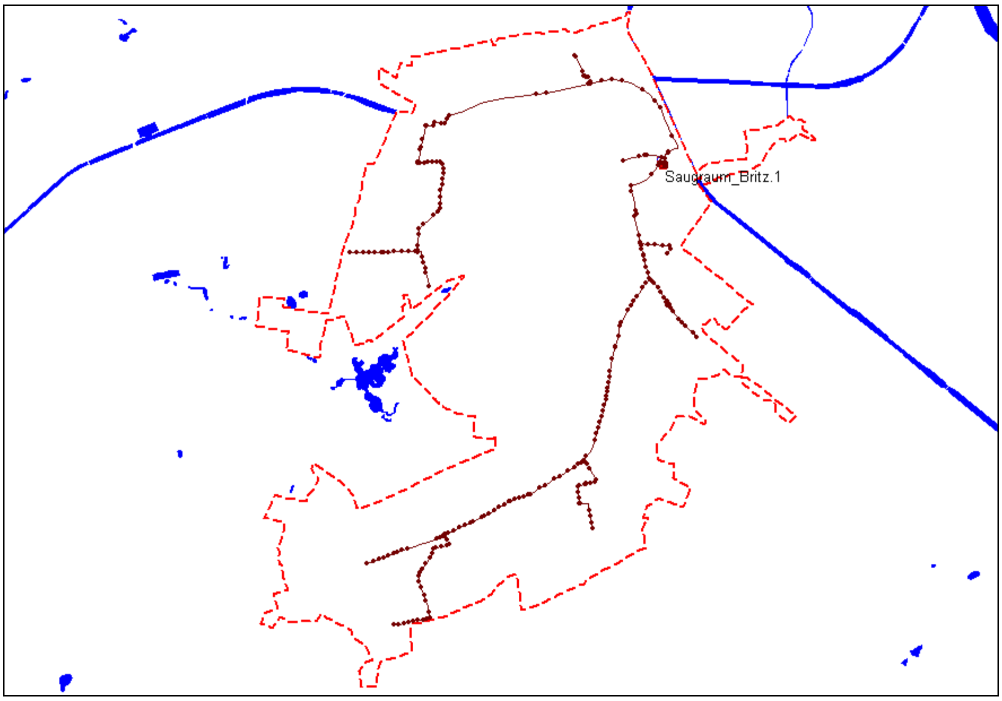
Combined: -
Waste water: 16.524 km
Storm water: -
Other: -

Number of Nodes 259

Number of Pump Stations 1

Pump Station: HPw Bri, Späthstr.
Node ID: Saugraum_Britz
Average dry wheather flow: 159.00 l/s
Maximum Capacity
local: 0.400 m^3/s
global: -
Destination
dry weather: Waßmannsdorf
storm weather: Waßmannsdorf

Number of emergency outlets: 1
Node ID: 06154109
invert level [maD]: 32.89

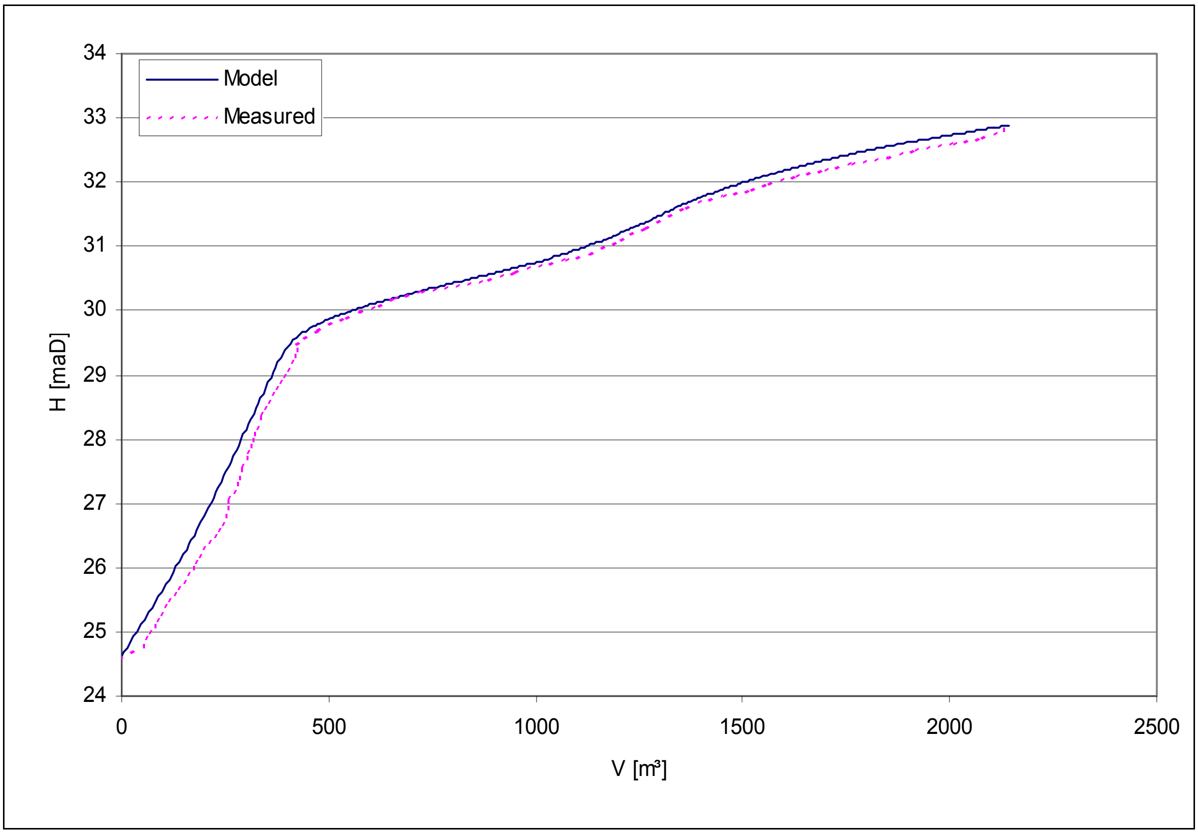


Network model of subcatchment Britz

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	2142	2130
storage level [maD]:	32.89	32.89
invert level of emergency outlet [maD]:	32.89	

HPw Bri



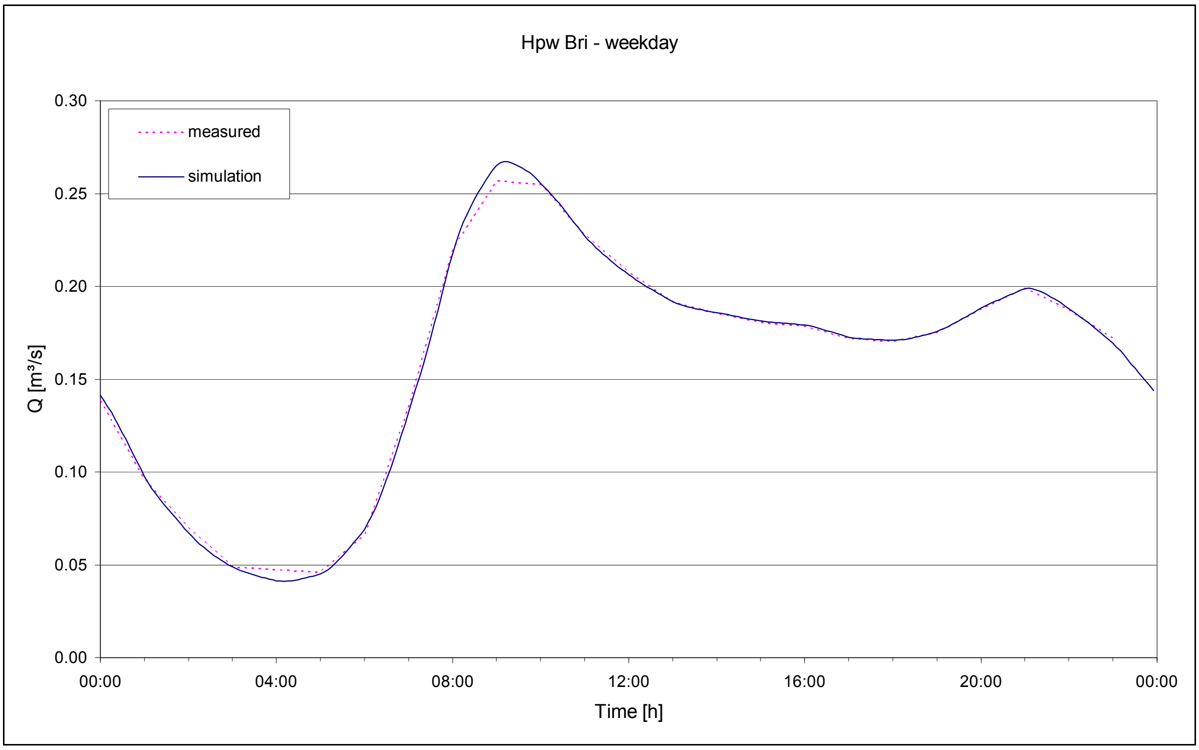
Storage characteristic of sewer network Britz

Calibration

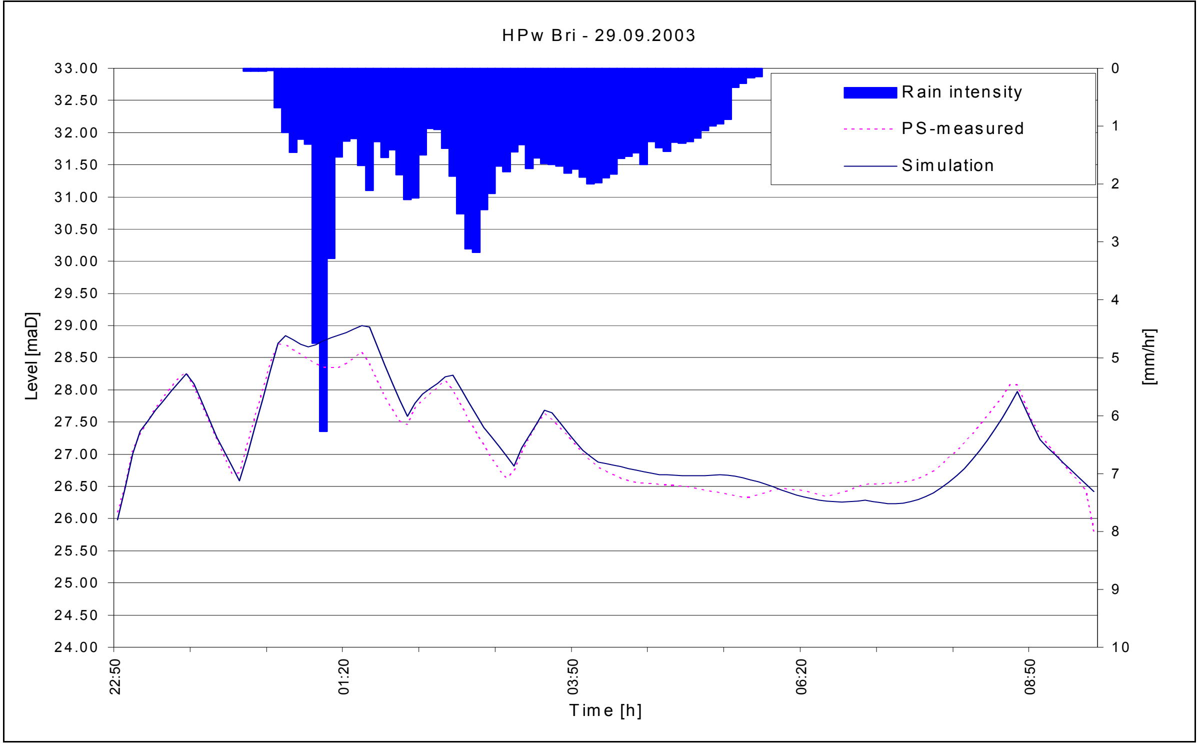
Dry Weather: Flow at Pump station Bri, 09.05.2000, adapted to data from 2004

min flow: 0.041 m³/s

max flow: 0.267 m³/s



Storm Weather: Level at Pump station Bri



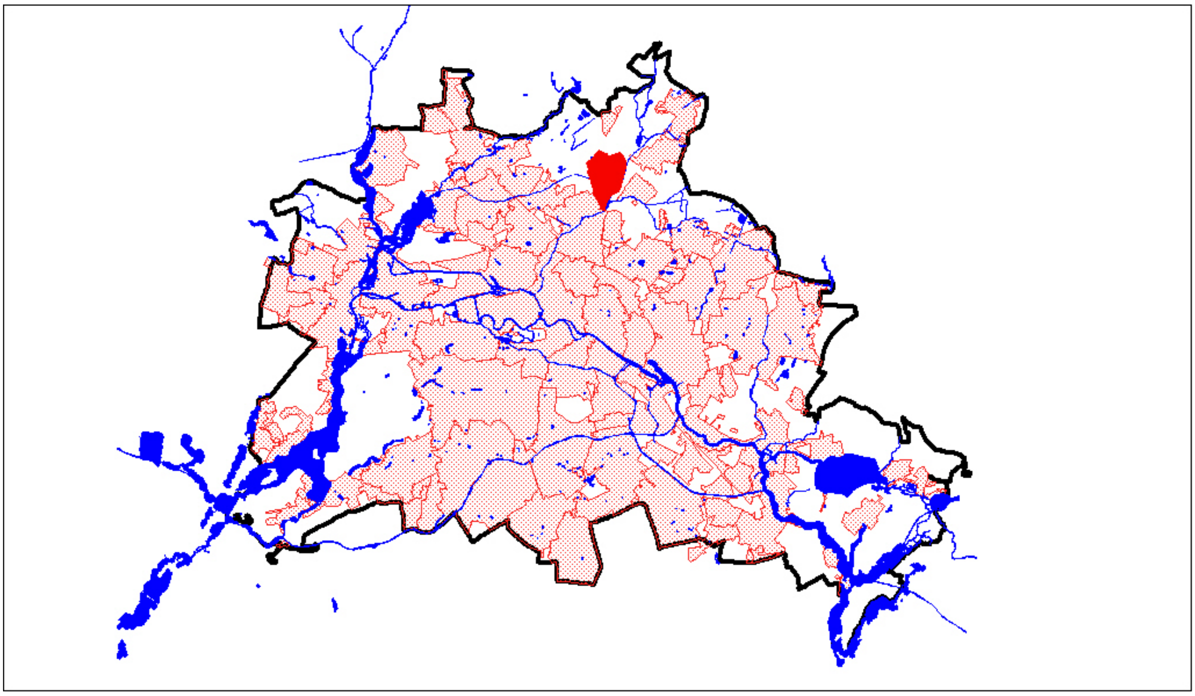
3.4.22 APw Buchholz

Subcatchment: Buchholz

Total Area: 556 ha

Population: 17581 Inh.

WWTP: dry weather: Schönerlinde
rain weather: Schönerlinde



Location of subcatchment Buchholz

Model characteristics Buchholz

System type: Separate

Length of modelled pipes

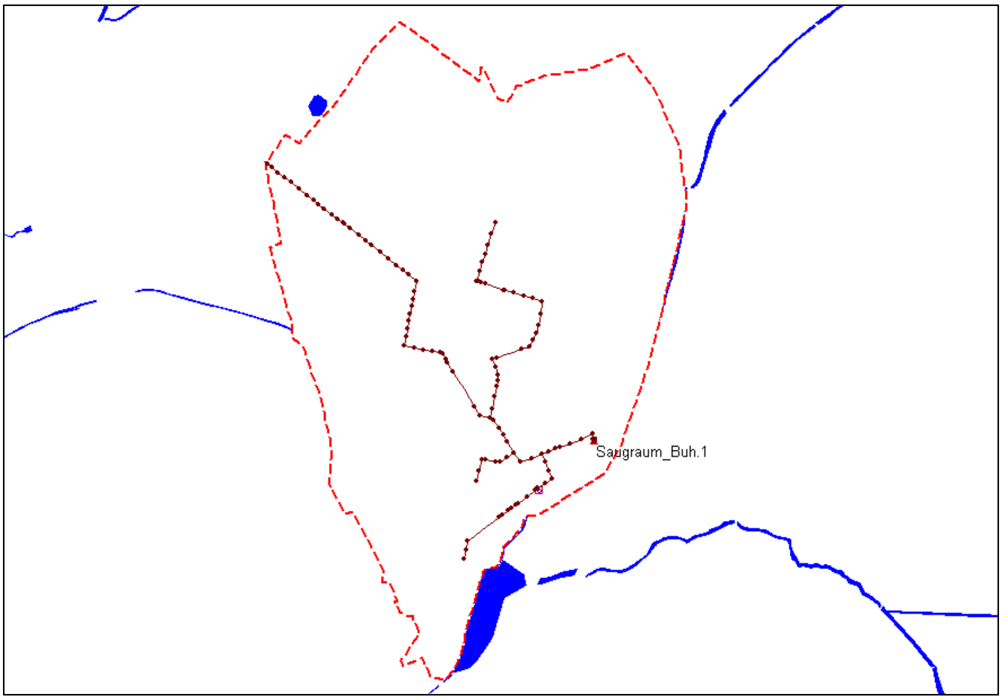
Combined: -
Waste water: 5.711 km
Storm water: -
Other: -

Number of Nodes 115

Number of Pump Stations 1

Pump Station: APw Buh, Straße 49
Node ID: Saugraum_Buh
Average dry wheather flow: 21.50 l/s
Maximum Capacity
local: 0.120 m^3/s
global: 0.160 m^3/s
Destination
dry weather: Schönerlinde
storm weather: Schönerlinde

Number of emergency outlets:	1
Node ID:	32163006
invert level [maD]:	43.41

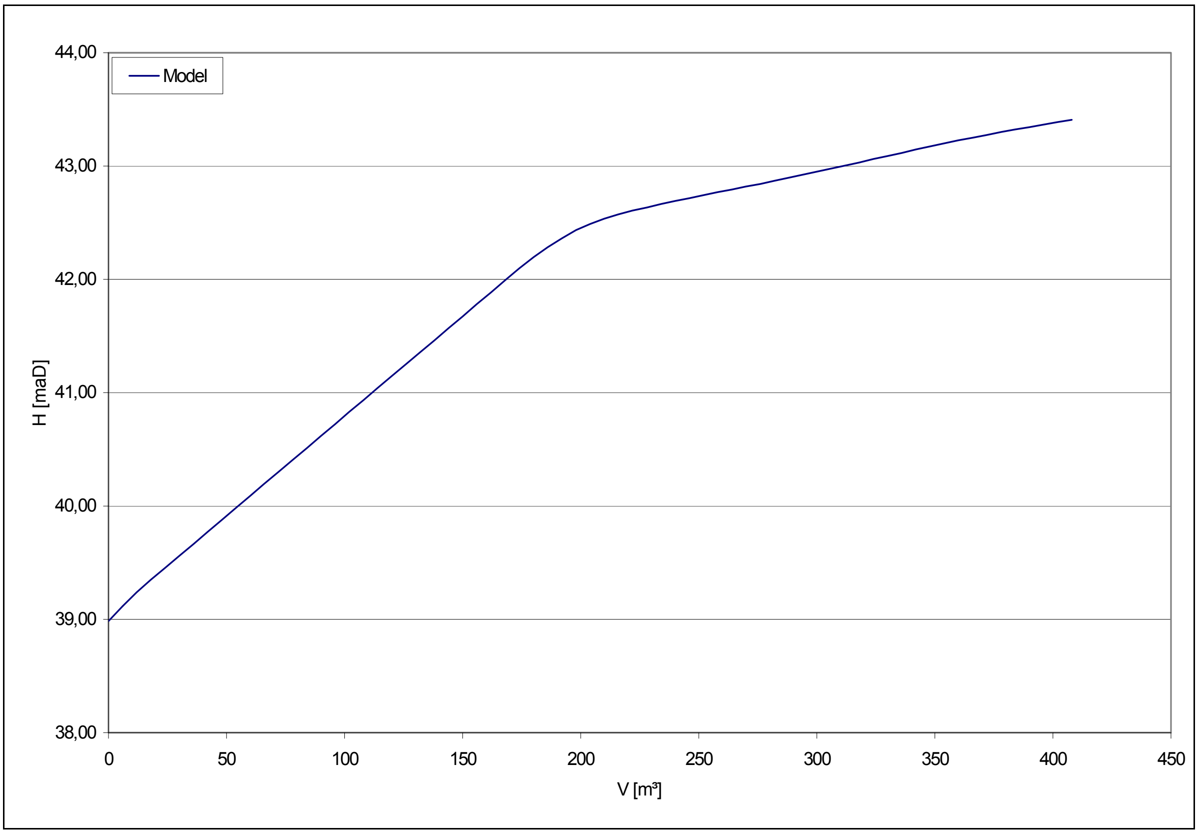


Network model of subcatchment Buchholz

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	408	-
storage level [maaD]:	43.41	-
invert level of emergency outlet [maD]:	43.41	

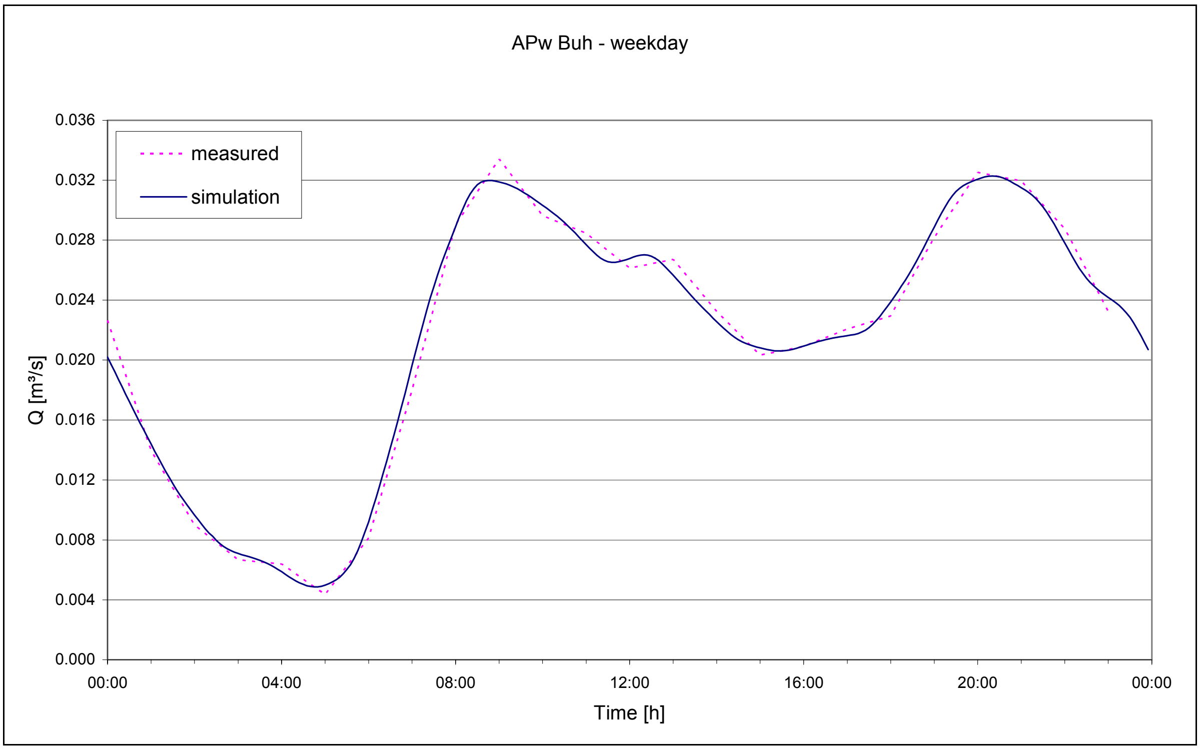
APw Buh



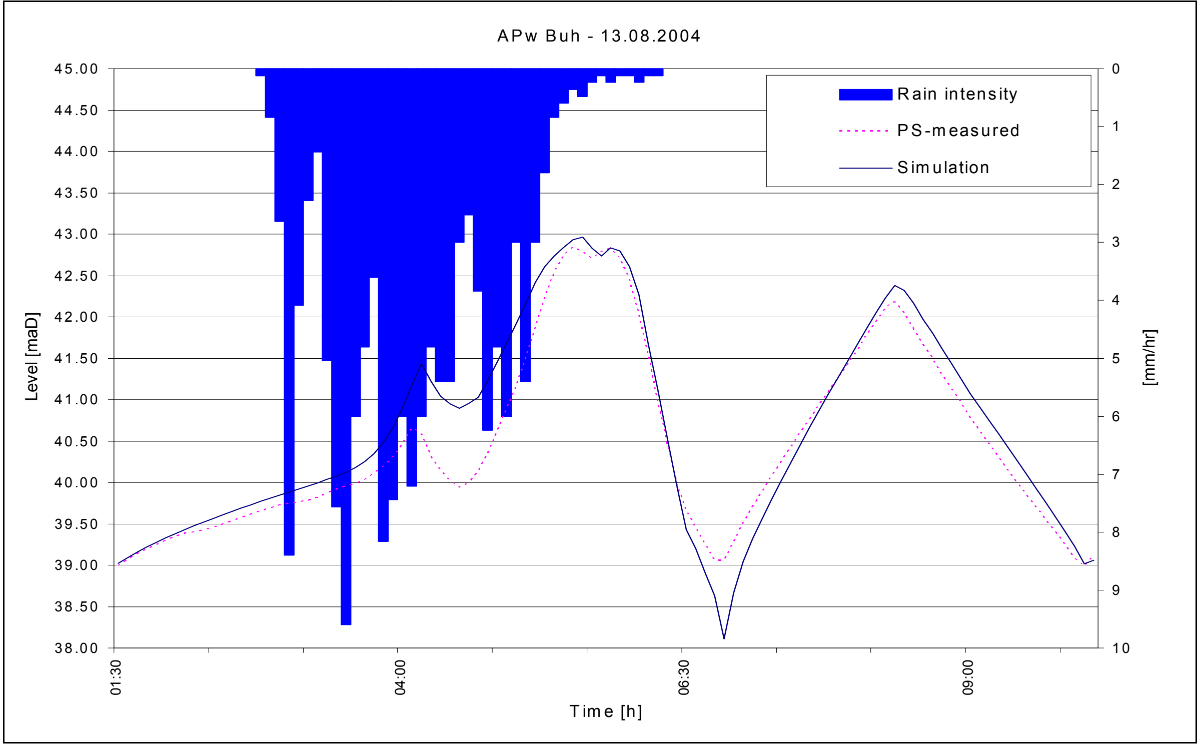
Storage characteristic of sewer network Buchholz

Calibration

Dry Weather: Flow at Pump station Buh, 12.07.2000, adapted to data from 2004
min flow: 0.005 m³/s
max flow: 0.032 m³/s

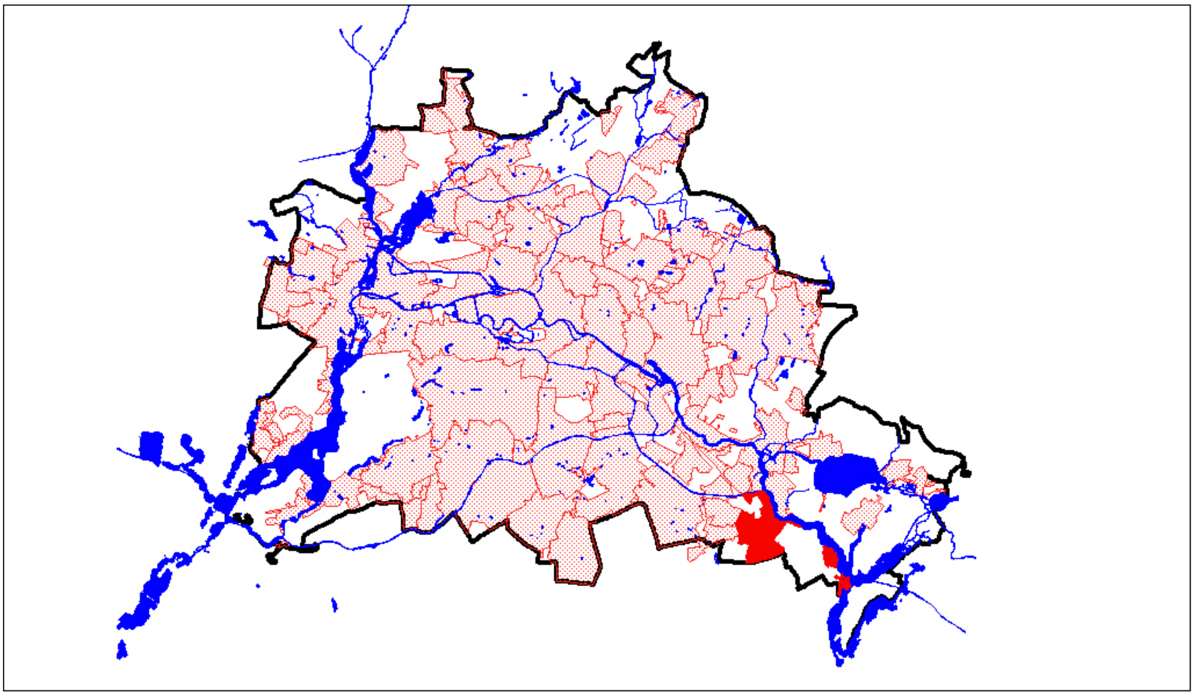


Storm Weather: Level at Pump station Buh



3.4.23 APw Grünau

Subcatchment:	Grünau	
Total Area:	924 ha	
Population:	19853 Inh.	
WWTP:	dry weather:	Waßmannsdorf
	rain weather:	Waßmannsdorf

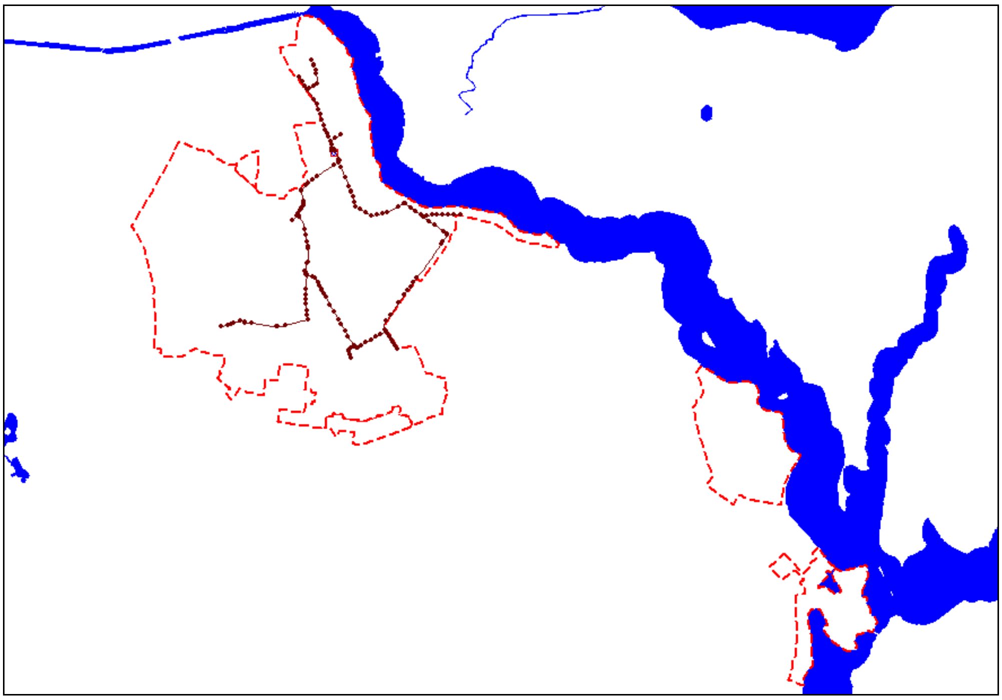


Location of subcatchment Grünau

Model characteristics Grünau

System type:	Separate
Length of modelled pipes	
Combined:	-
Waste water:	8.688 km
Storm water:	-
Other:	-
Number of Nodes	164
Number of Pump Stations	1
Pump Station:	APw Grü, Walchenseestr.
Node ID:	Saugraum_Grue
Average dry wheather flow:	38.30 l/s
Maximum Capacity	
local:	0.100 m^3/s
global:	-
Destination	
dry weather:	Waßmannsdorf
storm weather:	Waßmannsdorf

Number of emergency outlets:	1
Node ID:	90052121
invert level [maD]:	32.90

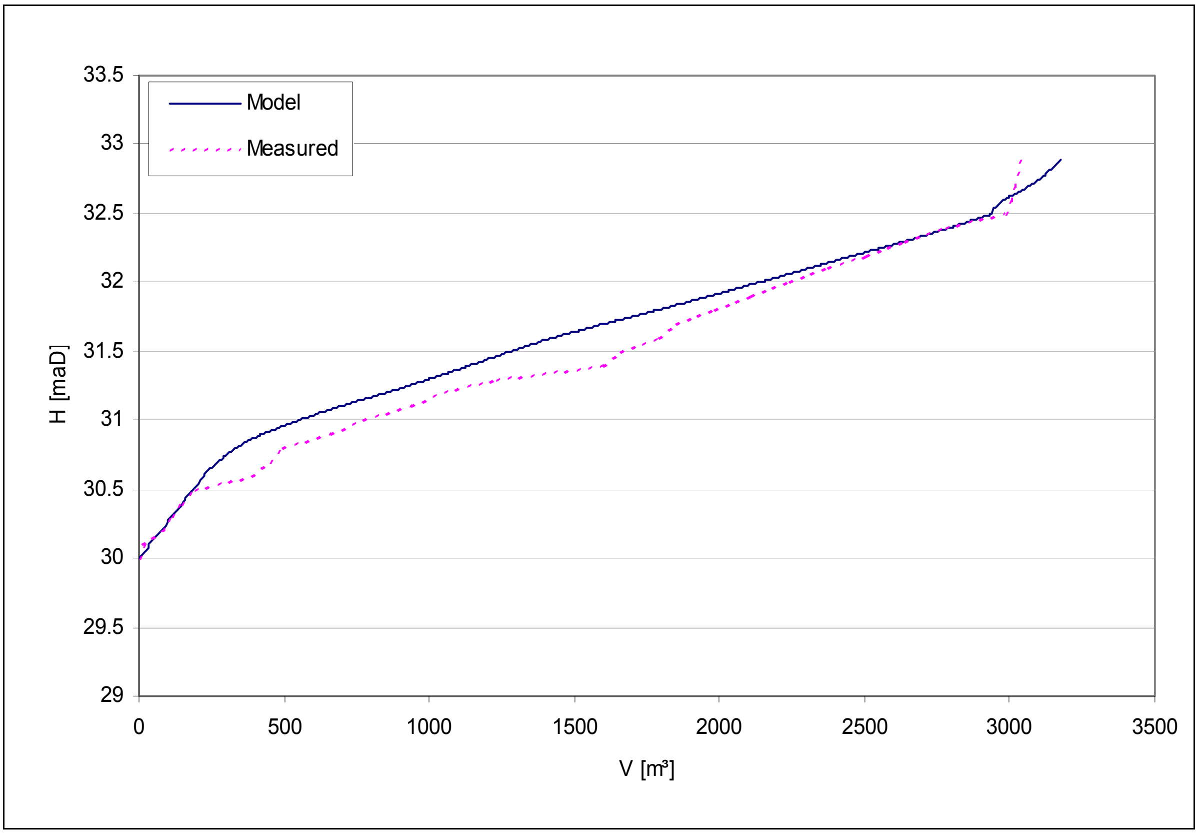


Network model of subcatchment Grünau

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	3174	3034
storage level [maD]:	32.90	32.90
invert level of emergency outlet [maD]:	32.90	

APw Grü

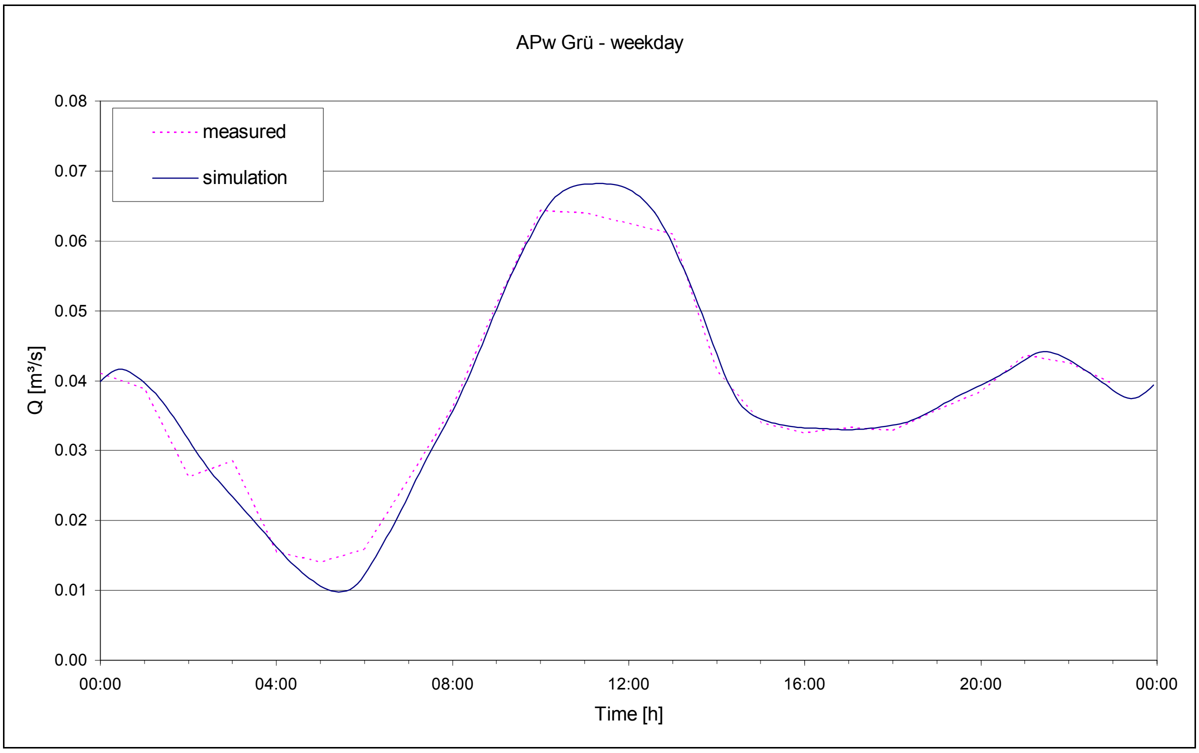


Storage characteristic of sewer network Grünau

Calibration

Dry Weather: Flow at Pump station Grü, 23.06.1999, adapted to data from 2004

min flow:	0.010 m³/s
max flow:	0.068 m³/s

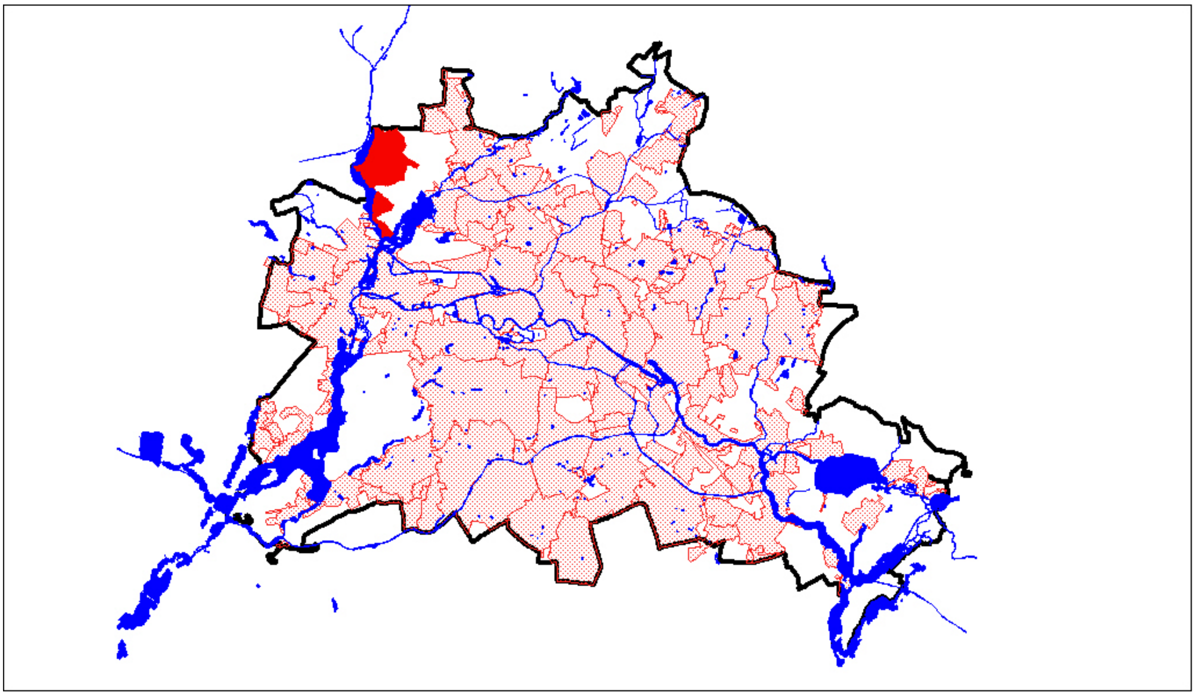


Storm Weather:

Due to the high variation in dry weather flow and a lack of data a storm weather calibration could not be carried out.

3.4.24 APw Heiligensee

Subcatchment:	Heiligensee	
Total Area:	814 ha	
Population:	23553 Inh.	
WWTP:	dry weather:	Ruhleben
	rain weather:	Ruhleben



Location of subcatchment Heiligensee

Model characteristics Heiligensee

System type: Separate

Length of modelled pipes

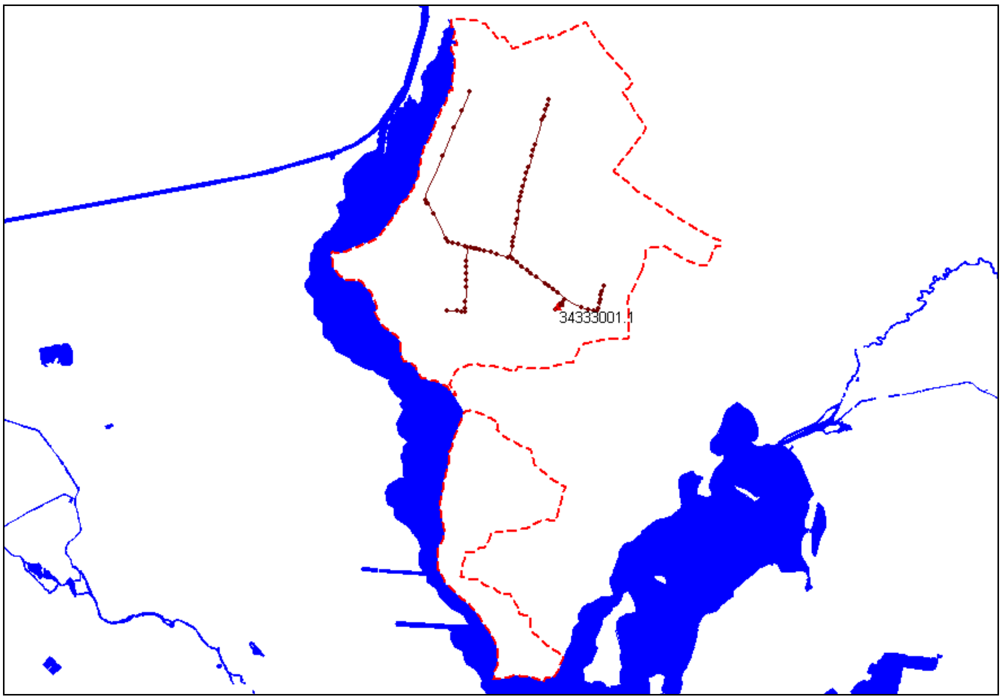
- **Combined:** -
- **Waste water:** 6.261 km
- **Storm water:** -
- **Other:** -

Number of Nodes 81

Number of Pump Stations 2

- **Pump Station:** APw Hlg, Heiligenseestr.
- **Node ID:** Saugraum_Hlg
- **Average dry wheather flow:** 33.60 l/s
- **Maximum Capacity**
  - **local:** 0.150 m^3/s
  - **global:** 0.150 m^3/s
- **Destination**
  - **dry weather:** Ruhleben
  - **storm weather:** Ruhleben

Number of emergency outlets: 1
Node ID: 35354101
invert level [maD]: 31.40

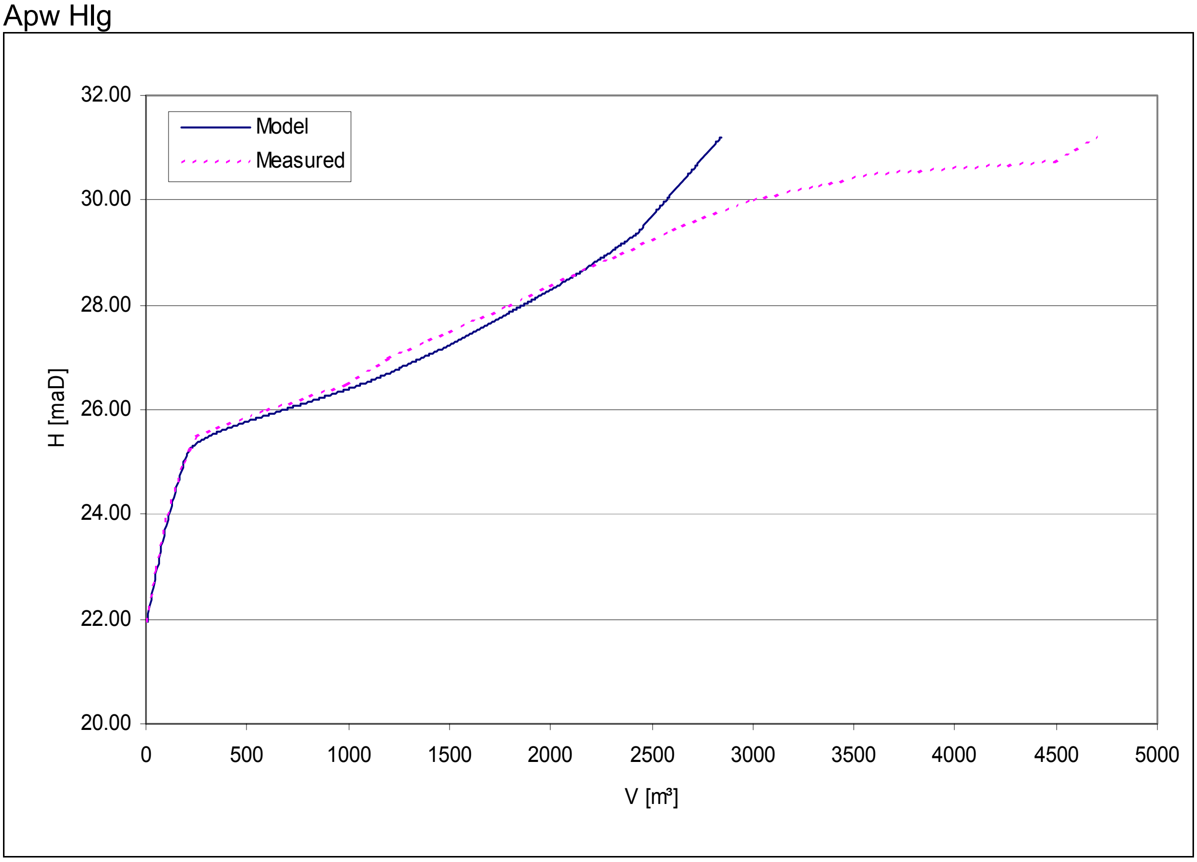


Network model of subcatchment Heiligensee

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	2844	4700
storage level [maD]:	31.20	31.20
invert level of emergency outlet [maD]:	31.40	

Apw Hlg

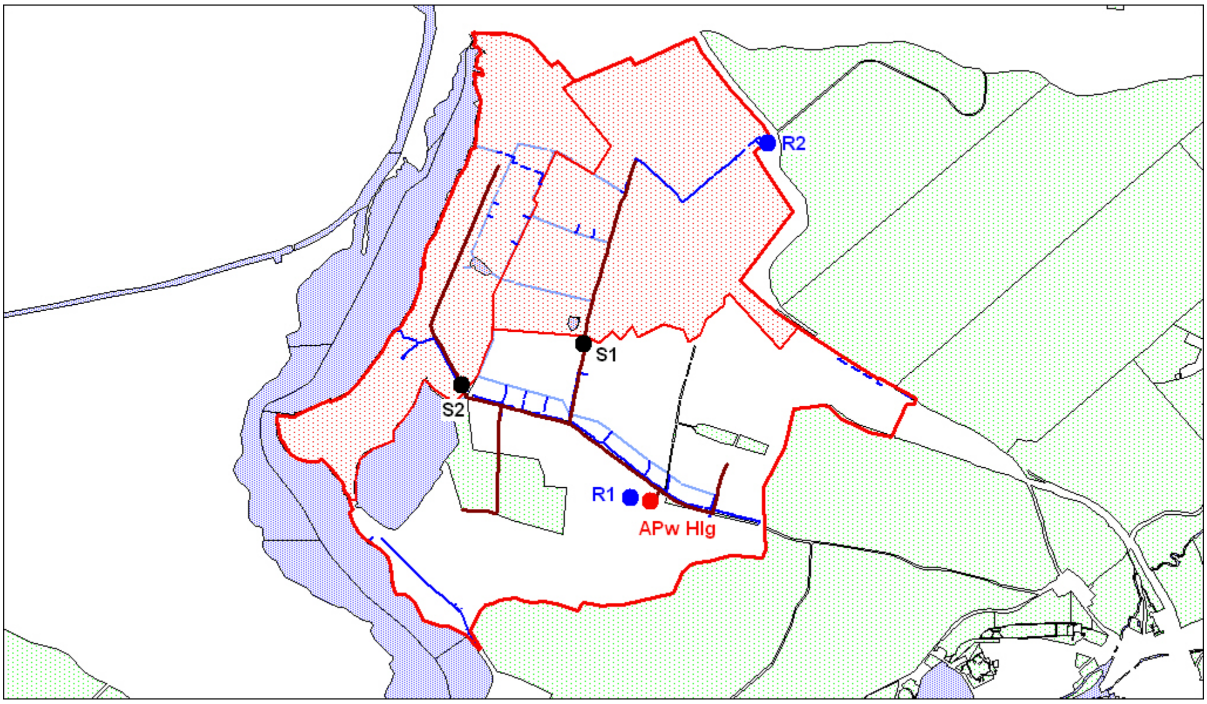


Storage characteristic of sewer network Heiligensee

Measurement Campaign

Measurement points: 5

Measurement period: 29/04/2003 - 04/11/2003



Location of measurement points, Hlg

Name:	PS
Location:	Pump station Hlg, Heiligenseestr.
Measurements:	Pumpage
Analyzed parameters:	No sampling
Measurement period:	29/04/2003 - 04/11/2003

Measurement point PS, Hlg

Name: S1

Location: Am Dachsbau

Measurements: Flow, water level

Analyzed parameters: No sampling

Measurement period: 29/04/2003 - 04/11/2003

Measurement point S1, Hlg

Name: S2

Location: Heiligenseestr.

Measurements: Flow, water level

Analyzed parameters: No sampling

Measurement period: 29/04/2003 - 04/11/2003

Measurement point S2, Hlg

Name: R1

Location: Pump station Hlg, Heiligenseestr.

Measurements: Rainfall

Measurement period: 29/04/2003 – 26/08/2003

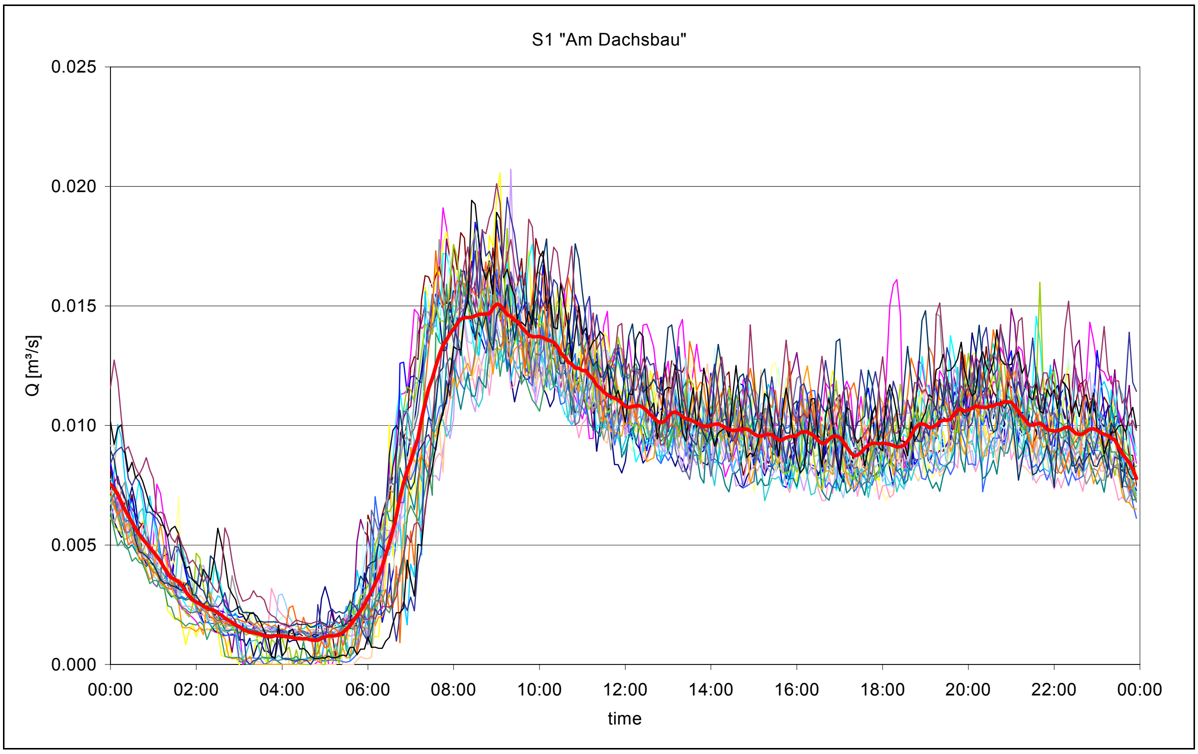
Name: R2

Location: Rain pump station Wit b, Kiefheider Weg

Measurements: Rainfall

Measurement period: 26/08/2003 - 04/11/2003

Measured dry weather events



Dry weather flow, S1 “Am Dachsbau”

Calibration

Event Identification S1

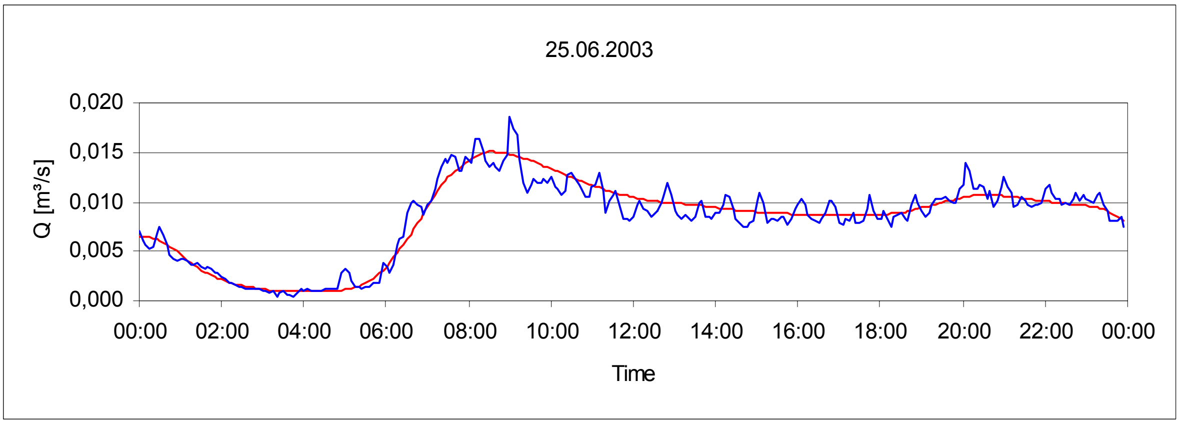
Date	Start	End	Rain Duration	Rain Height	Rain I_{max}
Dry Weather, Hydraulic					
25.06.2003	00:00	00:00	-	-	-
26.06.2003	00:00	00:00	-	-	-
Storm Weather, Hydraulic					
12.05.2003	08:40	09:30	00:50 h	6.5 mm	58.8 mm/h

Comparison Measurement – Simulation S1

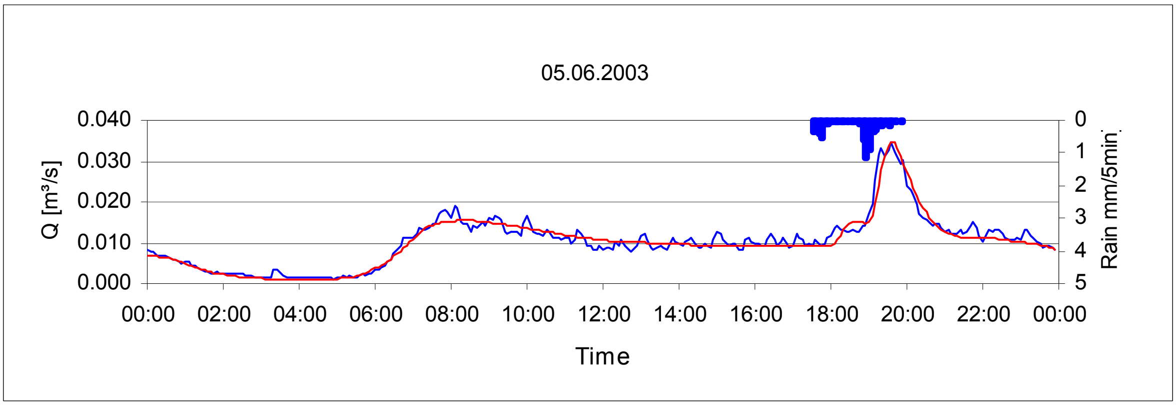
Hydraulic

Date	V_{meas} [m³]	V_{sim} [m³]	$Qmax_{meas}$ [m³/s]	$Qmax_{sim}$ [m³/s]	$Qmin_{meas}$ [m³/s]	$Qmin_{sim}$ [m³/s]
Dry Weather						
25.06.2003	715	719	0,019	0,015	0,001	0,001
26.06.2003	712	719	0,016	0,015	0,001	0,001
Storm Weather						
12.05.2003	127	119	0,055	0,055	0,013	0,013
05.06.2003	107	105	0,035	0,035	0,010	0,010

Dry Weather: Flow at S1



Storm Weather: Flow at S1



Validation

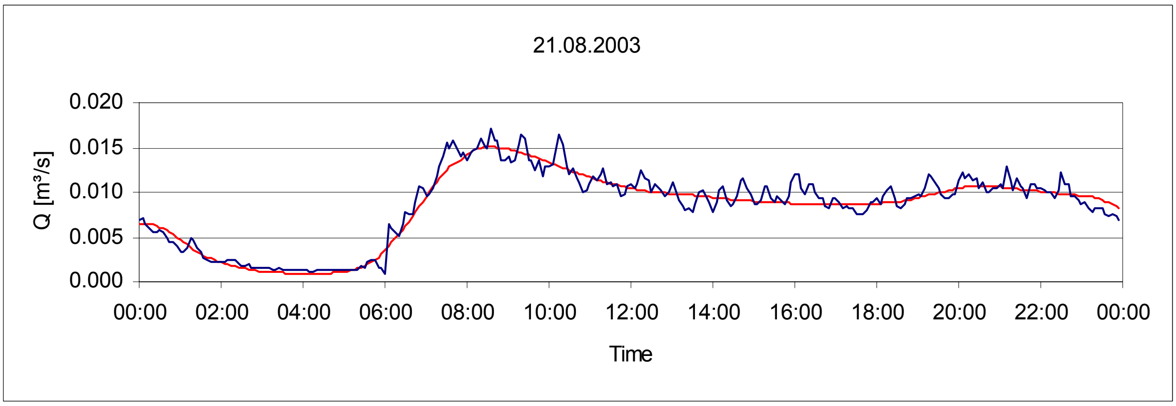
Event Identification S1

Date	Start	End	Rain Duration	Rain Height	Rain I_{max}
Dry Weather, Hydraulic					
21.08.2003	00:00	00:00	-	-	-
22.09.2003	00:00	00:00	-	-	-
Storm Weather, Hydraulic					
20.06.2003	14:05	21:40	07:35 h	13.4 mm	20.2 mm/h

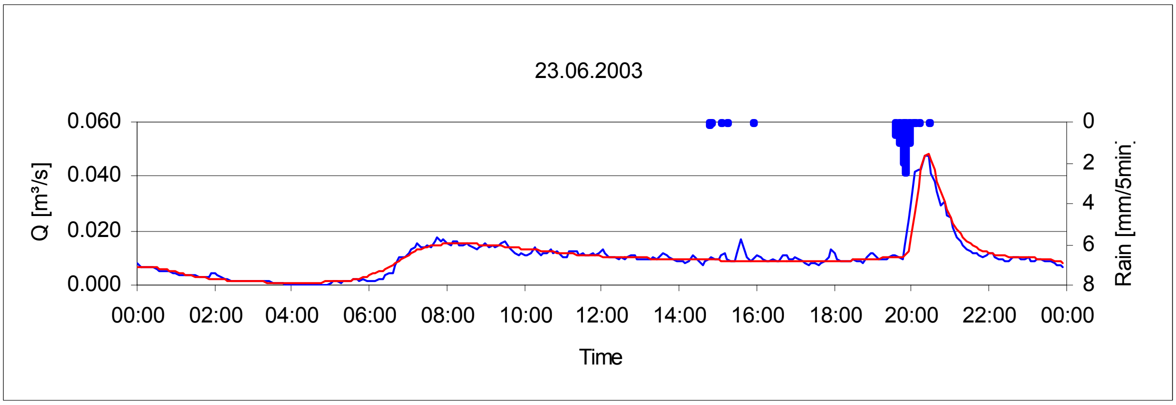
Comparison Measurement – Simulation S1

Date	V_{meas} [m³]	V_{sim} [m³]	$Qmax_{meas}$ [m³/s]	$Qmax_{sim}$ [m³/s]	$Qmin_{meas}$ [m³/s]	$Qmin_{sim}$ [m³/s]
Dry Weather						
21.08.2003	737	719	0.017	0.015	0.001	0.001
22.09.2003	711	719	0.017	0.015	0.000	0.001
Storm Weather						
20.06.2003	223	225	0.050	0.050	0.012	0.010
23.06.2003	117	120	0.048	0.048	0.010	0.011

Dry Weather: Flow at S1



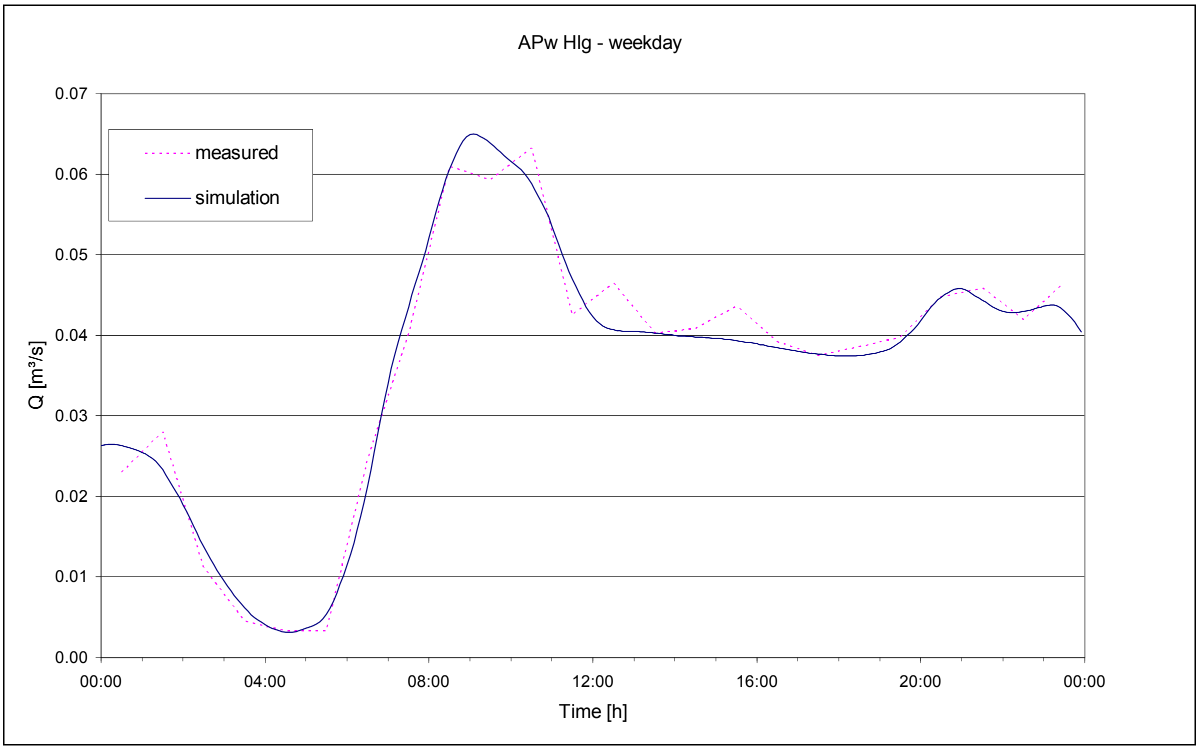
Storm Weather: Flow at S1



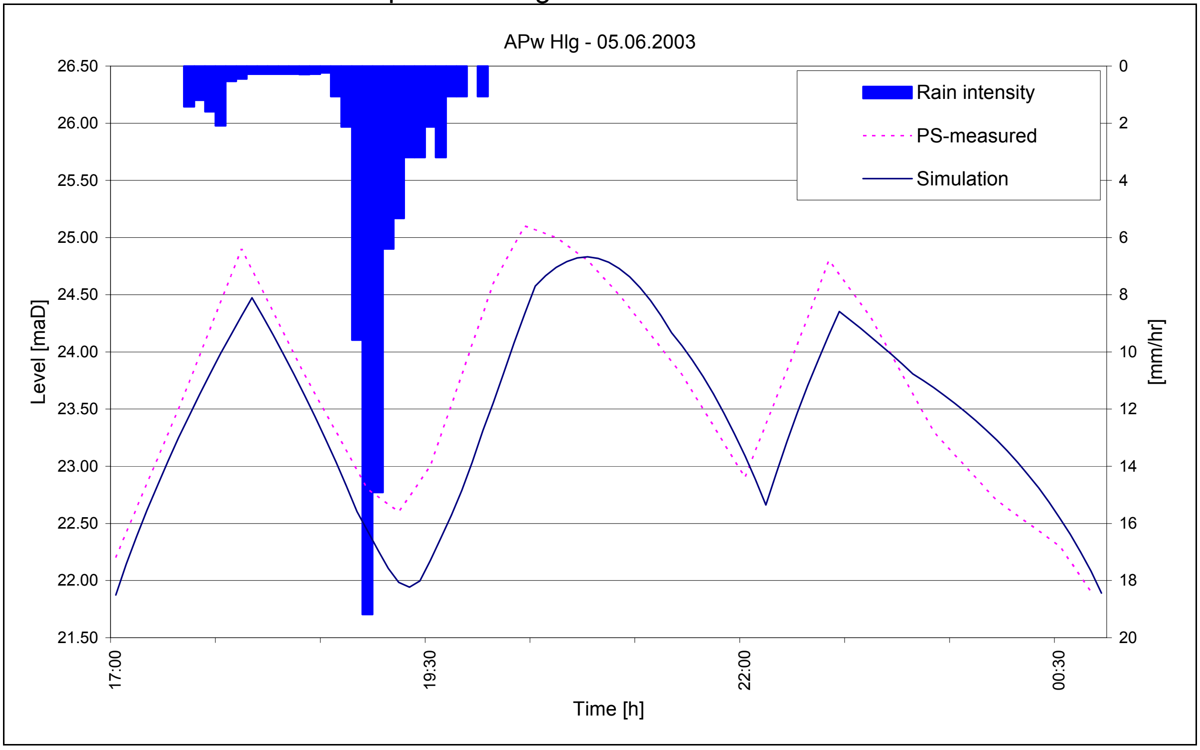
Dry Weather: Flow at Pump station Hlg, 29.06.2000, adapted to data from 2004

min flow: 0.003 m³/s

max flow: 0.065 m³/s



Storm Weather: Level at Pump station Hlg



Specifics

It is absolutely necessary to take into account the inflow from misconnected areas to assess the correct storm water impact on the system.
A measurement campaign has been carried out within the catchment to calibrate this part of the model.

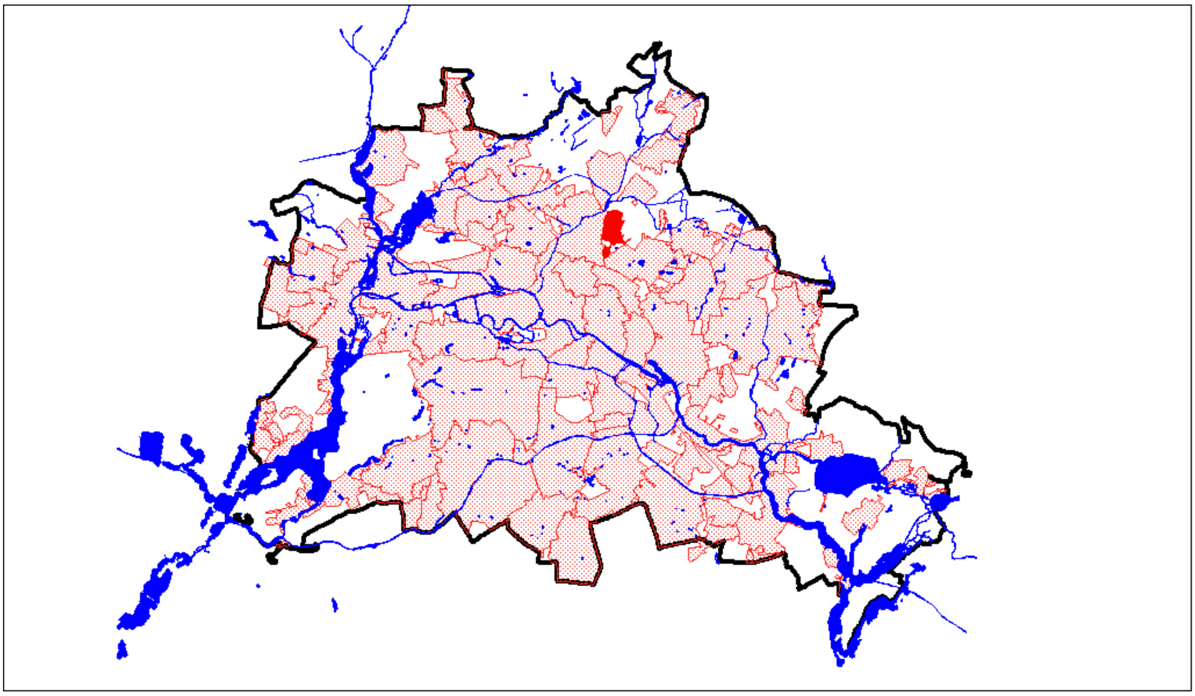
Results from the measurement campaign:

For the entire catchment Heiligensee (including ÜPw Konradshöhe) a ratio of misconnected areas of 0.95 % with respect to the total connected area has been determined. That corresponds to an area of 7.7 ha. The ratios of misconnected areas for the individual subcatchments examined during the campaign read as follows:
S1, „Am Dachsbau“: 0.72 % (1.6 ha)
S2, „Heiligenssestraße“: 0.77 % (1.2 ha)
These figures have been validated during simulation.

Furthermore, for the relative runoff routing factor small values (0.3 - 0.4) have been determined. Under this approach the fast surface runoff can be simulated with a high accuracy.

3.4.25 APw Heinersdorf

Subcatchment:	Heinersdorf	
Total Area:	233 ha	
Population:	3857 Inh.	
WWTP:	dry weather:	Schönerlinde
	rain weather:	Schönerlinde

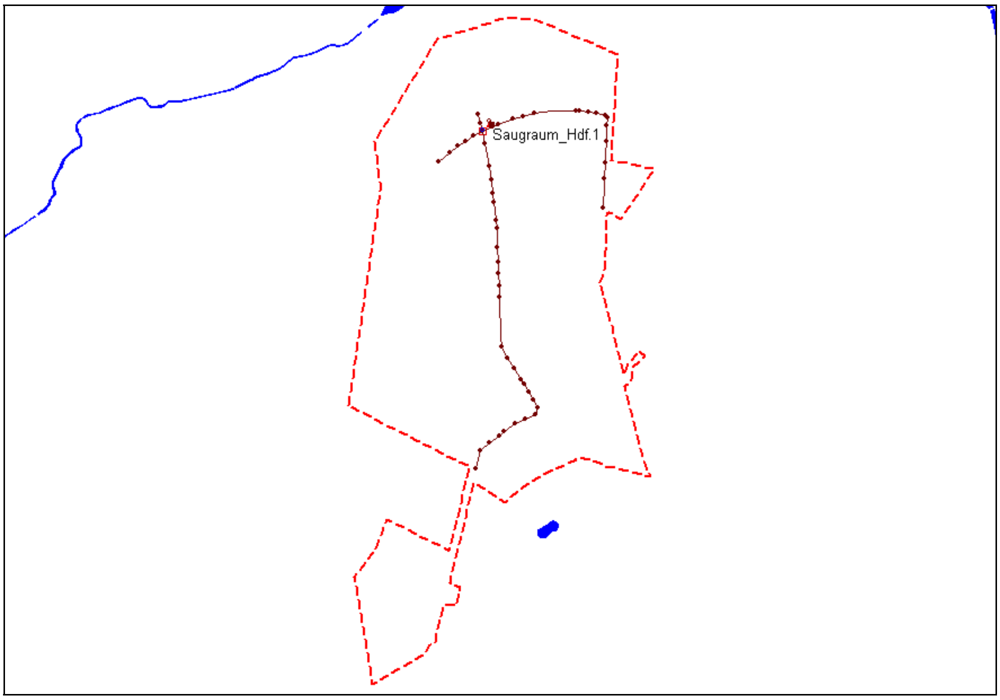


Location of subcatchment Heinersdorf

Model characteristics Heinersdorf

System type:	Separate
Length of modelled pipes	
Combined:	-
Waste water:	3.021 km
Storm water:	-
Other:	-
Number of Nodes	55
Number of Pump Stations	1
Pump Station:	APw Hdf, Romain-Rolland-Str.
Node ID:	Saugraum_Hdf
Average dry wheather flow:	12.00 l/s
Maximum Capacity	
local:	0.170 m^3/s
global:	0.200 m^3/s
Destination	
dry weather:	Schönerlinde
storm weather:	Schönerlinde

Number of emergency outlets: 1
Node ID: 29172001
invert level [maD]: 44.39

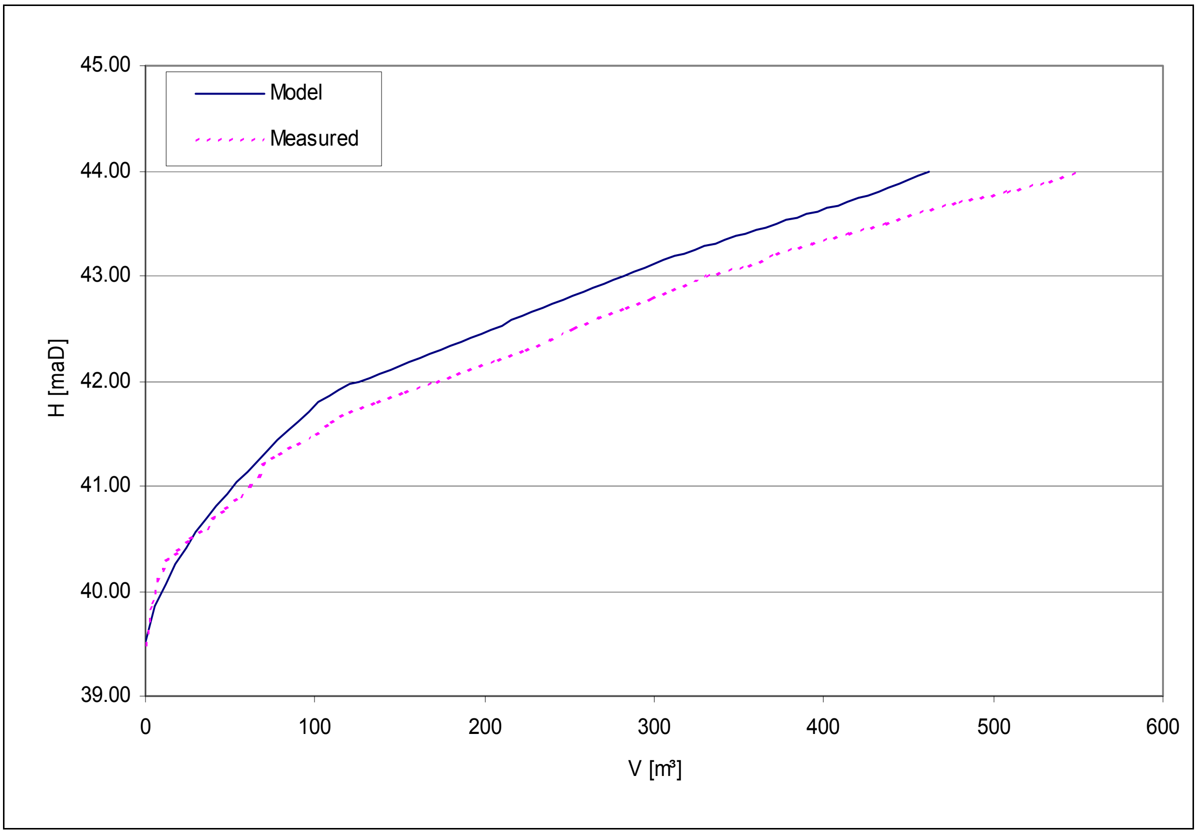


Network model of subcatchment Heinersdorf

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	462	551
storage level [maD]:	44.00	44.00
invert level of emergency outlet [maD]:	44.39	

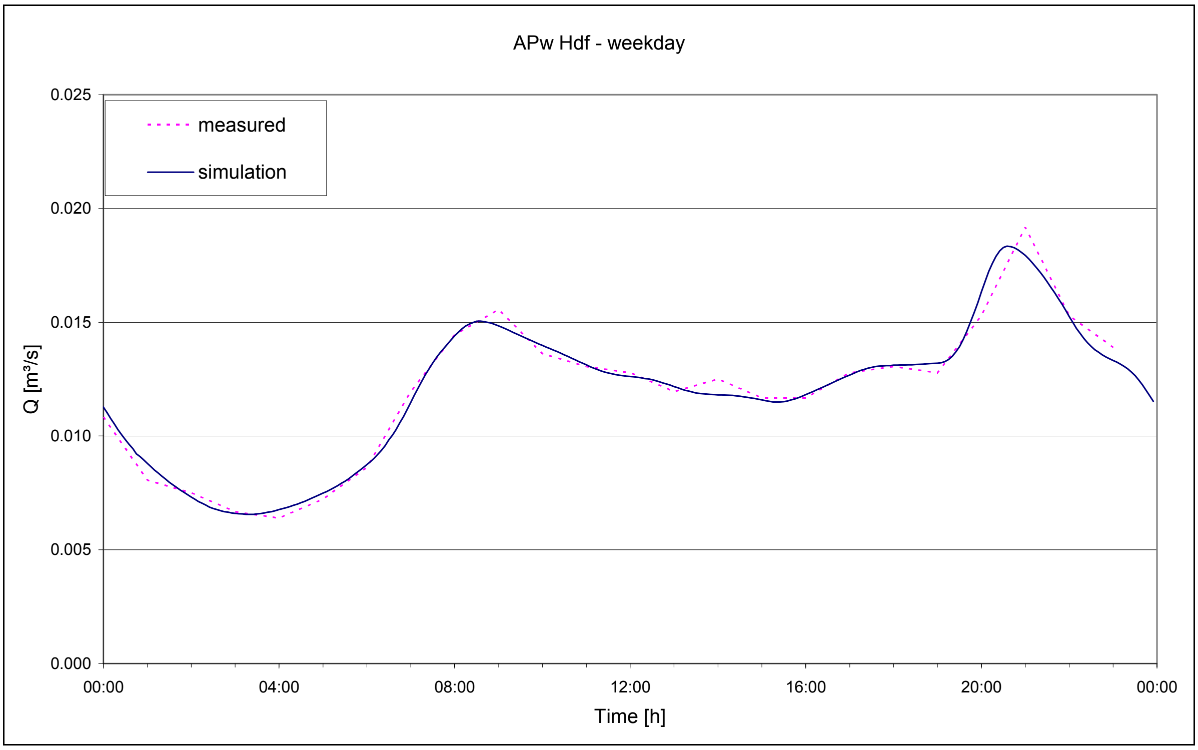
APw Hdf



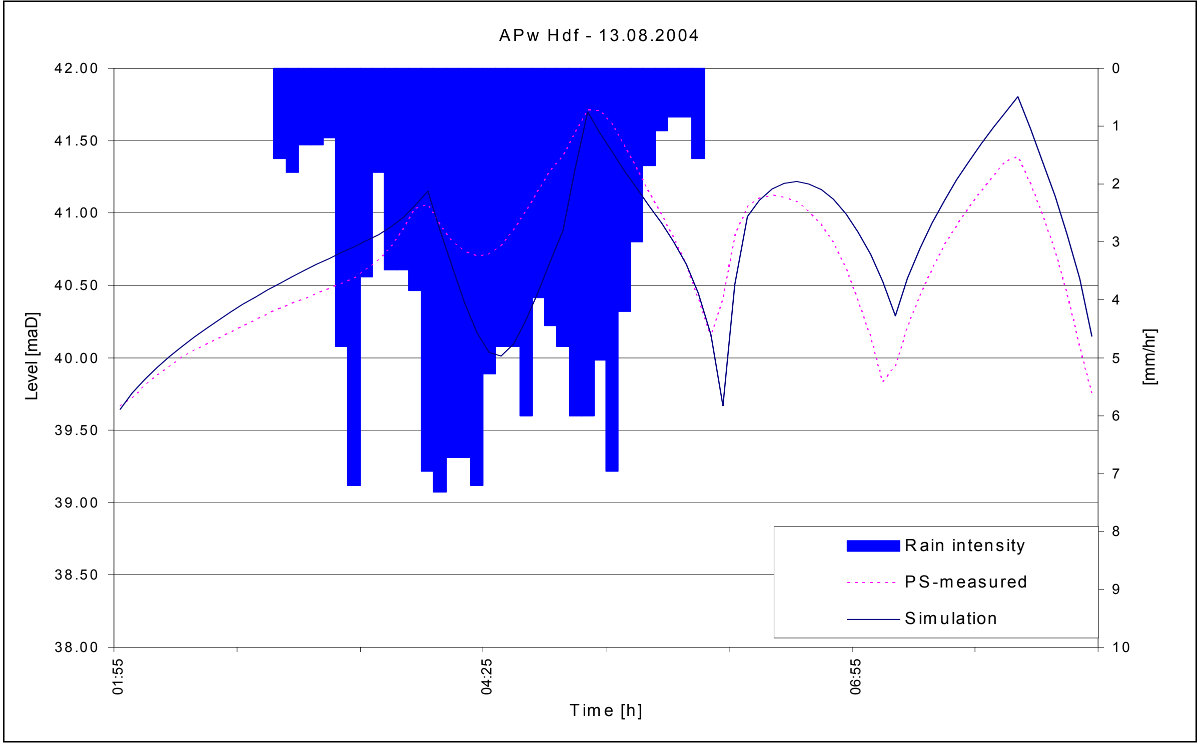
Storage characteristic of sewer network Heinersdorf

Calibration

Dry Weather: Flow at Pump station Hdf, 25.05.2000, still up to date
min flow: 0.007 m³/s
max flow: 0.018 m³/s

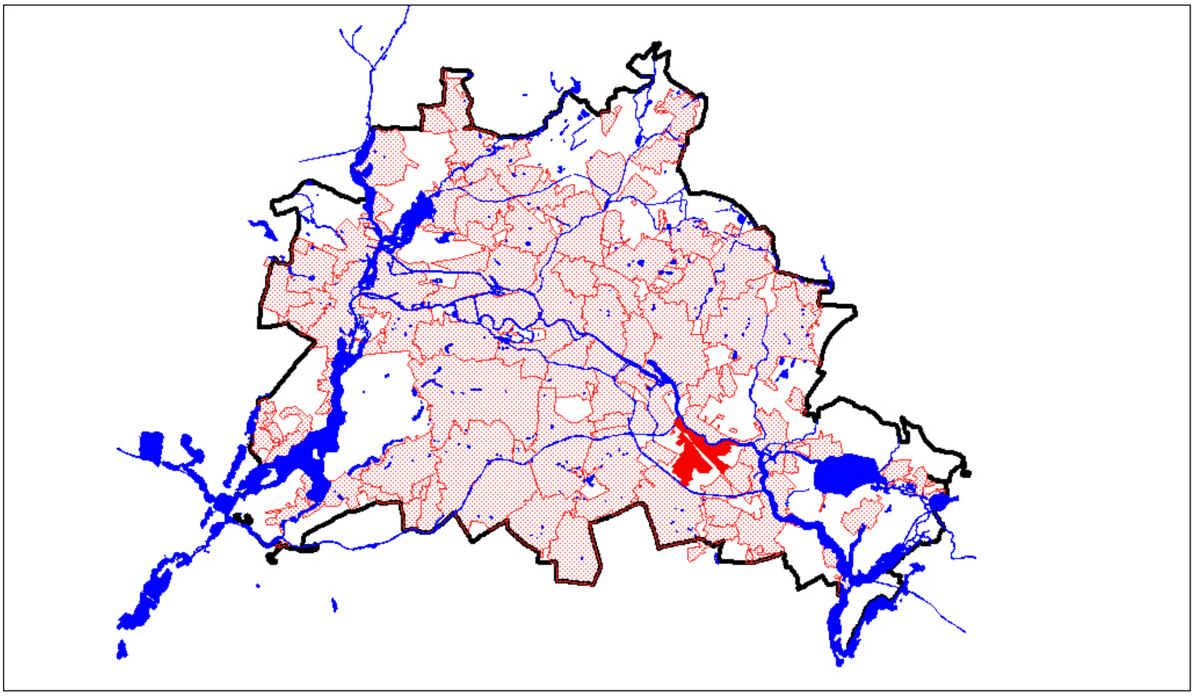


Storm Weather: Level at Pump station Hdf



3.4.26 APw Johannisthal

Subcatchment:	Johannisthal	
Total Area:	615 ha	
Population:	26814 Inh.	
WWTP:	dry weather:	Waßmannsdorf
	rain weather:	Waßmannsdorf

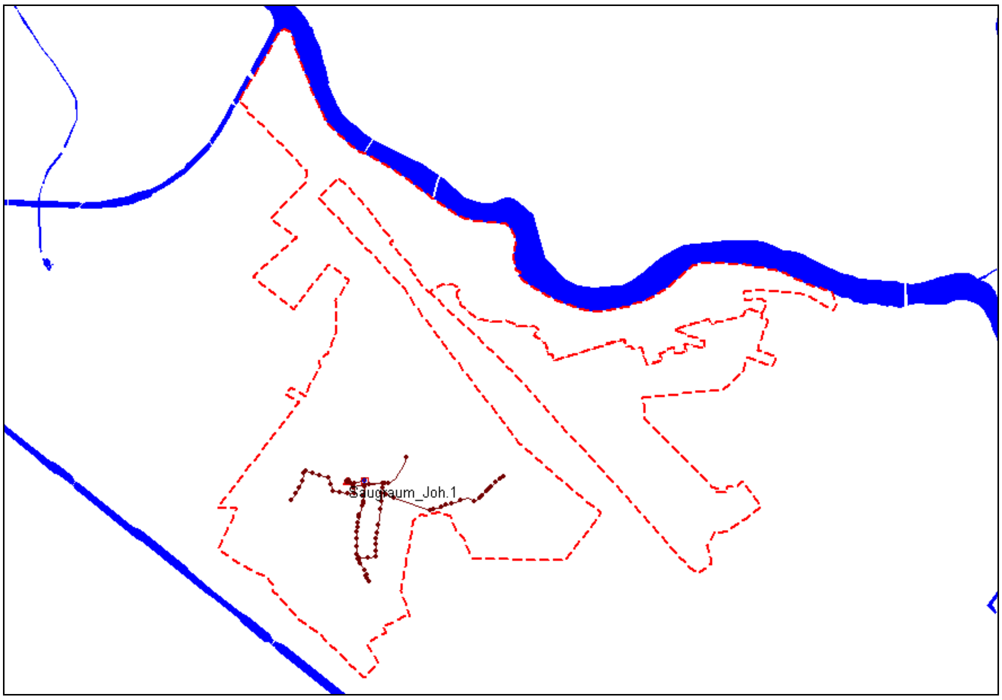


Location of subcatchment Johannisthal

Model characteristics Johannisthal

System type:	Separate
Length of modelled pipes	
Combined:	-
Waste water:	3.558 km
Storm water:	-
Other:	-
Number of Nodes	81
Number of Pump Stations	1
Pump Station:	APw Joh, Winckelmannstr.
Node ID:	Saugraum_Joh
Average dry wheather flow:	52.90 l/s
Maximum Capacity	
local:	0.200 m^3/s
global:	-
Destination	
dry weather:	Waßmannsdorf
storm weather:	Waßmannsdorf

Number of emergency outlets: 2
Node ID: 04112003
invert level [maD]: 32.99
Node ID: 05114005 (not in model)
invert level [maD]: 32.74

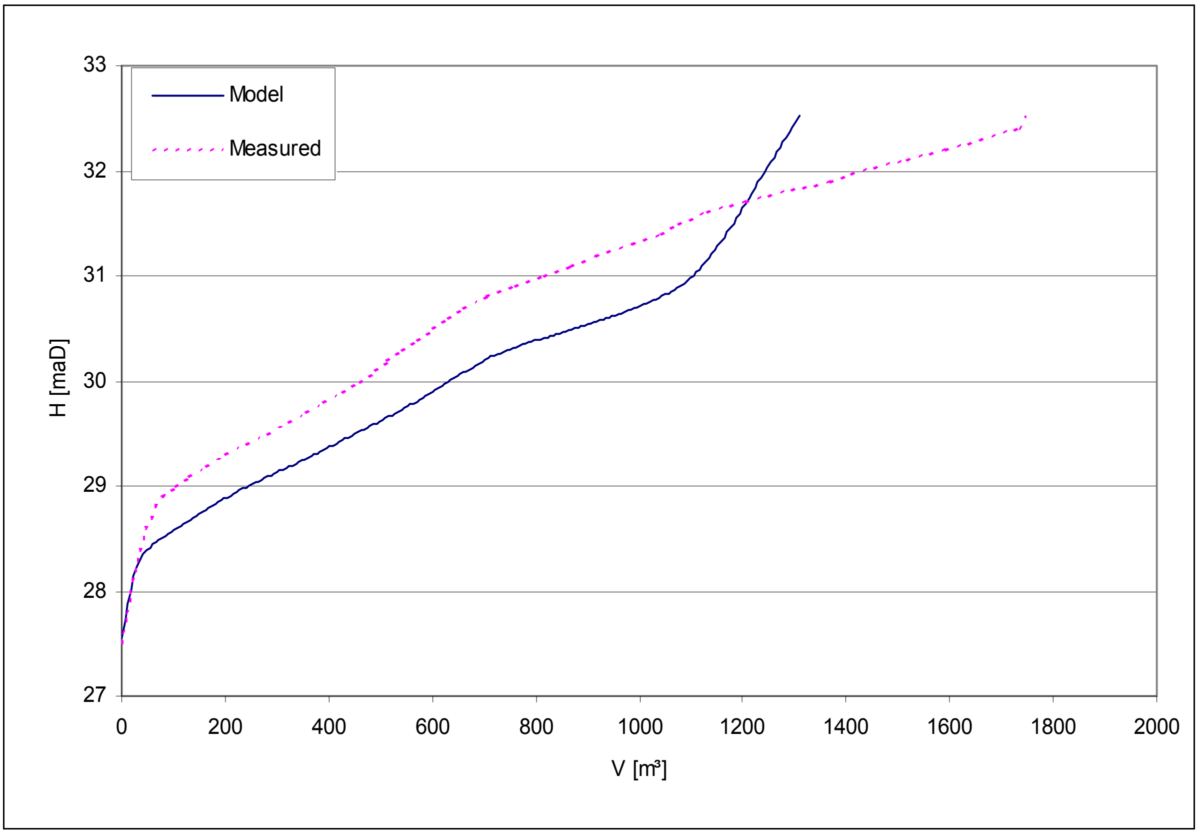


Network model of subcatchment Johannisthal

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	1308	1743
storage level [maD]:	32.50	32.50
invert level of emergency outlet [maD]:	32.74	

APw Joh



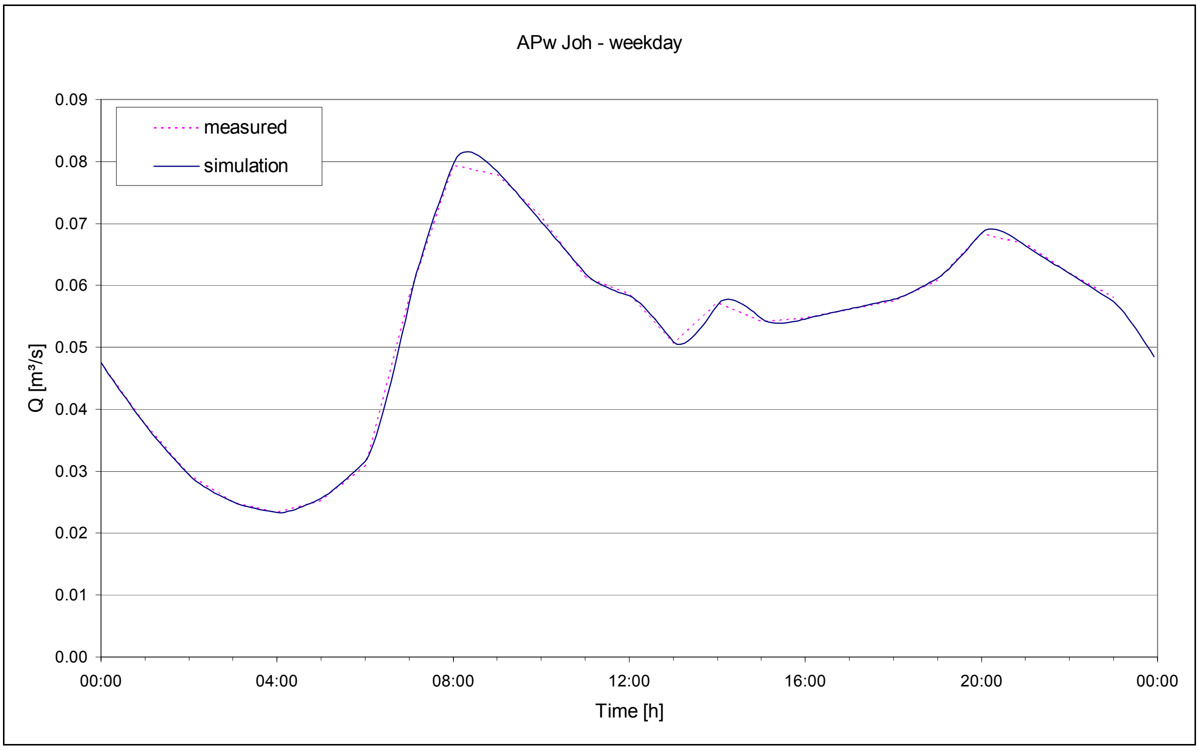
Storage characteristic of sewer network Johannisthal

Calibration

Dry Weather: Flow at Pump station Joh, 20.06.2000

min flow: 0.023 m³/s

max flow: 0.082 m³/s

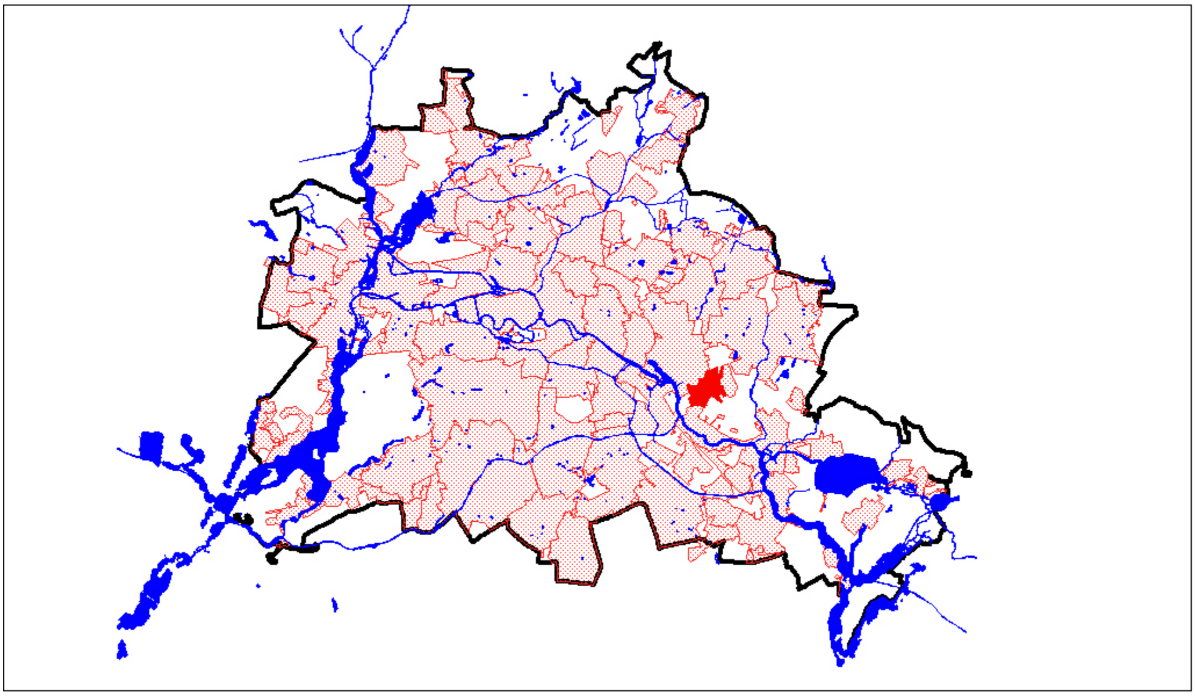


Storm Weather:

Due to the high variation in dry weather flow and a lack of data a storm weather calibration could not be carried out.

3.4.27 APw Karlshorst I

Subcatchment:	Karlshorst I	
Total Area:	460 ha	
Population:	18158 Inh.	
WWTP:	dry weather:	Waßmannsdorf
	rain weather:	Waßmannsdorf

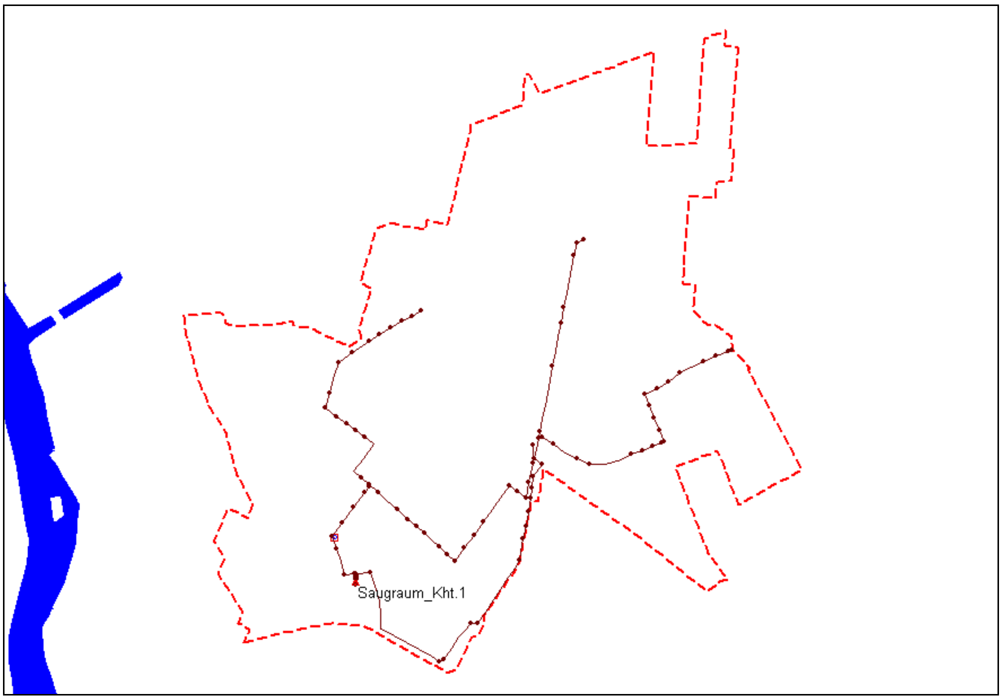


Location of subcatchment Karlshorst I

Model characteristics Karlshorst I

System type:		Separate
Length of modelled pipes		
Combined:		-
Waste water:		6.257 km
Storm water:		-
Other:		-
Number of Nodes		88
Number of Pump Stations		1
Pump Station:		APw Kht I, Sadowastr.
Node ID:		Saugraum_Kht
Average dry wheather flow:		23.80 l/s
Maximum Capacity		
	local:	0.100 m^3/s
	global:	-
Destination		
	dry weather:	Waßmannsdorf
	storm weather:	Waßmannsdorf

Number of emergency outlets: 1
Node ID: 11104003
invert level [maD]: 32.93

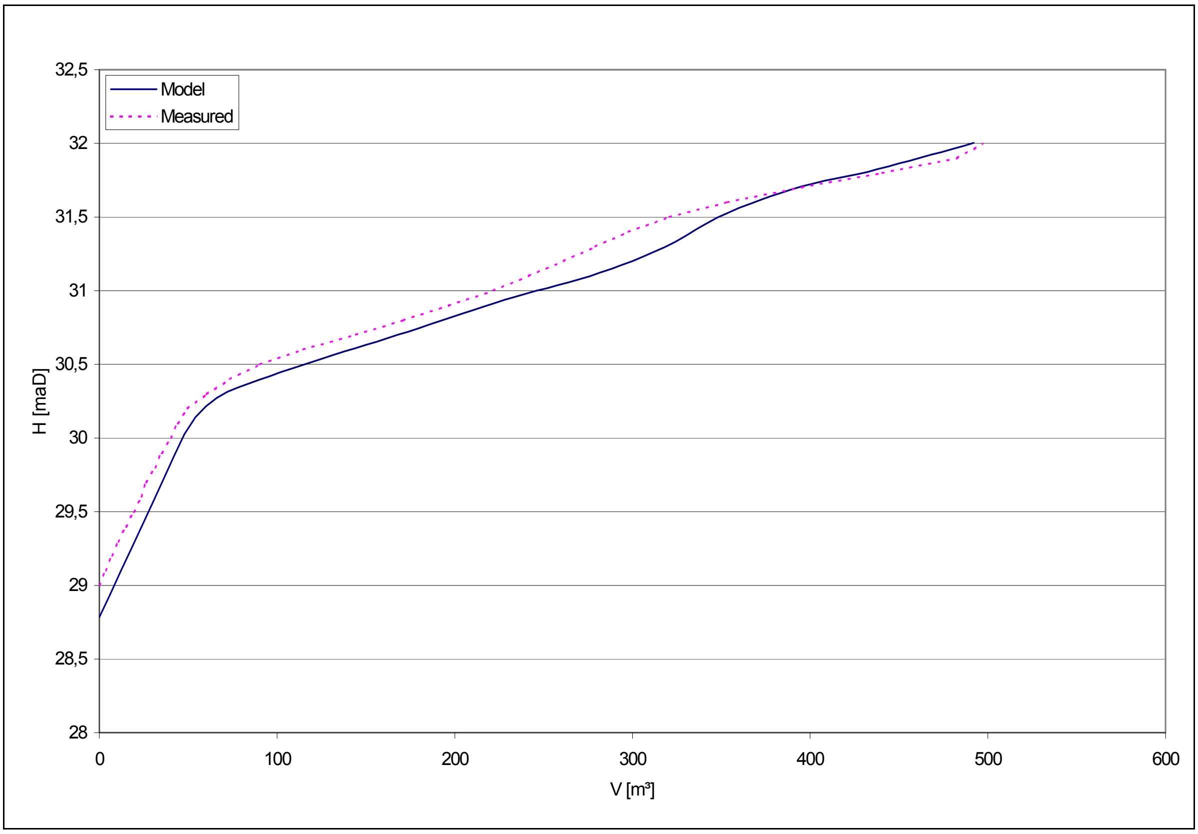


Network model of subcatchment Karlshorst I

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	492	497
storage level [maD]:	32.00	32.00
invert level of emergency outlet [maD]:	32.93	

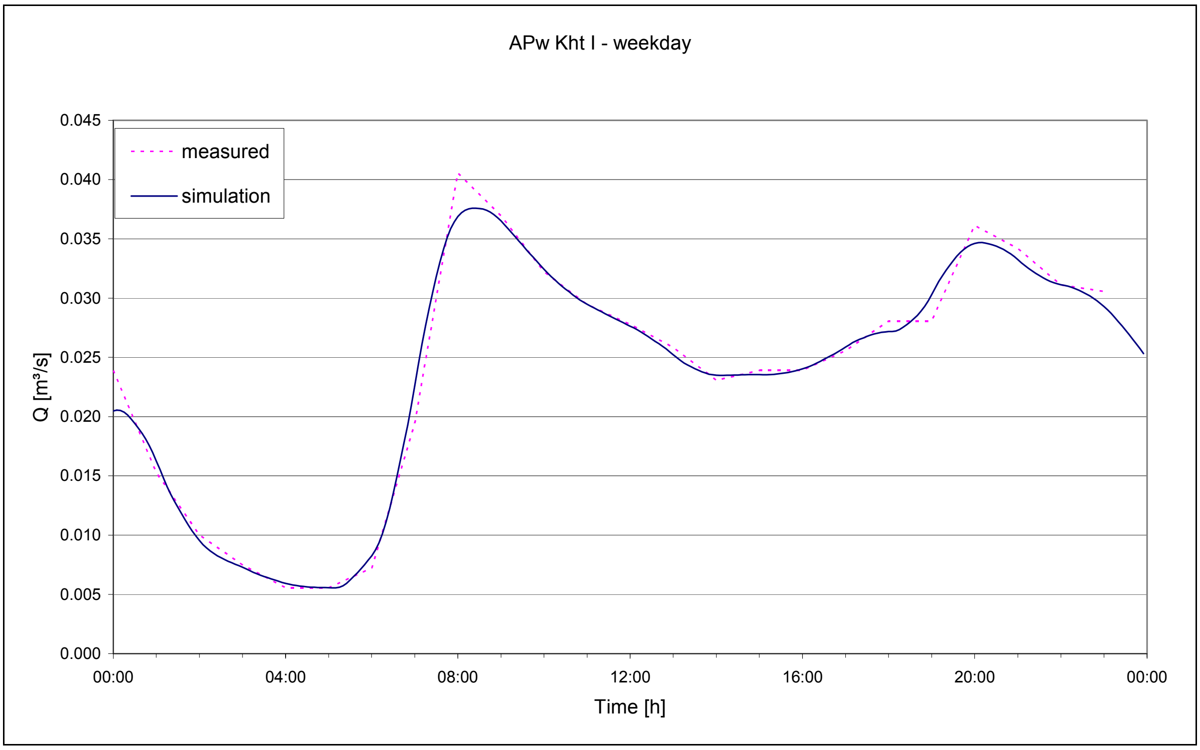
APw Kht I



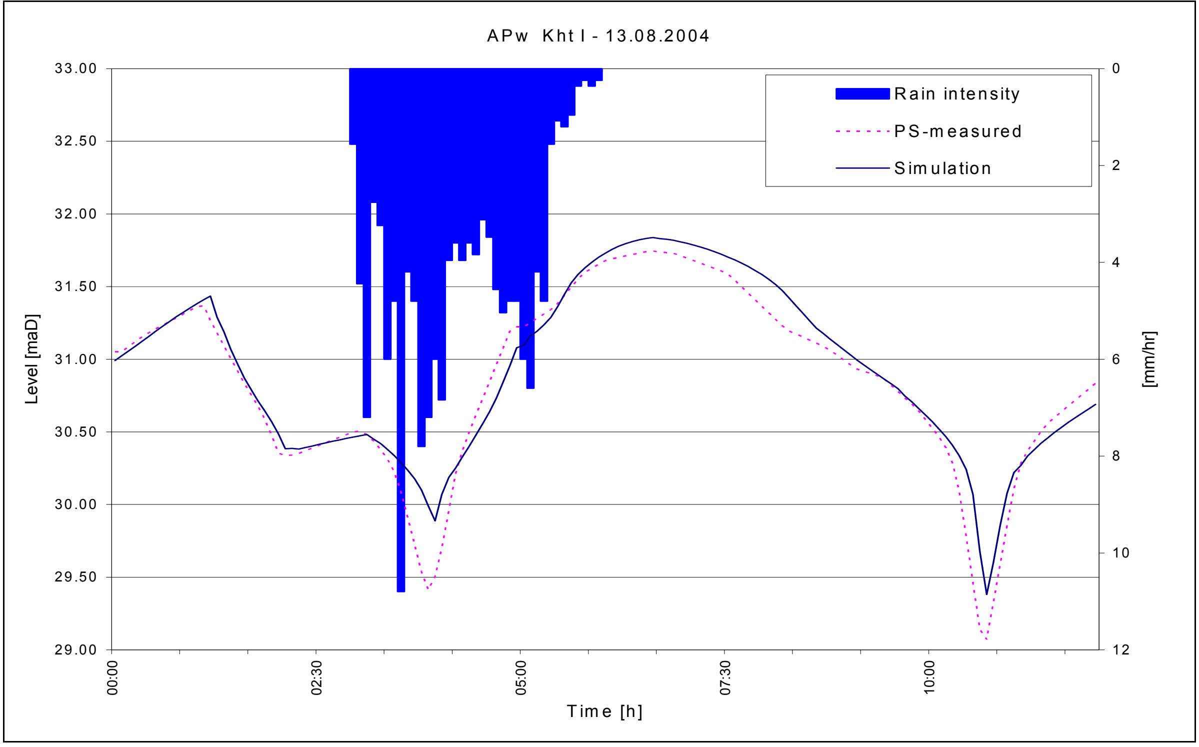
Storage characteristic of sewer network Karlshorst I

Calibration

Dry Weather: Flow at Pump station Kht I, 19.10.2000, still up to date
min flow: 0.006 m³/s
max flow: 0.038 m³/s

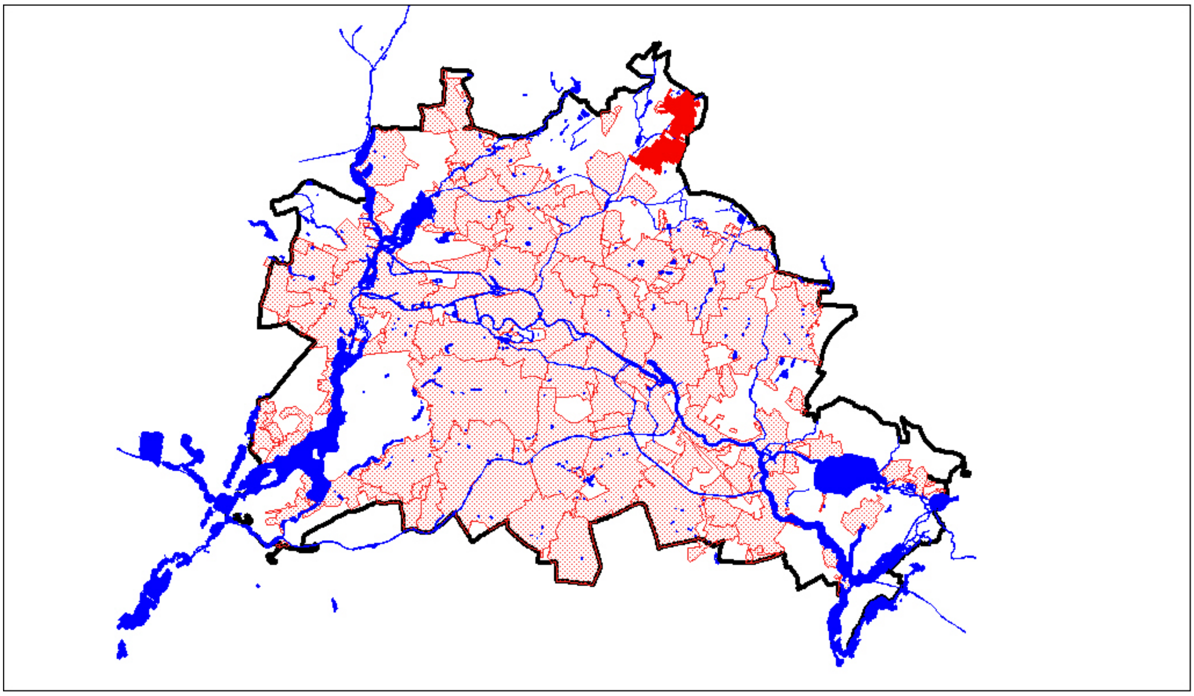


Storm Weather: Level at Pump station Kht I



3.4.28 HPw Karow

Subcatchment:	Karow	
Total Area:	828 ha	
Population:	26878 Inh.	
WWTP:	dry weather:	Schönerlinde
	rain weather:	Schönerlinde



Location of subcatchment Karow

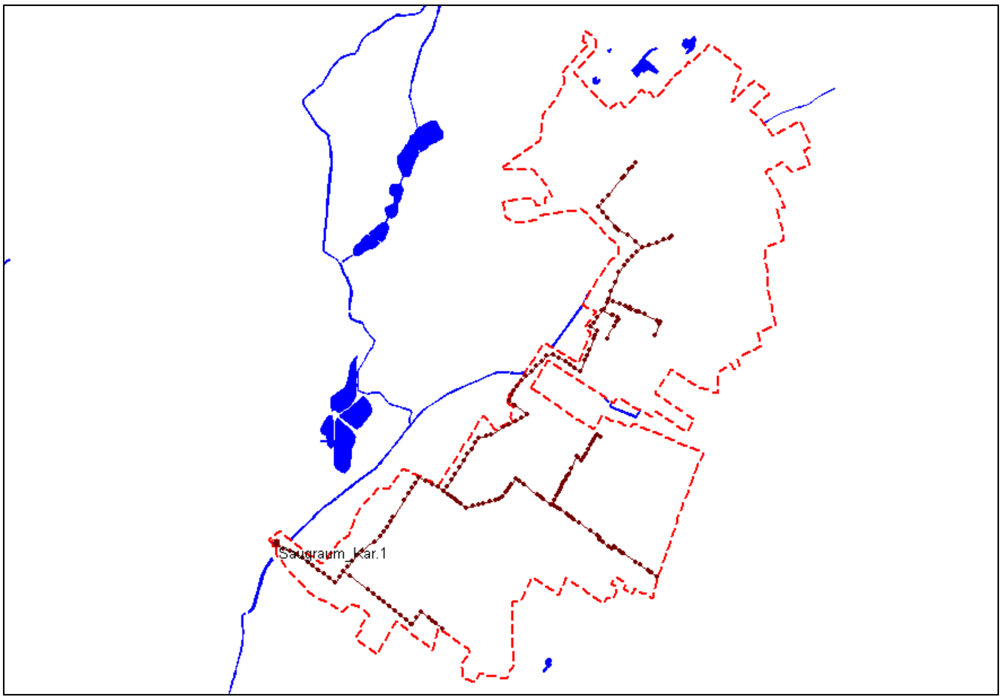
Model characteristics Karow

System type:	Separate
Length of modelled pipes	
Combined:	-
Waste water:	11.275 km
Storm water:	-
Other:	-
Number of Nodes	229
Number of Pump Stations	1
Pump Station:	HPw Kar, Pankgrafenstr.
Node ID:	Saugraum_Kar
Average dry wheather flow:	45.00 l/s
Maximum Capacity	
local:	0.170 m^3/s
global:	0.220 m^3/s
Destination	
dry weather:	Schönerlinde
storm weather:	Schönerlinde

Number of emergency outlets: 1

Node ID: 36153101

invert level [maD]: 46.65

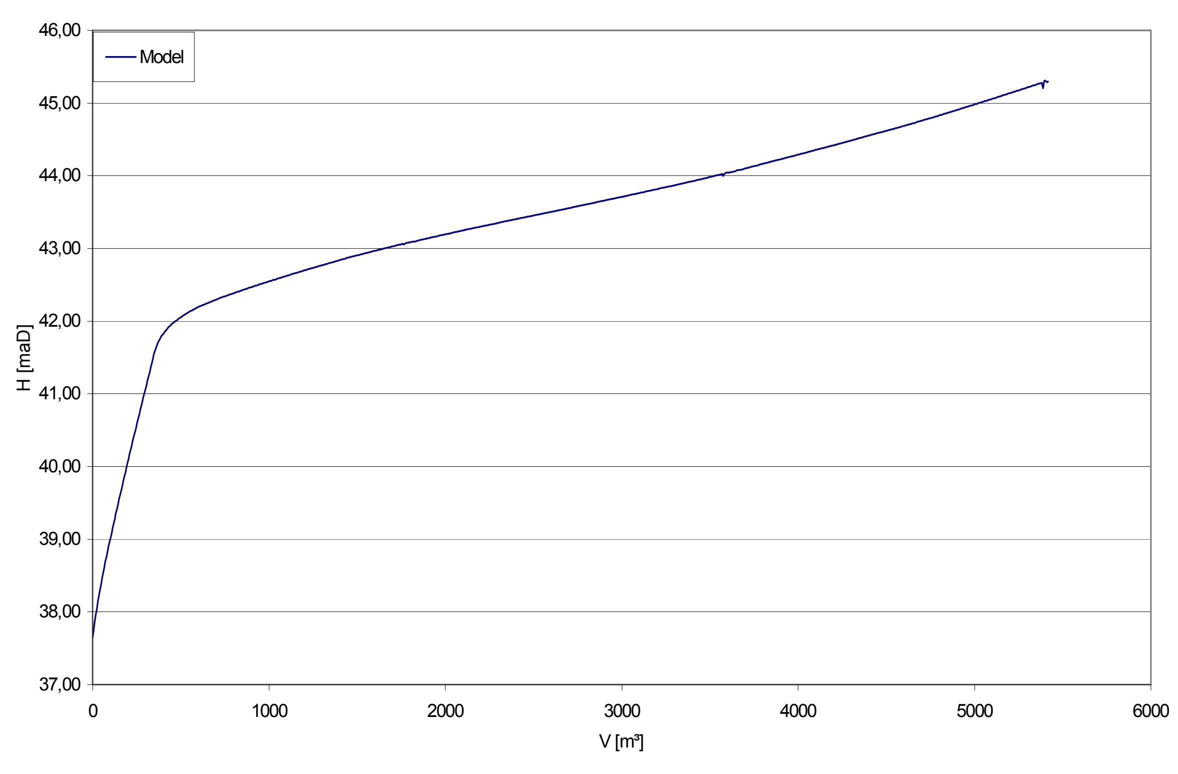


Network model of subcatchment Karow

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	5418	-
storage level [maD]:	45,30	-
invert level of emergency outlet [maD]:	46,65	

HPw Kar

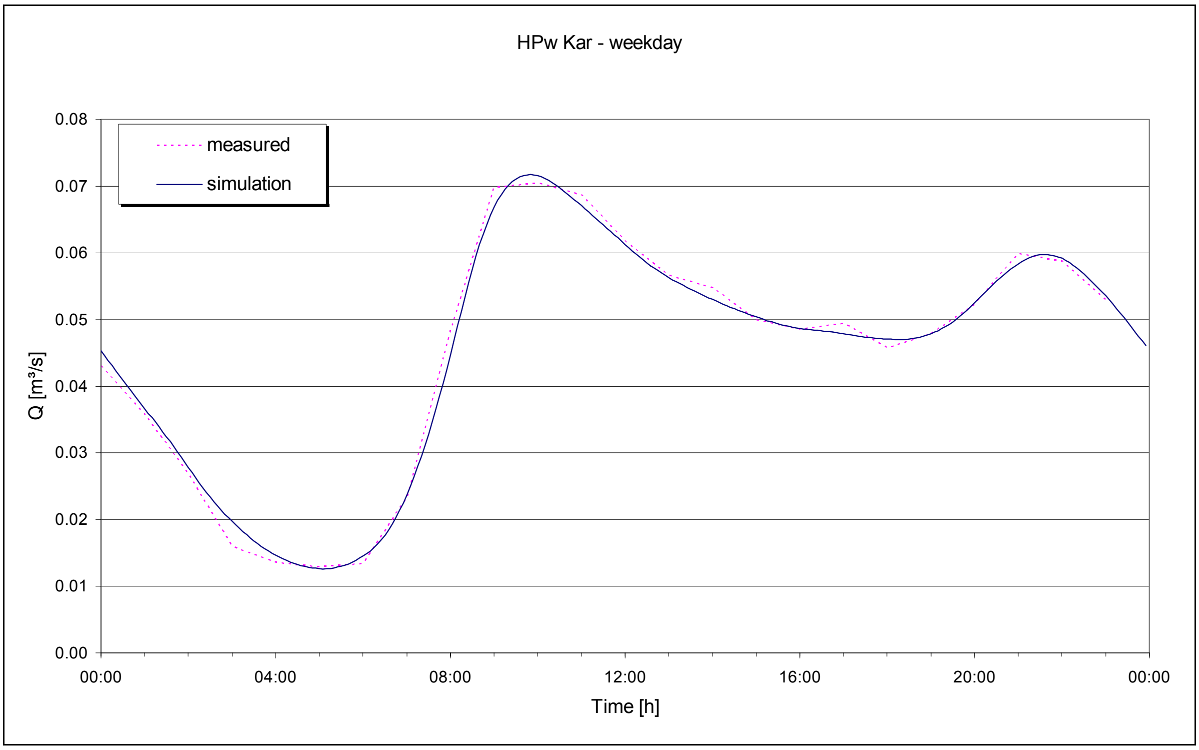


Storage characteristic of sewer network Karow

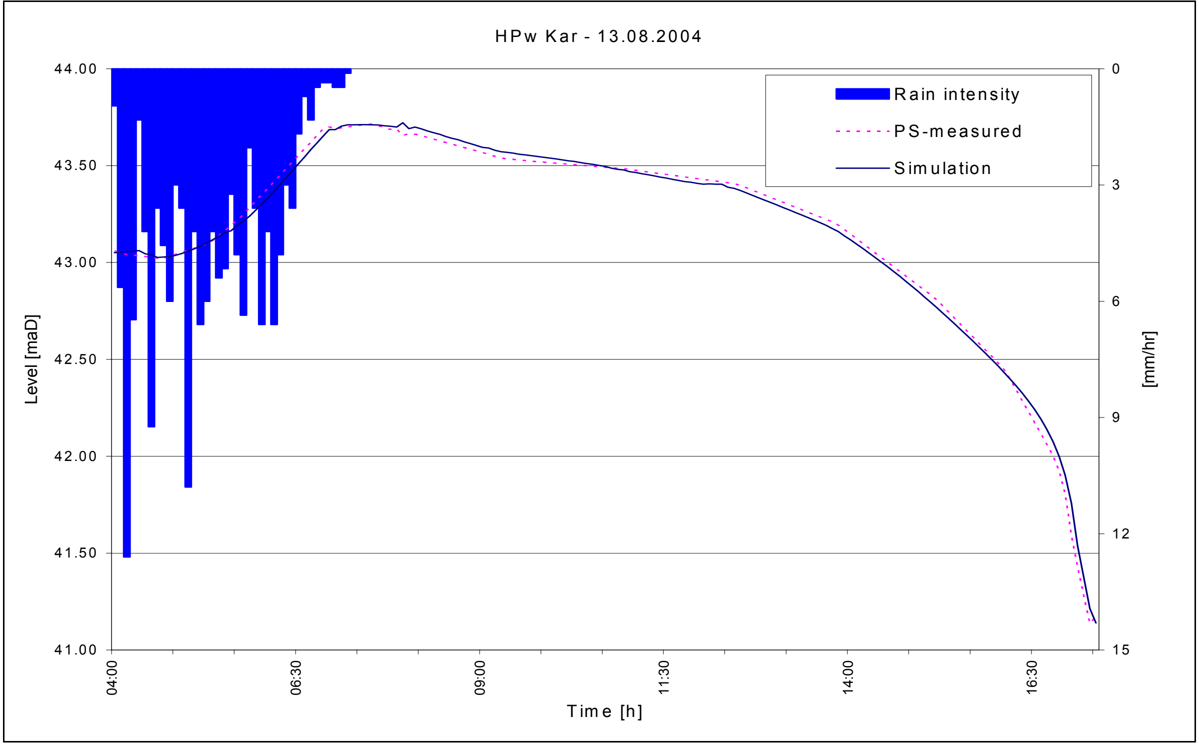
Calibration

Dry Weather: Flow at Pump station Kar, 09.05.2000, adapted to data from 2004

min flow: 0.013 m³/s
max flow: 0.072 m³/s



Storm Weather: Level at Pump station Kar



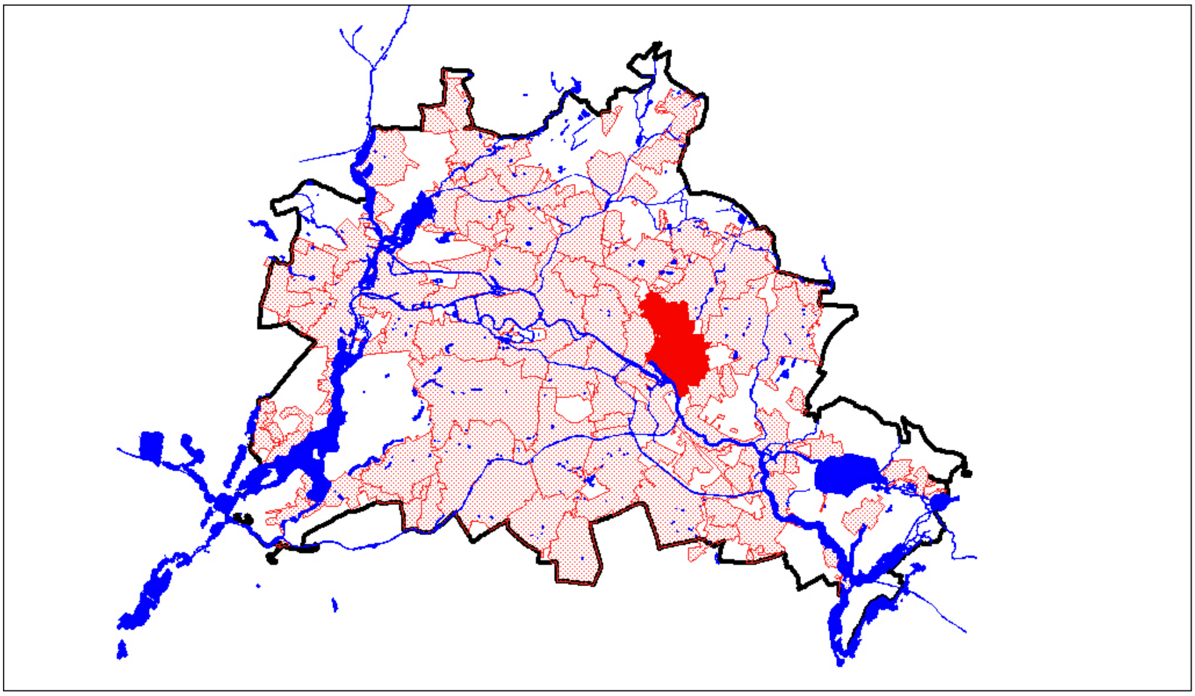
3.4.29 HPw Lichtenberg

Subcatchment: Lichtenberg

Total Area: 1531 ha

Population: 119505 Inh.

WWTP: dry weather: Waßmannsdorf
rain weather: Waßmannsdorf



Location of subcatchment Lichtenberg

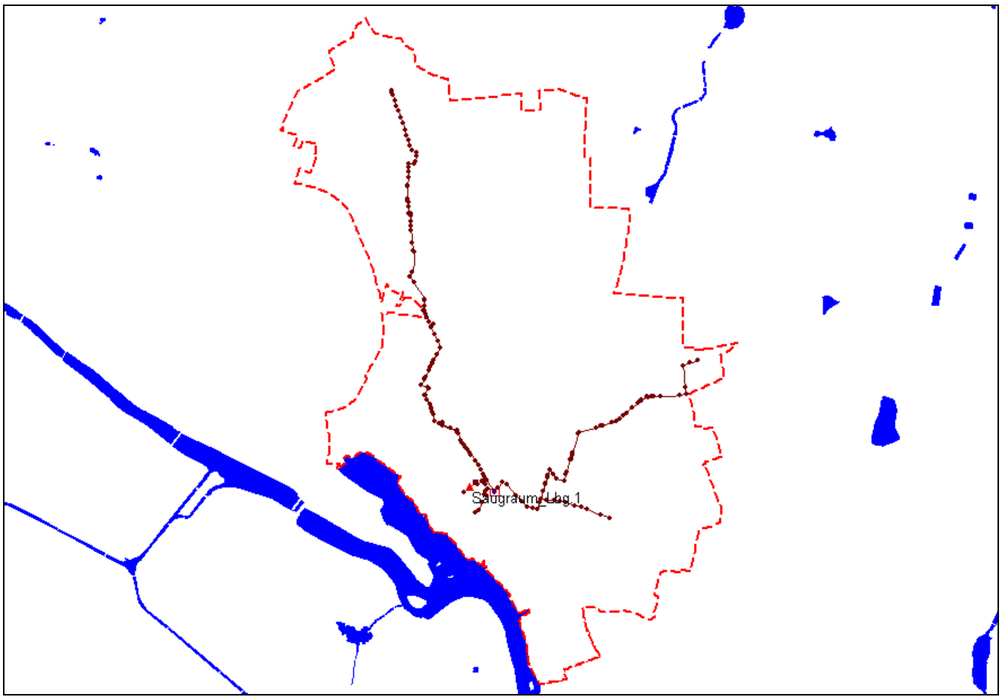
Model characteristics Lichtenberg

System type:	Separate
Length of modelled pipes	
Combined:	-
Waste water:	10.818 km
Storm water:	-
Other:	-
Number of Nodes	190
Number of Pump Stations	1
Pump Station:	HPw Lbg, Fischerstr.
Node ID:	Saugraum_Lbg
Average dry wheather flow:	184.40 l/s
Maximum Capacity	
local:	0.720 m^3/s
global:	-
Destination	
dry weather:	Waßmannsdorf
storm weather:	Waßmannsdorf

Number of emergency outlets: 1

Node ID: 14122007

invert level [maD]: 32.42

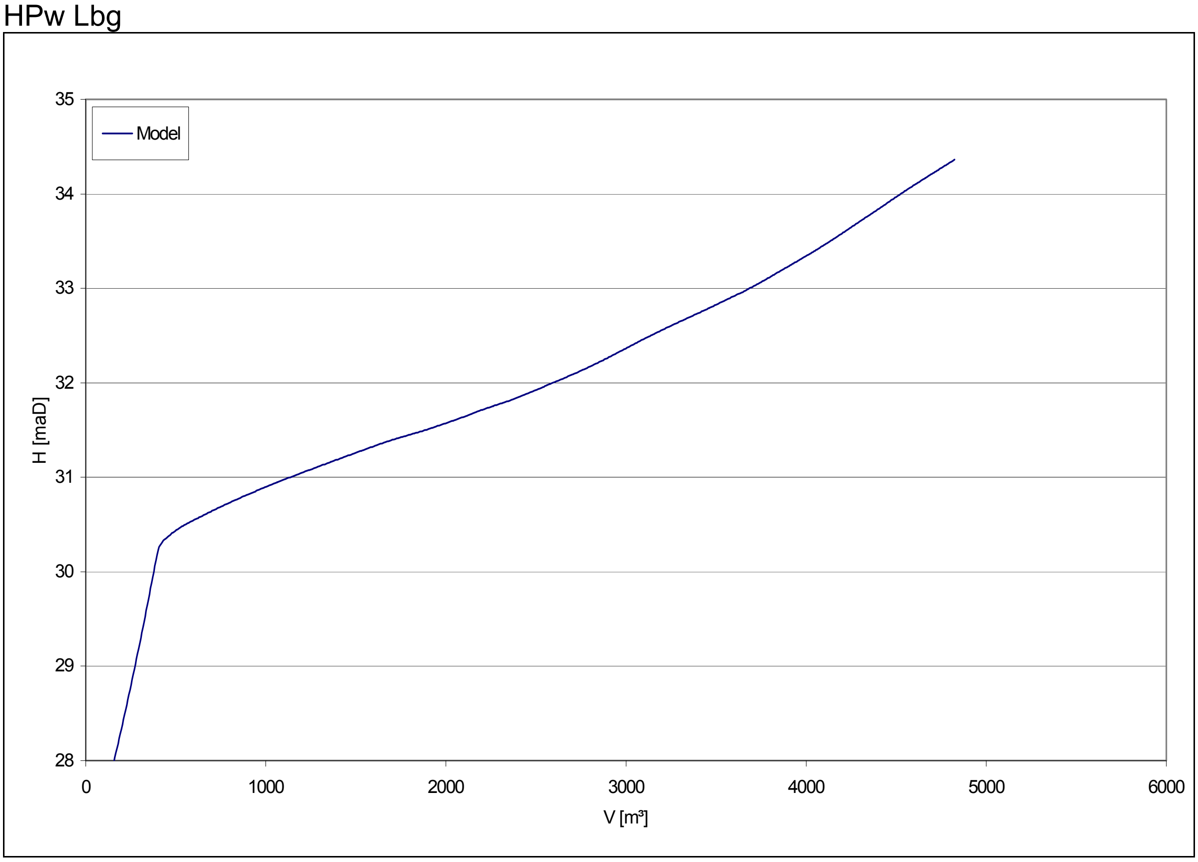


Network model of subcatchment Lichtenberg

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	4824	-
storage level [maD]:	34,36	-
invert level of emergency outlet [maD]:	32,42	

HPw Lbg

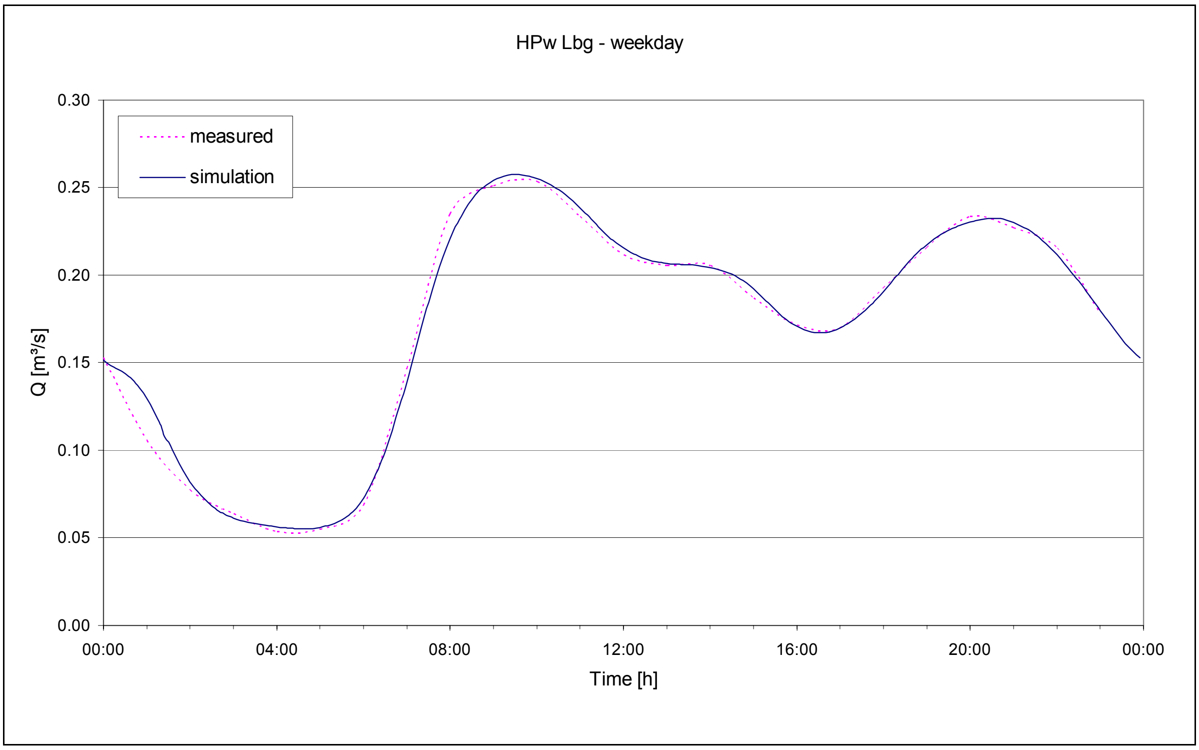


Storage characteristic of sewer network Lichtenberg

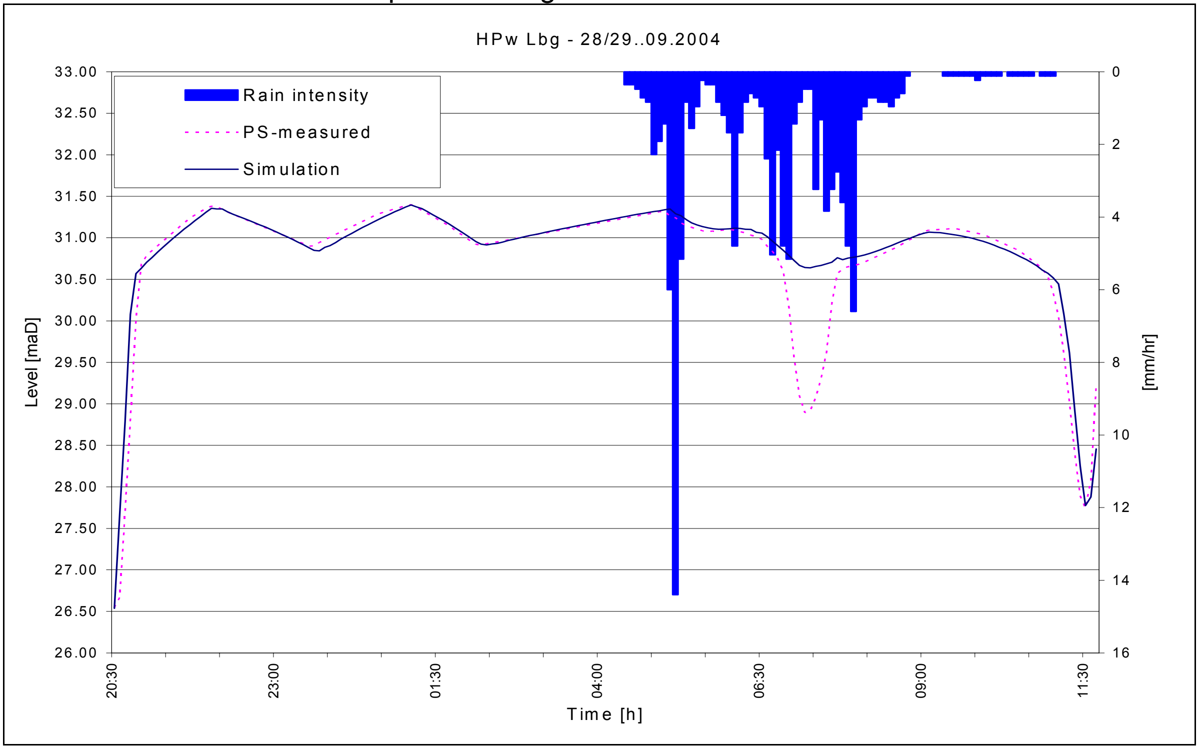
Calibration

Dry Weather: Flow at Pump station Lbg, 08.11.2000, adapted to data from 2004

min flow:	0.055 m³/s
max flow:	0.258 m³/s

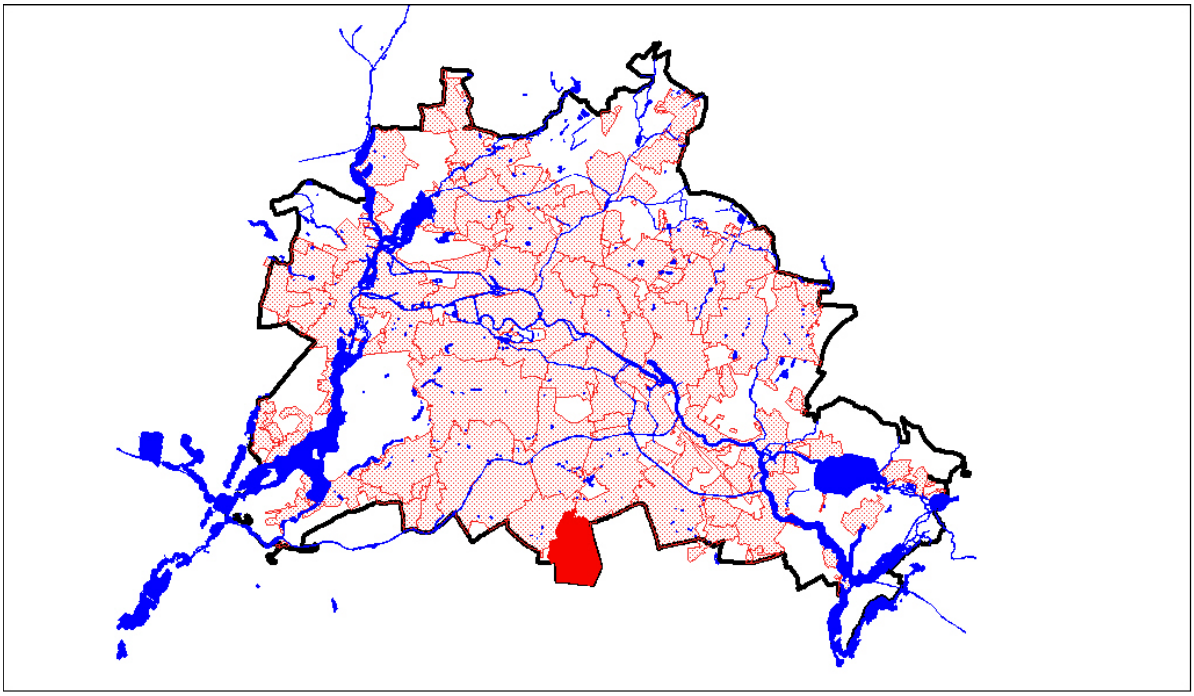


Storm Weather: Level at Pump station Lbg



3.4.30 APw Lichtenrade

Subcatchment:	Lichtenrade	
Total Area:	1018 ha	
Population:	51488 Inh.	
WWTP:	dry weather:	Waßmannsdorf
	rain weather:	Waßmannsdorf



Location of subcatchment Lichtenrade

Model characteristics Lichtenrade

System type: Separate

Length of modelled pipes

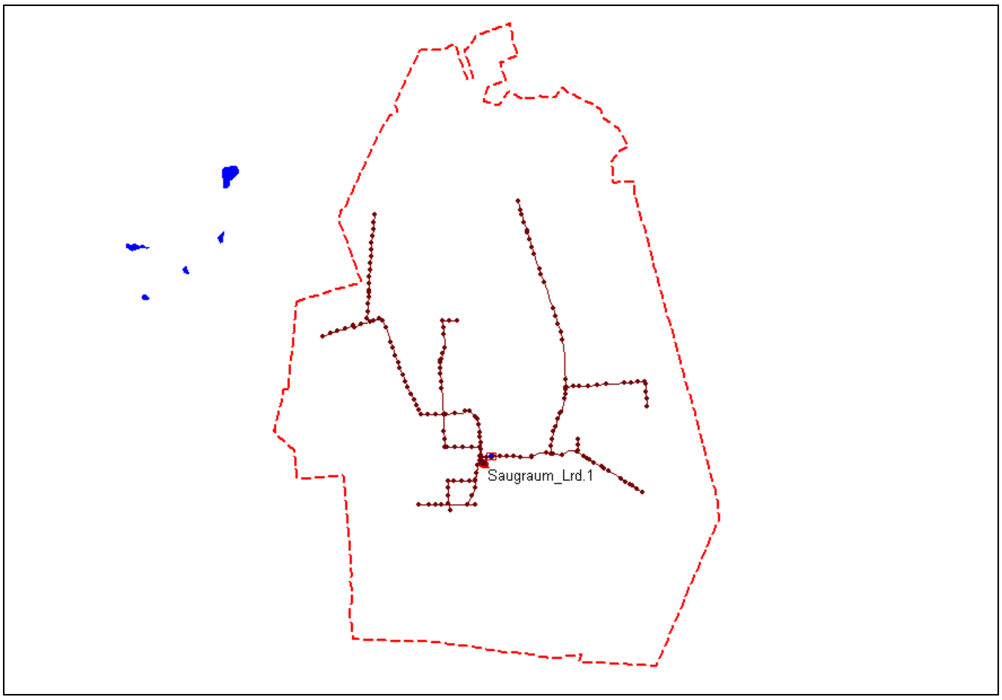
- **Combined:** -
- **Waste water:** 9.576 km
- **Storm water:** -
- **Other:** -

Number of Nodes 188

Number of Pump Stations 1

- **Pump Station:** APw Lrd, John-Locke-Str.
- **Node ID:** Saugraum_Lrd
- **Average dry wheather flow:** 73.70 l/s
- **Maximum Capacity**
  - **local:** 0.170 m^3/s
  - **global:** -
- **Destination**
  - **dry weather:** Waßmannsdorf
  - **storm weather:** Waßmannsdorf

Number of emergency outlets: 2
Node ID: 95191907
invert level [maD]: 41.27
Node ID: 95191703
invert level [maD]: 40.54

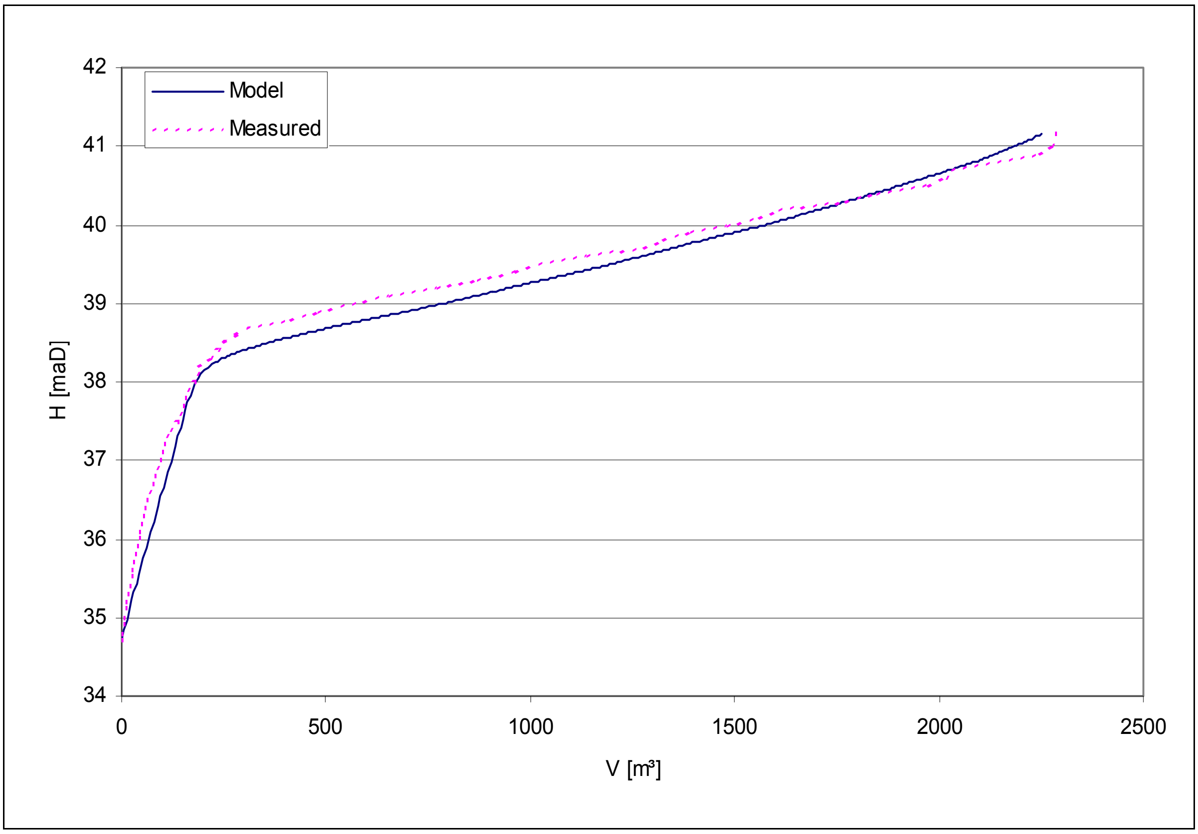


Network model of subcatchment Lichtenrade

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	2250	2284
storage level [maD]:	41,15	41,15
invert level of emergency outlet [maD]:	40.54	

APw Lrd



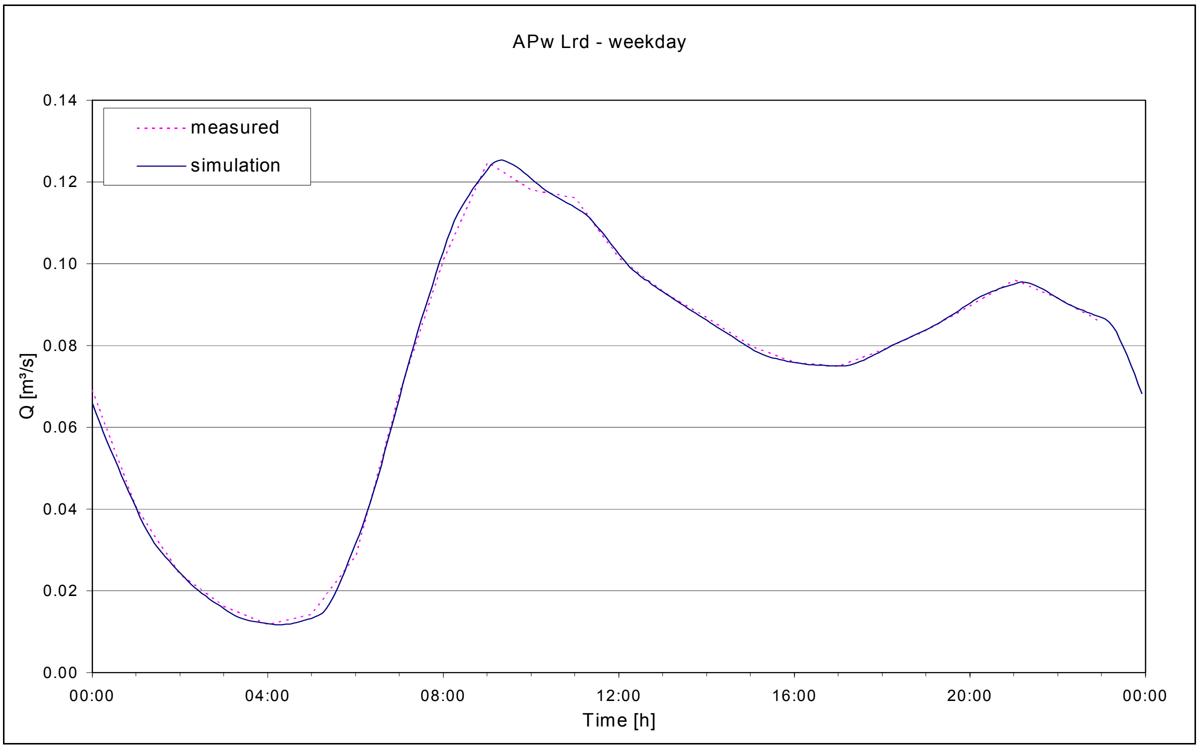
Storage characteristic of sewer network Lichtenrade

Calibration

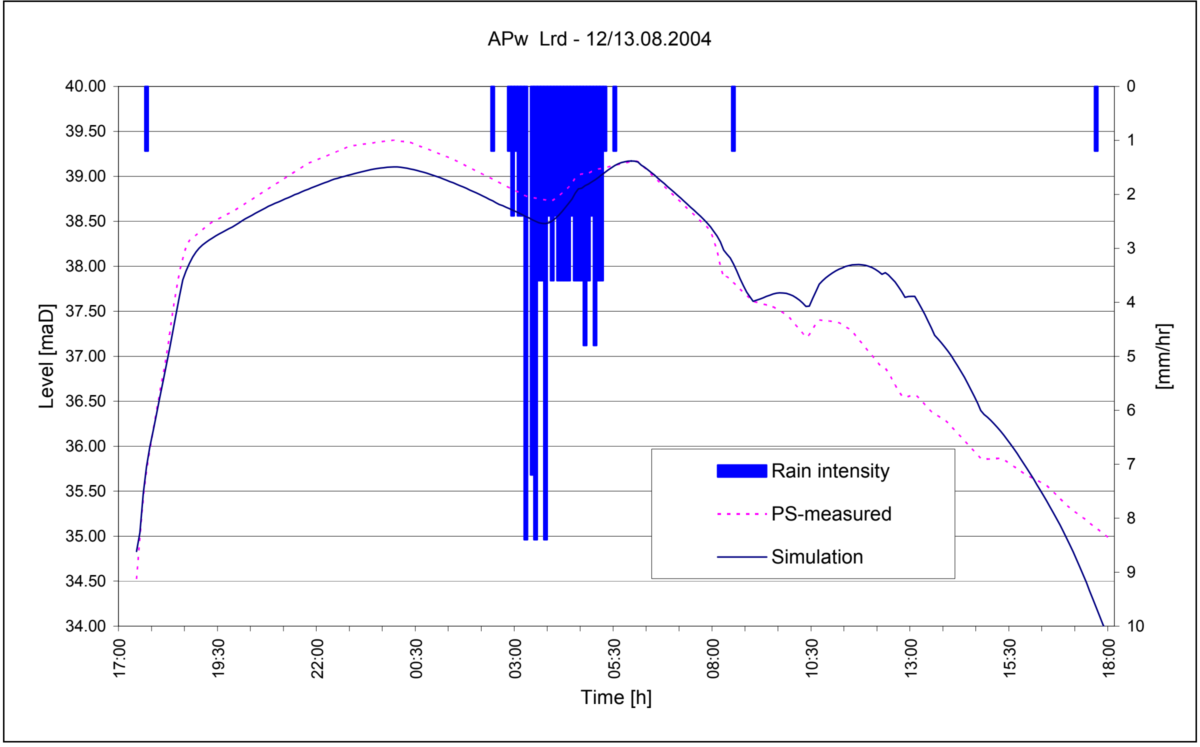
Dry Weather: Flow at Pump station Lrd, 13.06.2000, adapted to data from 2004

min flow: 0.012 m³/s

max flow: 0.128 m³/s

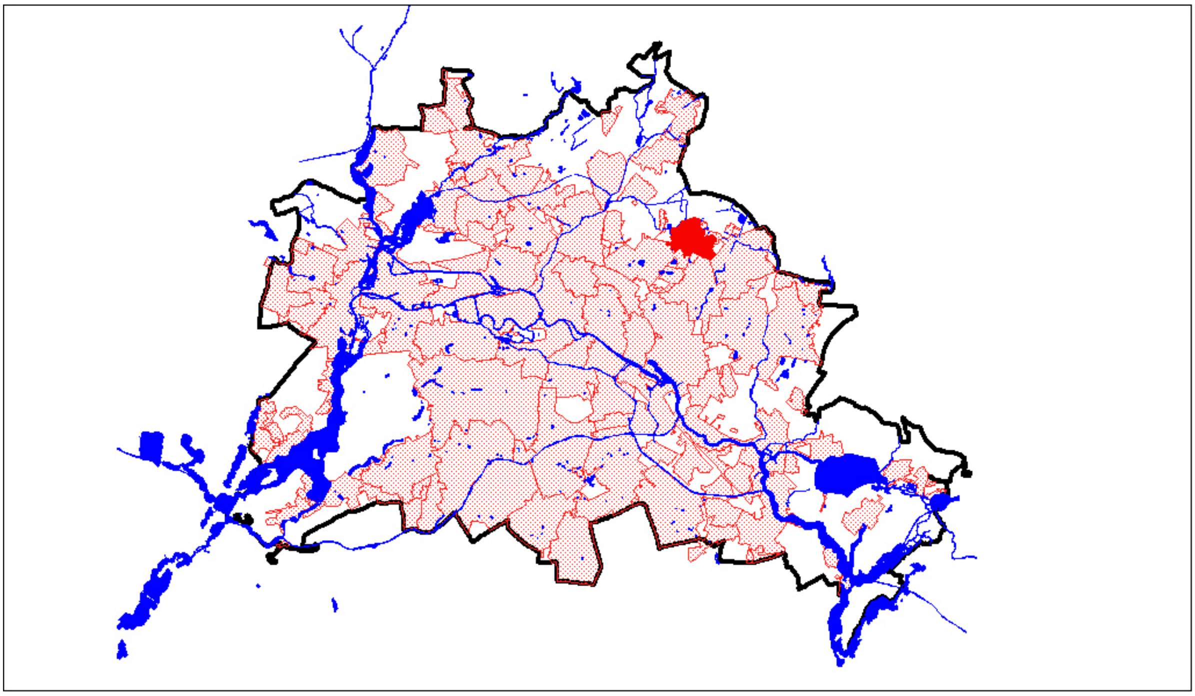


Storm Weather: Level at Pump station Lrd



3.4.31 APw Malchow

Subcatchment:	Malchow	
Total Area:	474 ha	
Population:	57434 Inh.	
WWTP:	dry weather:	Schönerlinde
	rain weather:	Schönerlinde

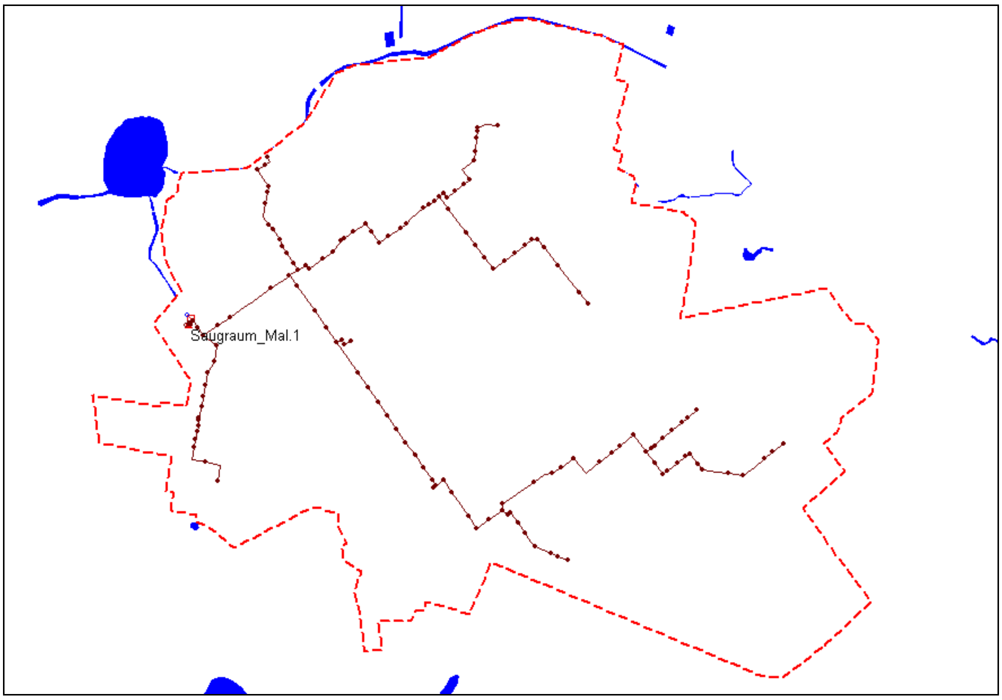


Location of subcatchment Malchow

Model characteristics Malchow

System type:	Separate
Length of modelled pipes	
Combined:	-
Waste water:	7.355 km
Storm water:	-
Other:	-
Number of Nodes	141
Number of Pump Stations	1
Pump Station:	APw Mal, Ribnitzer Str.
Node ID:	Saugraum_Mal
Average dry wheather flow:	61.90 l/s
Maximum Capacity	
local:	0.180 m^3/s
global:	0.350 m^3/s
Destination	
dry weather:	Schönerlinde
storm weather:	Schönerlinde

Number of emergency outlets: 1
- **Node ID:** 28126001
- **invert level [maD]:** 46.49

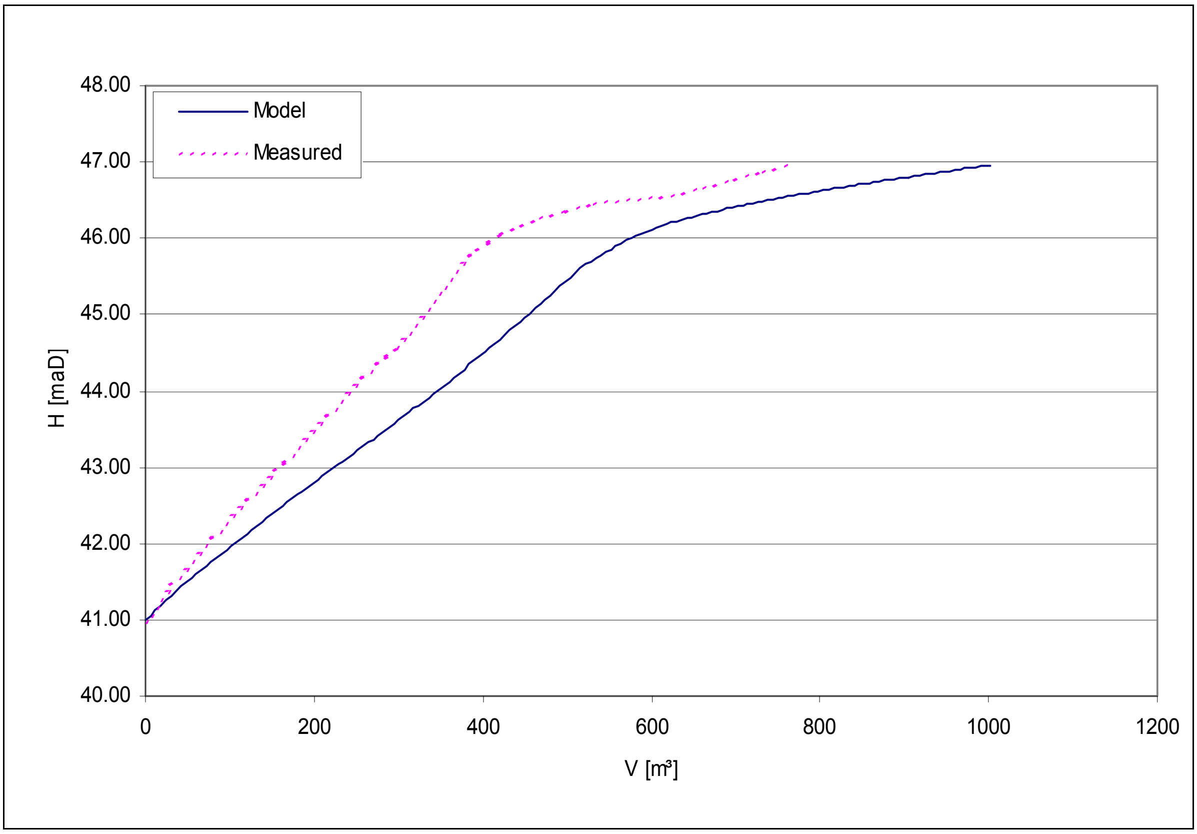


Network model of subcatchment Malchow

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	1002	762
storage level [maD]:	46.96	46.96
invert level of emergency outlet [maD]:	46.49	

APw Mal



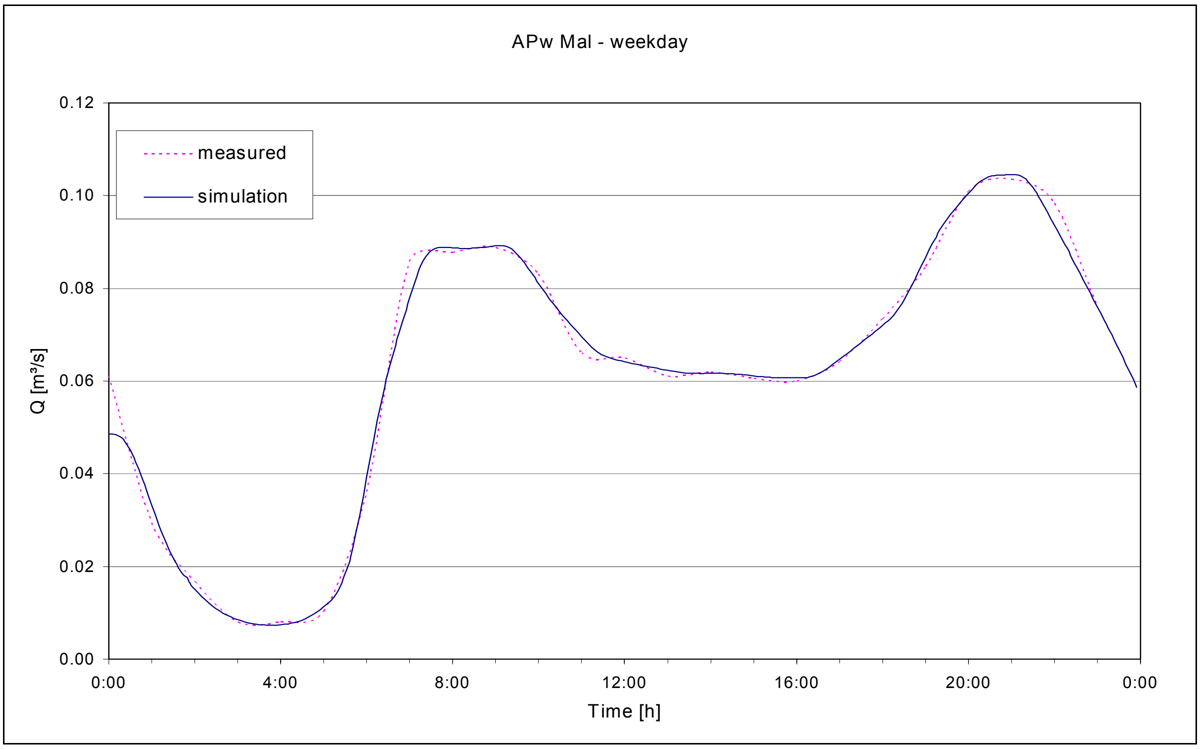
Storage characteristic of sewer network Malchow

Calibration

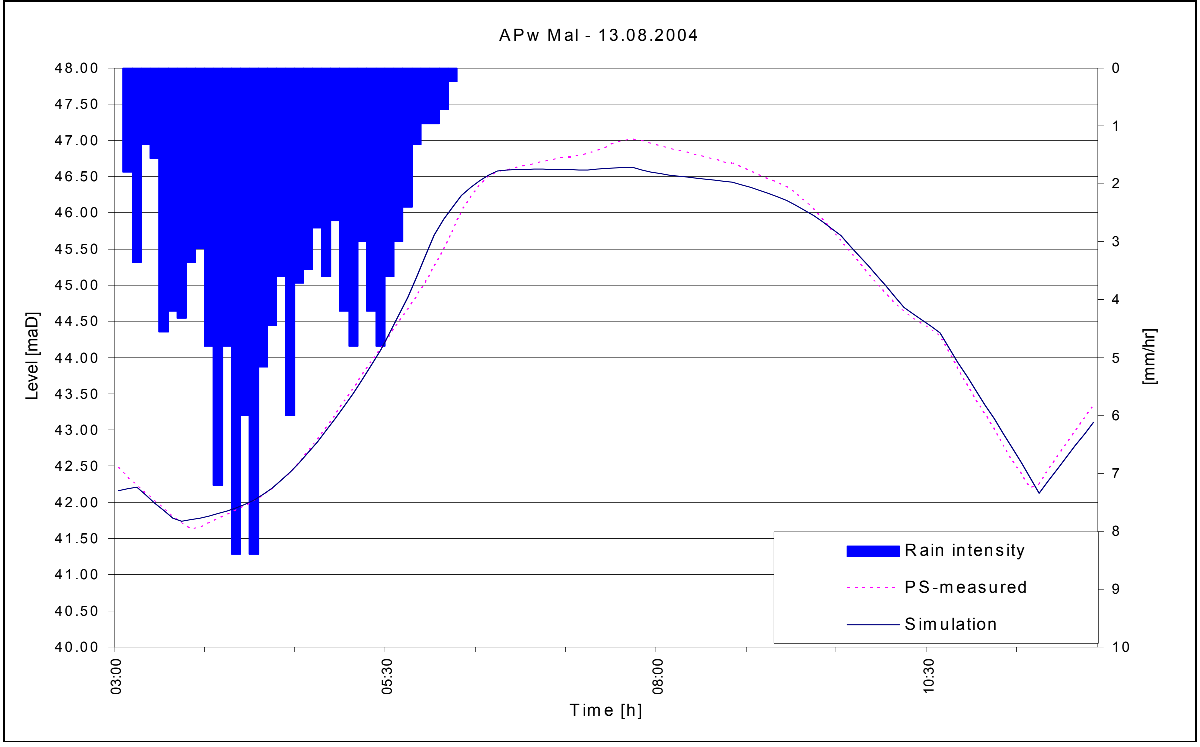
Dry Weather: Flow at Pump station Mal, 27.05.2003, still up to date

min flow: 0.007 m³/s

max flow: 0.105 m³/s

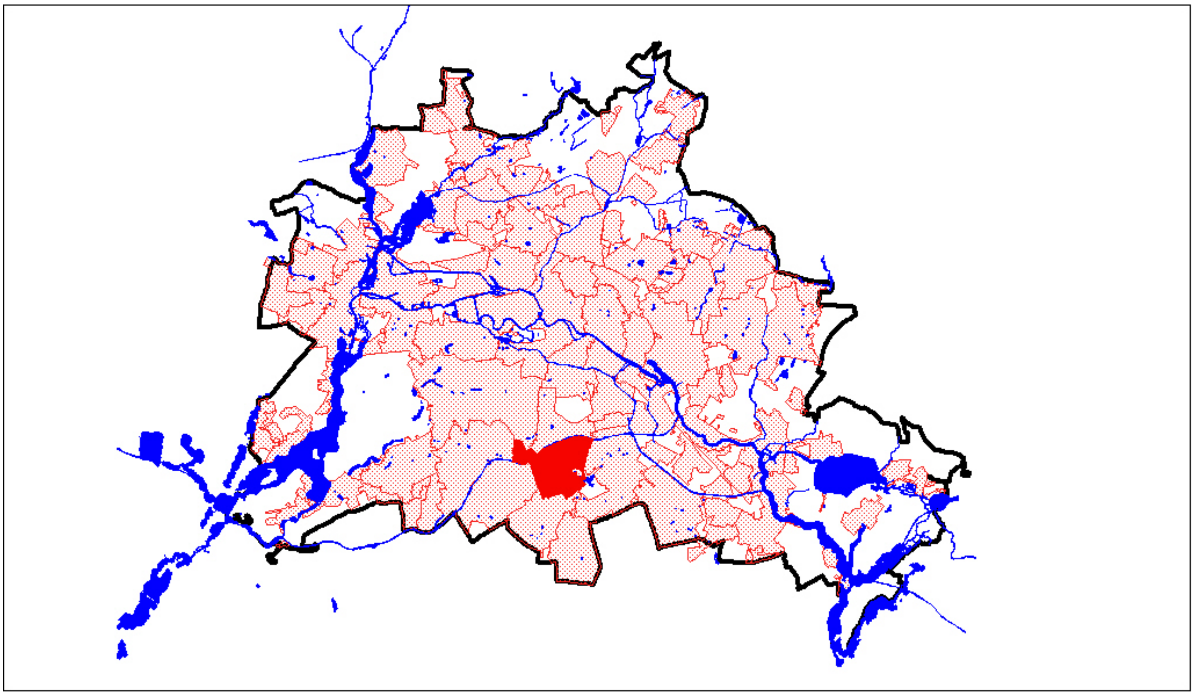


Storm Weather: Level at Pump station Mal



3.4.32 APw Mariendorf

Subcatchment:	Mariendorf	
Total Area:	1116 ha	
Population:	53436 Inh.	
WWTP:	dry weather:	Waßmannsdorf
	rain weather:	Waßmannsdorf

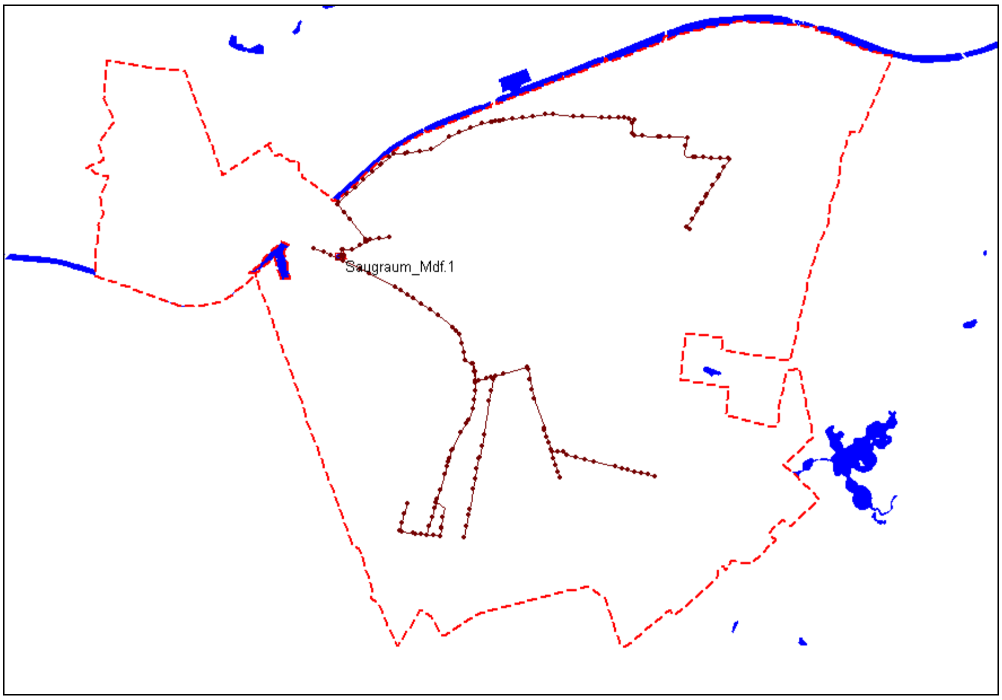


Location of subcatchment Mariendorf

Model characteristics Mariendorf

System type:	Separate
Length of modelled pipes	
Combined:	-
Waste water:	10.202 km
Storm water:	-
Other:	-
Number of Nodes	194
Number of Pump Stations	1
Pump Station:	APw Mdf, Blumenweg.
Node ID:	Saugraum_Mdf
Average dry wheather flow:	92.00 l/s
Maximum Capacity	
local:	0.180 m^3/s
global:	-
Destination	
dry weather:	Waßmannsdorf
storm weather:	Waßmannsdorf

Number of emergency outlets:	1
Node ID:	05225002
invert level [maD]:	37.15

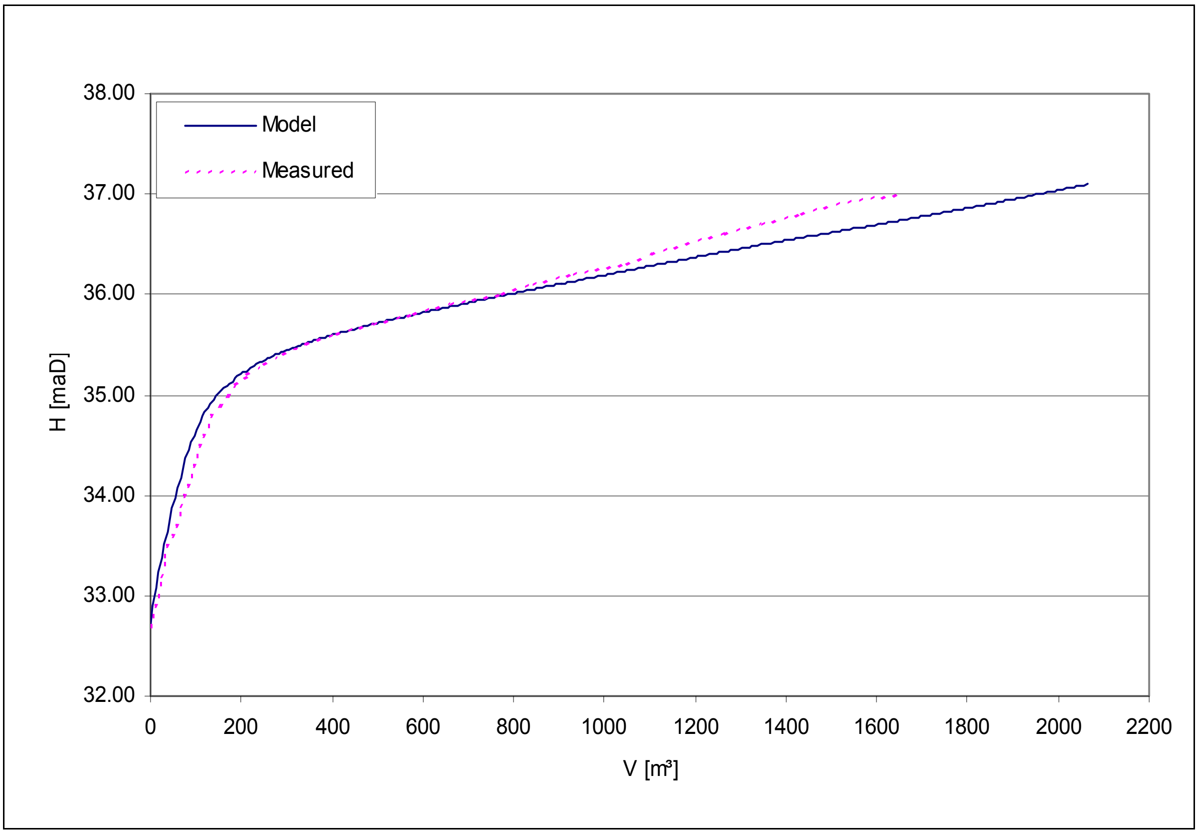


Network model of subcatchment Mariendorf

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	2064	1660
storage level [maD]:	37.10	37.00
invert level of emergency outlet [maD]:	37.15	

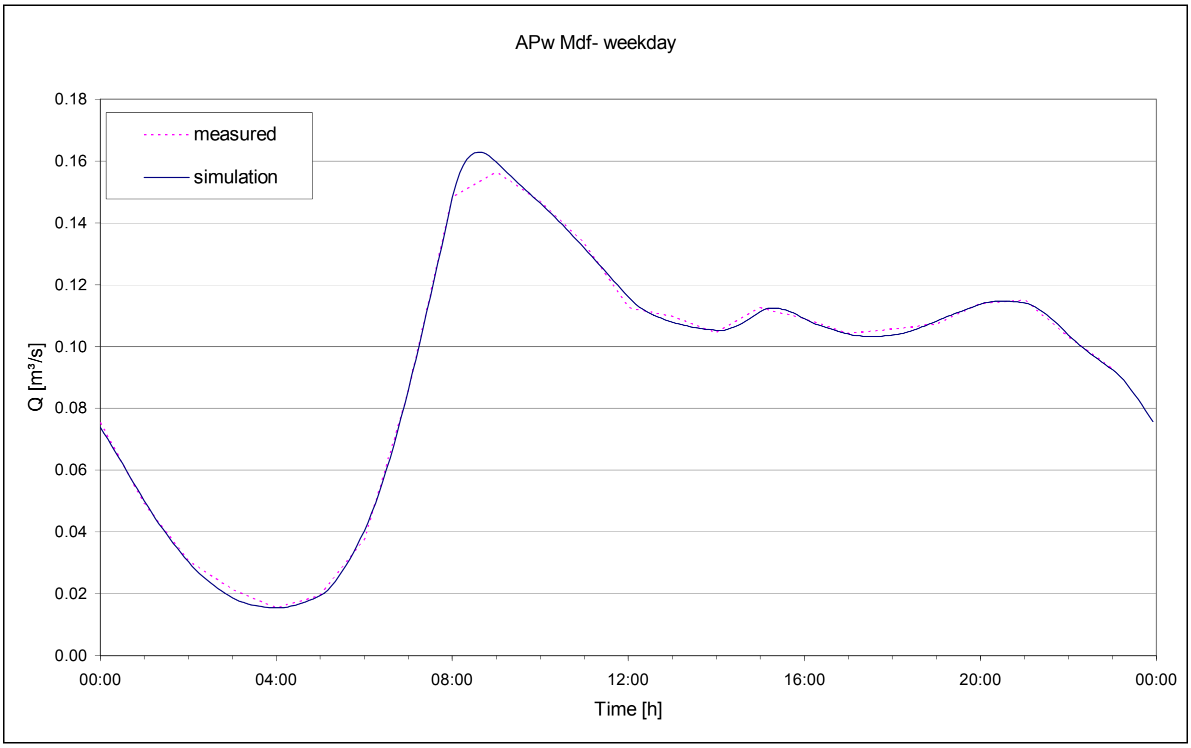
APw Mdf



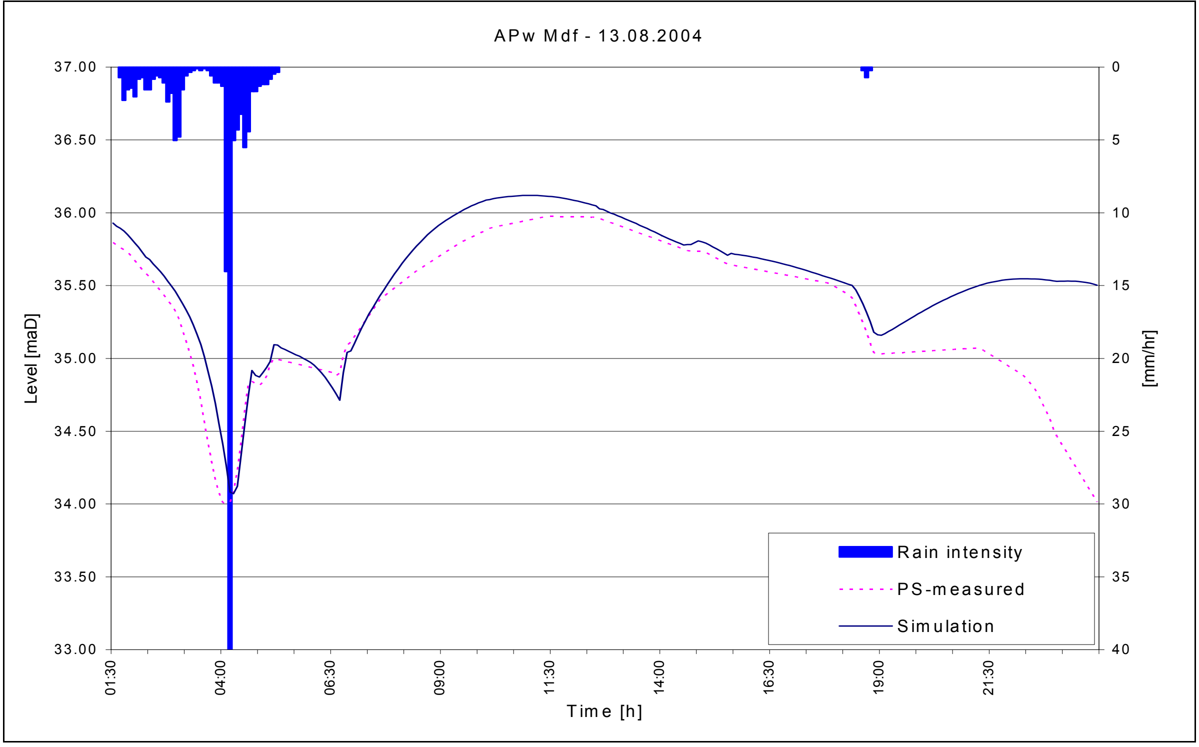
Storage characteristic of sewer network Mariendorf

Calibration

Dry Weather: Flow at Pump station Mdf, 24.05.2000, still up to date
min flow: 0.015 m³/s
max flow: 0.163 m³/s

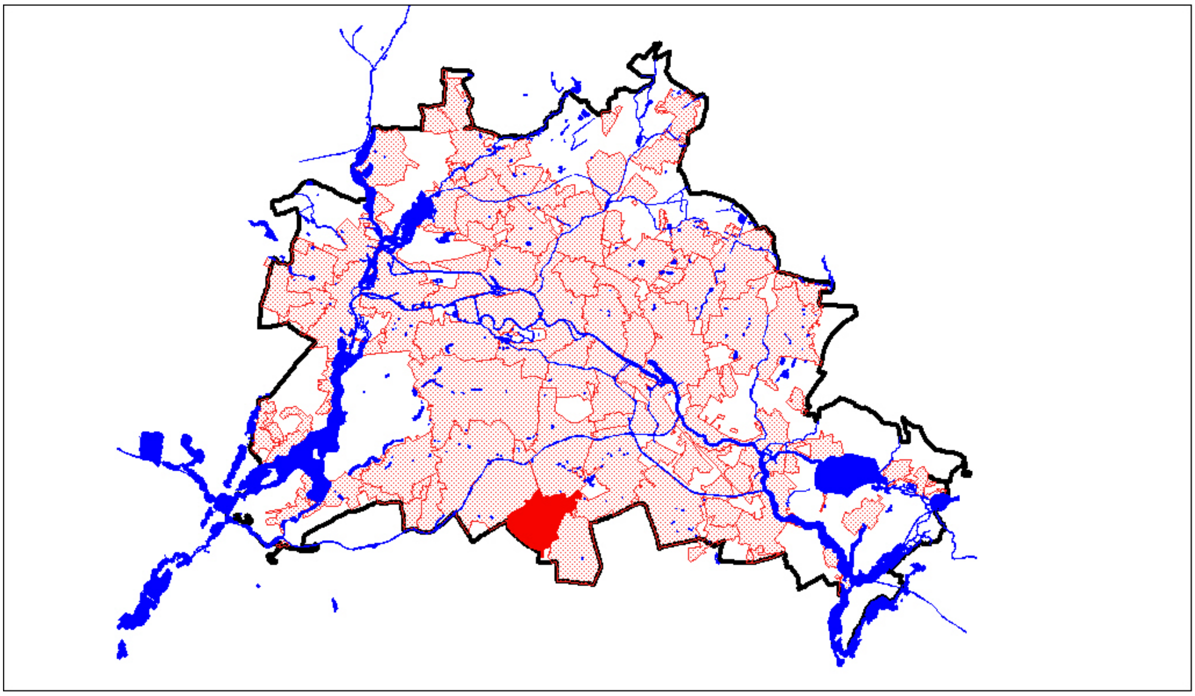


Storm Weather: Level at Pump station Mdf



3.4.33 APw Marienfelde I

Subcatchment:	Marienfelde I	
Total Area:	943 ha	
Population:	36663 Inh.	
WWTP:	dry weather:	Waßmannsdorf
	rain weather:	Waßmannsdorf



Location of subcatchment Marienfelde I

Model characteristics Marienfelde I

System type: Separate

Length of modelled pipes

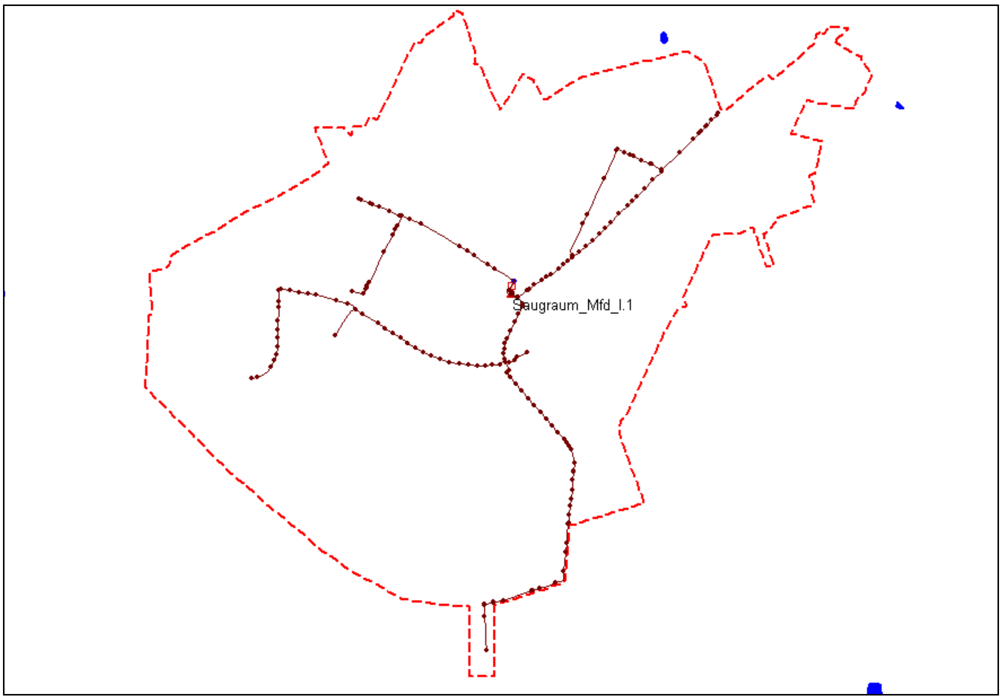
- **Combined:** -
- **Waste water:** 9.990 km
- **Storm water:** -
- **Other:** -

Number of Nodes 177

Number of Pump Stations 1

- **Pump Station:** APw Mfd I, Grillostr..
- **Node ID:** Saugraum_Mfd_I
- **Average dry wheather flow:** 77.60 l/s
- **Maximum Capacity**
  - **local:** 0.120 m^3/s
  - **global:** -
- **Destination**
  - **dry weather:** Waßmannsdorf
  - **storm weather:** Waßmannsdorf

Number of emergency outlets:	1
Node ID:	90226006
invert level [maD]:	37.96

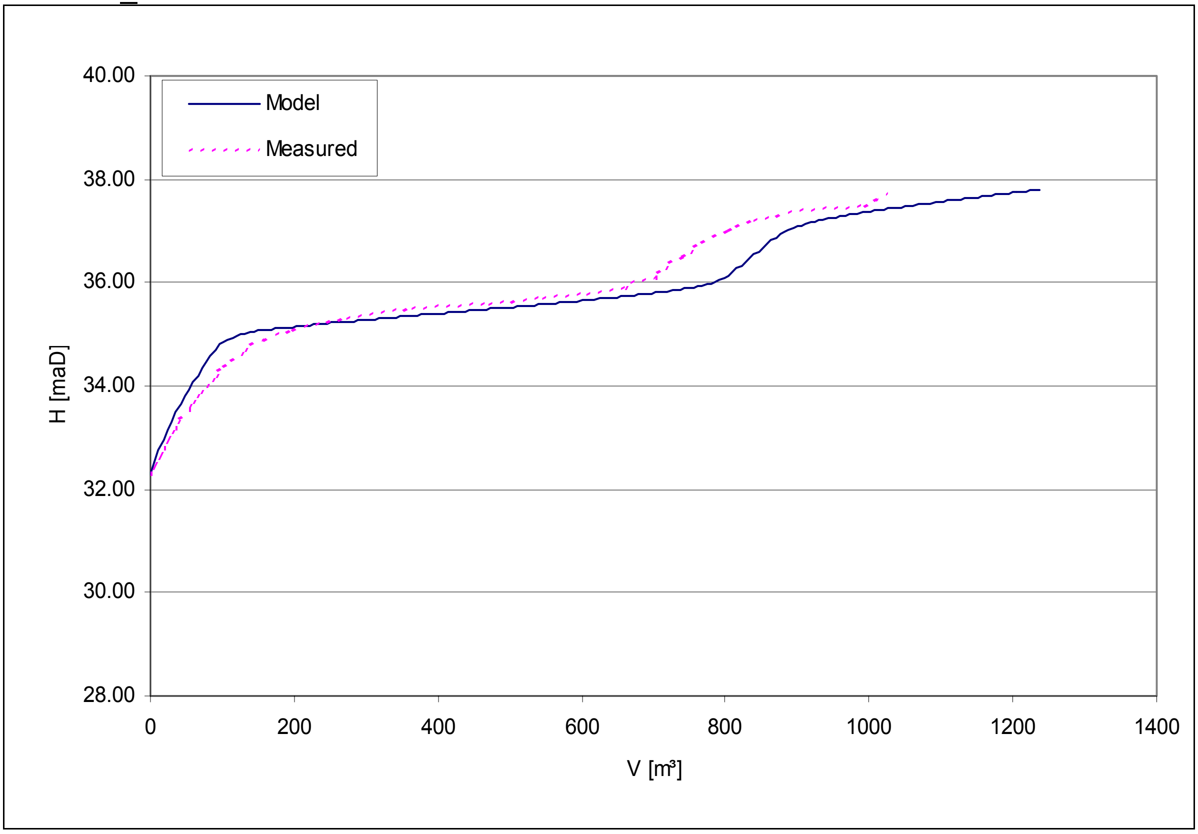


Network model of subcatchment Marienfelde I

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	1236	1024
storage level [maD]:	37.80	37.70
invert level of emergency outlet [maD]:	37.96	

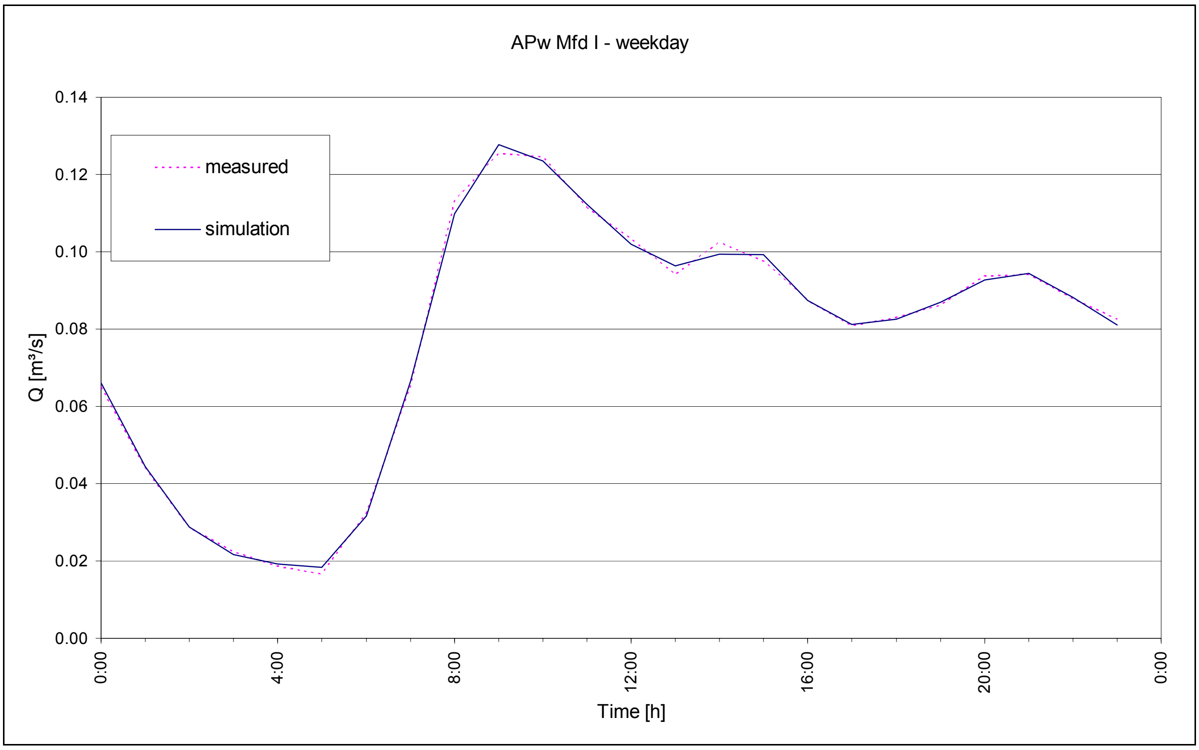
APw Mfd_I



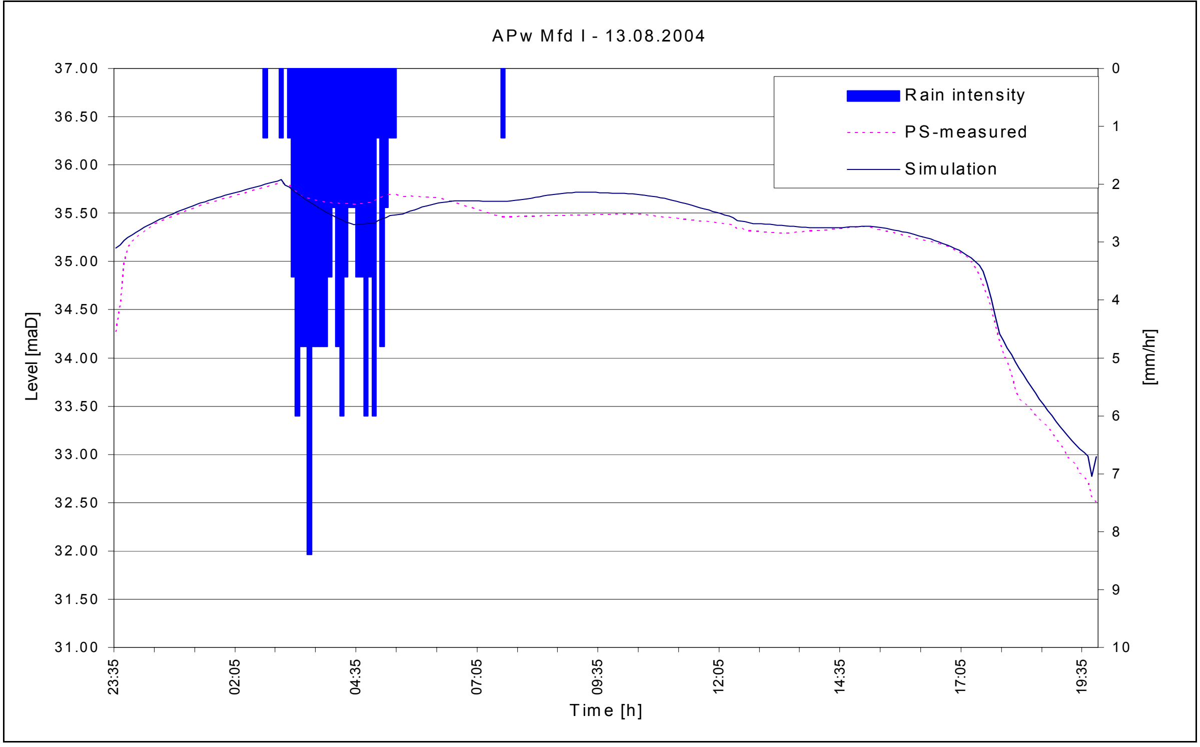
Storage characteristic of sewer network Marienfelde I

Calibration

Dry Weather: Flow at Pump station Mfd_I, 07.06.2000, adapted to data from 2004
min flow: 0.018 m³/s
max flow: 0.128 m³/s

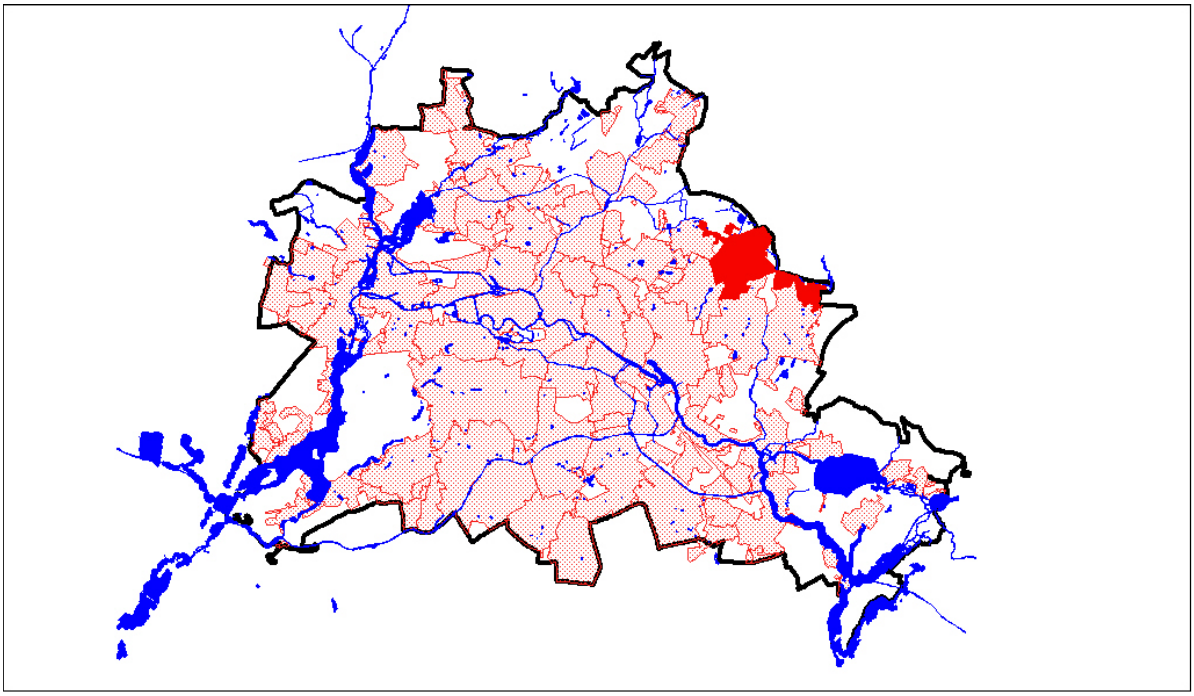


Storm Weather: Level at Pump station Mfd_I



3.4.34 HPw Marzahn I

Subcatchment:	Marzahn I	
Total Area:	1516 ha	
Population:	118123 Inh.	
WWTP:	dry weather:	Waßmannsdorf
	rain weather:	Waßmannsdorf

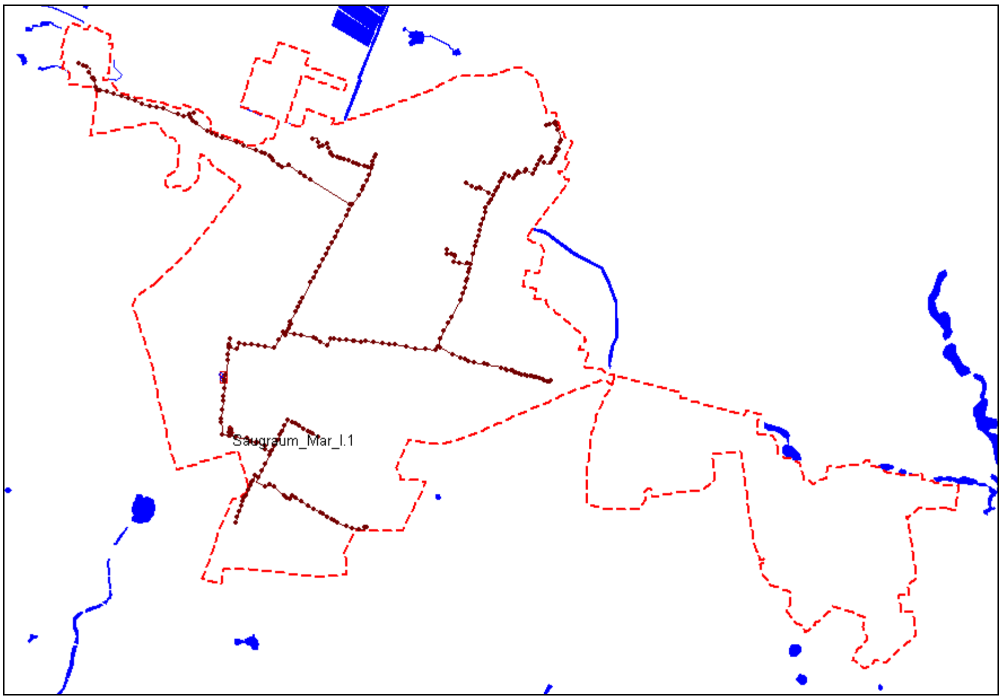


Location of subcatchment Marzahn I

Model characteristics Marzahn I

System type:	Separate
Length of modelled pipes	
Combined:	-
Waste water:	15592 km
Storm water:	-
Other:	-
Number of Nodes	319
Number of Pump Stations	1
Pump Station:	HPw Mar I, Wiesenburger Weg.
Node ID:	Saugraum_Mar_I
Average dry wheather flow:	157.80 l/s
Maximum Capacity	
local:	0.590 m^3/s
global:	0.750 m^3/s
Destination	
dry weather:	Waßmannsdorf
storm weather:	Waßmannsdorf

Number of emergency outlets: 2
- **Node ID:** 24084001
- **invert level [maD]:** 48.00
- **Node ID:** 24084002
- **invert level [maD]:** 48.00

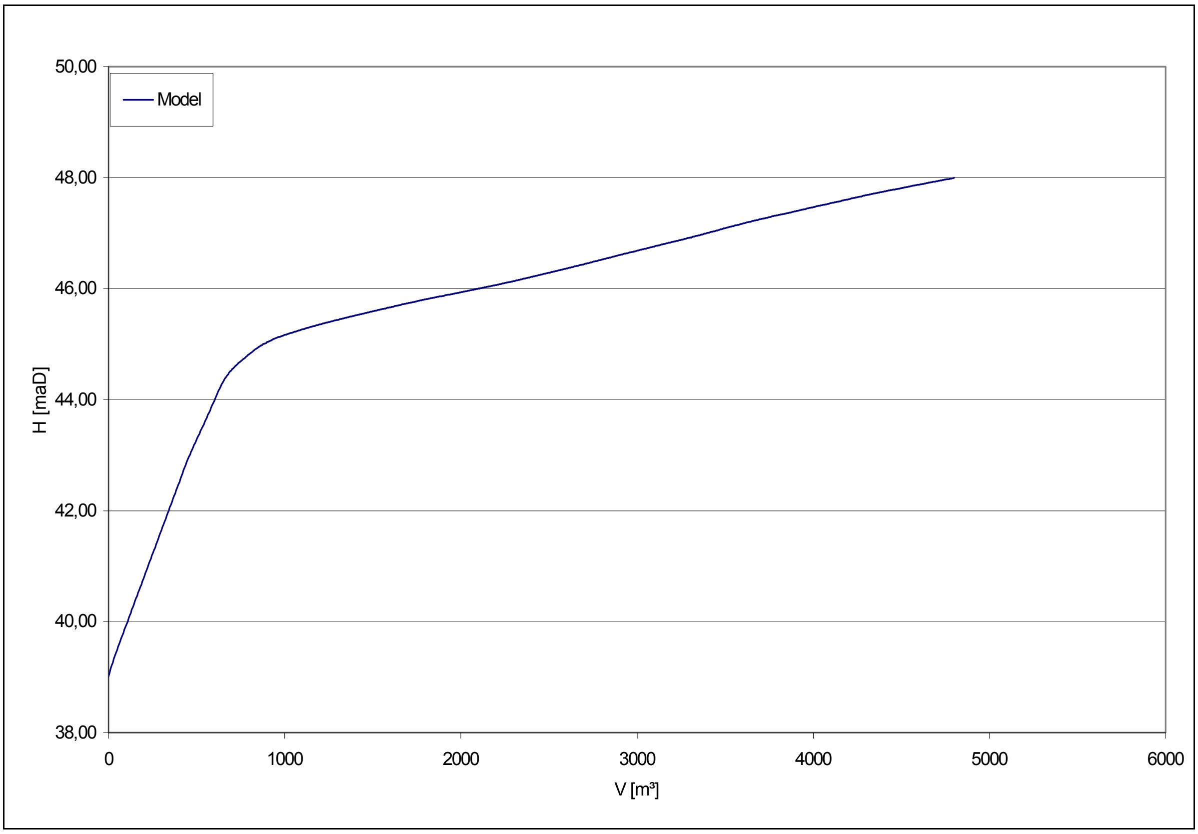


Network model of subcatchment Marzahn I

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	4800	-
storage level [maD]:	48.00	-
invert level of emergency outlet [maD]:	48.00	

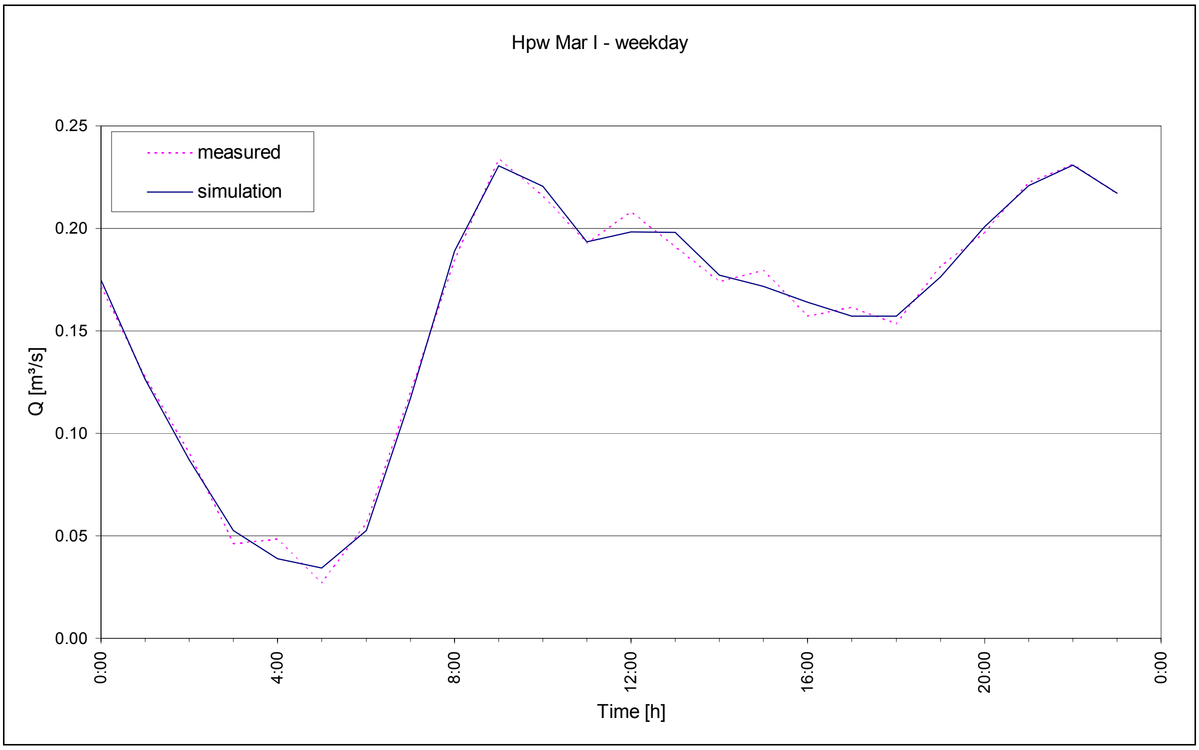
HPw Mar I



Storage characteristic of sewer network Marzahn I

Calibration

Dry Weather: Flow at Pump station Mar I, 30.06.2003, adapted to data from 2004
min flow: 0.034 m³/s
max flow: 0.231 m³/s



Storm Weather:

Due to a lack of data a storm weather calibration could not be carried out.

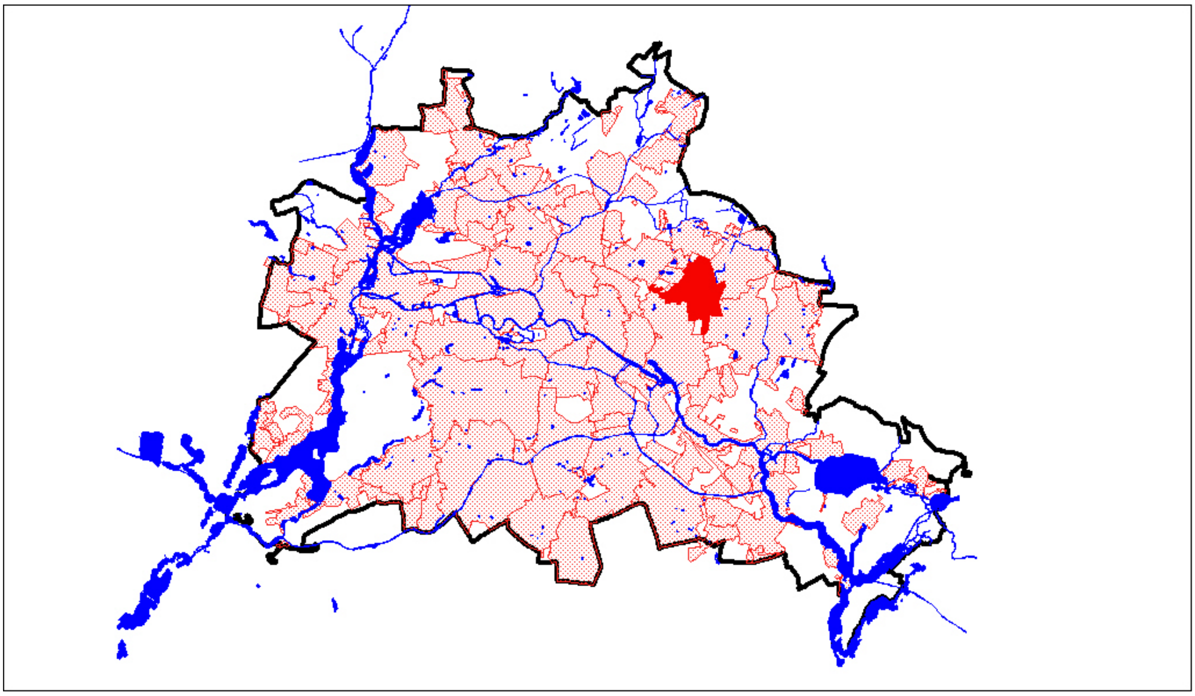
3.4.35 APw Marzahn II

Subcatchment: Marzahn II

Total Area: 920 ha

Population: 30811 Inh.

WWTP: dry weather: Waßmannsdorf
rain weather: Waßmannsdorf



Location of subcatchment Marzahn II

Model characteristics Marzahn II

System type: Separate

Length of modelled pipes

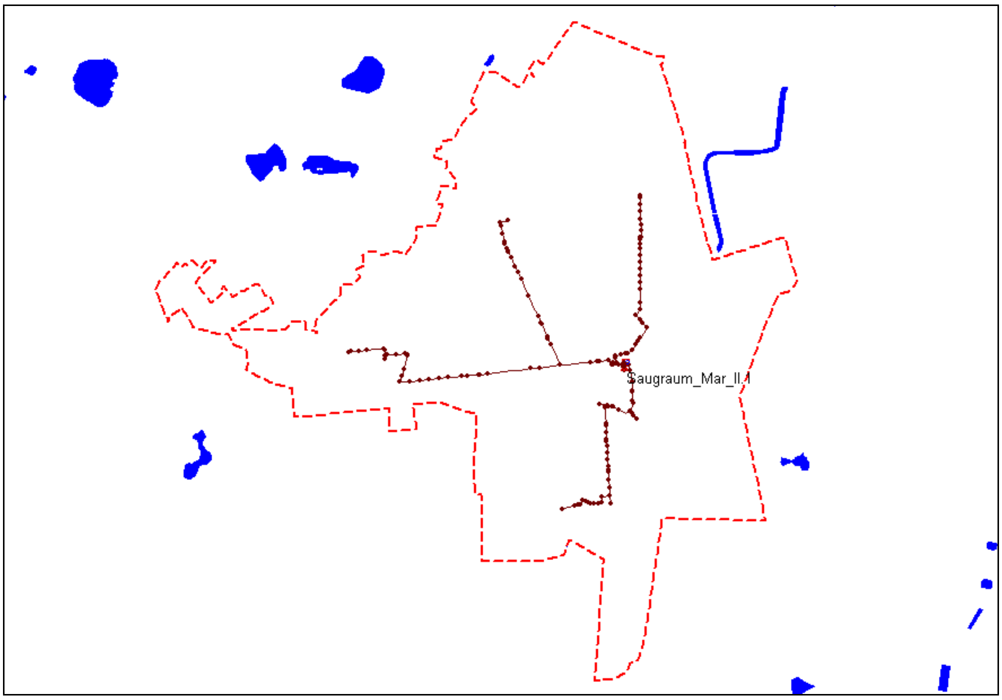
Combined: -
Waste water: 7052 km
Storm water: -
Other: -

Number of Nodes 144

Number of Pump Stations 1

Pump Station: APw Mar II, Landsberger Allee.
Node ID: Saugraum_Mar_II
Average dry wheather flow: 60.90 l/s
Maximum Capacity
local: 0.260 m^3/s
global: -
Destination
dry weather: Waßmannsdorf
storm weather: Waßmannsdorf

Number of emergency outlets:	1
Node ID:	21091002
invert level [maD]:	48.35

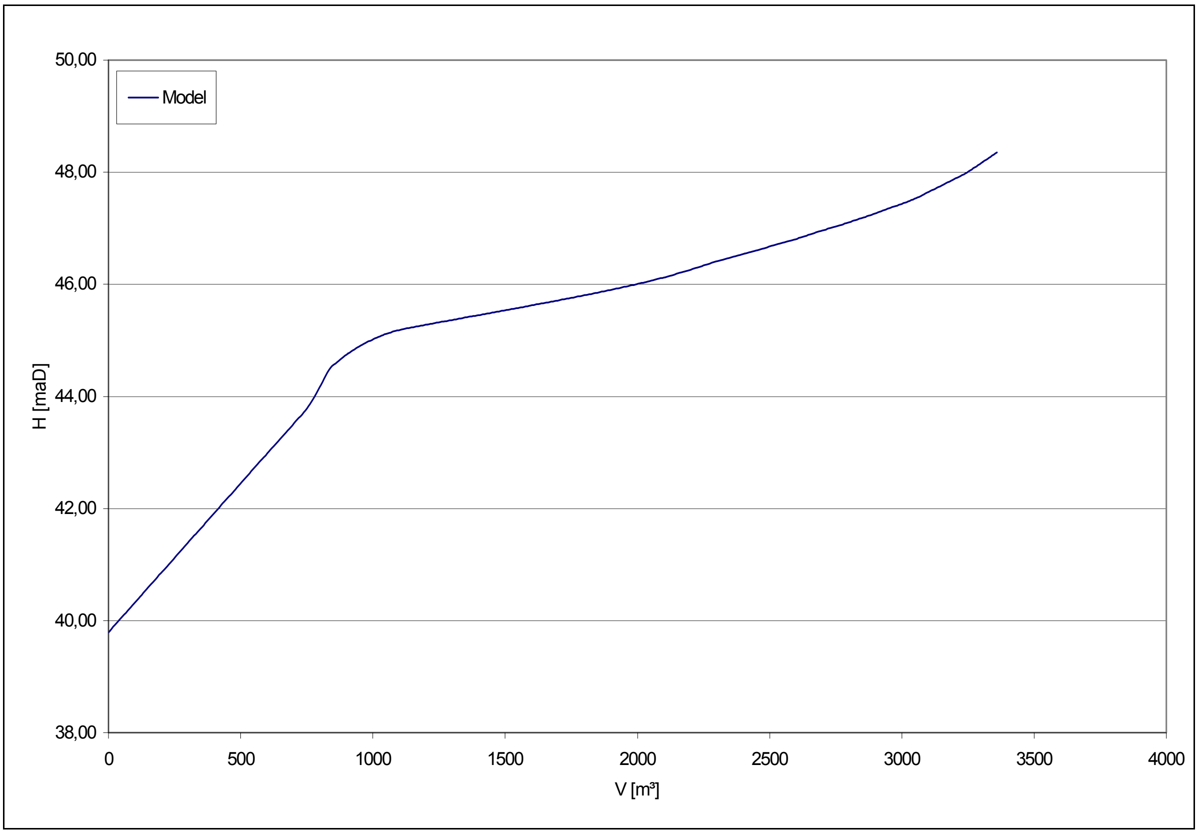


Network model of subcatchment Marzahn II

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	3360	-
storage level [maD]:	48.35	-
invert level of emergency outlet [maD]:	48.35	

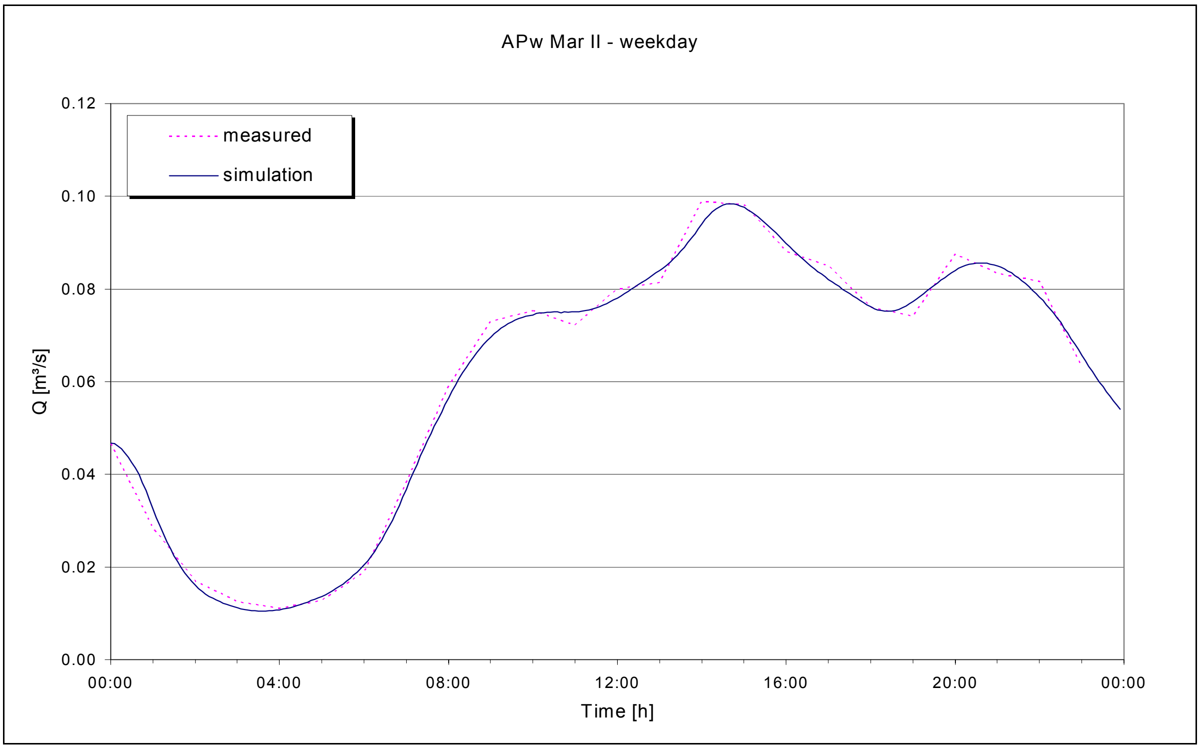
APw Mar II



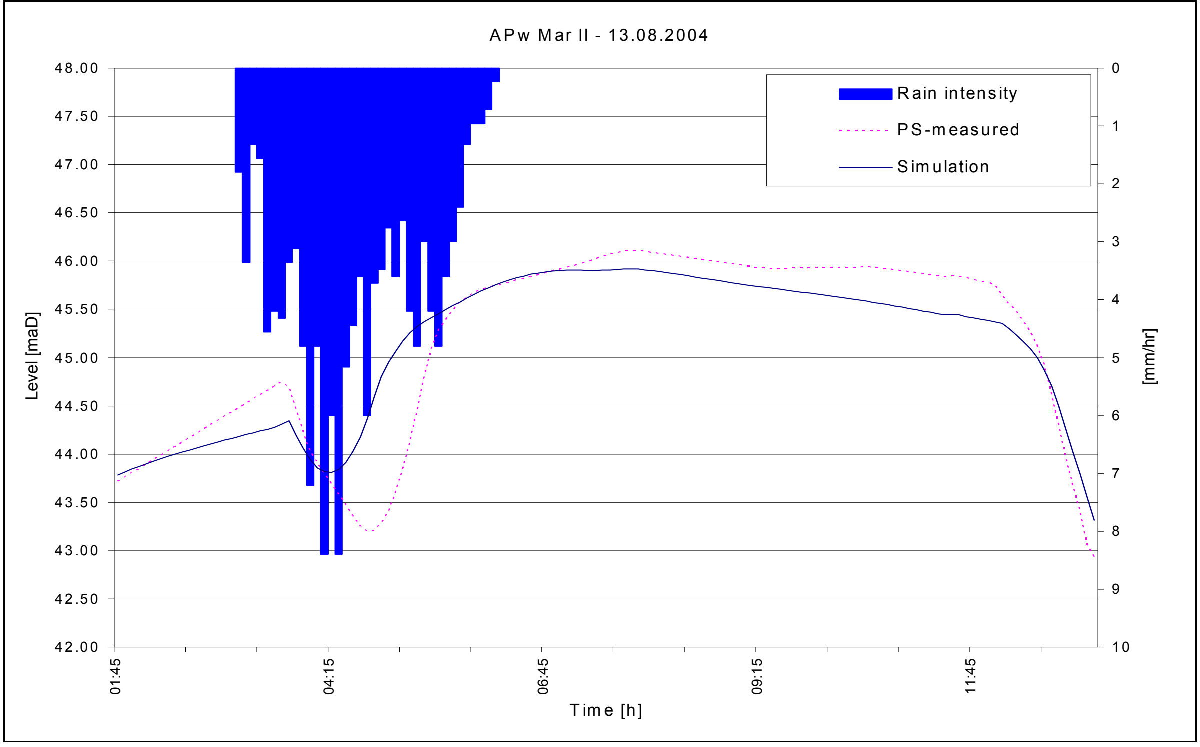
Storage characteristic of sewer network Marzahn II

Calibration

Dry Weather: Flow at Pump station Mar II, 18.11.2003, still up to date
min flow: 0.010 m³/s
max flow: 0.098 m³/s

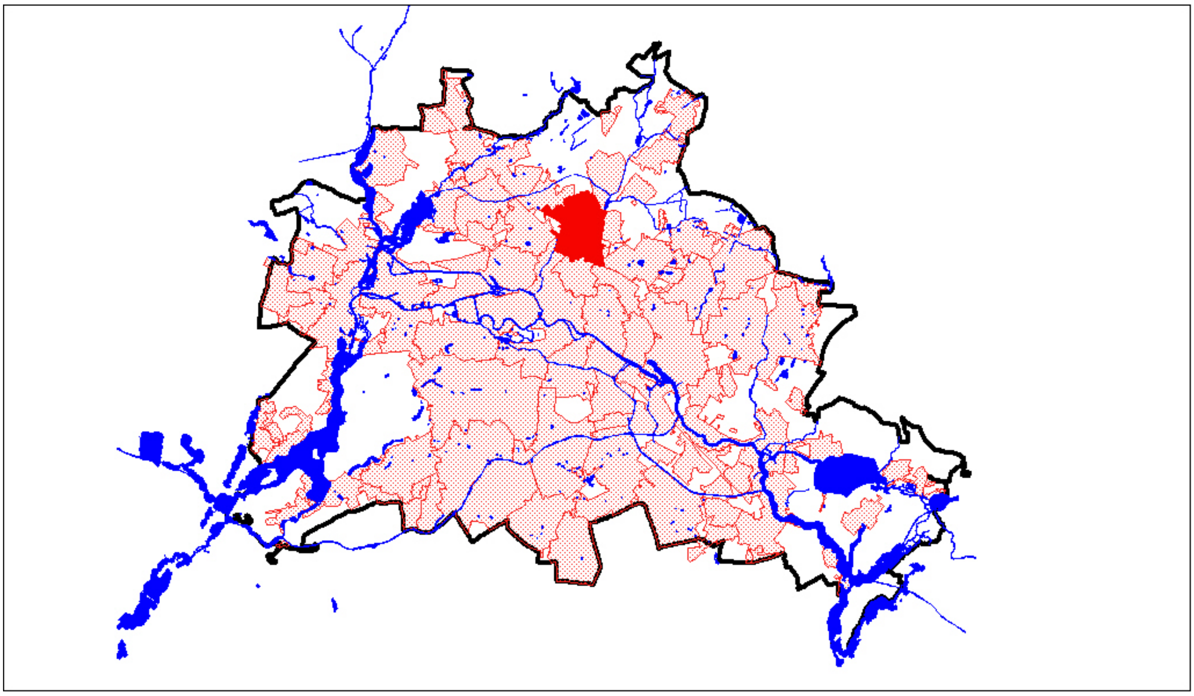


Storm Weather: Level at Pump station Mar II



3.4.36 APw Niederschönhausen

Subcatchment:	Niederschönhausen	
Total Area:	1131 ha	
Population:	81826 Inh	
WWTP:	dry weather:	Schönerlinde
	rain weather:	Schönerlinde

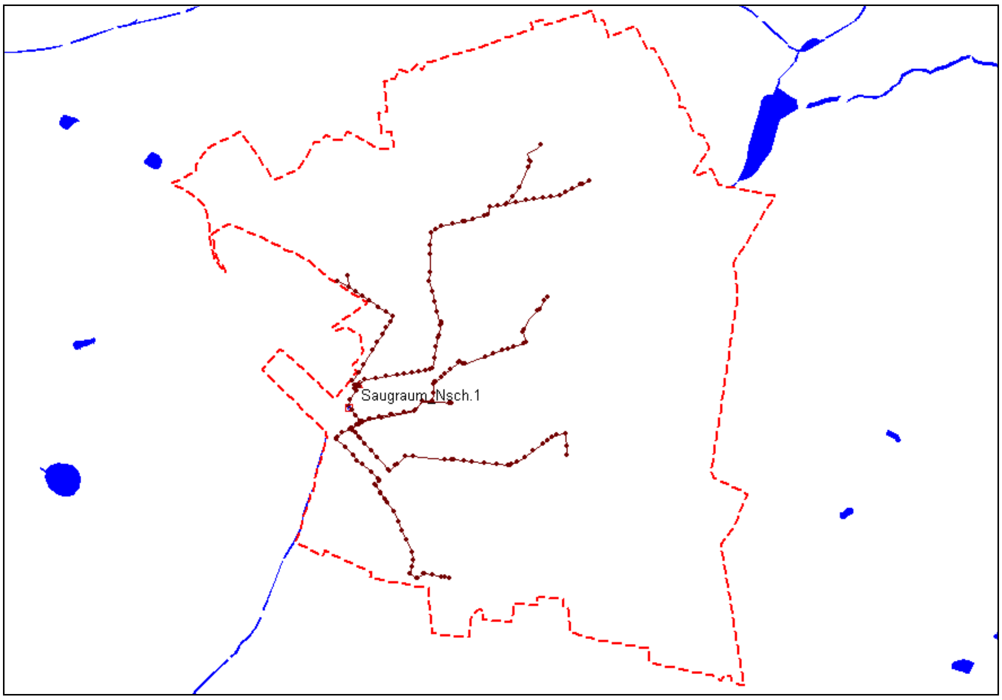


Location of subcatchment Niederschönhausen

Model characteristics Niederschönhausen

System type:	Separate
Length of modelled pipes	
Combined:	-
Waste water:	10.798 km
Storm water:	-
Other:	-
Number of Nodes	204
Number of Pump Stations	1
Pump Station:	APw Nsch, Leonhard-Franke-Str.
Node ID:	Saugraum_Nsch
Average dry wheather flow:	115.60 l/s
Maximum Capacity	
local:	0.400 m^3/s
global:	0.500 m^3/s
Destination	
dry weather:	Schönerlinde
storm weather:	Schönerlinde

Number of emergency outlets: 1
Node ID: 28205001
invert level [maD]: 38.63

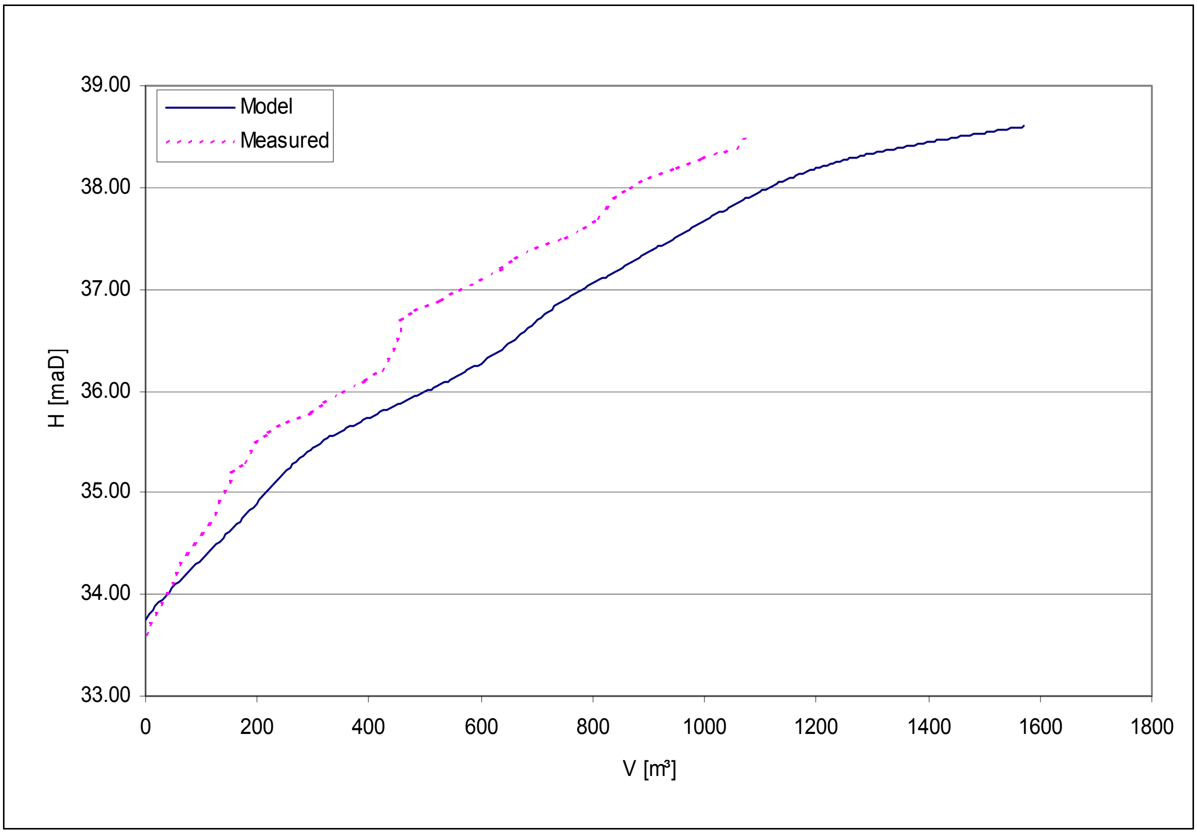


Network model of subcatchment Niederschönhausen

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	1572	1075
storage level [maD]:	38.50	38.50
invert level of emergency outlet [maD]:	38.63	

APw Nsch



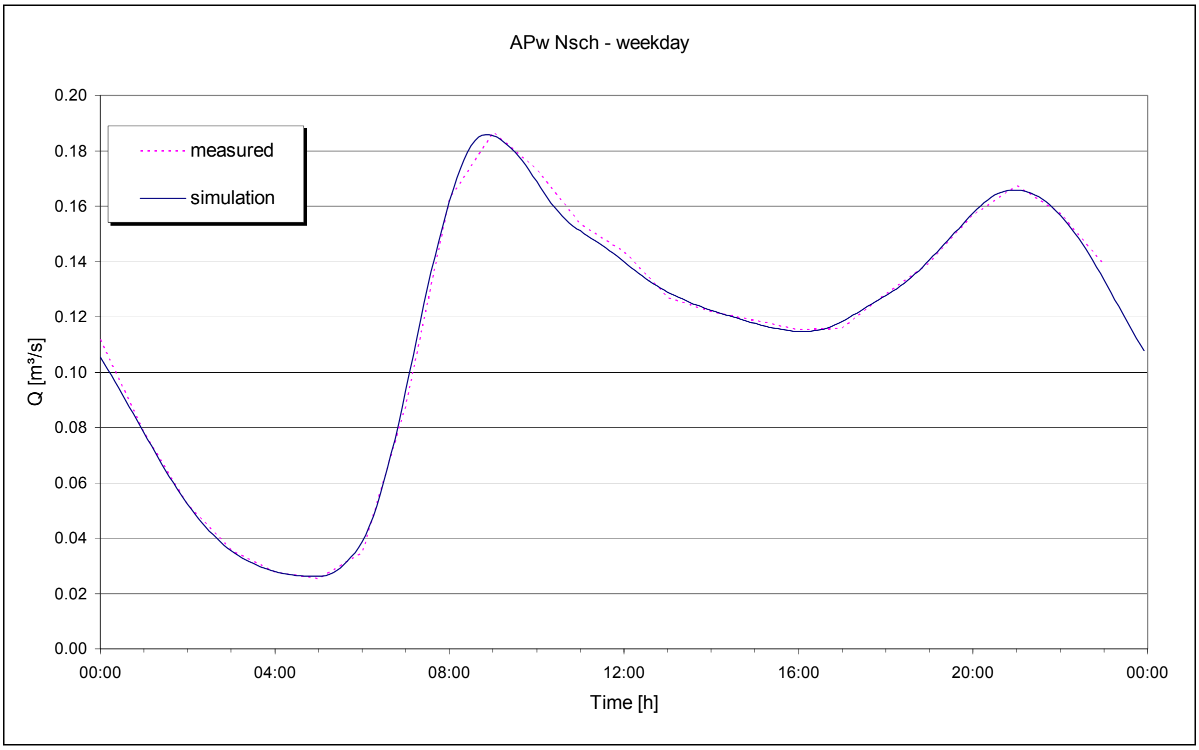
Storage characteristic of sewer network Niederschönhausen

Calibration

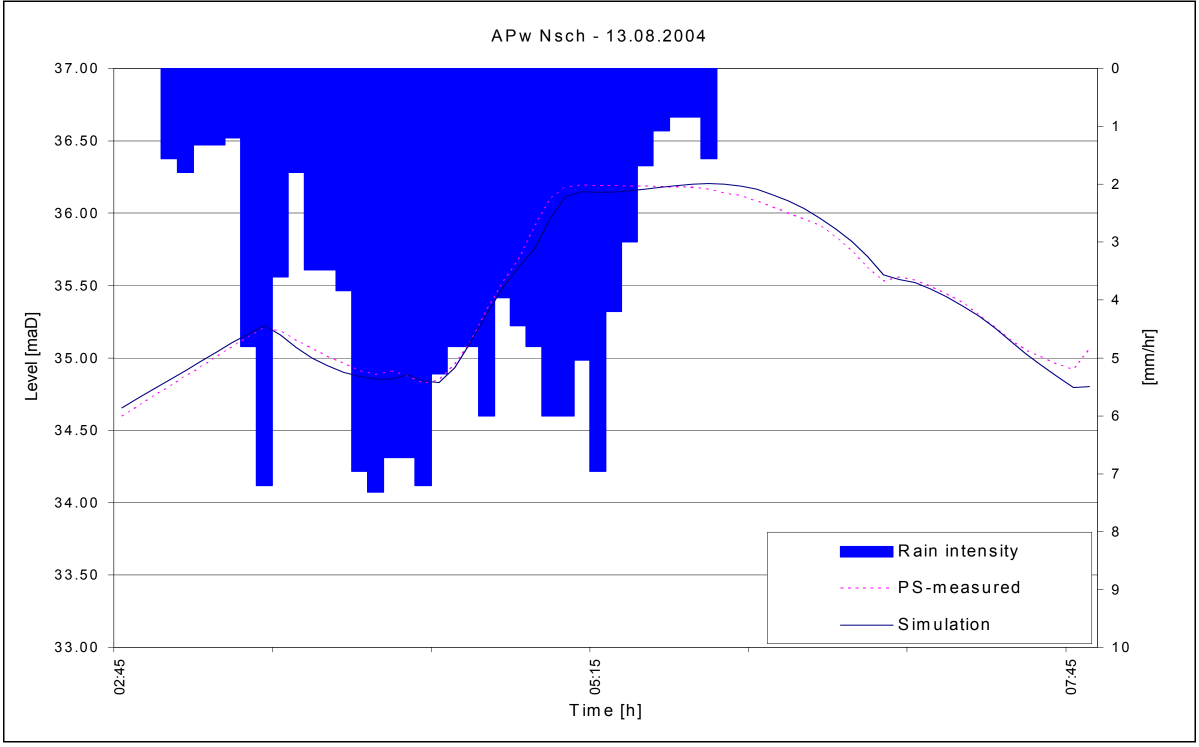
Dry Weather: Flow at Pump station Nsch, 23.06.1999, adapted to data from 2004

min flow: 0.026 m³/s

max flow: 0.186 m³/s



Storm Weather: Level at Pump station Nsch



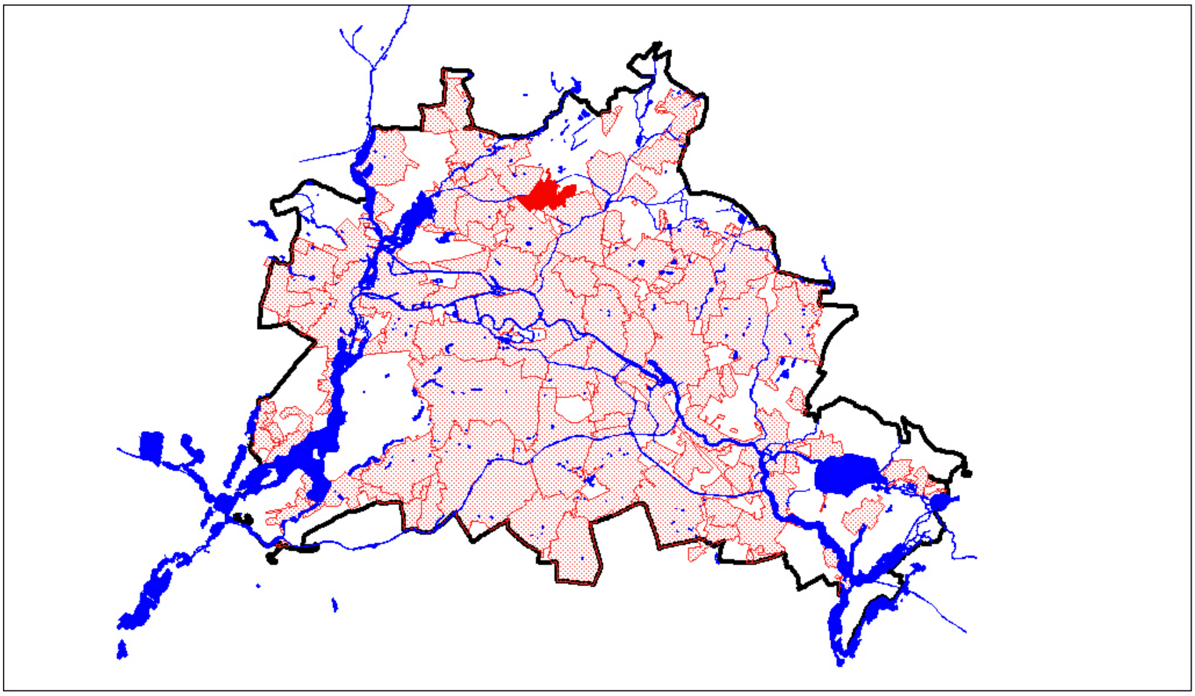
3.4.37 APw Rosenthal

Subcatchment: Rosenthal

Total Area: 401 ha

Population: 14584 Inh.

WWTP: dry weather: Schönerlinde
rain weather: Schönerlinde



Location of subcatchment Rosenthal

Model characteristics Rosenthal

System type: Separate

Length of modelled pipes

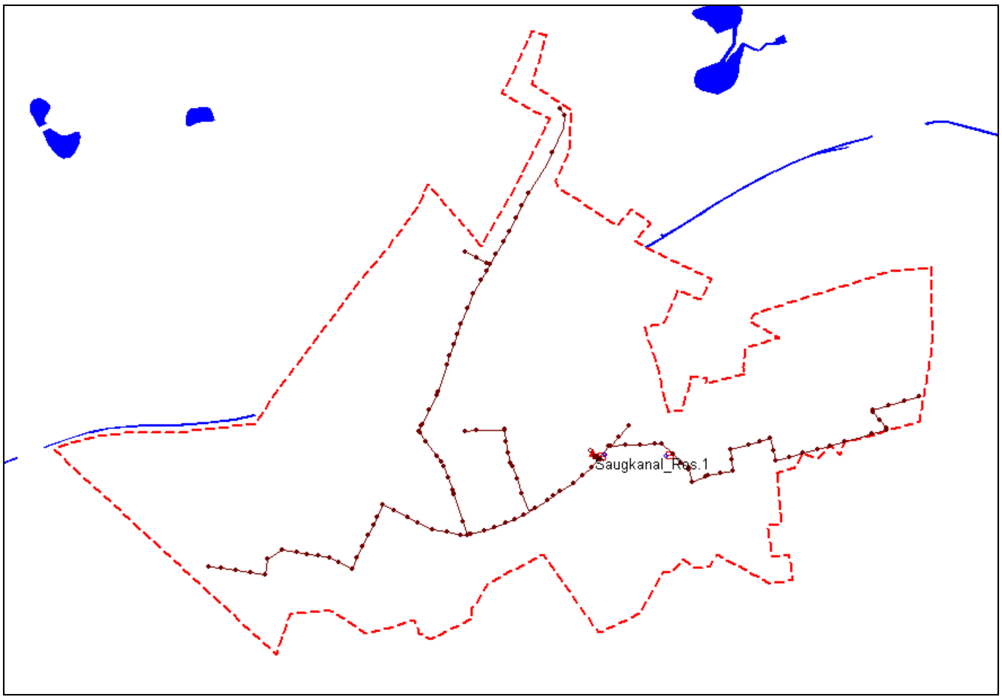
- **Combined:** -
- **Waste water:** 6.720 km
- **Storm water:** -
- **Other:** -

Number of Nodes 132

Number of Pump Stations 1

- **Pump Station:** APw Ros, Angerweg
- **Node ID:** Saugkanal_Ros
- **Average dry wheather flow:** 21.20 l/s
- **Maximum Capacity**
  - **local:** 0.110 m^3/s
  - **global:** 0.150 m^3/s
- **Destination**
  - **dry weather:** Schönerlinde
  - **storm weather:** Schönerlinde

Number of emergency outlets:	2
Node ID:	32215002
invert level [maD]:	42.73
Node ID:	32216006
invert level [maD]:	42.73

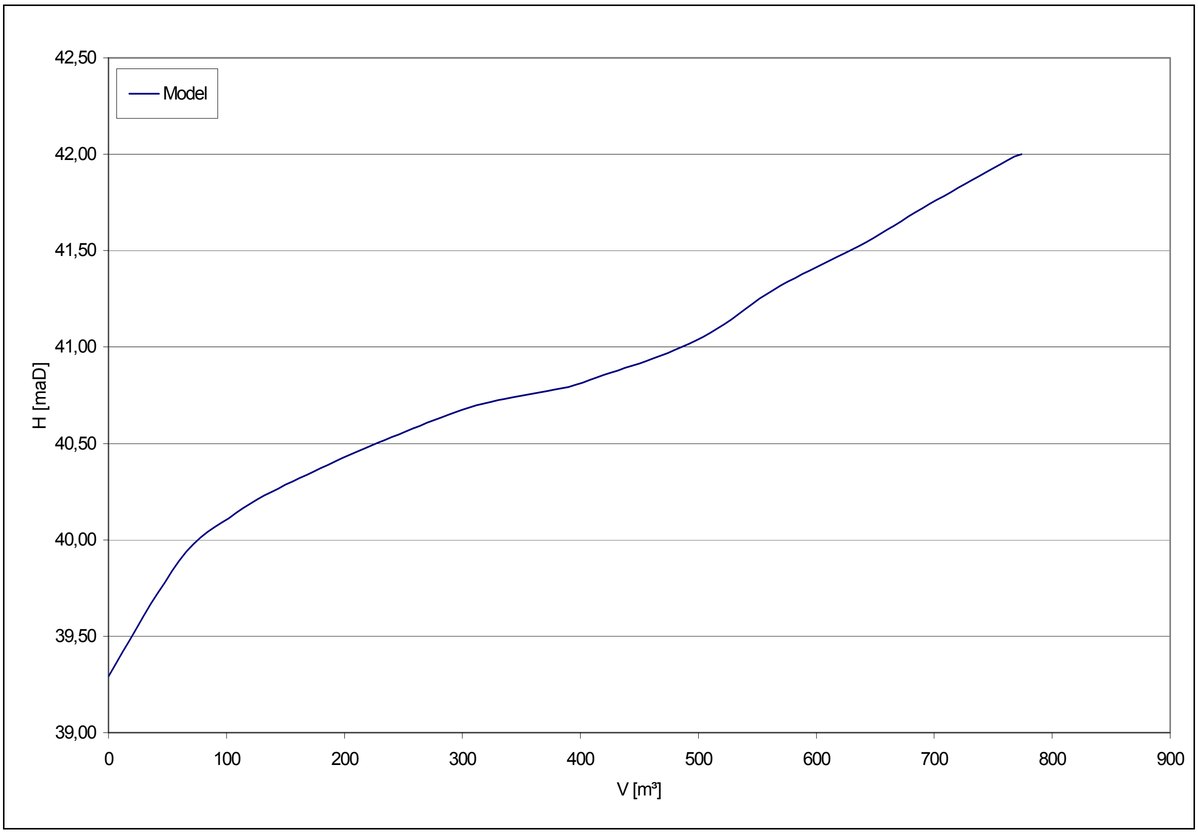


Network model of subcatchment Rosenthal

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	774	-
storage level [maD]:	42.00	-
invert level of emergency outlet [maD]:	42.73	

APw Ros



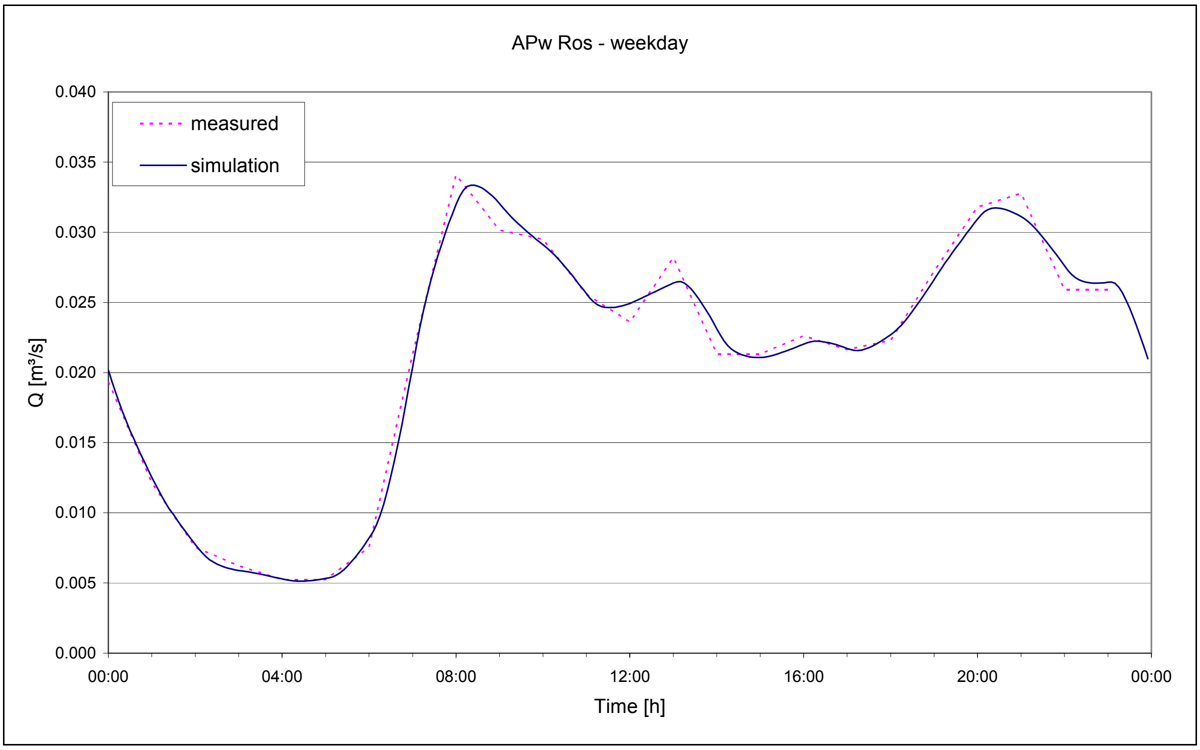
Storage characteristic of sewer network Rosenthal

Calibration

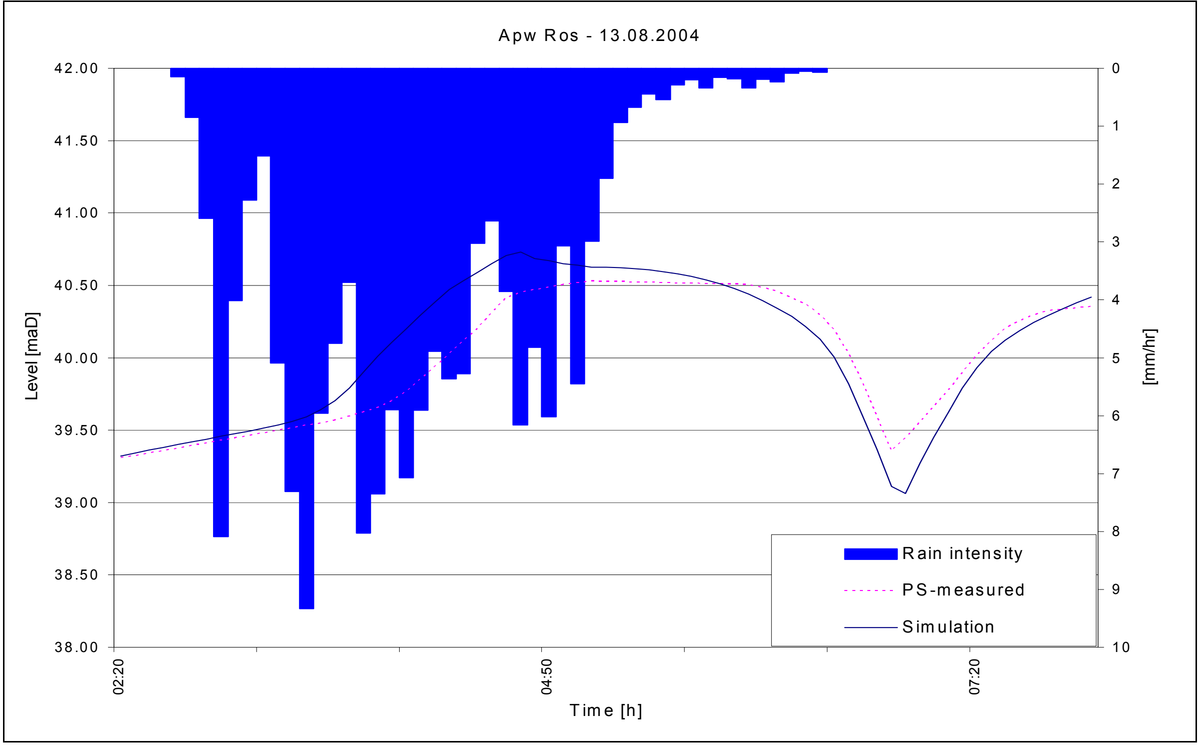
Dry Weather: Flow at Pump station Ros, 23.09.1998, adapted to data from 2004

min flow: 0.005 m³/s

max flow: 0.033 m³/s

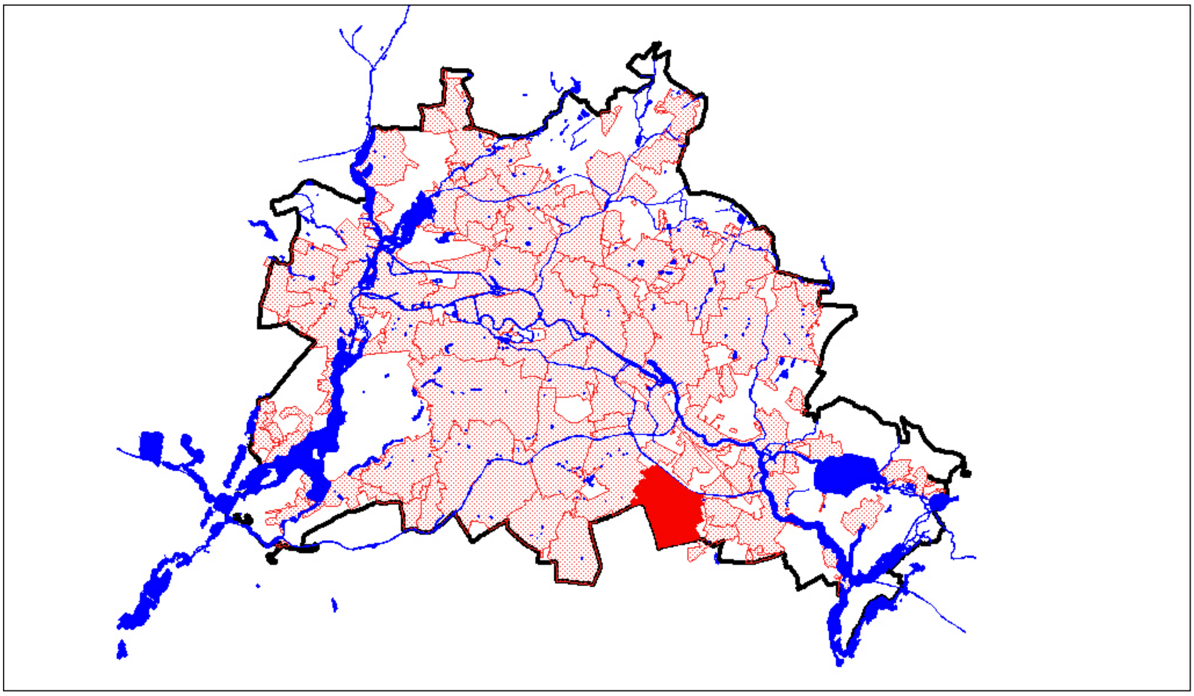


Storm Weather: Level at Pump station Ros



3.4.38 APw Rudow

Subcatchment:	Rudow	
Total Area:	1345 ha	
Population:	68784 Inh.	
WWTP:	dry weather:	Waßmannsdorf
	rain weather:	Waßmannsdorf

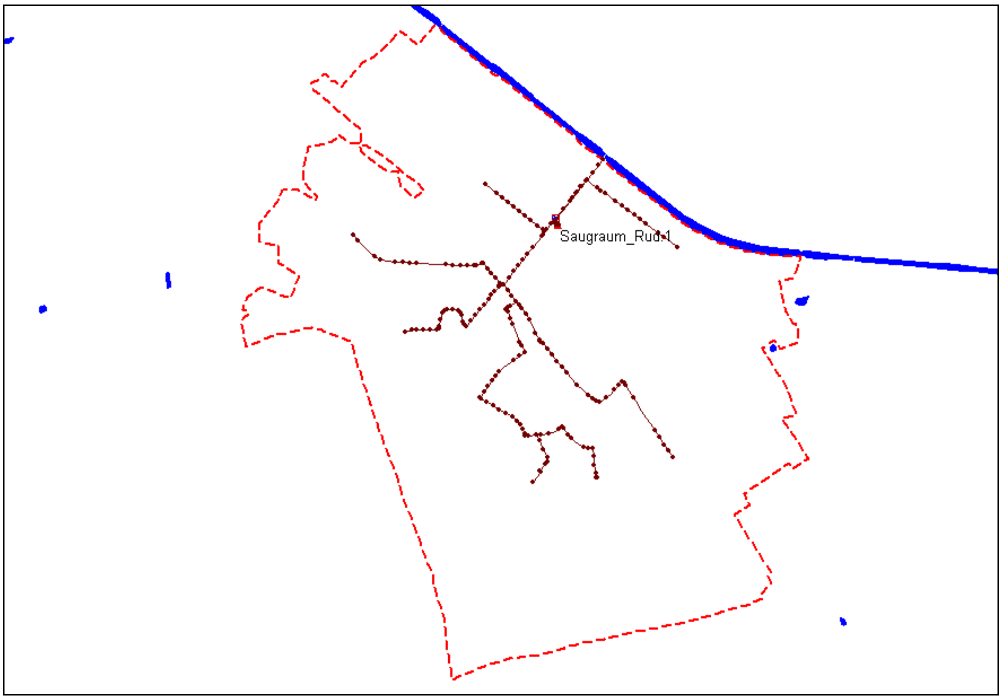


Location of subcatchment Rudow

Model characteristics Rudow

System type:	Separate
Length of modelled pipes	
Combined:	-
Waste water:	10.679 km
Storm water:	-
Other:	-
Number of Nodes	194
Number of Pump Stations	1
Pump Station:	APw Rud, Stubenrauchstr.
Node ID:	Saugraum Rud
Average dry wheather flow:	104.50 l/s
Maximum Capacity	
local:	0.300 m^3/s
global:	-
Destination	
dry weather:	Waßmannsdorf
storm weather:	Waßmannsdorf

Number of emergency outlets:	1
Node ID:	02126005
invert level [maD]:	32.90

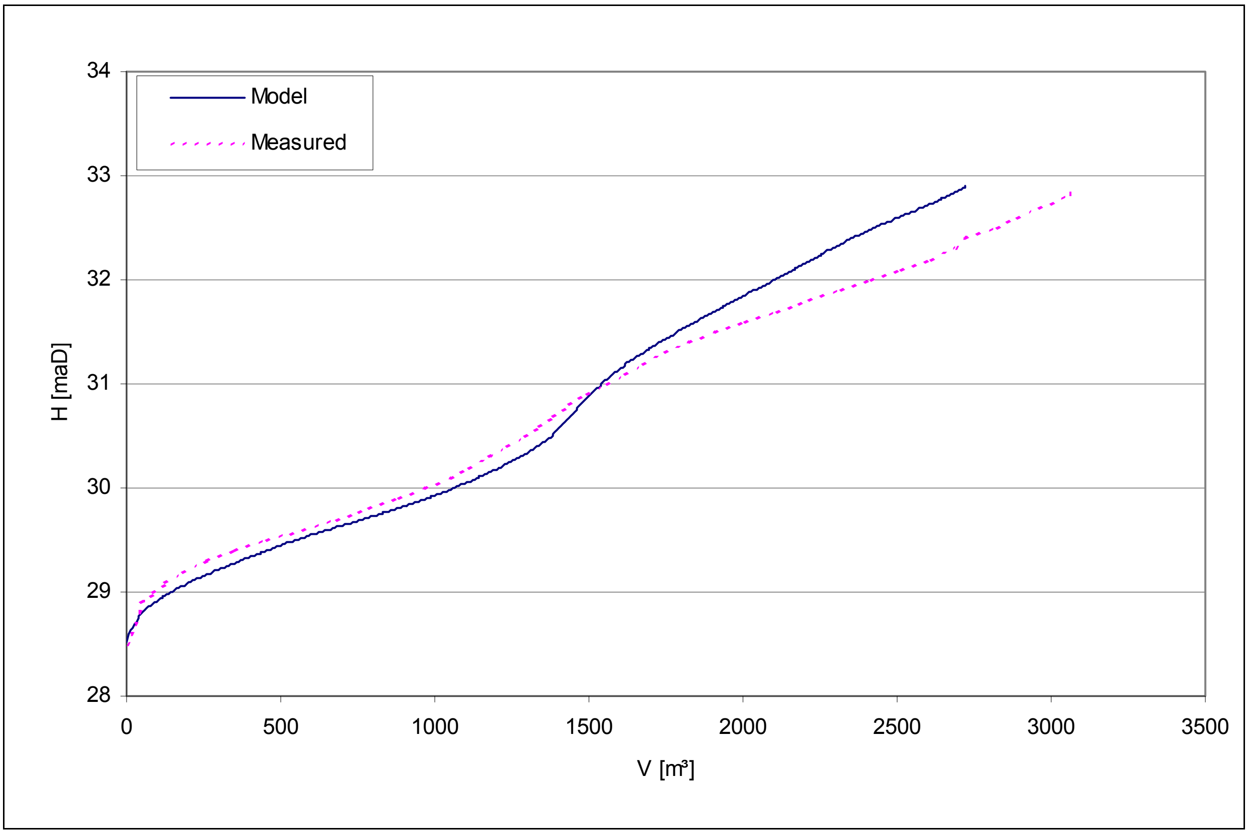


Network model of subcatchment Rudow

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	2724	3060
storage level [maD]:	32.90	32.90
invert level of emergency outlet [maD]:	32.90	

APw Rud

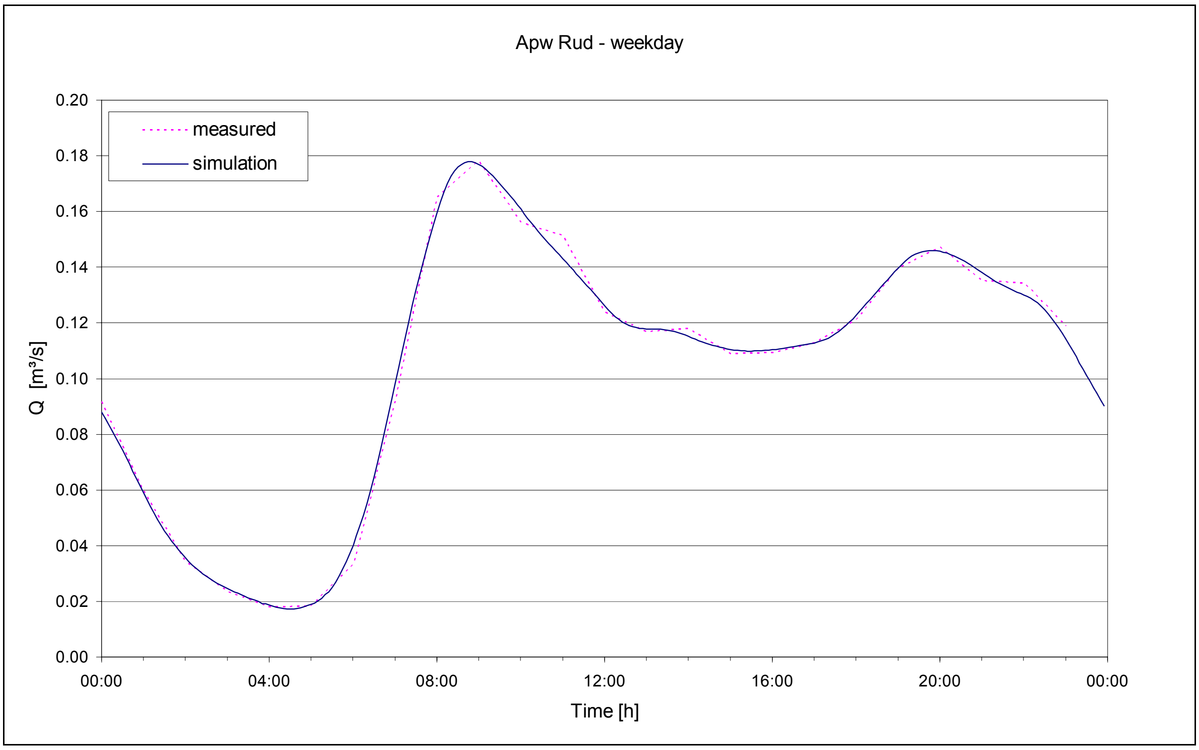


Storage characteristic of sewer network Rudow

Calibration

Dry Weather: Flow at Pump station Rud, 07.06.2000

min flow:	0.017 m³/s
max flow:	0.178 m³/s

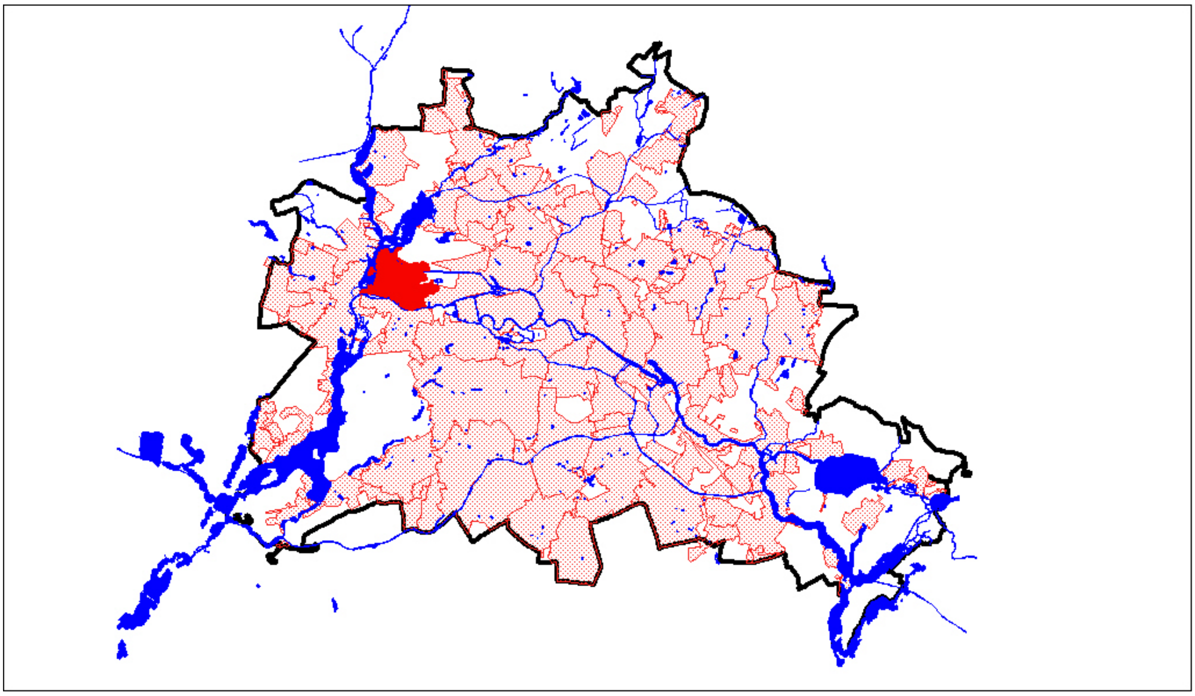


Storm Weather:

Due to the high variation in dry weather flow and a lack of data a storm weather calibration could not be carried out.

3.4.39 APw Spandau II

Subcatchment:	Spandau II	
Total Area:	680 ha	
Population:	25402 Inh.	
WWTP:	dry weather:	Ruhleben
	rain weather:	Ruhleben

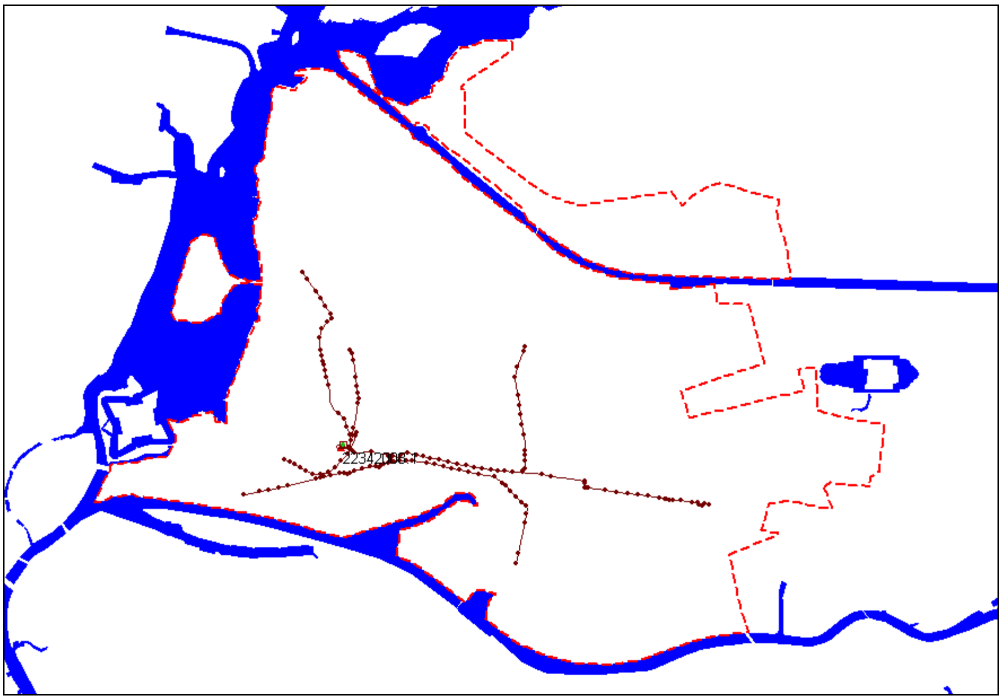


Location of subcatchment Spandau II

Model characteristics Spandau II

System type:		Separate
Length of modelled pipes		
Combined:		-
Waste water:		8.027 km
Storm water:		-
Other:		-
Number of Nodes		170
Number of Pump Stations		1
Pump Station:		APw Spa II, Daumstr.
Node ID:		Saugraum_Spa_II
Average dry wheather flow:		73.40 l/s
Maximum Capacity		
	local:	0.250 m^3/s
	global:	0.250 m^3/s
Destination		
	dry weather:	Ruhleben
	storm weather:	Ruhleben

Number of emergency outlets:	1
Node ID:	Saugraum_Spa_II
invert level [maD]:	29.82

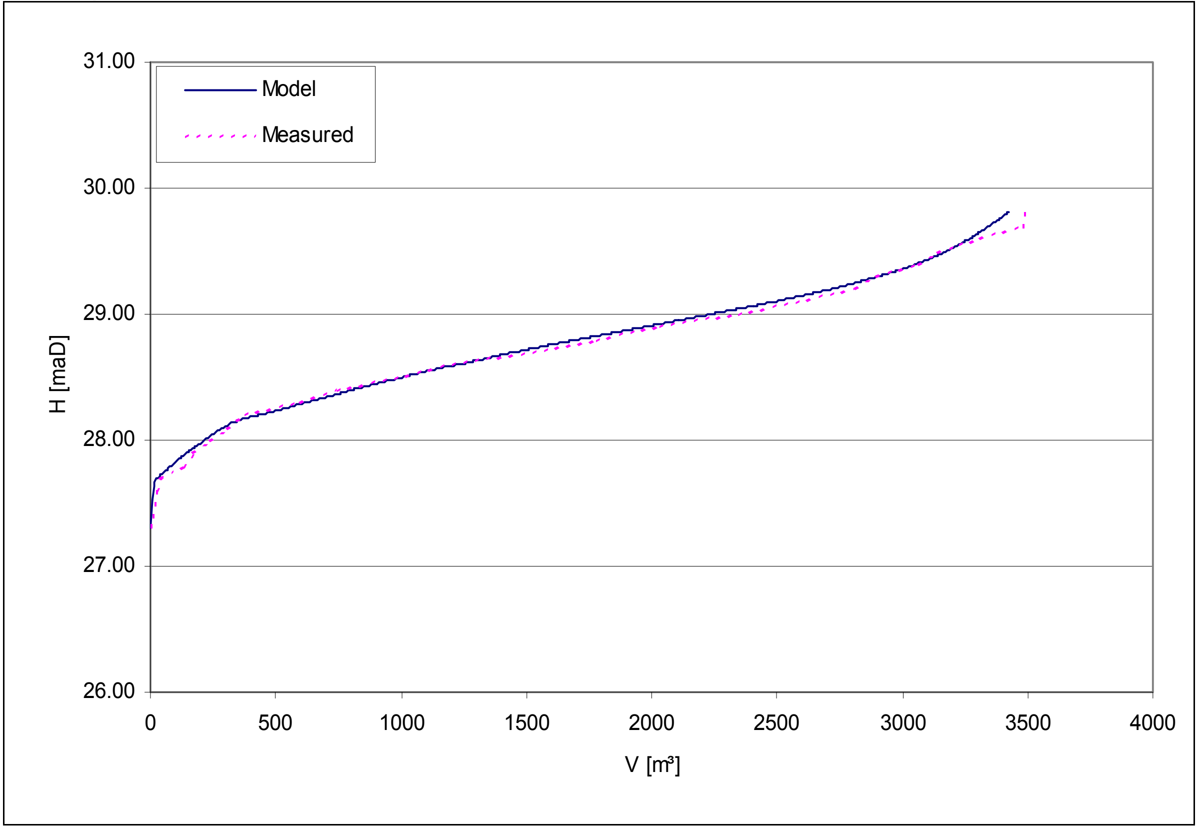


Network model of subcatchment Spandau II

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	3426	3488
storage level [maD]:	29.82	29.82
invert level of emergency outlet [maD]:	29.82	

APw Spa II



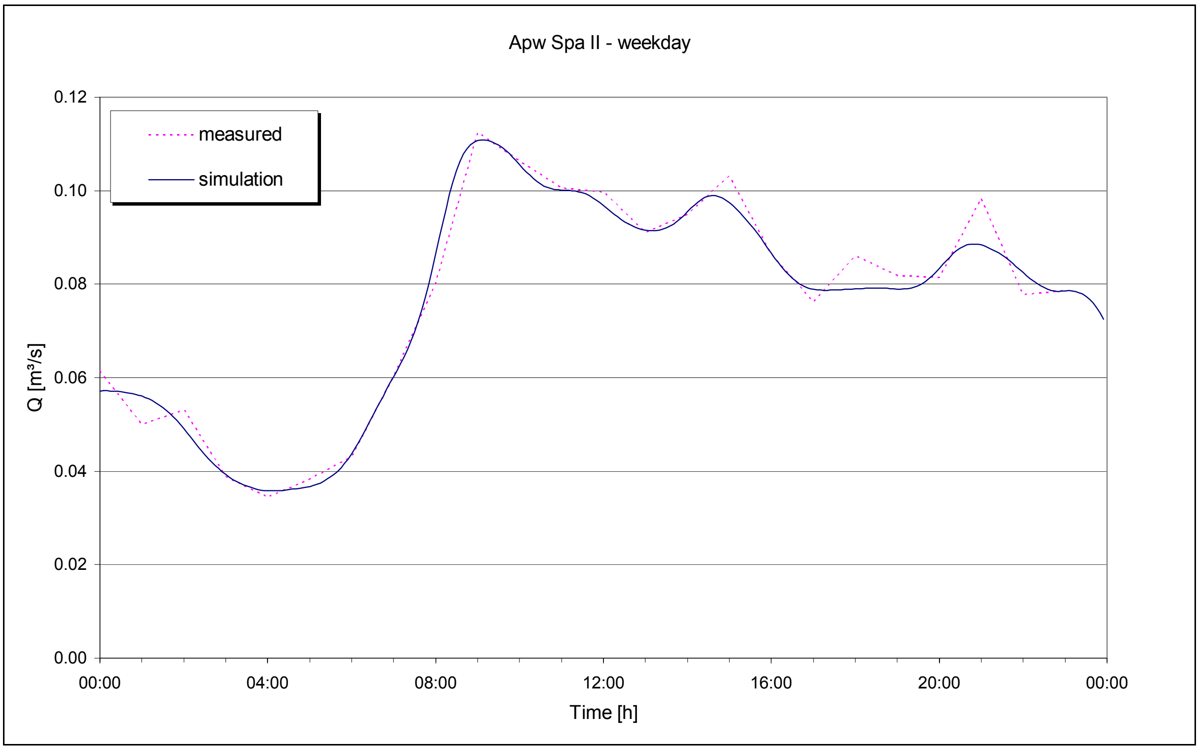
Storage characteristic of sewer network Spandau II

Calibration

Dry Weather: Flow at Pump station Spa II, 10.09.2002, adapted to data from 2004

min flow: 0.036 m³/s

max flow: 0.111 m³/s



Storm Weather:

Due to a lack of data a storm weather calibration could not be carried out.

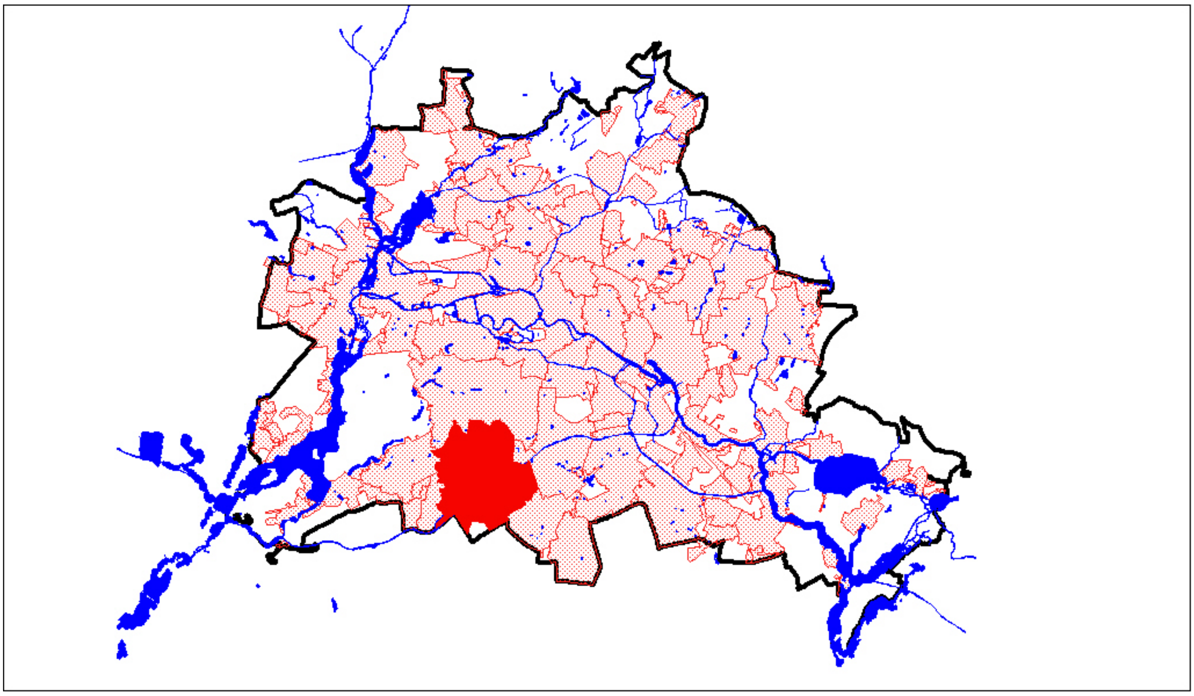
3.4.40 HPw Steglitz

Subcatchment: Steglitz

Total Area: 3000 ha

Population: 179264 Inh.

WWTP: dry weather: Stahnsdorf/Waßmannsdorf
rain weather: Stahnsdorf/Waßmannsdorf

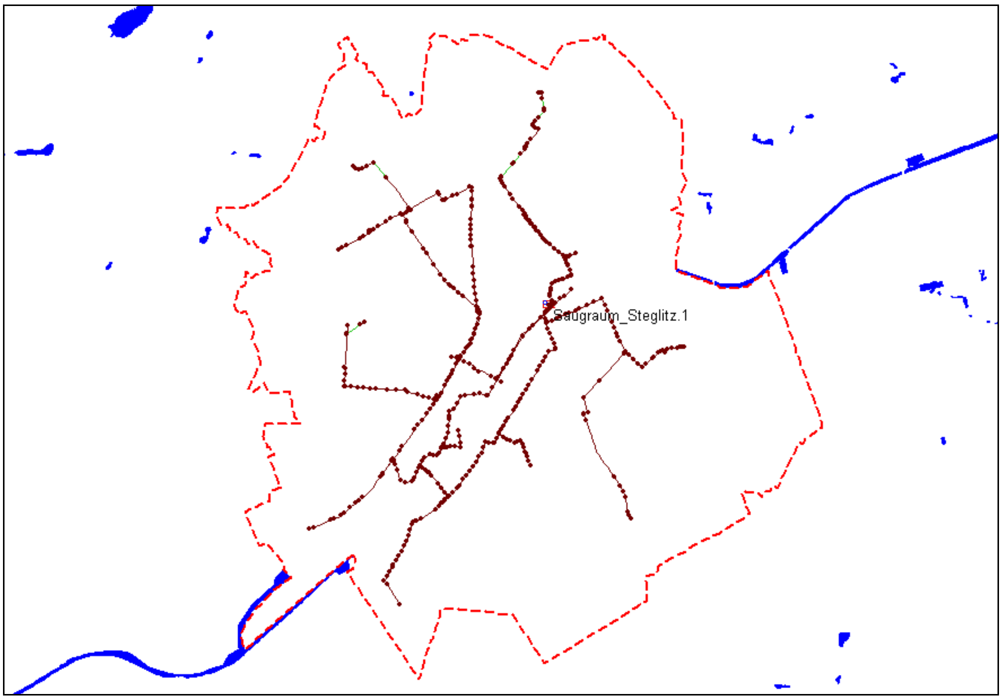


Location of subcatchment Steglitz

Model characteristics Steglitz

System type:	Separate
Length of modelled pipes	
Combined:	-
Waste water:	29.353 km
Storm water:	-
Other:	-
Number of Nodes	489
Number of Pump Stations	1
Pump Station:	HPw Stg, Siemensstr.
Node ID:	Saugraum_Steglitz
Average dry wheather flow:	308.50 l/s
Maximum Capacity	
local:	0.650 m^3/s
global:	-
Destination	
dry weather:	Stahnsdorf/Waßmannsdorf
storm weather:	Stahnsdorf/Waßmannsdorf

Number of emergency outlets:	1
Node ID:	04264004
invert level [maD]:	32.91

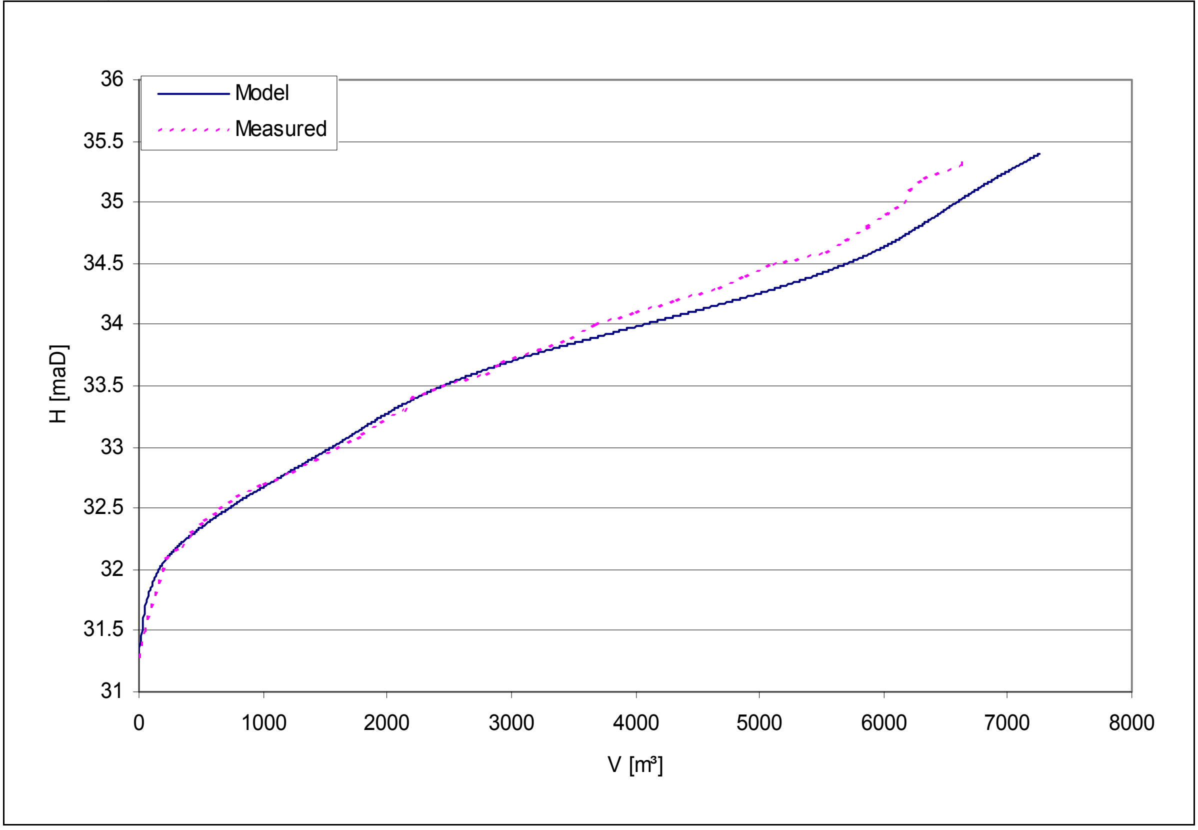


Network model of subcatchment Steglitz

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	7260	6627
storage level [maD]:	35.40	35.40
invert level of emergency outlet [maD]:	32.91	

HPw Stg

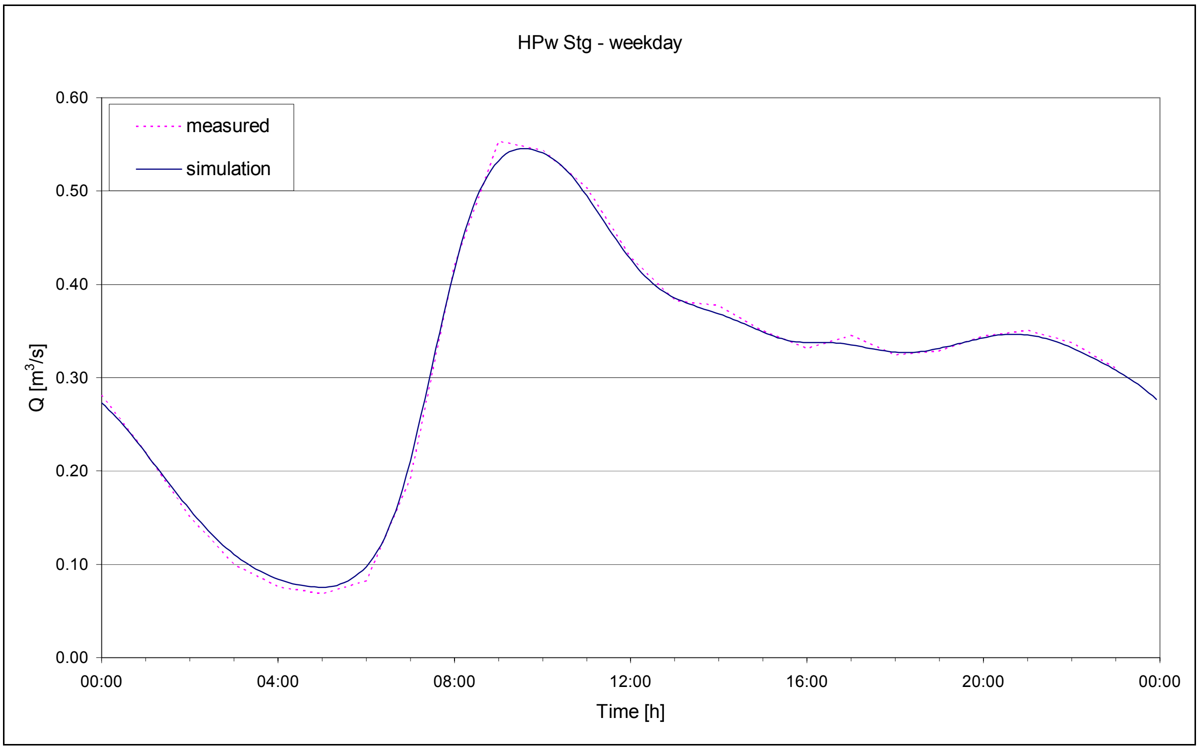


Storage characteristic of sewer network Steglitz

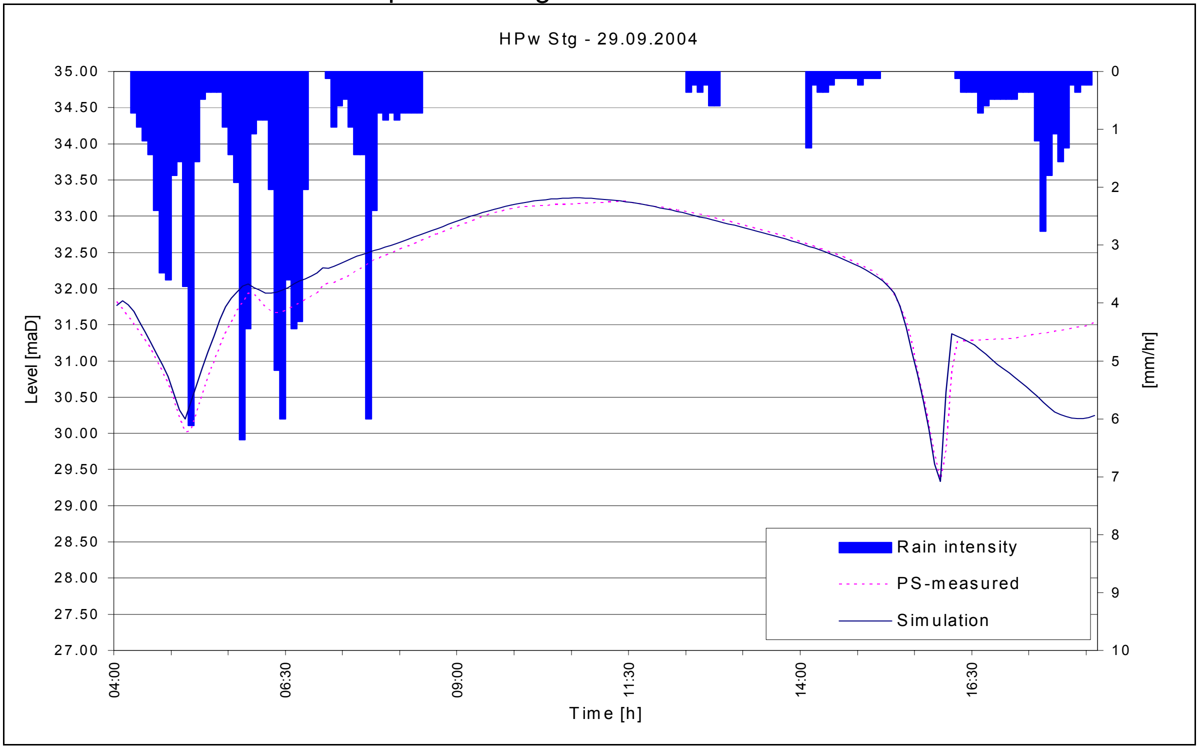
Calibration

Dry Weather: Flow at Pump station Stg, 31.05.2000, adapted to data from 2004

min flow:	0.075 m³/s
max flow:	0.546 m³/s

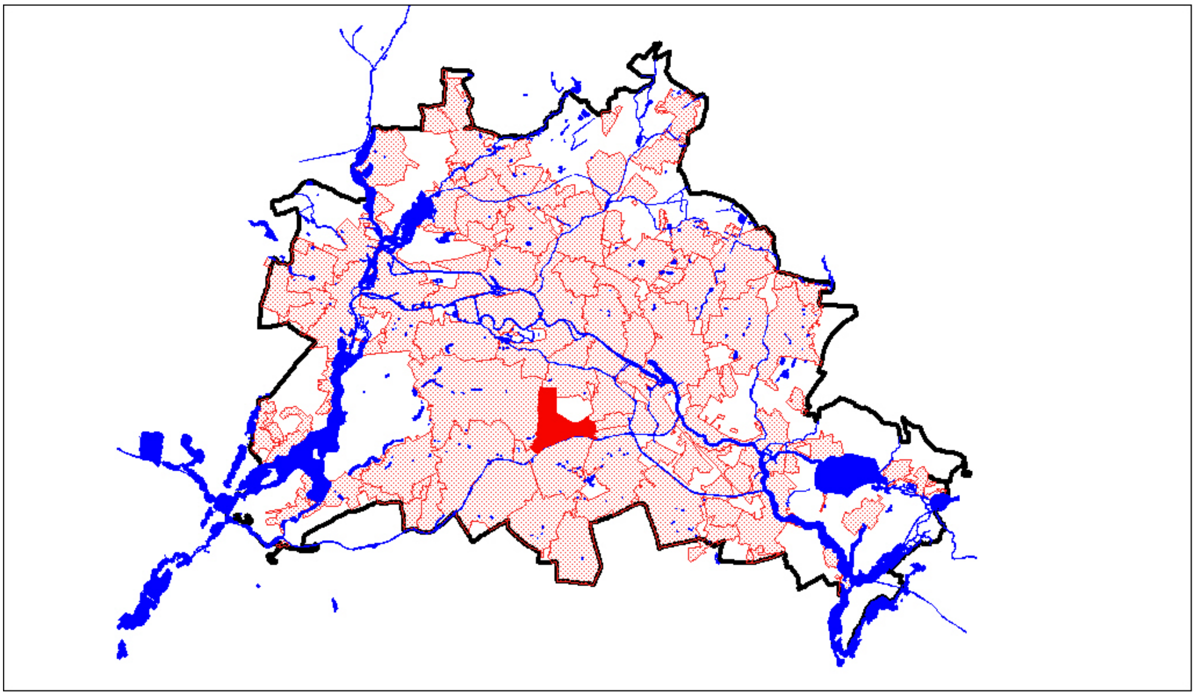


Storm Weather: Level at Pump station Stg



3.4.41 APw Tempelhof

Subcatchment:	Tempelhof	
Total Area:	688 ha	
Population:	52179 Inh.	
WWTP:	dry weather:	Waßmannsdorf
	rain weather:	Waßmannsdorf

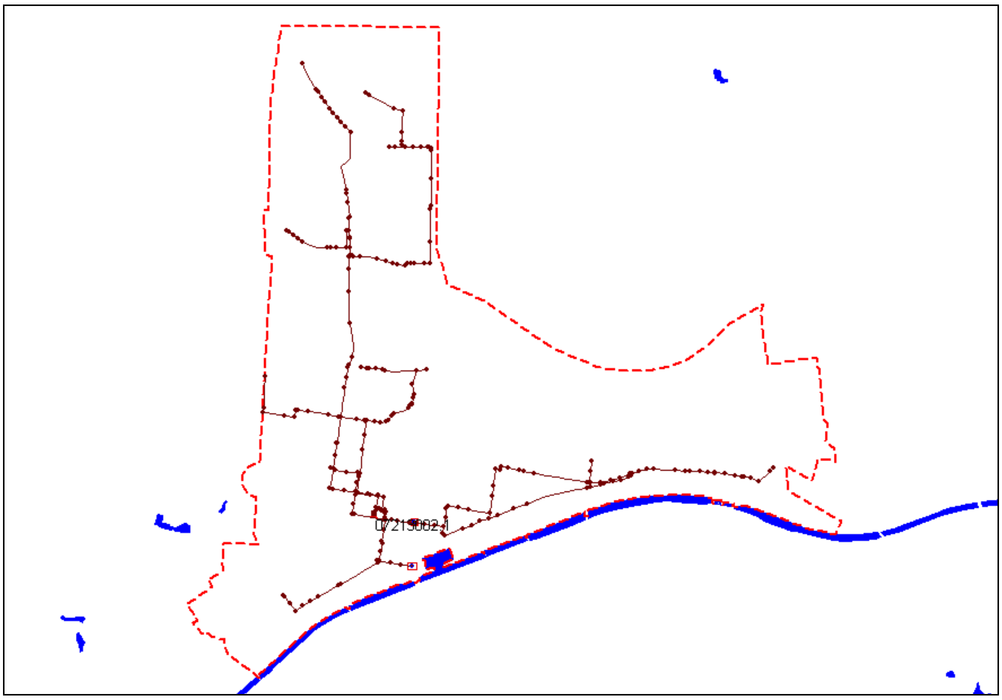


Location of subcatchment Tempelhof

Model characteristics Tempelhof

System type:	Separate
Length of modelled pipes	
Combined:	-
Waste water:	14.933 km
Storm water:	-
Other:	-
Number of Nodes	250
Number of Pump Stations	1
Pump Station:	APw Thf, Burgemeisterstr.
Node ID:	Saugraum_Thf
Average dry wheather flow:	92.50 l/s
Maximum Capacity	
local:	0.210 m^3/s
global:	-
Destination	
dry weather:	Waßmannsdorf
storm weather:	Waßmannsdorf

Number of emergency outlets:	2
Node ID:	06211003
invert level [maD]:	37.76
Node ID:	07213134
invert level [maD]:	38.76

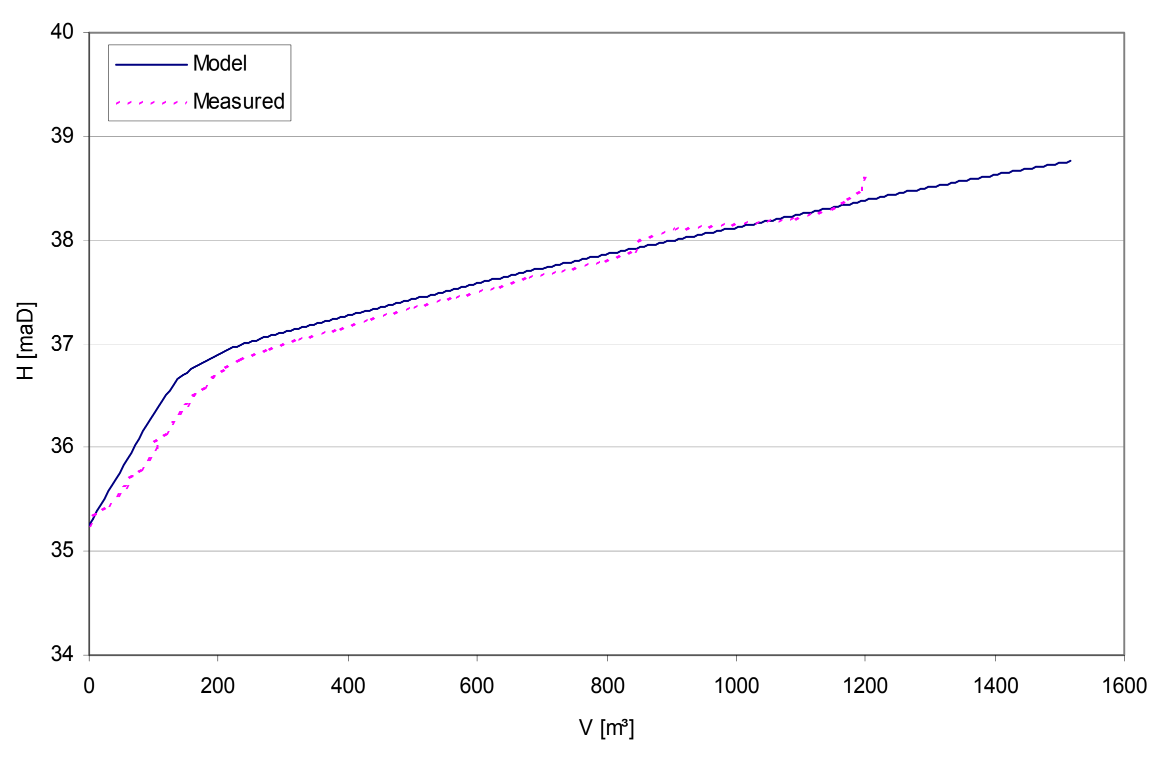


Network model of subcatchment Tempelhof

Storage characteristic of sewer network

	Model	Measured
maximum Volume [m³]:	1518	1205
storage level [maD]:	38.76	38.65
invert level of emergency outlet [maD]:	37.76	

APw Thf



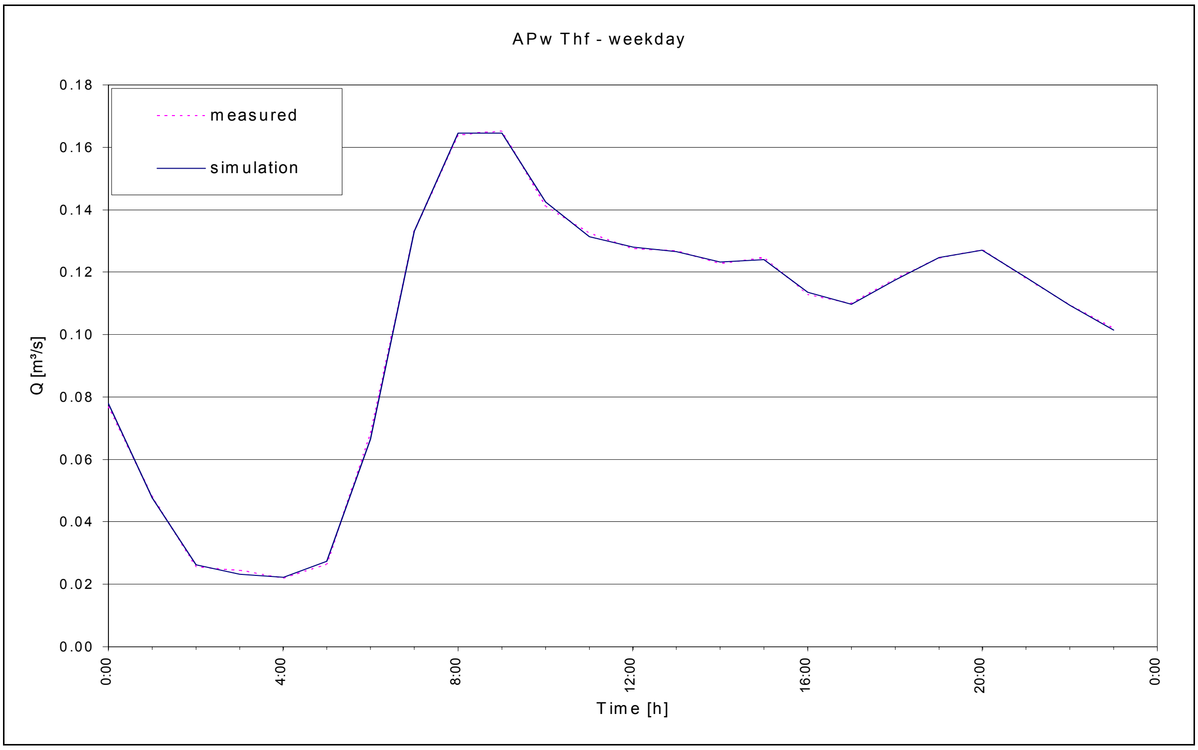
Storage characteristic of sewer network Tempelhof

Calibration

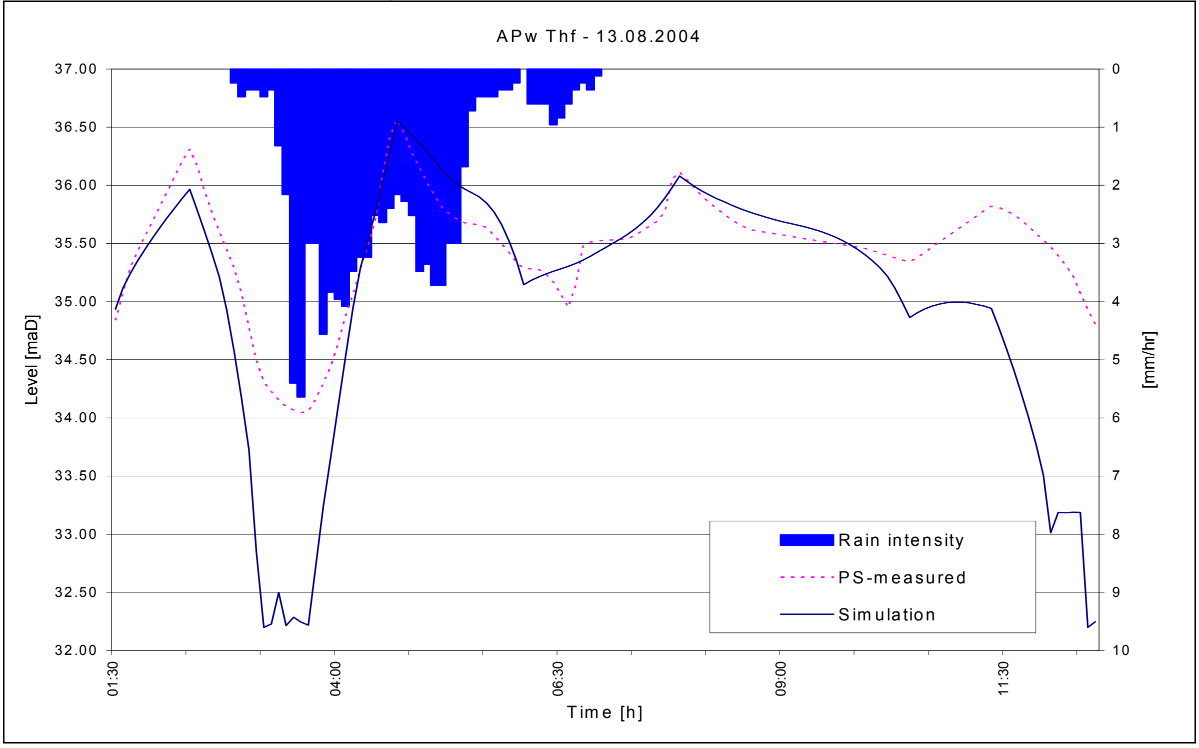
Dry Weather: Flow at Pump station Thf, 30.05.2000, adapted to data from 2004

min flow: 0.022 m³/s

max flow: 0.165 m³/s

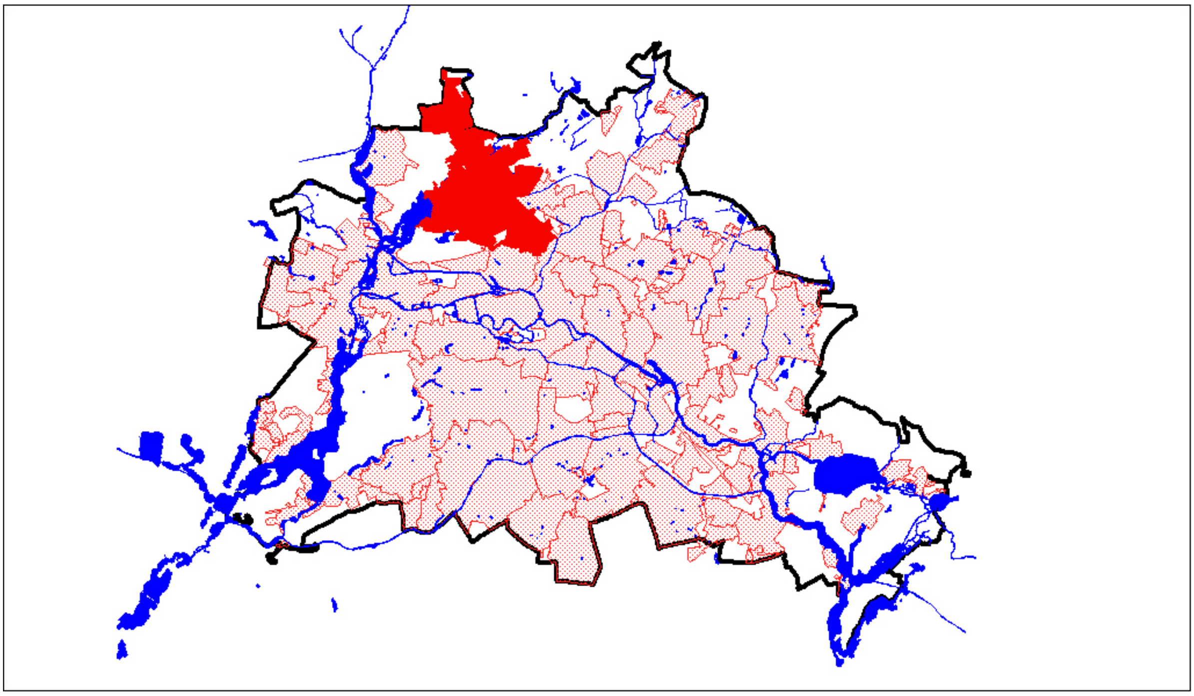


Storm Weather: Level at Pump station Thf



3.4.42 HPw Wittenau

Subcatchment:	Wittenau	
Total Area:	4393 ha	
Population:	220284 Inh.	
WWTP:	dry weather:	Ruhleben
	rain weather:	Ruhleben/Schönerlinde



Location of subcatchment Wittenau

Model characteristics Wittenau

System type: Separate

Length of modelled pipes

- **Combined:** -
- **Waste water:** 43.399 km
- **Storm water:** -
- **Other:** -

Number of Nodes 709

Number of Pump Stations 5

Pump Station: HPw Wittenau, Breitenbachstr.
Node ID: Saugraum_Wit
Average dry wheather flow: 408.20 l/s
Maximum Capacity
- **local:** 1.150 m^3/s
- **global:** 0.950 m^3/s

Destination
- **dry weather:** Ruhleben
- **storm weather:** Ruhleben/Schönerlinde

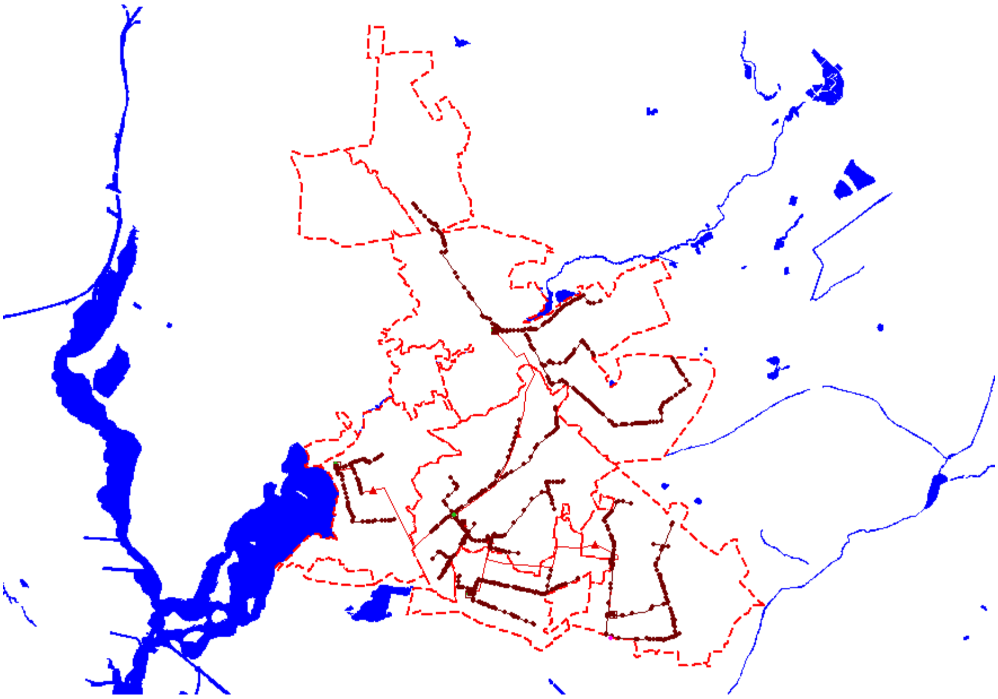
Booster Station: ÜPw Reinickendorf I, Zermatter Str.
Node ID: Saugraum_Rei_I
Destination: HPw Wittenau
Node ID: Saugraum_Wit

Booster Station: ÜPw Reinickendorf II, Klixstr.
Node ID: Saugraum_Rei_II
Destination: HPw Wittenau
Node ID: Saugraum_Wit

Booster Station: ÜPw Tegel, Wilkestr.
Node ID: Saugraum_Tgl
Destination: HPw Wittenau
Node ID: Saugraum_Wit

Booster Station: ÜPw Waidmannslust, Dianastr.
Node ID: Saugraum_Waid
Destination: HPw Wittenau
Node ID: Saugraum_Wit

Number of emergency outlets:		5
Wit	**Node ID:**	30284001
	invert level [maD]:	34.22
Rei_I	**Node ID:**	27243006
	invert level [maD]:	37.00
Rei_II	**Node ID:**	28275001
	invert level [maD]:	33.81
Tgl	**Node ID:**	32305001
	invert level [maD]:	31.96
Waid	**Node ID:**	36276005
	invert level [maD]:	33.85

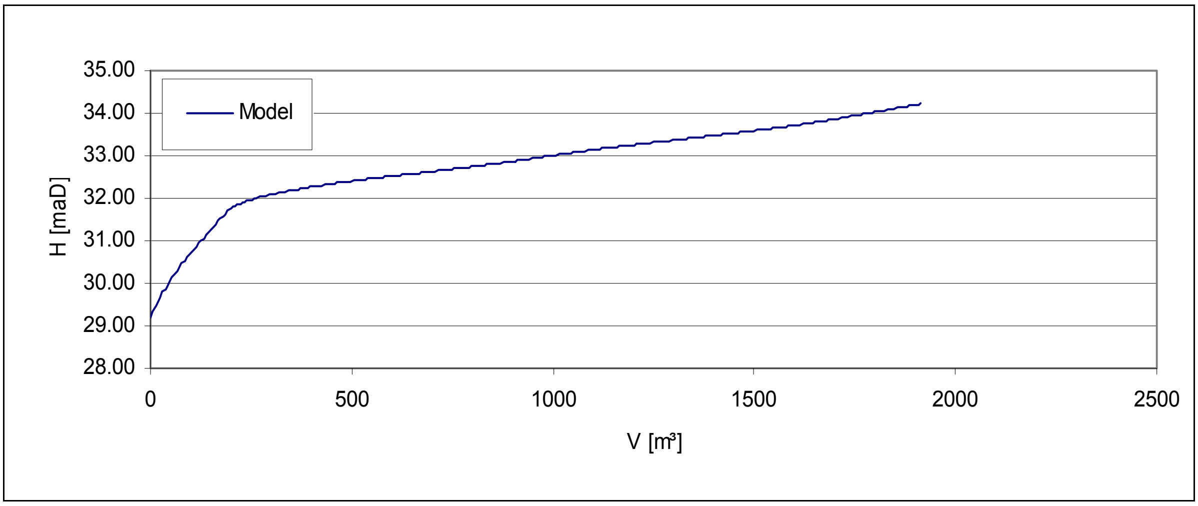


Network model of subcatchment Wittenau

Storage characteristic of sewer network

Wit	Model	Measured
maximum Volume [m³]:	1914	-
storage level [maD]:	34.22	-
invert level of emergency outlet [maD]:	34.22	

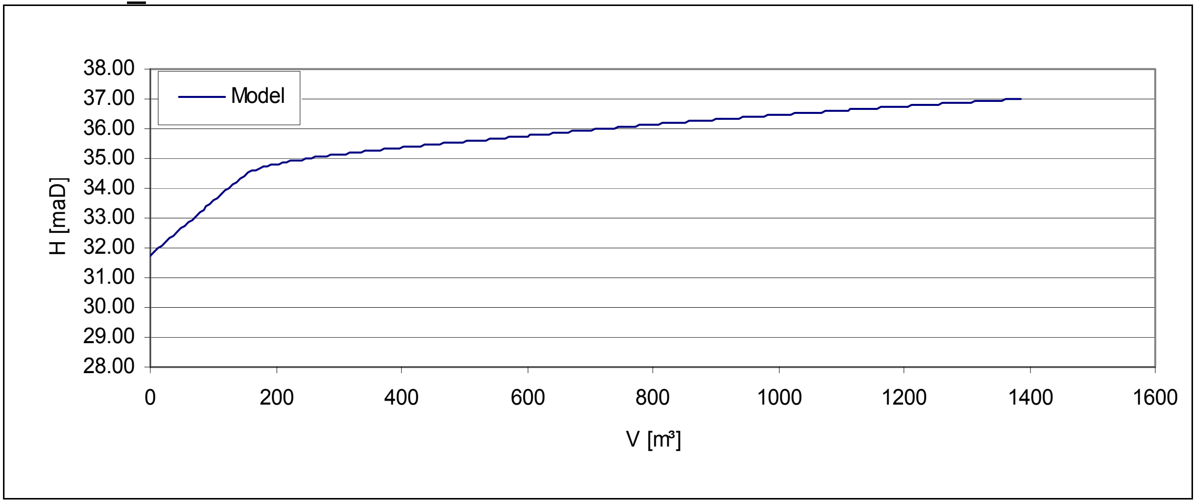
HPw Wit



Storage characteristic of sewer network Wittenau

Rei_I	Model	Measured
maximum Volume [m³]:	1386	-
storage level [maD]:	37.00	-
invert level of emergency outlet [maD]:	37.00	

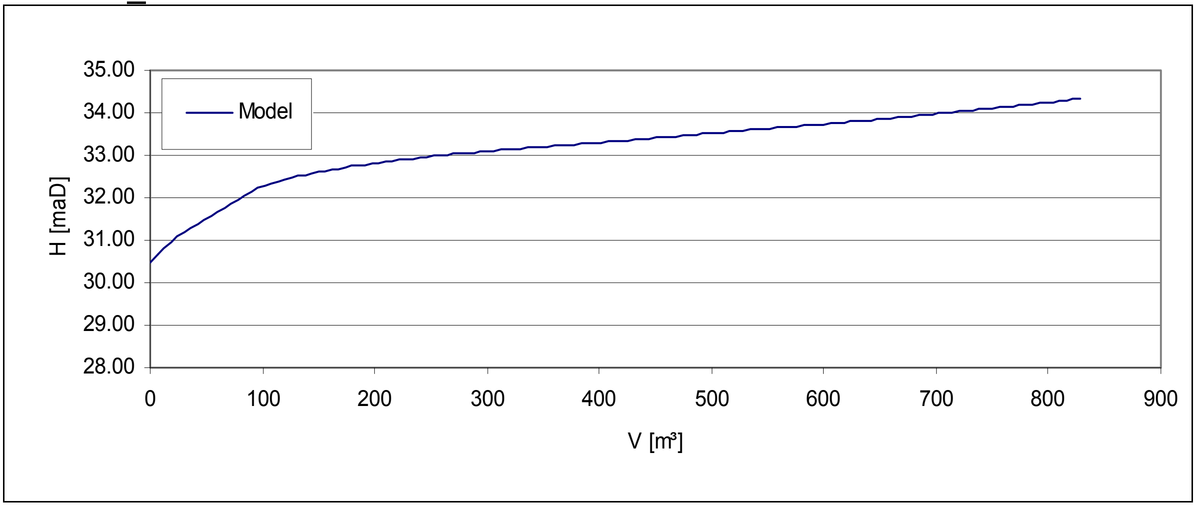
ÜPw Rei_I



Storage characteristic of sewer network Reinickendorf_I

Rei_II	Model	Measured
maximum Volume [m³]:	828	-
storage level [maD]:	34.35	-
invert level of emergency outlet [maD]:	33.81	

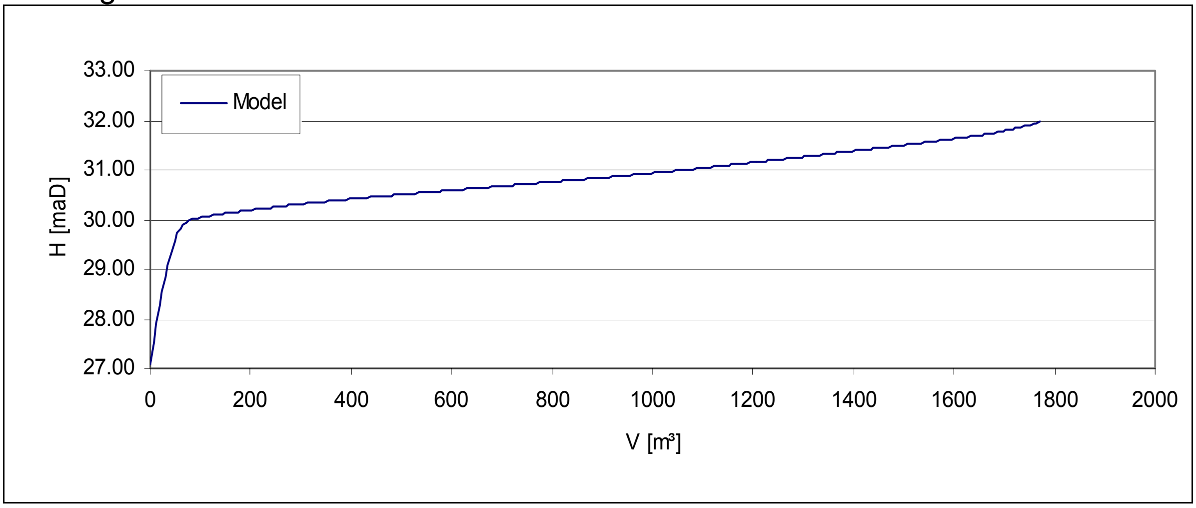
ÜPw Rei_II



Storage characteristic of sewer network Reinickendorf_II

Tgl	Model	Measured
maximum Volume [m³]:	1770	-
storage level [maD]:	31.96	-
invert level of emergency outlet [maD]:	31.96	

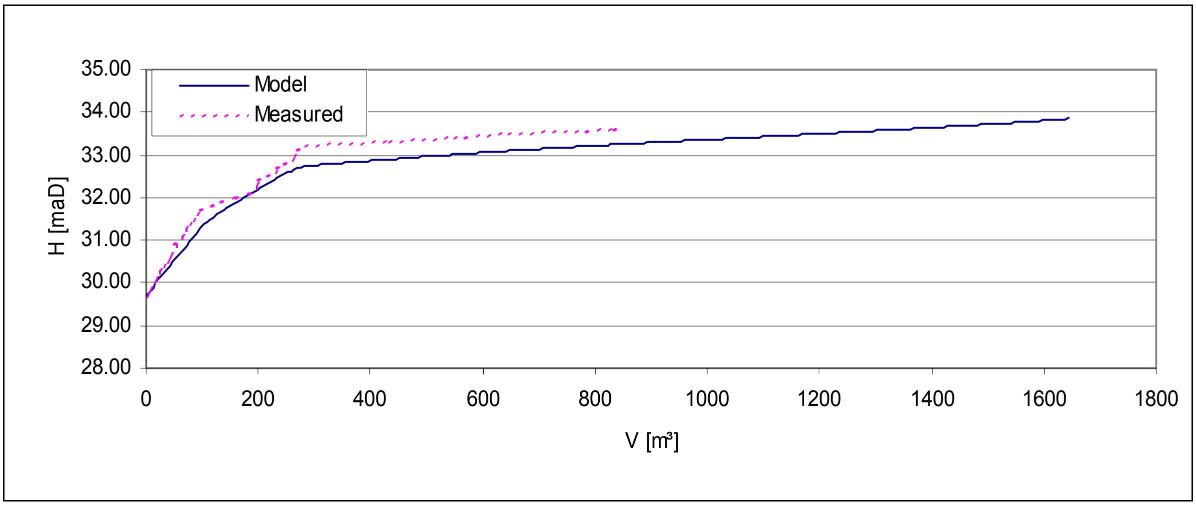
ÜPw Tgl



Storage characteristic of sewer network Tegel

Waid	Model	Measured
maximum Volume [m³]:	1644	849
storage level [maD]:	33.85	33.70
invert level of emergency outlet [maD]:	33.85	

ÜPw Waid



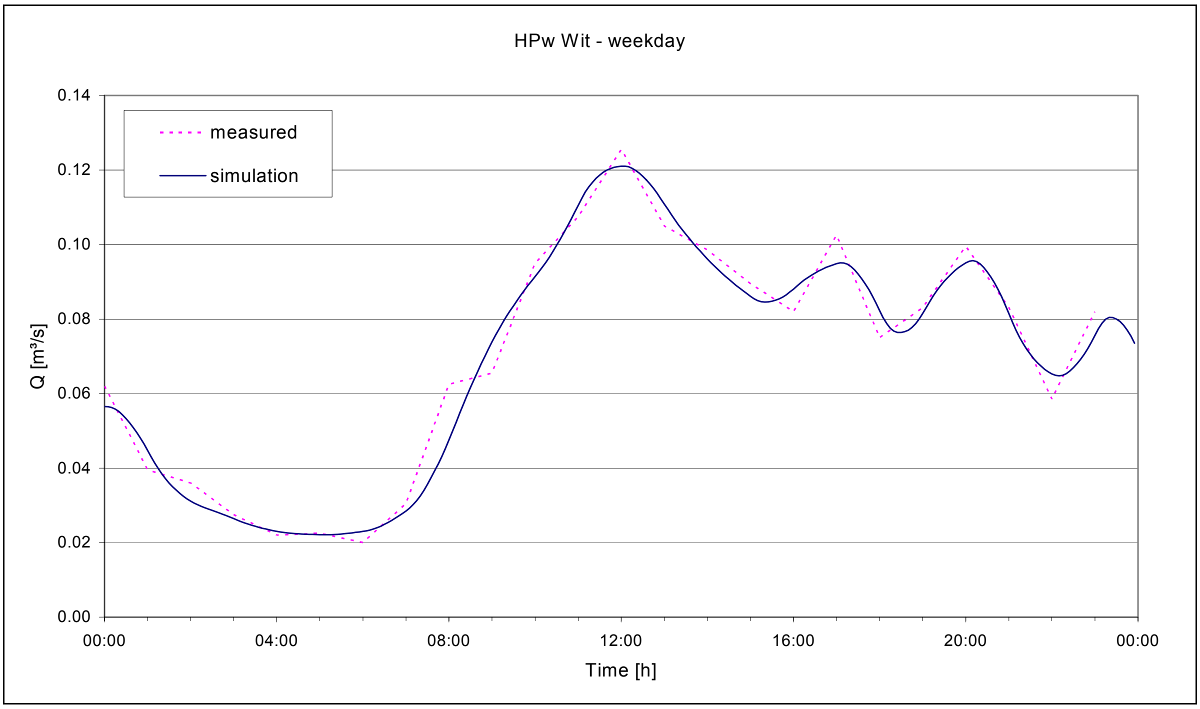
Storage characteristic of sewer network Waidmannslust

Calibration

Dry Weather: Flow at Pump station Wit, Sept.-Nov. 2001

min flow: 0.022 m³/s

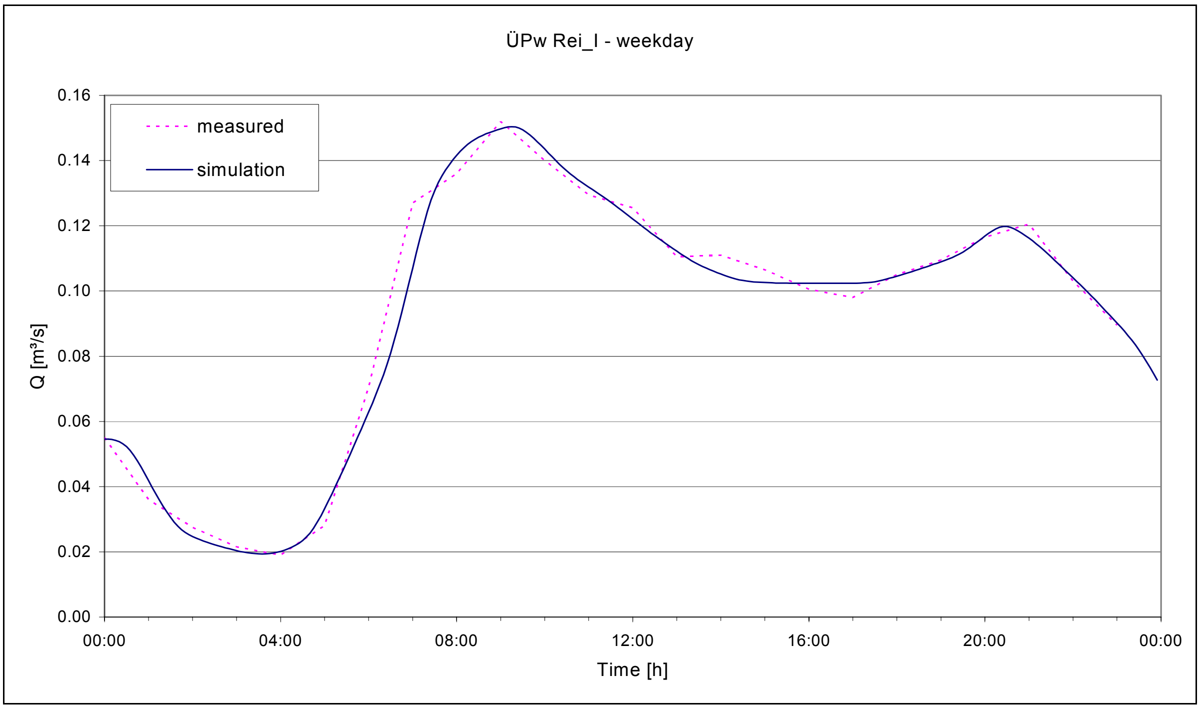
max flow: 0.121 m³/s



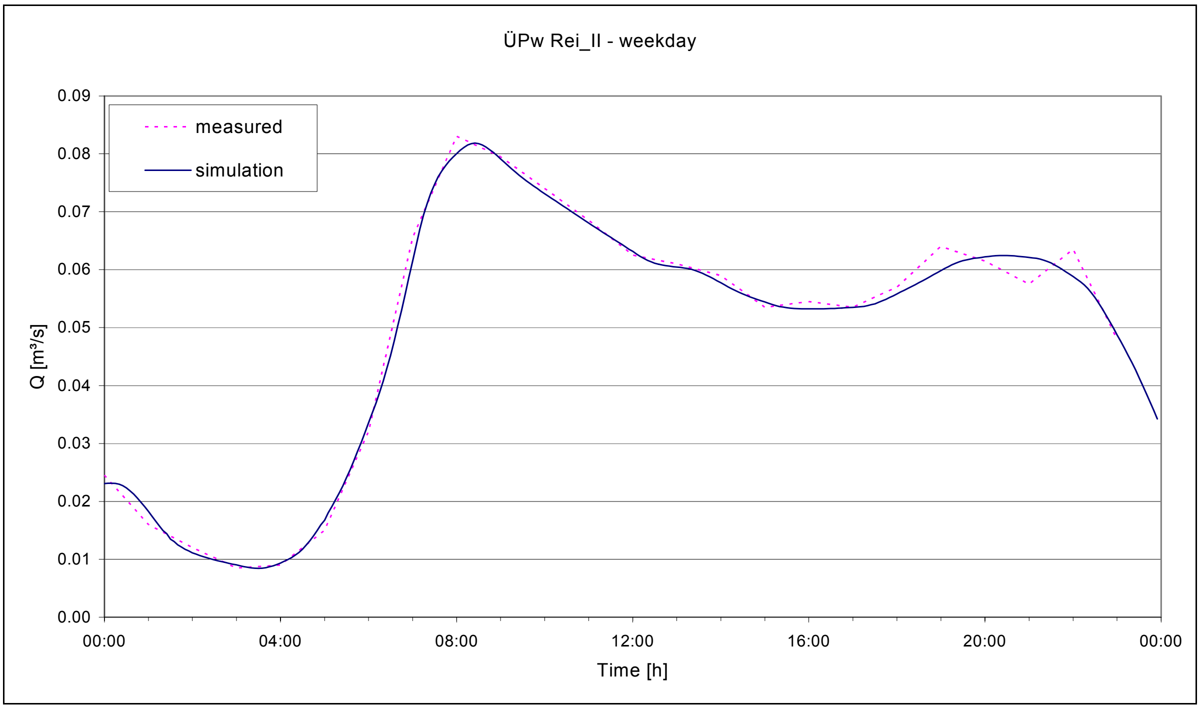
Dry Weather: Flow at Pump station Rei_I, 19.05.1999

min flow: 0.019 m³/s

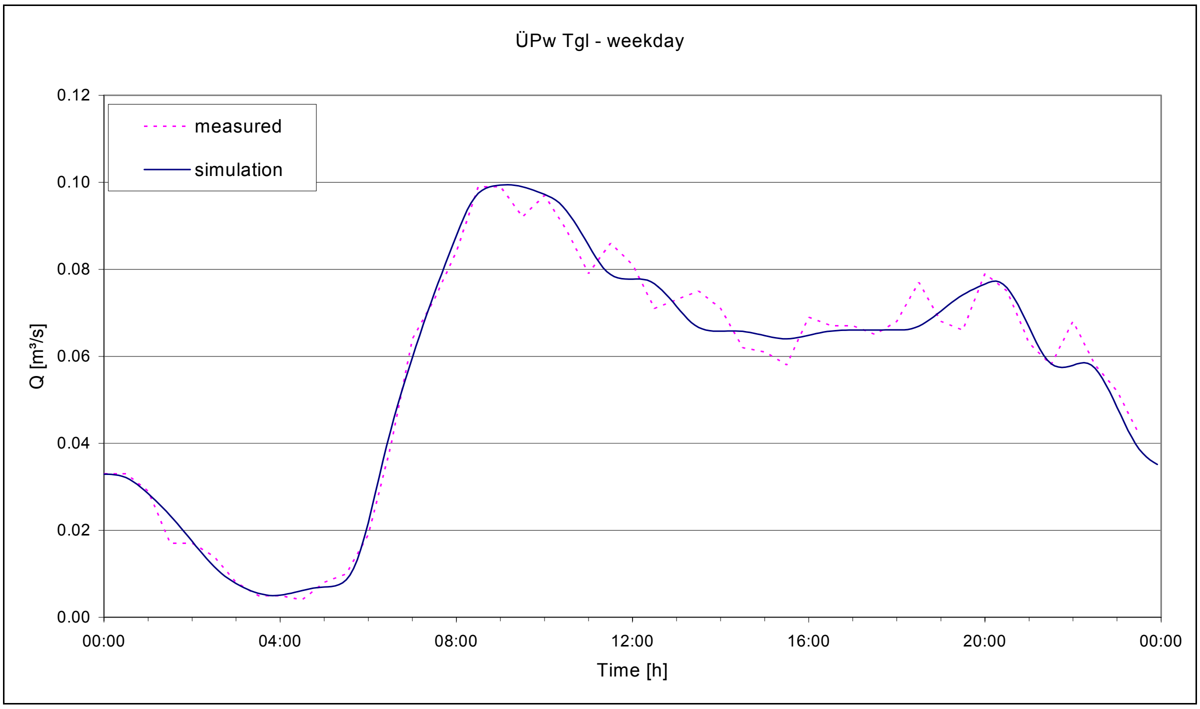
max flow: 0.150 m³/s



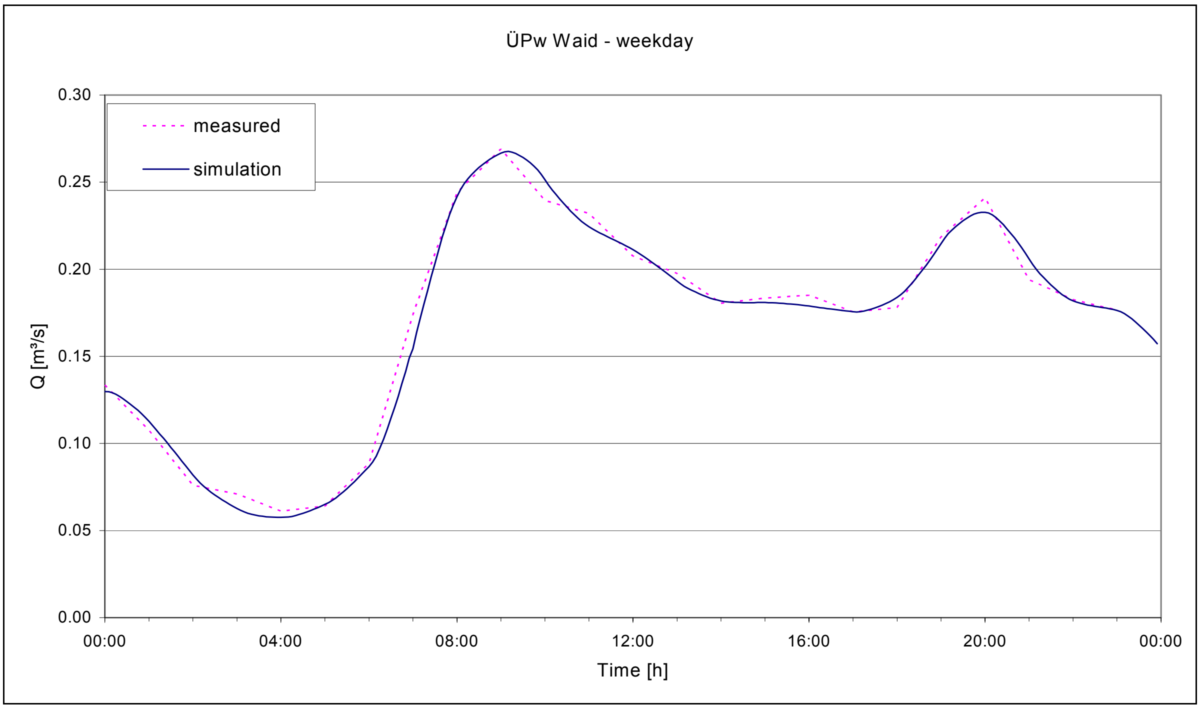
Dry Weather: Flow at Pump station Rei_II, 04.04.2001
min flow: 0.008 m³/s
max flow: 0.082 m³/s



Dry Weather: Flow at Pump station Tgl, 16.11.2000
min flow: 0.005 m³/s
max flow: 0.099 m³/s



Dry Weather: Flow at Pump station Waid, 30.03.2000
min flow: 0.058 m³/s
max flow: 0.268 m³/s



Storm Weather:

Due to a lack of data a storm weather calibration could not be carried out.

Specifics

- After reconstructions in January 2006, pump stations Waidmannslust and Tegel will be directly connected to the pressure network (ÜPw → APw).

4 Concepts of real-time control for the catchment of wastewater treatment plant Ruhleben

The model described in chapter 3 has been used to study and analyse different concepts of real-time control for the Berlin drainage system. According to the particular point of interest either the sub model of the collection system alone or the integrated model of collection system, pressure network and wwtp have been applied.
Foremost, a screening test according to the recommendations of DWA-workgroup ES 2.4 “Real time control of sewer systems” (DWA, 2005) has been carried out to assess the control potential of the system (chapter 4.1). After rating the subsystems and the entire system a local control strategy (chapter 4.2) and a global control strategy (chapter 4.3) have been analysed and evaluated.

4.1 Potential of the Berlin drainage system concerning real-time control

The conceptual design of an rtc system needs time and is a cost-intensive engineering work. Under consideration of water management, financial and legal aspects one has to clarify, whether rtc can help to reach the defined targets for the regarded system. To support and simplify this process the DWA-workgroup on real-time control of sewer systems, ES 2.4 provides a catalogue of criteria for the assessment of the real time controlling potential for a drainage system. In the form of a matrix this screening test allows for a preliminary and simplified estimation of the control potential.

The catalogue titled “Checklist for the collection and evaluation of specific system data and boundary conditions concerning global real-time control” had primarily been published as the 5th work report of the workgroup in the journal “Korrespondenz Abwasser” in January 1995 (in German). Meanwhile, also a software tool of the workgroup is available under the title “Planning aids for real time control in sewer networks (PASST, http://www.dwa.de/news/news-ref.asp?ID=2066)”. The assessment matrix has been revised for the electronic form. In 2005 the report DWA-M 180 “Framework for planning real-time control systems of sewer networks” (DWA, 2005) has been published summarising the experiences of the work group (in German). The table inside the paper is identically with PASST. To assess the control potential of the different Berlin subcatchments as described below the catalogue of the report DWA-M 180 (DWA, 2005) has been used.

In the course of the assessment characteristic data of the drainage system are evaluated in reference to their importance for real-time control. The sum of all points in a catchment area indicates the control potential. Table 4.1 shows the applied assessment matrix.

	Criterion	**Evaluation** Scores (value in brackets)		
A.	**Catchment**			
A.1	Topography (average surface slope)	flat <0,3% (2)	medium <1% (1)	steep >1% (0)
A.2	Catchment area (Flow length in the main collector)	long >5 km (2)	medium (1)	short <1 km (0)
A.3	Difference between current and planned development of the area	large (2)	small (1)	none (0)
B.	**Wastewater production**			
B.1	Area with increased pollution of surface runoff	several (2)	1-2 (1)	none (0)
B.2	Variability in time and space of wastewater production (e.g. producers of heavily polluted wastewater, connections from separate systems)	hign (2)	medium (1)	none (0)
C.	**Sewer system**			
C.1	Number of existing control devices (e.g. pumps, slides, weirs)	several (4)	1-2 (2)	none (0)
C.2	Slope of trunk sewers	flat < 0,2 % (4)	medium (2)	steep > 0,5 % (0)
C.3	Loops in the sewer system	several (4)	1-2 (2)	none (0)
C.4	Number of existing storage tanks (tanks and storage pipes)	> 3 (4)	1-3 (2)	0 (0)
C.5	Number of discharge devices	> 6 (4)	2-6 (2)	< 2 (0)
C.6	Total storage volume (tanks and storage pipes)	> 5000 m^3 (4)	2000-5000 m^3 (2)	< 2000 m^3 (0)
C.7	Specific storage volume (= total storage volume related to impervious area)	> 40 m^3/ha (4)	20-40 m^3/ha (2)	< 20 m^3/ha (0)
C.8	Number of collectors to wwtp	> 2 (3)	2 (1)	1 (0)
D.	**Operational system behaviour**			
D.1	Local flood areas	several (2)	1-2 (1)	none (0)
D.2	Number of non-uniformly used tanks	> 1 (4)	1 (2)	none (0)
D.3	Non-uniform discharge behaviour	significant (4)	medium (2)	insignificant (0)
E	**Receiving water**			
E.1	Local differences in hydraulic capacity	significant (4)	medium (2)	none (0)
E.2	Local differences of load capacity (swimming, fish farming, protected areas)	significant (4)	medium (2)	none (0)
E.3	Sensitivity of the receiving water body	very sensitive (2)		less sensitive (0)
F	**Wwtp**			
F.1	Admissible combined water inflow ($f_{S,Qm}$ is related to the German guideline ATV-DVWK-A 198 (2003)	$> 1{,}5\ f_{S,Qm} \cdot Q_{S,aM} + Q_{F,aM}$ (3)	$> f_{S,Qm} \cdot Q_{S,aM} + Q_{F,aM}$ (1)	$< f_{S,Qm} \cdot Q_{S,aM} + Q_{F,aM}$ (0)
F.2	Sensitivity of wwtp to hydraulic or pollutant peaks	very sensitive (2)		less sensitive (1)

Scores: 0-24: probably not suitable for rtc, 25-35: probably suitable for rtc, >36: very suitable for rtc

Table 4.1 Assessment table according to the report DWA-M 180

4.1.1 Studied areas

The assessment is divided into two parts. In the first part the individual subcatchments of the Berlin combined sewer system (not only catchment of wwtp Ruhleben) are regarded. The second part deals with the entire combined sewer system (sum of the subsystems). The assessment is exclusively focusing on the combined sewer system areas since a control of the processes at the separate sewers is not carried out.

There are some cases where sewers from the separate system are connected to the combined system. Consequently, these separate sewers are considered, too.

In Berlin there are 18 subcatchments within the combined sewer system (6 having an inflow from separate sewers: Berlin XII, Wilmersdorf, Neukölln II, Charlottenburg III, Spandau I and Ruhleben). 13 of them are connected to wwtp Ruhleben; the others supply wwtp Schönerlinde or Waßmannsdorf.

4.1.2 Data sources

For the collection of the characteristic catchment and sewerage data following sources were used:

- General reports of “bpi Hannover - Beratende Ingenieure” concerning the modelling and simulation of the combined sewer networks within the framework of rehabilitation studies
- Catchment characteristics and sewer network data from the combined sewerage models of “bpi Hannover” and from the InfoWorks model
- Storage characteristics of the collection systems from BWB, department AE
- Data collected during phase I of the project as described in chapter 2.

4.1.3 Definition and interpretation of the categories

In general, the structure of drainage systems is manifold. Nevertheless, the criteria that are used for the pre-assessment shall be applicable to any system. Thus, it is necessary to interpret some of the questions corresponding to the analysed system. Furthermore, predicates like “medium” or “significant” underlie a subjective valuation. Therefore, the applied evaluation criteria will be discussed below and particularities with respect to the Berlin drainage situation are stated.

A. Catchment

A.1 Topography

Activation of sewer storage volume in areas with steep land gradient is possible only to limited extent and/or with high expense (more cascades). Furthermore, sewers in areas with steep surface slopes are often characterised by small profile dimensions.

The ATV worksheet ATV-A 118 (1999) defines four slope groups that can also be found in the sewer network data of BWB. However, for the assessment of the rtc potential these figures are too coarse. Therefore, the mean slope of a catchment is calculated from the surface levels above the manholes. Overflow sewers are not regarded. The mean slope of a catchment is calculated from the sum of the surface gradients above the conduits divided by the number of conduits.

$$I_G = \frac{\sum \frac{\left| h_{o,i} - h_{u,i} \right|}{L_i}}{n} * 100$$

where

I_G = mean surface slope at a catchment in %
$h_{o,i}$ = upstream surface level in maD
$h_{u,i}$ = downstream surface level in maD
L_i = length of accordant conduit in m
n = number of regarded conduits at the catchment

A.2 Catchment area

In large catchments, rainfall is usually non-uniformly distributed. Therefore, the system is often non-uniformly utilised, in particular when there are long flow times in the sewer system. Storage volume available in some parts of the catchment can possibly be used for a reduction of the pollution load in other parts. Alternatively, available sewer capacity can be used for an increased flow of the heavily polluted wastewater towards the WWTP.

The catchment length is derived from the total length of the longest collector at the catchment taken from the InfoWorks model. For this evaluation of the total system the longest collector of all catchments is taken (catchment HPw Wilmersdorf).

A.3 Difference between current and planned development of the area

Sewer systems are designed for a specific load and specific boundary conditions (area size / wastewater flow). In case of non-completed development of urban areas, the flows are lower than planned. Storage volumes are possibly not used optimally. With the help of RTC it is possible to react flexibly to the different degrees of development of the area.

In the Berlin city area no big area development is planned. Just three smaller development areas have to be named. Those are:

- New building of the headquarter “Bundesnachrichtendienst, Chausseestraße”
- “Schöneberger Linse”
- “Ostbahnhof”

In the corresponding catchments the development is rated as “small”.

B. Wastewater production

B.1 Area with increased pollution of surface runoff

Some catchment areas have specific parts with particularly polluted runoff. It may be beneficial to direct this heavily polluted water to the WWTP with high priority, or to store it and not to discharge this heavily polluted water, but the water from less polluted areas.

There are a lot of companies situated in the city of Berlin, but there is no information about the surface pollutant runoff from these areas. BWB assume, that this surface runoff is not heavily polluted.
In contrary to rural areas it doesn’t make sense to include highly frequented roads, since they can be found at any catchment. However, the inner city highways are taken into account as special pollutant sources for the evaluation. Near highway A 111 there are rain basins that are emptied into wastewater collectors of the separate system. The same situation can be found at the southern part of highway A 100 that is connected to the separate system of “Halensee”. Parts of the “Südring” highway drain into catchment “Neukölln II”. At catchment “Charlottenburg I” a sedimentation tank is used to lead heavily polluted storm water towards the combined system. The storm water from highway A 115 and from the central area of highway A 100 is lead via a big storm water collector through catchment “Charlottenburg I” to combined sewer pump station “Charlottenburg III”.

B.2 Variability in time and space of wastewater production

Inflows from separate sewer systems or single source inflows of heavily polluted wastewater can cause significantly higher pollutant concentrations in specific areas of the sewer system. With the help of rtc, flows can be set dynamically so as to prevent combined sewer overflows from the areas with highly polluted wastewaters.

In the case of inflows from wastewater collectors of the separate system into the combined system the predicate “high” has been given.
As data source for the evaluation of industrial inflows the table “Großeinleiter-Mischgebiete” (department LA-S/A of BWB) has been used. The inflows are between 5.000 and 400.000 m^3/a.

C. Sewer system

C.1 Number of existing control devices

Rtc control actions take place at pumps, slides, weirs etc. If such control devices are already available in the system rtc can be realised easily by only a few additions with regard to measurement or control devices.

Only dynamic installations were taken into account. Sluice gates that are used for the filling or emptying of storm water tanks have not been considered since storage tanks are regarded under C.4.
For the evaluation of the single catchment areas pump stations with connection to the pressure network have not been regarded. However, for the global view of all catchments these assets have been taken into account due to their throttle effect.

C.2 Slope of trunk sewers

In trunk sewers with large profile dimensions and small slopes additional storage volume can be activated by cascades.

In combined sewer systems trunk sewers with a cross section ≥ DN 800 represent on average 70-90 % of the total sewer storage volume (ATV, 1999). Due to the old structure of the Berlin combined sewerage with irregular cross sections, all trunk sewers with a cross section ≥ 0.5 m^2 are included.
A high number of collectors have slopes from 0.1 % to 0.2 %. On average the slope is around 0.3 %.

C.3 Loops in the sewer network

Loops in the sewer system provide the possibility to distribute the flow through different branches of the network. Therefore, a more flexible management of flows is possible.

Corresponding to the assumption in C.2 only loops at collectors with cross sections ≥ DN 800 are considered.
For the assessment of the global system also loops within the pressure network have been regarded. The exact number could not be determined. Due to redundant pipes and complex connections the rating is high.

C.4 Number of existing storage tanks

In general, fixed throttle outflows of the storage tanks can result in uneven utilisation of tanks. With an increasing number of storage tanks the potential of equalising the utilisation of the tanks with the help of rtc grows.

In Berlin this assessment point is less important. With the exception of catchment “Berlin II” (HPw Kreuzberg) there is no subsystem with more than one basin.

C.5 Number of discharge devices

If there are several discharge devices (cso) in the sewer system, it is possible to react to different conditions in a more flexible way. The advantages of rtc can be better utilised than in a system with a small number of discharge devices.

Internal cso’s have not been taken into account.

C.6 Total storage volume

The storage volume of a sewer system is decisive for the amount of discharged wastewater. Total storage volume is given by the sum of in-sewer storage volume and tank storage volume.

Information about the storage volume of tanks has been taken from BWB data. The in-pipe storage volume of the sewer systems has been calculated by means of the InfoWorks model.

C.7 Specific storage volume

The specific storage volume is the total storage volume of a sewer network related to the impervious area of the catchment (ATV, 1992). If there is only little specific storage volume, this volume is full even during small rain events. In this case, rtc cannot help significantly to reduce the discharge volume.

C.8 Number of collectors to the wastewater treatment plant

If there are several collectors leading to the WWTP, it can be expected that in case of rainfall the collectors are not used in a uniform way. With the help of rtc, less used sewers can be used in a better way. An uneven utilisation of the in-sewer volumes can occur through:

- Uneven distribution of rainfall
- Different degrees of impervious surface area connected at the catchments
- Different flow concentrations due to different sewer gradients at the catchments
- Different settlement structures (e.g. industries) and thus eventually, high deviations in dry weather patterns

For the estimation of the single subcatchments the accordant pump stations have been regarded synonymously as wwtp. For total system evaluation the number of catchments connected to the pressure network has been used.

D. Operational system behaviour

D.1 Local flood areas

In case of heavy rainfall there are often locally limited areas which are flooded whilst other areas have enough flow capacity available. If there are no structural bottlenecks, such flooding indicates that available resources are being insufficiently used. This situation can be improved by rtc.

In the city area the following regions are known as areas with flooding problems:

- Sickingenstraße, Moabit (Berlin VIII)
- Friedenau (Wilmersdorf)
- Train underpass near pump station Ruhleben

D.2 Number of non-uniformly used tanks

An uneven utilisation of storage tanks is an indication that the available volumes are not used in an optimum way. If the performance of one single tank alone is not optimal then already local rtc can result in a better utilisation of the available storage volume. If several tanks are used in an unbalanced way, global rtc, enabling dynamic operation of throttle outflows depending on the current state of the network, can improve the situation.

As mentioned under C.4, in Berlin usually there is only one retention tank at each catchment. For the evaluation of the total system's control potential the total number of 13 tanks has been considered.

D. 3 Non-uniform discharge behaviour

Non-uniform discharge behaviour indicates non-optimum use of the storage capacities. The stronger the differences concerning discharge behaviour are, the more improvement can be expected with regard to a better utilisation of the storage capacity, (for example by operation of throttle outflows depending on the current state of the network).

However, in Berlin the subsystems are designed to have the major cso activity nearby the pump station. If the remainder of discharges is evenly distributed over the sewer system this behaviour is rated as insignificant concerning rtc potential.

E. Receiving water

E.1 Local differences in hydraulic capacity

If there are differences in the hydraulic capacity of the receiving water bodies, rtc can be used for discharging hydraulic peaks into those receiving water bodies, which have higher hydraulic capacity (e.g. with the help of adjustable weirs).

At subcatchments with discharges into both, river Spree and smaller waterways the predicate “medium” has been given. At catchments “Berlin IV” and “Berlin X” the predicate “significant” has been given, due to the sensitive situation of river Panke.

E.2 Local differences of load capacity

By better operation of the flows, discharges can be influenced in such a way that priority is given to discharges into receiving waters with higher capacity.

Generally, the receiving waters of the Berlin combined sewer system show a high initial level of water pollution. Therefore, the differences are not significant. Again, the smaller waterways are more sensitive than river Spree. Catchment “Charlottenburg III” discharges into an old anabranch of the Spree. Both, catchment “Charlottenburg III” and catchment “Ruhleben” are located within water protection areas. Due to these boundary conditions the receiving waters are rated as extremely sensible.

E.3 Sensitivity of the receiving water body

Where there are sensitive receiving waters, it is necessary to either avoid discharges or to reduce discharge volume significantly. Rtc is useful in this case because the system becomes more flexible and the existing storage volume can be better utilised.

The Berlin water bodies can be declared throughout as extremely sensitive. The slow flow velocity of the weir-regulated waters lead to the risk of nitrification. Moreover, all combined water discharges finally flow through river Havel and lake Wannsee that is used as a public bathing water.

F. Wastewater treatment plant

F.1 Admissible combined water inflow

In some cases the wwtp is able to treat more than "$f_{S,Qm} \cdot Q_{S,aM} + Q_{F,aM}$", even during longer periods and without impairing the treatment efficiency. The result can be a reduction of discharges from the sewer system. Rtc enables an increased inflow to the wwtp depending on its current treatment capacity (integrated rtc).

To guarantee process stability in Germany inflows to the wwtp have been limited to twice the dry weather flow (2*Qs+Qf) according to the guidelines ATV-DVWK-A 131 (1991) and ATV-A 128 (1992). Now, the new German guideline ATV-DVWK-A 198 (2003) allows for a more flexible combined water inflow range. The fixed value of 2*Qs+Qf is replaced by a factor $f_{S,Qm}$ to calculate the admissible combined water inflow. On the basis of the standard wastewater distribution of the Berlin pump stations $f_{S,Qm}$-values between 2.5 and 4.5 can be calculated according to ATV-DVWK-A 198 (2003). For comparison, the guideline ATV-DVWK-A 198 (2003) supposes a factor $f_{S,Qm}$ between 3 and 6 for big cities over 100.000 inhabitants.

F.2 Sensitivity of wwtp to hydraulic or pollutant peaks

If the wwtp is sensitive to hydraulic or load peaks, rtc can assist in increasing slowly the inflow to the wwtp during rain. This results in a better utilisation of storage volume in the sewer system. Integrated rtc of sewer system and wwtp can possibly reconcile the contradicting requirements of the subsystems (sewer system and wwtp) and lead to an optimum operation of the entire system.

The Berlin wwtps are able to receive the peak load at the beginning of rainfall events. But due to the long duration of high mass inflow the wwtp’s capacity for nitrification decreases after a while. For wwtp Ruhleben the hydraulic rate of increase is limited to Q=2000 l/s in 60 minutes during rain. The other plants only have limitations during dry weather situation. All catchments are rated as “less sensitive”.

4.1.4 Results of the estimation of control potential

Firstly, the individual subcatchments of the Berlin combined sewer system are rated. Thereon, the evaluation of the total system is stated.

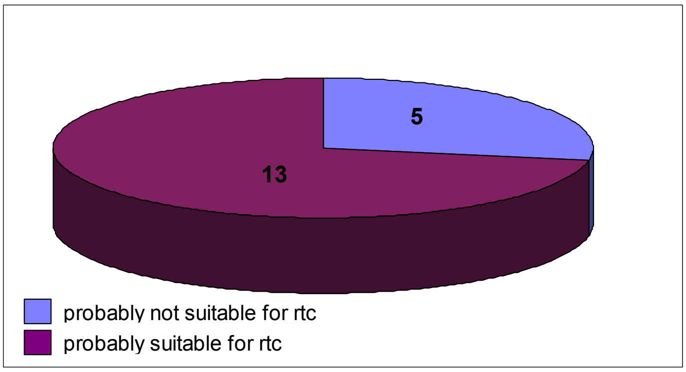


Figure 4.1 Distribution of rating categories for the 18 subcatchments of the Berlin combined sewer system according to guideline DWA-M 180

4.1.4.1 Subcatchments

The evaluation of the individual catchments shows a big potential for rtc. Only five catchments (Berlin X, Berlin XI, Neukölln I, Neukölln II and Ruhleben, = 28 %) are rated as “probably not suitable for rtc”. However the catchments of Berlin X and Neukölln I are placed at the top border of this category. All other catchments are situated in category 2 and are rated as “probably suitable for rtc”. Appendix 6 gives an overview of the ratings for each subcatchment. Figure 4.1 shows the distribution of rating categories for the 18 subcatchments of the combined sewer system. Figure 4.2 gives an overview of the evaluation results for both, the subcatchments and the total system.

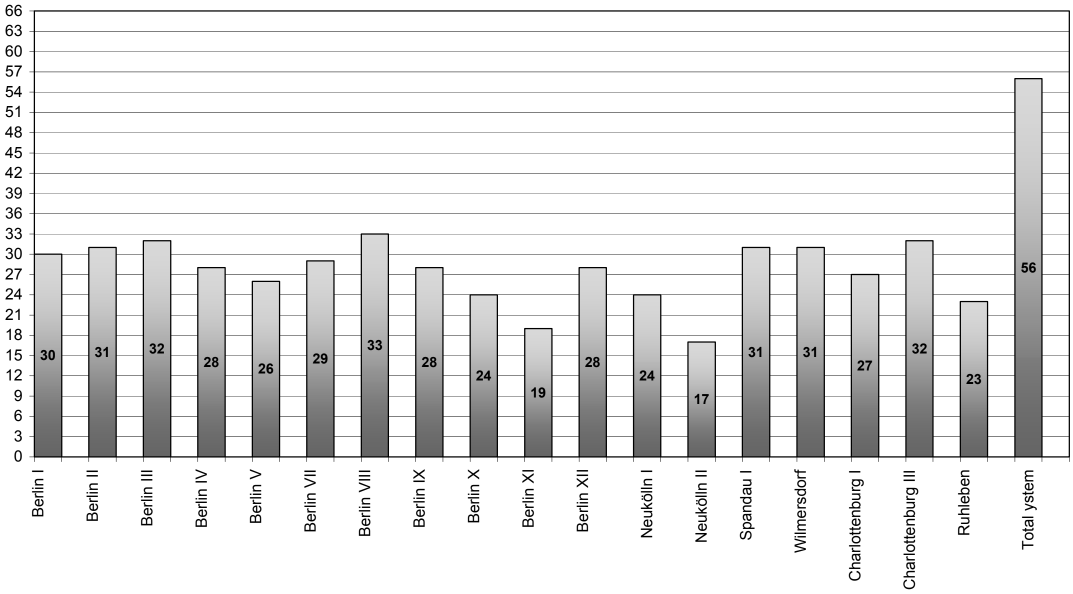


Figure 4.2 Overview of the evaluation results for both, the subcatchments and the total Berlin system according to guideline DWA-M 180. Scores: 0-24: probably not suitable for rtc, 25-35: probably suitable for rtc, >36: very suitable for rtc

Irrespective to these evaluation results the conception for combined sewer system rehabilitation includes many measures of rtc even at catchments, which were estimated as not being suitable for rtc (Berlin X and Ruhleben).
When all measures of the rehabilitation conception will be realised, the specific storage capacity and the potential for rtc of the catchments will consequently be increased.

4.1.4.2 Total system

All catchments of the Berlin drainage system are connected to the pressure pipe network. This system structure is leading to an enormous interdependency between the individual subcatchments. This situation and the possibility of a coordination of the wastewater flows justify a global view on all catchments concerning the control potential of the total combined sewer system as one entity. Through the connection of the three sub systems

- sewer network
- pressure pipe network
- wwtp

to an integrated system a high potential for real-time control can be pre-identified. The evaluation of the total system gives a rating of 56 points. This value corresponds with 85 % of the maximal possible score and shows that the Berlin combined sewer system can definitely be rated as “suitable for real-time control”.

4.2 Local level-dependant pump station control

This chapter will introduce, describe and evaluate a concept for a local control of sewage pump stations. The concept is based on the measurement of the water level at the pump station’s well and consequently referred to as “level-dependant” control.

According to (ATV-DVWK, 2000) the function of pumping stations within the urban drainage system can be specified as follows: By lifting the sewage it is possible to reduce the installation depths of conduits and assets and consequently improve the economic efficiency of a system. To a large extent, pump facilities are independent from topographic conditions and have the ability to move wastewater to higher elevation or remotely located destinations, e.g. wastewater treatment plants.
Moreover, pumps can be used on the basis of real-time control strategies acting as actuators (Schütze et al., 2002). The control range covers two-point (on/off) and multiple-step control as well as continuously variable control (ATV, 1985). In the last years sophisticated real-time control systems including pumps have been implemented. (Schilling, 1994) reports about a fully automatic global rtc system that is operated in Werveshoof, Netherlands. Here, 28 pump stations are co-ordinated with respect to locally available storage and treatment capacities to optimise the performance of the complete system.

In Berlin, Germany, due to very low topographic gradients, pumps have been used since 1878 to transport waste and storm water out of the city. The urban area had grown to 60 square km, which was comparably large for that time. So the basic idea was not to build one single sewer network for the entire city but to develop a system of twelve subcatchments, each one drained by a combined sewerage. Natural watersheds divided these subsystems from each other. Within each catchment at a topographic low point the sewage was collected and pumped through pressurised pipes towards sewage farms (Bärthel, 2003). Today, Berlin is drained by both combined and separated sewer systems. The wastewater is delivered to six treatment plants that have replaced the sewage farms. However, the centre of the city with 167 square km is still drained by a combined system that is based on the structure of the original system and in major parts consists of the constructions of the original system.

In the course of current rehabilitations two major changes concerning the operation of the pump stations are carried out. At first, old fixed speed pumps are exchanged by modern variable speed pumps with frequency drives that can be (to some extent) controlled in a continuously variable mode. Secondly, a control program will be put on to further the operation of the pump stations towards an automatic mode. Beneath automation the objectives for the pump control are the reduction of combined sewer overflows and the prevention of adverse effects on pressurised pipes and wastewater treatment plants. Moreover, the control algorithm shall work stable and allow easy tuning.

4.2.1 The idea of a continuous level dependant pump control (LDPC)

In case of rainfall the pump stations limit the delivery of combined water to the wastewater treatment plants (usually to twice the dry weather peak flow). Hence, the pumps act as throttles on the outflows of the collection systems. In doing so, and due to very low sewer gradients, high storage volumes can be activated within the sewer networks. This chapter will introduce an algorithm for a level dependant pump control that allows continuously varying the pumpage and implicitly managing the available inline storage capacities.

The essential element of the algorithm is the target delivery, which is a continuous function of the level at the pump well (see equation). The curve progression can be linear, exponential or logarithmic as shown in Figure 4.3. The progression of the curve is tuned solely by the parameter k and can be adapted to the boundary conditions of the individual pump station and connected catchment area.

$$Q = \frac{10^{k} \cdot H}{1 + (10^{k} - 1) \cdot H}$$

where

Q = pumpage
H = water level at pump well.

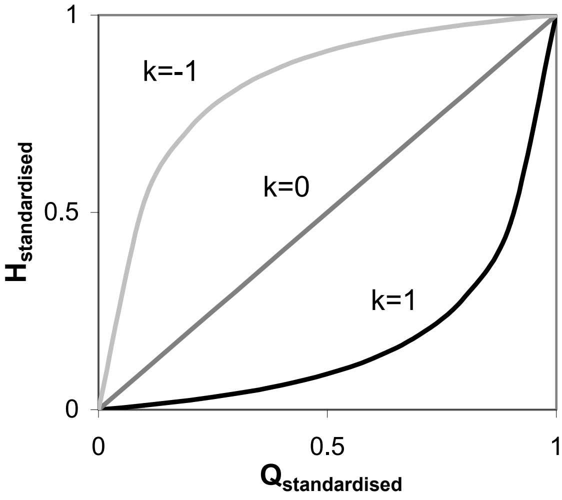


Figure 4.3 Different progressions of the control function

Tuning the curve exponentially (k=1) leads to an immediate increase of pumpage when the water level is rising. In doing so, the water level is retained low as long as the inflow to the pump well is below the maximum pump capacity. The advantage of this regime is that number and duration of wet weather events where collectors are dammed up are minimised. Hence, the adverse effects of sediment deposition within the sewers and the risk of csos are reduced. On the other hand the delivery of wastewater towards the treatment plant is very “direct”. Particularly, the fact that the pressure main is full of high concentrated wastewater at the beginning of a rain event leads to a massive impact of pollutant load on the wwtp when increasing rapidly the flow velocity.

By giving the curve a logarithmic run (k=-1) the pump reacts more slowly on the rising water level. Until the water level reaches a maximum range the pump speed is retained moderate. In doing so, it is possible to activate and control the inline storage volume. Hence, the flow and mass flow towards the wwtp is evened out. On the other hand collectors are more often filled. That can lead to the above-mentioned adverse effects.

By varying the coefficient k between the extreme values 1 and –1 it is possible to obtain system conditions in-between those mentioned. The objective is to deduce the optimal parameter k for the individual subsystems. That will lead to a more even inflow to the wastewater treatment plant while threshold values for combined sewer overflows are kept.

4.2.2 Evaluation of the control algorithm

The algorithm is evaluated by means of the InfoWorks model that has been built up in the framework of the project. The evaluation draws upon data from a spectrum of simulations for three subcatchments of the Berlin drainage system. The data is analysed with regard to the efficiency of inline storage activation, cso behaviour and the impact on pressure mains and treatment plant processes.

4.2.2.1 Determination of the optimal control parameter

A preliminary assessment of the control function and the derivation of optimal control parameters have been carried out on the basis of long-time simulations for the catchment Berlin VII. The catchment has a population of 41,100 and a total area of 414 ha (242 ha impervious). It is drained by a combined sewer system with a total length of 71 km and 14 combined sewer overflows. The inline storage capacity of the network is 11,760 m³ (48.6 m³/ha A_{imp}). Simulations have been carried out with varying values for the parameter k that describes the deflexion of the control curve and the parameter H_{max} that gives the maximum allowable water level. The results have been compared with those for a step-control where fixed pumps of different capacities are switched on or off depending on the water level within the pump well.

The first result is that only a negligible reduction of cso activity is possible by applying the control function. To achieve this effect the parameter k has to be set to 1 involving a very “direct” delivery. By this means a significant retention of combined water and a smoothing of the delivery is not possible.

A second general insight is that a maximum allowable water level within the range of the pump well does not allow activating inline storage capacities and consequently does not lead to retention of combined water. Simulations for such a low maximum allowable water level have shown that the flow characteristic towards the wastewater treatment plant is not improved compared to the usual pump regime.

Hence, the maximum allowable water level has been increased to enable inline storage activation. Figure 4.4 shows the pumpage towards the wastewater treatment plant for a measured rainfall event depending on the variation of the parameter k.

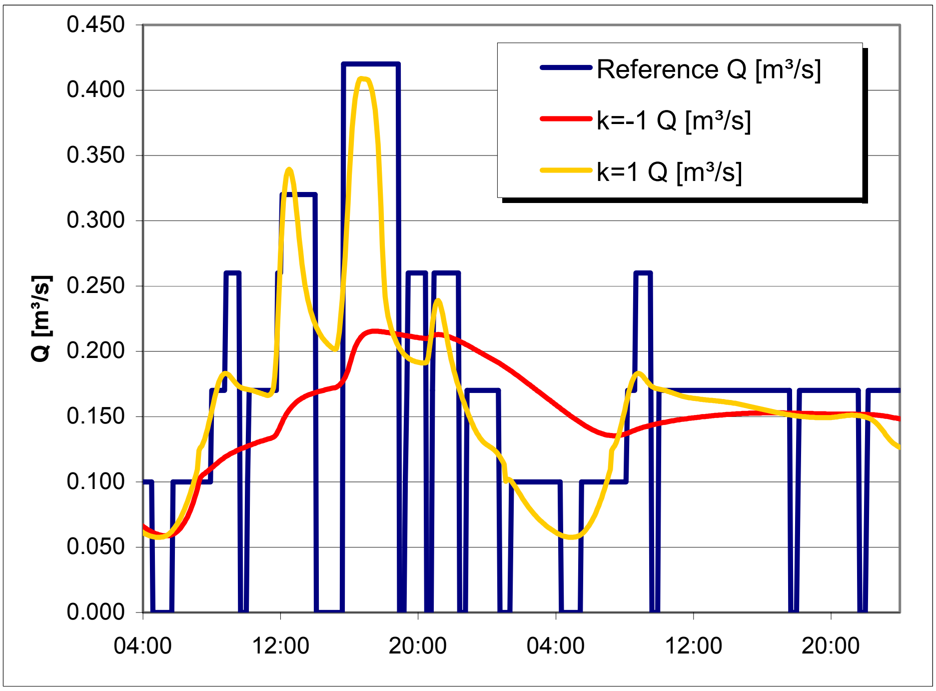


Figure 4.4 Continuous modification of pumps for different values of parameter k

The reference regime leads to a discontinuous delivery linked with high peaks and periods of stagnancy. Whereas the developed control function leads to a continuous modification of pumpage. As afore-stated there is only low retention when choosing k=1. A high retention effect can be realised with a value of –1 for parameter k. As the hydrograph indicates a reduction of the peak flow by 50 % can be achieved.

On the one hand, this activation of inline storage capacities and thereby the retention of combined water leads to a smoother charging of the wwtp. On the other hand, the storage of wastewater within the sewers can bring up adverse effects like deposition of sediments, formation of hydrogen sulphide and increases the risk of csos.

Hence, an optimal value depending on catchment and sewer specifics was sought for the control parameter k. The setting should enable combined water retention but on the other hand minimise the risk of the afore-mentioned adverse effects. Figure 4.5 illustrates the definition of the optimal control curve and its functioning.

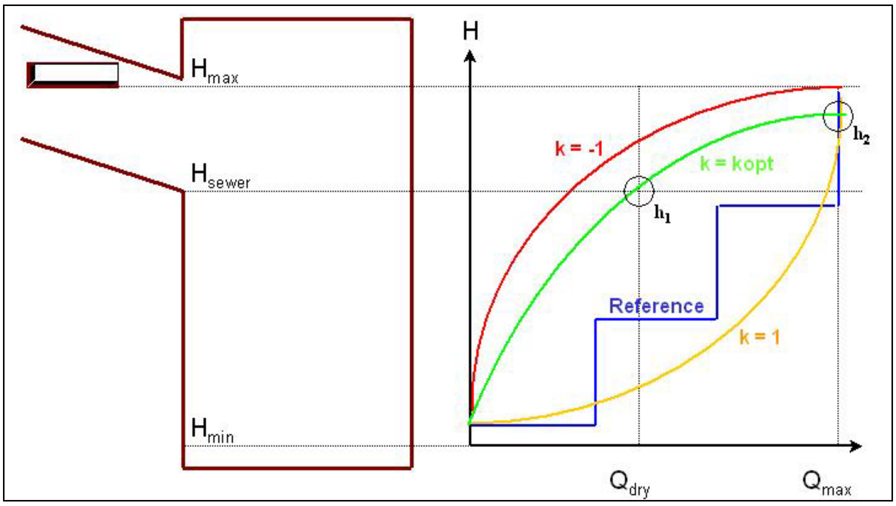


Figure 4.5 Illustration of the control curve in reference to the geometry of the pump well

Two major constraints are given for the definition of the optimal curve progression. Firstly, to avoid backwater during dry weather the dry weather inflow has to be pumped to the wwtp without being throttled. In other words, during dry weather peak flow the water level may not rise above the conduit invert (H_{sewer}). This constraint is indicated by the characteristic point h_1 in Figure 4.5. The second condition is to comply with the requirements for cso activity given by the reference regime. The values for cso frequency, duration, volumes and loads may not worsen. To achieve this situation the maximum allowable water level H_{max} has to be decreased compared to the curve for k=-1. By means of an iterative approach the optimum characteristic point h_2 can be found that ensures compliance with cso requirements.

The points h_1 and h_2 afford the definition of the optimal control curve. The accordant control parameter is called k_{opt}. Applying this optimal parameter allows utilising the retention capacity of a sewer network smoothing the flow to the wastewater treatment plant. Furthermore, adverse effects within the sewerage can be avoided.

4.2.2.2 Simulation results for three different catchments

The evaluation of the control function is carried out for three catchments with highly different characteristics concerning the inline storage capacity. Table 4.2 gives an overview of the characteristic figures of the catchments.

Subcatchment	**Berlin VII**	**Berlin X**	**Charlottenburg III**
System type	Combined	Combined	Combined / Separate
Total area	414.0 [ha]	458.0 [ha]	891.0 [ha]
Impervious area	242.0 [ha]	290.0 [ha]	152.0 + 63.9 = 215.9 [ha] *
Inhabitants	41,100	68,200	33,100
Total length of conduits	71.0 [km]	98.7 [km]	76.8 [km]
Number of CSOs	14	21	12
Inline storage capacity	11,760 [m³]	1,620 [m³]	14,600 [m³]
Specific inline storage capacity	48.6 [m³/ha A_{imp}]	5.6 [m³/ha A_{imp}]	67.6 [m³/ha A_{imp}]
Dry weather flow	11,950 [m³/d]	10,610 [m³/d]	5,360 [m³/d]
Dry weather peak flow	0.227 [m³/s]	0.172 [m³/s]	0.100 [m³/s]

* 63.9 ha of impervious area from highway A 100 and A 115

Table 4.2 Characteristic figures of the studied catchments

For all subsystems the optimum value for the control parameter k has been determined by means of preliminary iterative long-time simulations ($k_{opt,BlnVII} = -0.66$, $k_{opt,BlnX} = -1$, $k_{opt,ChbIII} = -1$). The following evaluation bases on simulations with a spectrum of synthetic rain events of constant intensity. The reference rain with a duration of 15 minutes and a frequency of 1 a^{-1} has been determined statistically (BWB, 1984). Conversions for durations between 5 and 300 minutes and frequencies between 0.1 and 10 a^{-1} have been carried out according to (ATV, 1977).

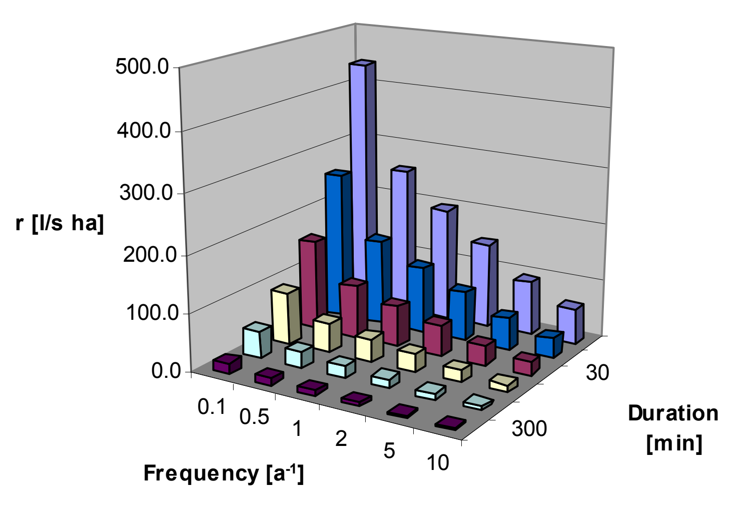


Figure 4.6 Spectrum of synthetic rain events used for the evaluation of the control function

The potential of the control function to improve the evenness of flow towards the wastewater treatment plant is evaluated by two indicators, the reduction of peak pumpage and the reduction of the standard deviation of the delivery hydrograph referred to the reference regime.

Figure 4.7 shows the reduction of the standard deviation subject to duration and frequency of the simulated rain events for catchment Berlin VII (48.6 m³/ha A_{imp}) and Berlin X (5.6 m³/ha A_{imp}). It can be observed that only for catchment Berlin VII (where an adequate retention capacity is available) and for rain events of short duration ($D \leq 15$ min) and high frequency ($n \geq 5$ a^{-1}) a significant reduction is achieved. Furthermore, a reduction of the peak pumpage cannot be realized except for rain events of very low intensity.

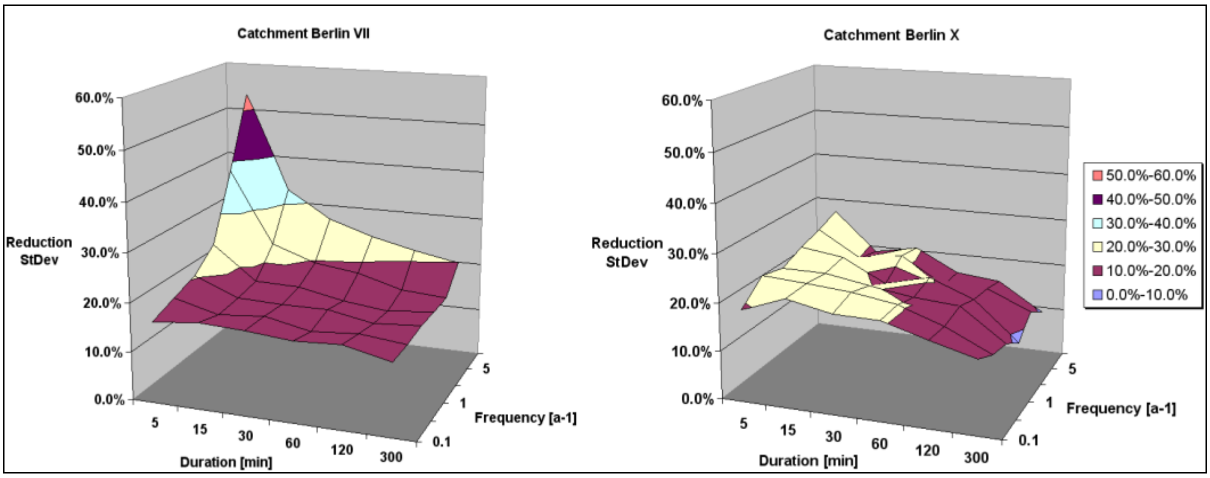


Figure 4.7 Reduction of standard deviation of delivery hydrographs by applying the control function

The analysis of the simulations for catchment Charlottenburg III (67.6 m³/ha A_{imp}) shows that the control function has a positive effect on the delivery if enough retention capacity is available. Figure 4.8 shows that the standard deviation of the delivery hydrographs can be reduced significantly. Furthermore, the peak pumpage can be reduced for all rain events of a frequency less or equal to $n=5$ a^{-1}.

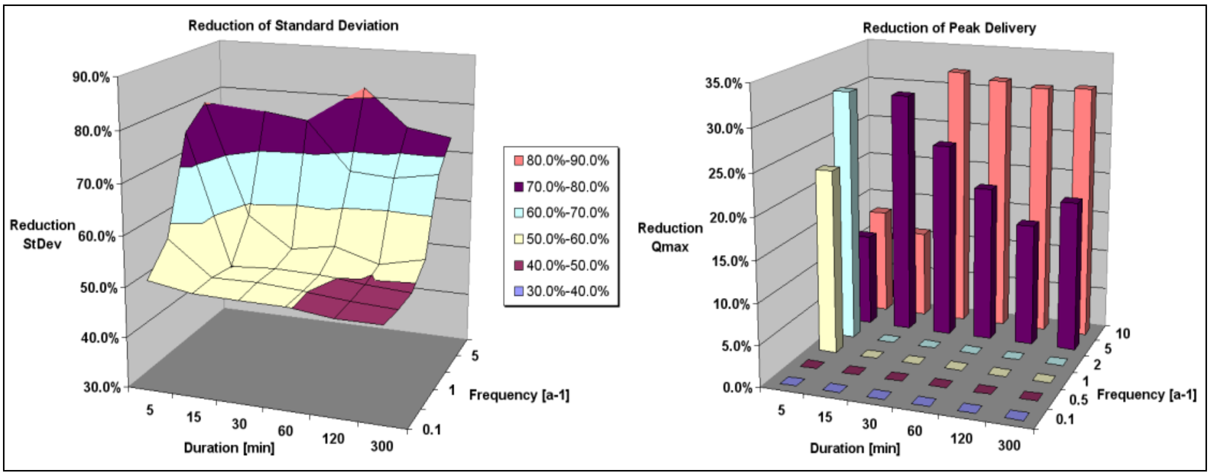


Figure 4.8 Reduction of standard deviation and peak pumpage for catchment Charlottenburg III

Recapitulatory, the analysis of the simulation results shows that a smoothing of pump delivery towards the wwtp by the introduced control concept is only possible if high inline storage capacity is available (here 67.6 m³/ha A_{imp}). If there is enough retention capacity within the sewer network a smoothing of the delivery hydrograph (expressed by the standard deviation) is possible. However, only for low intensity rain events ($n \geq 5\ a^{-1}$) a reduction of the peak pumpage can be achieved.

4.2.3 Summary of the results concerning local control

Since the first days of the Berlin drainage system any drop of wastewater has been pumped outside the city where it once was spread on sewage fields and now is treated by wastewater treatment plants. Nowadays, the control potential of the pumps has been identified. By variably throttling the outflow from the sewer networks high inline storage capacities can be activated and controlled. In doing so, the delivery of the wastewater towards the wwtp can be regulated.

In the framework of this chapter a level dependant real-time control for sewage pump stations has been introduced. The idea is to build an easy function that allows continuously varying the pumpage and implicitly managing the available inline storage capacities. The objective is to smooth the delivery towards the treatment plant to avoid peak loads. Furthermore, adverse effects that are linked to inline storage activation like deposition of sediments, formation of hydrogen sulphide and the increased risk of cso activity shall be minimised.

An evaluation of the control concept has been carried out on the basis of simulations with a spectrum of synthetic rain events of constant intensity. The evaluation bases on two indicators, the reduction of peak pumpage and the reduction of the standard deviation of the delivery hydrograph referred to the reference regime.

The simulation results show that an improvement of the flow characteristic towards the wwtp is hardly possible if there is not a high retention capacity within the sewer networks. For catchments with low (5.6 m³/ha A_{imp}) or medium (48.6 m³/ha A_{imp}) inline storage capacities no significant reduction of the standard deviation could be achieved. A reduction of the peak flow was not possible at all.

For a catchment with high inline storage capacities (67.6 m³/ha A_{imp}) a significant reduction of the standard deviation was possible. Furthermore, a reduction of the peak pumpage could be achieved. However, a significant improvement was possible only for low intensity rain events ($n \geq 5\ a^{-1}$).

Recapitulatory, the evaluation shows that it is possible to manage available inline storage volume by applying the control function. But only if there is an adequate retention volume of around 60.0 m³/ha A_{imp} or more a significant improvement of the flow characteristic towards the wwtp is possible. Table 4.3 gives an overview of the Berlin combined sewer catchments and the accordant inline storage volumes. It is indicated that only two catchments have the potential for the introduced control concept.

Pump station	Total area A_E ha	Impervious area $A_{E,Mi,k,b}$ ha	In-pipe storage volume V_k m³	Specific in-pipe storage volume $V_{S,k}$ m³/ha	Potential
APW Kreuzberg - Bln I	334	244	5000	20	no
HPW Kreuzberg - Bln II	749	483	8580	18	no
APW Kreuzberg - Bln III	452	303	12560	41	no
APW Mitte - Bln IV	967	566	2900	5	no
HPW Friedrichshain - Bln V	806	507	14330	28	no
APW Tiergarten - Bln VII	414	242	11760	49	no
APW Tiergarten - Bln VIII	721	388	9770	25	no
APW Wedding - Bln IX	769	312	5880	19	no
APW Wedding - Bln X	458	290	1620	6	no
APW Prenzlauer Berg - Bln XI	1318	275	5340	19	no
APW Friedrichshain - Bln XII	606	336	5180	15	no
APW Neukölln I	574	394	7970	20	no
APW Neukölln II	420	117	2740	23	no
HPW Spandau I	2134	170	5900	35	no
HPW Wilmersdorf	3120	996	5990	6	no
HPW Charlottenburg I	1309	806	8610	11	no
APW Charlottenburg III	891	216	14600	68	yes
APW Ruhleben	708	31	2020	65	yes

Table 4.3 Combined sewer catchments of the Berlin system, accordant inline storage volumes and indication of the potential for the LDPC concept

4.3 Global pump station control

In this chapter a concept for a global control of the sewage pump stations at the catchment of wwtp Ruhleben will be introduced. After the derivation and definition of the rtc concept the model-based evaluation will be described.

4.3.1 Derivation of the control algorithm

The primary function of a combined sewerage is to collect sewage and convey it to the treatment plant. Flooding within the drainage area shall be avoided and discharges over combined sewer overflows into the receiving water shall be kept down to a minimum. As the majority of load situations usually depart from the design load the combined sewerage will rarely fulfil its function optimally. The non-uniform spatio-temporary distribution of rainfall can lead to local overload of the system. At the same time elsewhere within the sewerage transport and storage capacities may be under-utilised.

The objective of real-time control is to influence and hence to even up the highly unsteady processes within the sewage system so that the above-mentioned adverse effects only occur after full utilisation of collection and storage capacities. Moreover, negative effects shall occur preferably where damage is slight (Schilling, 1996).

Concerning rtc systems there are three groups of elements that play an important role:

- The constructional assets like collectors, branchings, retention tanks, CSOs or throttles where flow processes take place.
- The actuators like sluice gates, weirs, valves or pumps, which influence the flow processes.
- The sensors, controllers and data transmission systems, which provide the necessary information to control the actuators.

In Berlin the pump stations have been identified as the central actuators to affect the system processes. In case of rainfall the stations control the delivery of combined water to the wastewater treatment plants. Hence, the pumps act as throttles on the outflows of the collection systems. In doing so, and due to very low sewer gradients, storage volume can be activated within the sewer networks.

The basic idea for the control algorithm is to achieve a uniform utilisation of the different storage facilities throughout the total system by controlling the pump stations in a global coordinated manner (global control). The following details will illustrate the model-based heuristic approach to derive the corresponding control algorithm. The material used has been:

- InfoWorks model (see chapter 3.3)
- Data from two rain events (04.07.2003 and 29.08.2003)
- Pump data (for the two events) that have been used as reference

Data from 15 rain gauges have been used for the study. The first rain event (04.07.2003) had a duration of 28 hours and 10 minutes with several breaks in between and on average a total rain height of 4.75 mm. The event intensity can be specified as low.
The second event (29.08.2003) is characterised by two rain periods. The first having a duration of 6 hours and 45 minutes, the second having a duration of 5 hours. On average the total rain height was 19.55 mm. At Heiligensee the second rain period had a return frequency of $n=0.2\ a^{-1}$.

Data from the pump stations (pumpages) have been prepared in form of rtc commands to the InfoWorks model to simulate the real operation of the system (reference). Figure 4.9 gives an impression of the real and simulated delivery and the usual dry weather inflow to pump station Bln X for the event from 04.07.2003.

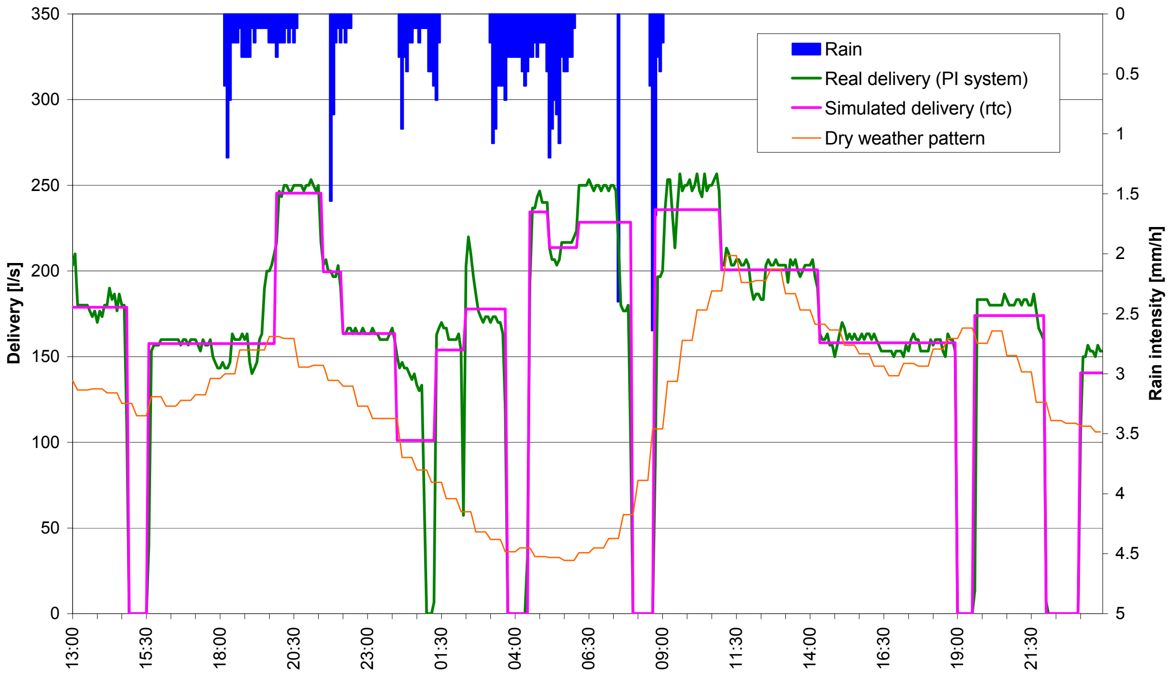


Figure 4.9 Real and simulated delivery and usual dry weather inflow to pump station Bln X for event 04.07.2003 illustrating the simulation of the reference scenario

The basic parameter that has been used was the storage utilisation ratio $\eta_{V,i}$ [%] of the sewer systems. The setpoint for the individual storage utilisation was the overall utilisation ratio (over all catchments), calculated in turn by the average of the capacity-weighted individual storage utilisations.

The delivery from those catchments has been increased that had a storage utilisation above the average utilisation ratio and vice versa. Weyand (1992) proposes an adjustment of the individual utilisation if the deviation from the average is higher than $\Delta\eta_{V,i}$ = 5 %. Here, the pumpage was modified if the deviation was higher than $\Delta\eta_{V,i}$ = 10 % or if there was a significant deviation in the gradient of the storage utilisation from the average utilisation curve.

The storage utilisation at the catchments was calculated on the basis of the known storage characteristics. The storage characteristic gives the activated volume within a sewer network as a function of the water level at the pump station (see chapter 3.3). To reduce the calculation effort the curves have been discretised as illustrated in figure 4.10. The relation between activated and totally available storage volume gives the storage utilisation ratio.

$$\eta_{v,i} = \frac{V_i(h)}{V_{tot}} \cdot 100$$

where

$\eta_{V,i}$ = Storage utilisation ratio of a catchment in %
V_i (h) = Activated storage volume of a catchment in m³
V_{tot} = Totally available storage volume of a catchment in m³

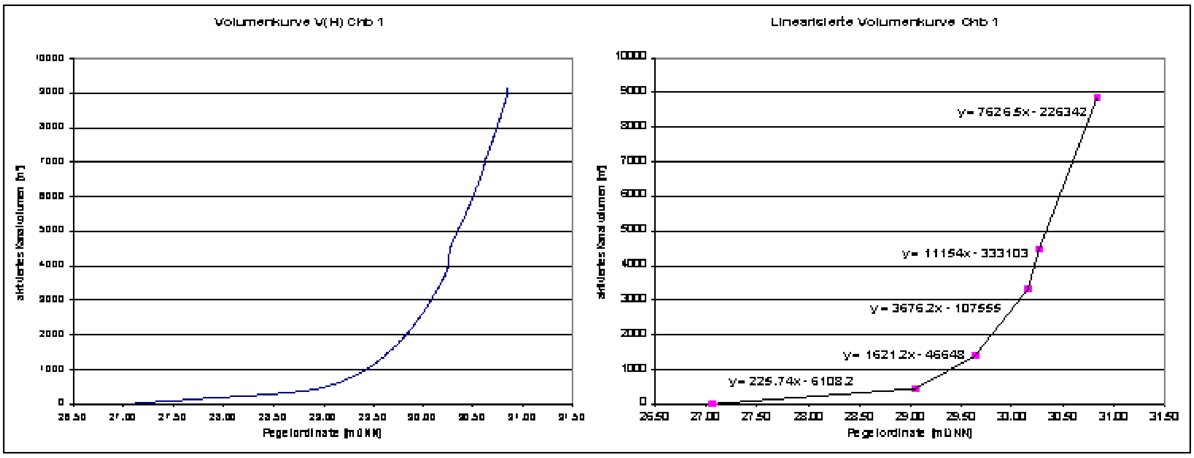


Figure 4.10 Continuous and discretised storage characteristic V(h) for catchment Charlottenburg I

An utilisation of 0 % represents an empty sewer network, whereas an utilisation of 100 % stands for a completely filled network and represents the beginning of combined sewer overflows. Under this approach the utilisation ratios of the catchments can be observed and compared over the entire simulation period.

The standard deviation can be used to illustrate the statistical spread of a value set. Here, the standard deviation of one catchment's utilisation (over the time) from the overall utilisation is used.

$$StDev_i = \sqrt{\frac{\sum_{i=1}^{n}\left(\eta_{V,i} - \eta_{V,m}\right)^2}{n-1}}$$

where

$StDev_i$ = Standard deviation of the utilisation of catchment i from the overall storage utilisation

$\eta_{V,i}$ = Storage utilisation ratio of a catchment in %

$\eta_{V,m}$ = Overall (average) storage utilisation ratio in %

n = Number of time steps in the value set

Figure 4.11 shows the standard deviation for the different catchments for the two rain events. For the smaller event from 04.07.2003 a good equalisation of the standard deviations around 10 % can be achieved. Through this combined sewer overflows could be prevented almost completely.

For the bigger event from 29.08.2003 the modification of the standard deviations of catchments Berlin II and IV are not satisfactory. In both cases, the individual utilisation is much higher than the overall one. The over-utilisation of catchment Bln IV can be explained by its low specific storage capacity of 5 m³/ha. At catchment Bln II the maximum storage ordinate has been set according to the crest of cso 78 that acts as an internal weir for the charging of RÜB Urbanstraße. This relatively low ordinate results in a low storage capacity. A similar situation (charging of storm water tank by gravity) can be found at catchment Bln IX.

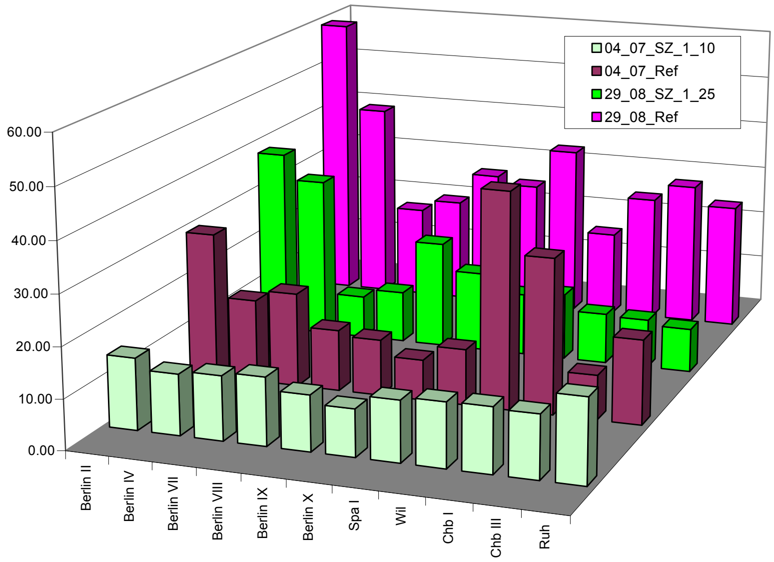


Figure 4.11 Standard deviation of the utilisation of storage capacities at different subcatchments of the Berlin drainage system for the rain events 04.07.2003 and 29.08.2003 applying manual control (Reference) and global control (Huß, 2005)

Figure 4.12 shows the standard deviation of the utilisation ratios of all catchments from the overall utilisation for each time step of the rain event from 29.08.2003. Due to the high intensity of the event it was not possible to balance significantly the utilisation of the storage capacities during the rain peaks. However, shortly after the peaks an improvement compared to the reference scenario can be observed.

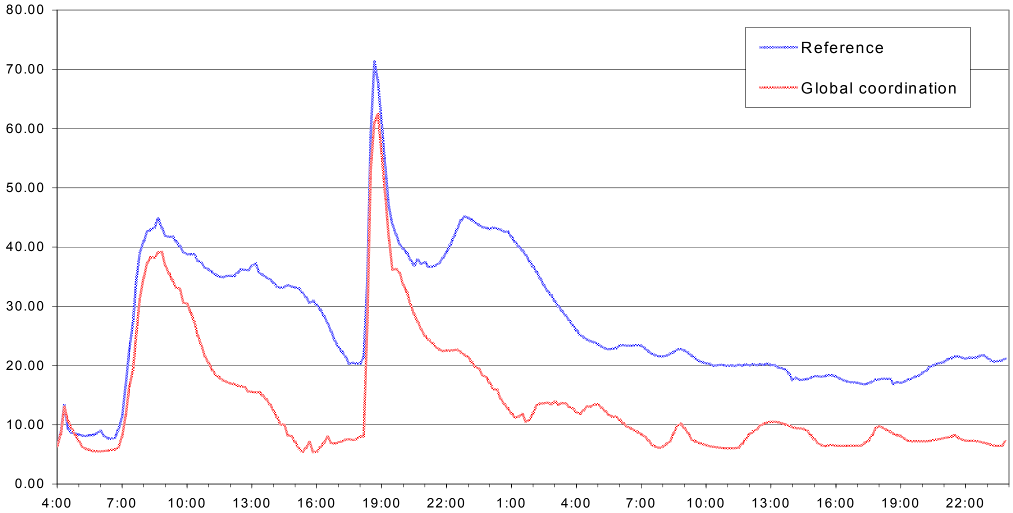


Figure 4.12 Standard deviation of the storage utilisation of all catchments for event 29.08.2003 for real situation (Reference) versus global coordination

Concerning sewer overflows, for the event from July 2003 a reduction of discharge volume from $V_{E,Ref}$ = 11.455 m³ to V_{E,SZ_1_10} = 12 m³ could be achieved. For the event from 29.08.2003 a significant reduction was not possible (from $V_{E,Ref}$ = 294.531 m³ to V_{E,SZ_1_25} = 293.204 m³). However, by equalising the utilisation of storage capacities the total duration of overflows could be reduced from 17830 minutes to 16610 minutes.

In both cases, the total delivery of combined water to the wwtp has been increased. For the event from 04.07.2003 combined water delivery of the reference scenario was $Q_{M,Ref}$ = 389.697 m³. After modifying the pump station control Q_{M,SZ_1_10} = 403.610 m³ have been delivered. This corresponds to an increase of ΔQ_M = +3,6 %. For the event from 29.08.2003 combined water delivery has been increased from $Q_{M,Ref}$ = 556.552 m³ by ΔQ_M = +3,4 % to Q_{M,SZ_1_25} = 575.635 m³.

4.3.2 Definition of the control algorithm

Based on the afore-mentioned considerations an algorithm was defined and formulated. The algorithm follows the ideas of Weyand (1990). It aims at a uniform utilisation of the storage volumes of the drainage systems by controlling the pump stations with respect to the measurement of water levels throughout the system. Water levels have been chosen as input for the control concept since these measurements are already available at the system and very robust.

The developed control algorithm is based on the imagination that the total storage volume of each of the subsystems can be considered as a tank or a reservoir. Assuming hydrostatic water level propagation within the collectors, the fill level of the virtual reservoir can be derived by the currently measured water level at the accordant pump station and the storage characteristic of the sewers. In addition the fill level of storm water tanks, if existing, are taken into account translated into the accordant volume and added to the in-pipe storage volume.

For the evaluation of the rtc algorithm also in-pipe storage capacities of the wastewater sewers have been taken into account where available and consequently activated during rainfall. In the course of an implementation this concept of sanitary sewer storage surely has to be coordinated with the sewer operator.

- The first step is to measure the **water levels** at the pump stations and the storm water tanks and also the current **pumpages**. These values are used as **input** to the algorithm.
- By interpreting the water levels a rain situation is detected. The control mode is switched to **“global”** if at least one catchment shows a **critical water level** and consequently rainfall inflow.
- The currently activated storage volume at each catchment is calculated by means of the accordant system’s storage characteristic, which is a function of the water level (see chapter 3.3). The **storage utilisation ratio** is defined as the currently activated storage volume in relation to the total available storage capacity.

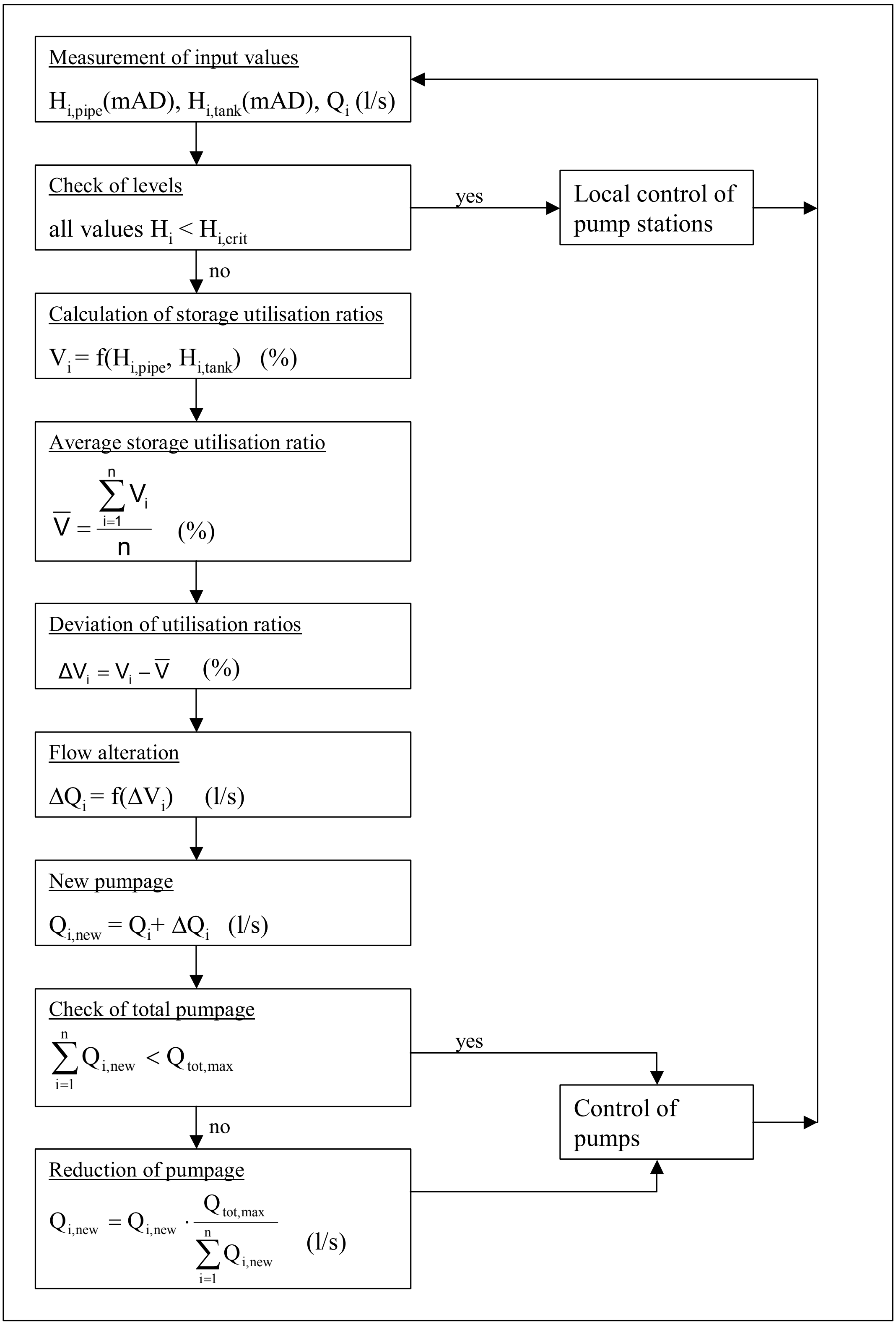


Figure 4.13 Flowchart of the developed control algorithm

- After calculating the **average storage utilisation ratio** of the entire system, the **deviation** of the utilisation ratio of each subsystem from the average can be determined.
- Finally the **change in pumpage** is carried out proportionally to the respective deviation of storage utilisation.
- Limits are set to both, the delivery from each individual pump station (technically maximum pumpage) and the total pumpage of the stations (according to the **capacity of the wwtp**). The wwtp's inflow capacity is defined as a fixed value derived from its hydraulic capacity. If the accumulated flow from the all pump stations exceed this inflow capacity, the settings of the pumps are adjusted accordingly to meet the set point.

Figure 4.13 describes the applied control algorithm in detail. Figure 4.14 gives a schematic impression of its functioning considering as example the catchments of Berlin IX, Berlin X and Heiligensee.

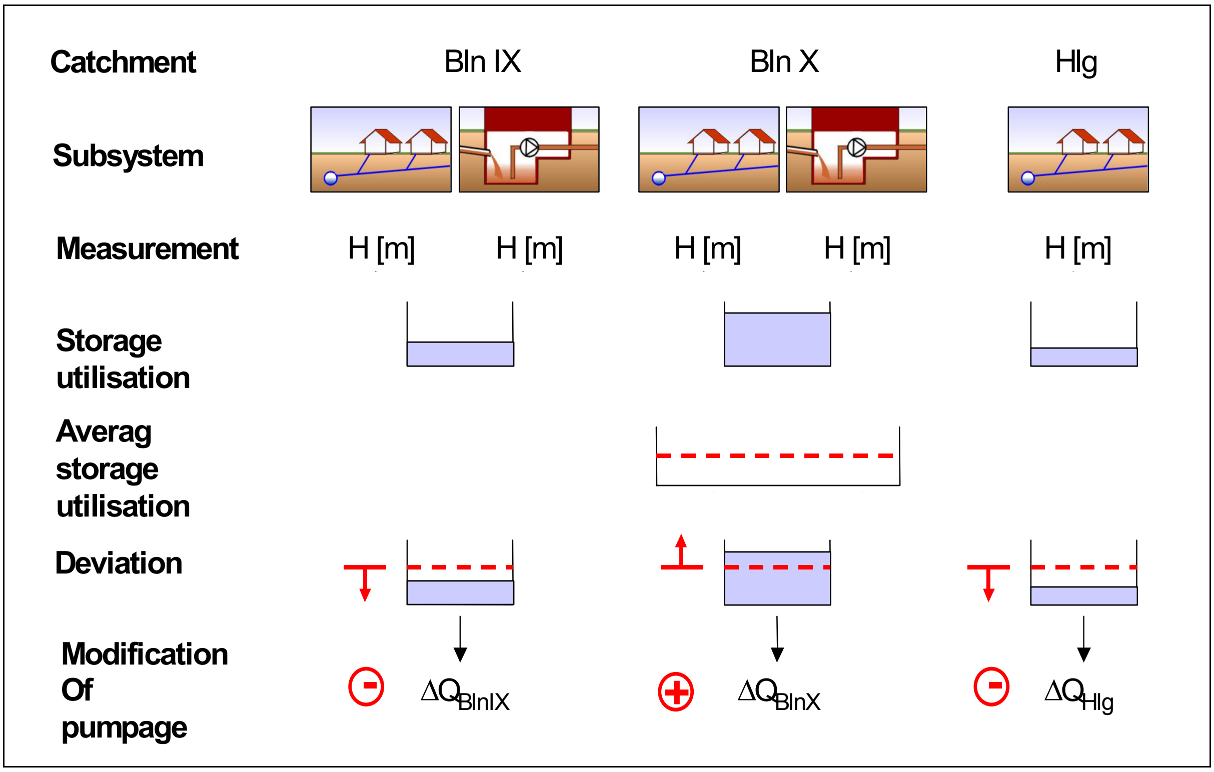


Figure 4.14 Schematic overview of the basic idea of the developed global control algorithm

At appendix 7 and 8 the InfoWorks code of the rtc algorithm and an explanation of the used variables and parameters (indicating sensitive parameters) are specified. Accordingly, the modification of the following parameters has an influence on the effectiveness of the algorithm. A sensitivity analysis has not been carried out.

- Water level at pump station indicating rainfall inflow (causing a switch into global control mode)

- Water level at pump station or tank corresponding with total utilisation of storage capacity
- Weighting of the storage utilisations of the different subsystems to give priority to certain catchments
- Relation between deviation of storage utilisations and modification of pumpage
- Minimum delivery of pump station during a rain event
- Maximum delivery of pump station
- Maximum total pumpage according to wwtp capacity

Further enhancements of the algorithm could consider the following parameters. However, the effect of taking into account those parameters has not yet been studied.

- Free storage volume of a subsystem relating to the contributing impervious area (currently available specific storage capacity)
- Current rainfall. The rain height multiplied with the impervious area of a subsystem can be added to the current storage utilisation to forecast the future storage situation
- Rainfall forecast (on the basis of radar measurements). Same principle of consideration as stated above.
- Discharge volume of combined sewer overflows. Where maximum storage capacity is exceeded the cso volume can be taken into account. Thus, discharges from different subsystems can be balanced.
- Discharge load of combined sewer overflows. Where maximum storage capacity is exceeded the cso load can be taken into account. Thus, discharged loads from different subsystems can be balanced. However, an implementation of this idea into operation will be difficult due to the susceptibility of pollutant online sensors to the harsh sewer environment.

During this study the parameter deviations from the set points are taken into account in a proportional way (proportional coefficient). However, also an integral and differential control behaviour or a combination could be possible (integral coefficient, differential coefficient, PID).

4.3.3 Model-based evaluation of the control concept

The described global control algorithm has been applied on the basis of the ISM model for the catchment of wwtp Ruhleben (see figure 4.15). Catchment Bln I and Bln IV have not been taken into account since they did not supply wwtp Ruhleben during the period that was chosen for evaluation. After defining evaluation criteria different scenario analyses have been carried out on the basis of long time simulations. The definition of the criteria, the different scenarios and results are stated.

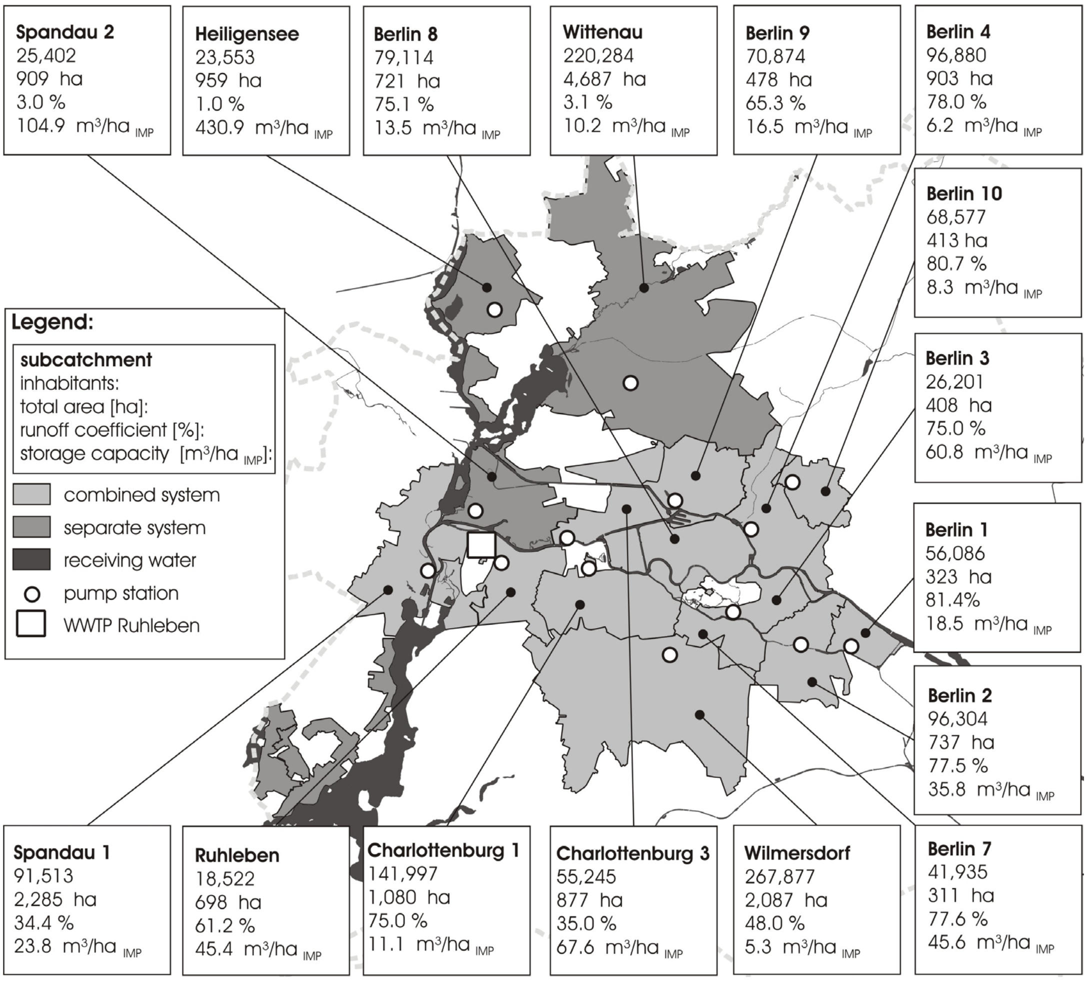


Figure 4.15 Overview of the sub catchments supplying wwtp Ruhleben

4.3.3.1 Description of the analysed scenarios

For the scenario analyses two different states of the combined sewer network, different variants of the global control concept and two different sets of data for rain input have been used.

Combined sewer network

To evaluate the benefit from the conception for combined sewerage rehabilitation that will be realised in the near future two different states of the combined sewer network have been compared. The network model *Ruhleben_2004* describes the current situation of the combined sewerage. The details are given in chapter 3.3. The network model *Ruhleben_2010* describes the future situation. Dry weather inflow is assumed as being unchanged but the following measures of rehabilitation have been taken into account in addition to network *Ruhleben_2004*:

- Levels of all cso crests have been adjusted according to rehabilitation plans
- Switch-on and switch-off levels for the pumps that charge storm water tanks have been modified according to rehabilitation plans
- Bln II: Control of sluice gates at pump station and at both storm water tanks has been modified

- Bln IX: Storm water tank has been modeled
- Bln X: Storage device “Bornholmer Str.” and reconstruction of “cso 27” has been modeled
- Wilmersdorf: Storm water tank “Wilmersdorf” and control of sluice board “Schöneberger Entlastungskanal” have been considered

The results for the network comparison are given in chapter 4.3.3.2.

Control concept

To evaluate the global control concept three different scenarios are compared.

Scenario *local* describes a local control of the pump stations. Here, pumps of different capacity are switched on and off according to the water level at the pump well (step regime). The maximum pumpage of each station is set according to the stipulations of the water authority (Wasserbehördliche Erlaubnis). For combined sewer pump stations this pumpage is usually twice the dry weather peak flow (2*$Q_{d,16}$). During peak rain situations the sum of the pumpages can temporarily exceed the current capacity of wwtp Ruhleben. In reality in this situation the operator intervenes manually to adjust the inflow to the wwtp capacity.

Scenario *global_a* describes a global control of the pump stations according to the introduced algorithm. The pumps are adjusted continuously. The maximum pumpage of each station is set to the technically possible capacity of the installed pumps. On average, this capacity exceeds the maximum pumpage of scenario *local* by 31 % (see Table 4.4). However, due to the pressure situation in the pipes during peak pumpage of several stations there are limitations to the maximum delivery. During peak rain situations the sum of the pumpages (= inflow to wwtp Ruhleben) is adjusted to the maximum value according to scenario local (7650 l/s).

Pump station	**$Q_{d,16}$ [l/s]**	**$Q_{r,Ruh}$ [l/s]**	**Q_{max} [l/s]**	**ΔQ_{max} [%]**
Chb I	450	900	1100	22%
Chb III	125	200	400	100%
Ruh	114	200	500	150%
Bln VIII	231	690	1000	45%
Bln IX	228	450	600	33%
Bln X	183	370	600	62%
Spa I	243	600	1000	67%
Spa II	119	250	250	0%
Wit	657	950	950	0%
Hlg	54	150	150	0%
Bln II	287	570	700	23%
Bln III	200	400	500	25%
Wilm	773	1450	1700	17%
Bln VII	209	420	500	19%

Table 4.4 Comparison of pumpage according to the stipulations of the water authority and technically maximum

During peak rain situations the sum of the pumpages can temporarily exceed the current capacity of wwtp Ruhleben. Therefore, an implementation of scenario *global_a* will only be possible after upgrading wwtp Ruhleben (from 6700 l/s to 7650 l/s).

Scenario *global_b* describes a global control of the pump stations according to the introduced algorithm. The pumps are adjusted continuously. The maximum pumpage of each station is set to the technically possible capacity of the installed pumps. On average, this capacity exceeds the maximum pumpage of scenario *local* by 31 % (see Table 4.4). However, due to the pressure situation within the pipes during peak pumpage of several stations there are limitations to the maximum delivery.
In contrast to scenario *global_a* during peak rain situations the sum of the pumpages (= inflow to wwtp Ruhleben) is adjusted to the mean capacity of the plant (6700 l/s).

The results of evaluation are stated in chapter 4.3.3.3. Table 4.5 gives on overview of the scenarios.

Scenario	Pump station	Wwtp inflow	Comment
Local	Local control	Qmax = 7650 l/s	Corresponds to a fully local automation of the pump stations (step-control without manual intervention). Leads temporarily to overloading of wwtp (current capacity).
global_a	Global control	Qmax = 7650 l/s	Global control of the pump stations. Leads temporarily to overloading of wwtp (current capacity).
global_b	Global control	Qmax = 6700 l/s	Global control of the pump stations. Corresponds to an optimum coordination between pump stations. Wwtp inflow is adjusted to current capacity.

Table 4.5 Description of the three different control scenarios

Rain data

Two different sets of rainfall data have been used as simulation input. To take into account the influence of non-uniform rainfall distribution the original set of data includes one year of rainfall (July 2004 – June 2005) from 12 rain gauges (rain: *N12*):

- Bln IX
- Bln VIII
- Bln X
- Charlottenburg I

- Heiligensee
- Neukölln I
- Spandau II
- Spandau III
- Spandau Ia
- Spandau Vc
- Waidmannslust a
- Wilmersdorf

The time period from July 2004 to June 2005 was chosen because a large number of digitally measured data from rain gauges were available. The rain gauges taken into account are all belonging to BWB. They are located on the enclosures of pump stations. The data are transmitted to the management system of the operating department. Lacks of rain data had been adjusted when information from neighbour stations existed. The total amount of precipitation measured by the rain gauges over this one year period ranges between 348.7 and 523.8 mm. The mean annual rainfall at Berlin amounts to 600 mm.

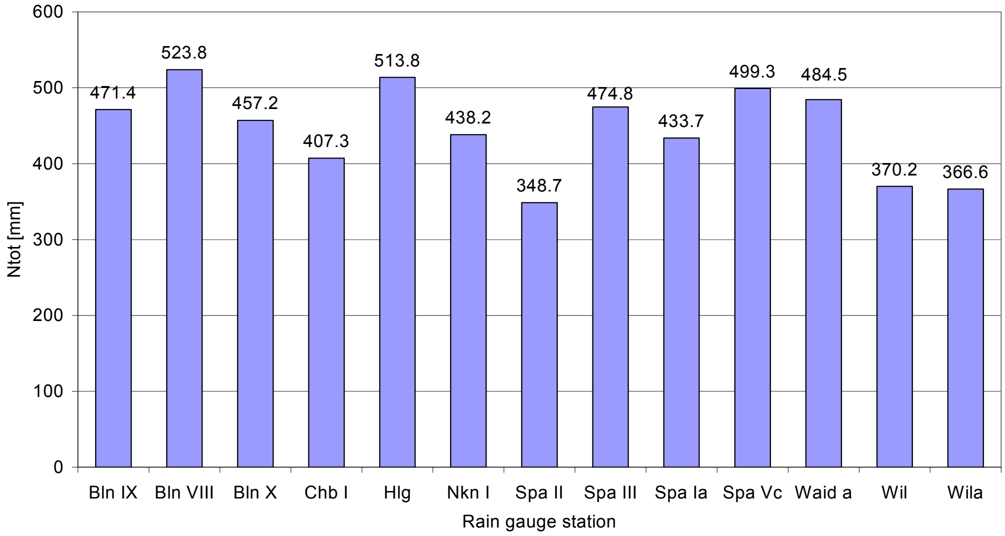


Figure 4.16 Sum of precipitation from 1st July 2004 to 30th June 2005 at each rain gauge within the catchment area of wwtp Ruhleben

Although the total amount of rainfall during this period was low, some large events occurred. At the 20th July 2004 an intensive rain event at the centrally located pump station Berlin X showed an amount of 17 mm during 65 minutes, which corresponds to a frequency of 1a $^{-1}$. At the 5th May 2005 two rain gauges in the northwest, amidst the separate system, showed intensities of 16 to 29 mm in half an hour, which corresponds to a frequency of 0,5 to 0,05 per year. To point up the allocation of the rainfall over the considered period figure 4.17 shows the amount of the solitary events of the gauge at pump station Berlin VIII, Tiergarten for the simulated period.

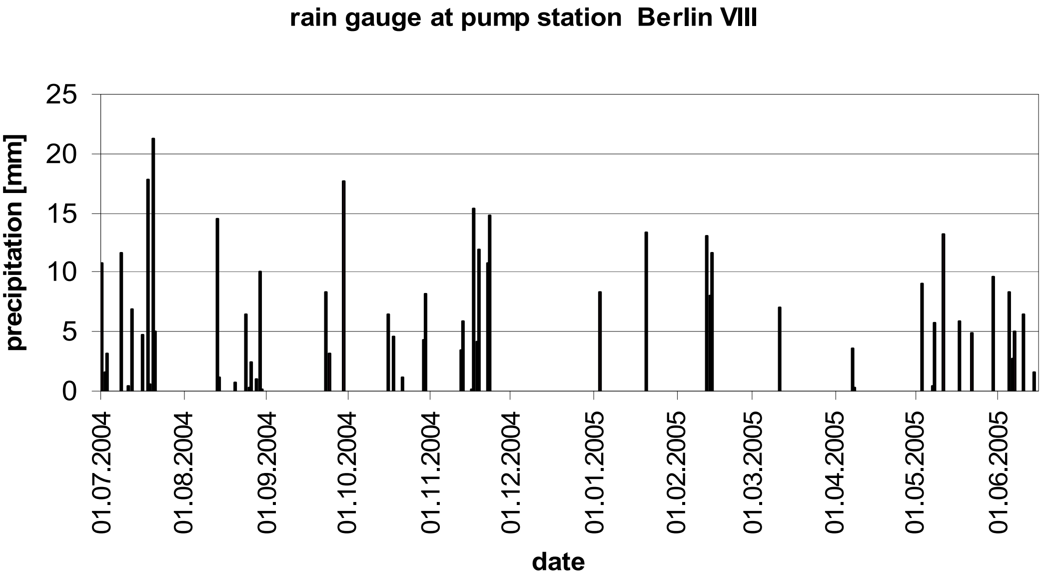


Figure 4.17 Chronology and size of rain events at a central pump station amidst the combined sewer system for the simulated times series

To derive the influence of each rain gauge on the sewage system in terms of run-off volume affecting the sewer system, a weighting of the rain heights by the dedicated contributing impervious areas is shown in figure 4.18. The partitioning of the entire catchment area into sub areas, dedicated to each rain gauge, was determined by Thiessen polygons (see appendix 9).

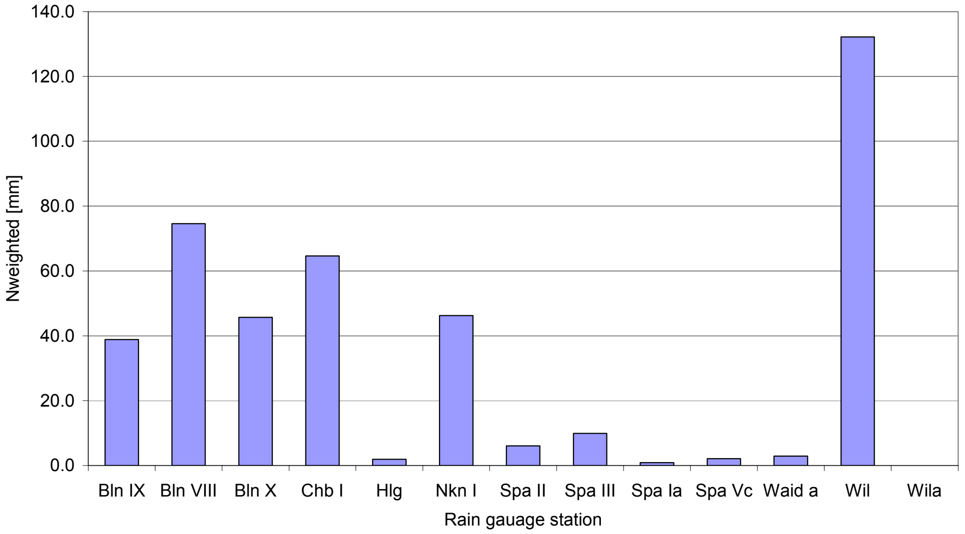


Figure 4.18 Area-weighted sum of precipitation from 1st July 2004 to 30th June 2005 at each rain gauge within the catchment area

The weighting factor describes the relation between the contributing impervious area dedicated to a gauge in relation to the contributing impervious area of the whole catchment area. The product of this weighting factor and the rainfall height is shown in figure 4.18. The height of the bars expresses the proportion of the effect of rain (falling on the related Thiessen polygon) on the amount of runoff. As one can see, the runoff from separated sewage systems has only little effects on the impact of runoff into the entire system, because the contributing impervious areas caused by misconnections are little in relation to a combined system. The high bar at the Wilmersdorf gauge reflects the high fraction of impervious area of combined and stormwater sewers within this Thiessen polygon that contributes to the modelled sewer system.

For the evaluation of the conception for combined sewerage rehabilitation (chapter 4.3.3.2) the original rainfall data *N12* has been reduced to a spatially uniform set of data (rain: *N1*). Therefore, only data from the Bln IX gauge, which is located in the centre of the entire catchment area, has been used (N_{tot} = 471.4 mm).

4.3.3.2 Evaluation of the conception for combined sewerage rehabilitation

As described above, two different states of the combined sewer network have been taken into account to analyse the benefit from the conception for combined sewerage rehabilitation. Hereafter, the results are stated. The used model components and data are:

- Network: *Ruhleben_2004* versus *Ruhleben_2010*
- Rtc: *local*
- Rain input: *N1*

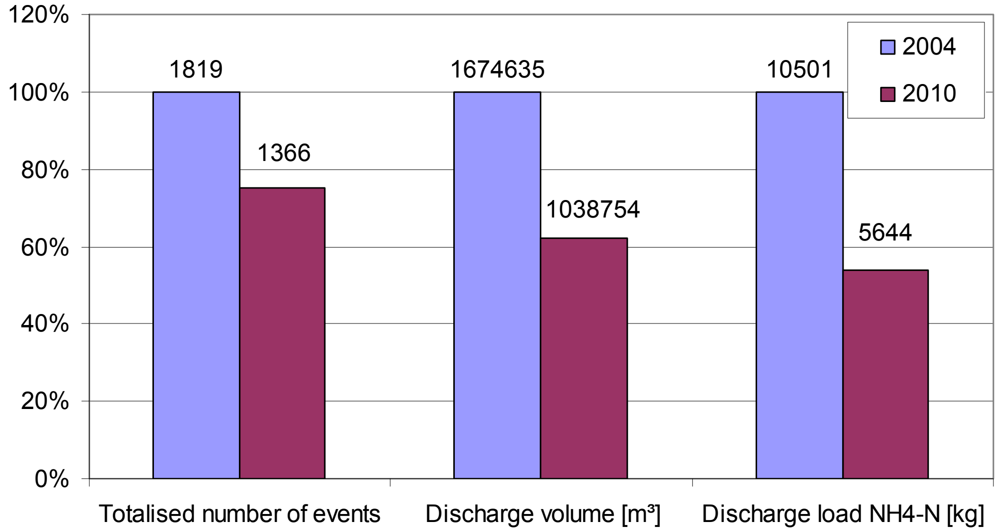


Figure 4.19 Simulated improvement of combined sewer overflows from 2004 to 2010 by implementing the conception for combined sewerage rehabilitation

As shown in figure 4.19 by implementing the conception for combined sewerage rehabilitation significant improvements are achieved concerning the number of discharge events (= sum of events at any single cso), total discharge volume and discharge load (ammonium load is illustrated).

Obviously, the reduction of the number of events lags behind the reduction in volume. This discrepancy can be explained by the strong influence of catchment Charlottenburg I on the number of discharge events. 60 out of 281 combined sewer overflows (21 %) are situated in Charlottenburg I. Since major measures of rehabilitation in this catchment will be implemented not until 2010 the number of events in 2010 differs only slightly from the number in 2004. This circumstance combined with the strong influence of the catchment lead to a subproportional reduction of the number of discharge events in comparison to the reduction of volume.

Furthermore, figure 4.19 points up that the reduction in NH_4-N load is higher than that in volume (46 % compared to 38 %). This phenomenon can be ascribed to the increased storage capacity within the main collectors that is provided by the measures of the rehabilitation program. Higher storage volume leads to a higher portion of rainwater that is stored in the sewers before overflow happens. Consequently, a higher dilution of wastewater and lower concentrations of combined water entering the rivers can be observed (5.4 mg NH_4-N/l in 2010 compared to 6.3 mg NH_4-N/l in 2004). Table 4.6 points out some characteristic figures of improvement in relation to rainfall and runoff volumes.

Parameter	**2004**	**2010**
Rain height [mm]	471.4	471.4
Runoff volume [m³]	14800972	14800972
Specific runoff volume [m³/ha$_{imp}$]	3547	3547
Totalised number of events	1819	1366
Discharge volume [m³]	1674635	1038754
Specific discharge volume [m³/ha$_{imp}$]	401	249
Discharge rate [%]	11%	7%
Discharge load NH_4-N [kg]	10501	5644
Specific discharge load NH_4-N [kg/ha$_{imp}$]	2.5	1.4

Table 4.6 Comparison of simulation results for state 2004 and state 2010 of the combined sewerage

Compared to the simulations of the single combined sewer catchments that have been carried out in the framework of the conception for rehabilitation (e.g. bpi, 1992) the values for the discharge rate (11 % and 7 %, respectively) appear to be very low. The official directive of the federal state of Berlin from the year 1998 demands that discharge rates of combined sewer overflows and storm water tanks shall fall below 25 % of the average annual rainfall runoff volume. Most of the catchments will meet this demand not until full implementation of rehabilitation measures. So, how can the low values from the ISM model be explained?

The reason for the discrepancy can be found in the different data basis. For the rehabilitation calculations a significant planning horizon has been chosen to take into account future urban developments (based on the Berlin land utilisation plan). These estimations involve an increase of population and impervious area compared to the current situation. In contrary, the ISM model has been calibrated recently and reflects the current situation. Consequently, the ISM simulations lead to lower wastewater and rainfall runoff volumes finally causing lower discharge rates.

Table 4.7 points out distribution and main areas of cso activity in the year 2004. Obviously, major discharges come from those catchments with a high portion of impervious area (Bln II, Charlottenburg I and Wilmersdorf). The high discharge portion of catchments Bln IX and Bln X can be explained by low specific storage capacities at these systems.

To point up the improvements from 2004 to 2010 within the single catchments specific discharge volumes and NH_4-N loads (related to A_{imp}) are illustrated in figure 4.20. By considering specific discharges the results are made uninfluenced by the size of impervious area and consequently comparable. One can see that catchments Bln II, Bln IX, Bln X and Charlottenburg I have outstanding discharge behaviours. Further on, major improvements are achieved especially at these catchments and in Wilmersdorf. The improvement in Charlottenburg I is lagging behind since major measures of rehabilitation in this catchment will be implemented not until 2010.

Catchment	Impervious area	Number of events	Discharge volume	Portion of total discharge	Discharge load NH_4-N	Portion of total discharge load NH_4-N
	[ha]		$[m^3]$	[%]	[kg]	[%]
Bln II	483	477	327883	20%	1545	15%
Bln III	303	103	27931	2%	81	1%
Bln IX	312	77	234789	14%	1134	11%
Bln VII	242	30	26995	2%	125	1%
Bln VIII	388	91	103142	6%	432	4%
Bln X	290	162	166972	10%	1431	14%
Charlottenburg I	806	558	493757	29%	3770	36%
Charlottenburg III	152	21	3077	0%	8	0%
Ruhleben	31	3	1998	0%	3	0%
Spa I	170	92	38881	2%	124	1%
Wilmersdorf	996	205	249210	15%	1847	18%
Sum	**4173**	**1819**	**1674635**	**100%**	**10501**	**100%**

Table 4.7 Distribution of discharges on the different combined sewer catchments in the year 2004

Summarised, the results show that already the measures of combined sewerage rehabilitation that are planned until 2010 will lead to an improvement of the cso situation. Especially, those catchments with high specific discharge volumes and loads benefit from the measures.

Furthermore, the simulations with the currently calibrated ISM model point out that the discharge rates are below those that have been calculated during the conception of rehabilitation. This can be explained by a discrepancy in the data basis of the models.

The conception for combined sewerage rehabilitation has to be seen as the basic and major action towards a state-of-the-art system and a sustainable water pollution control. It is the fundament for further measures like global real-time control.

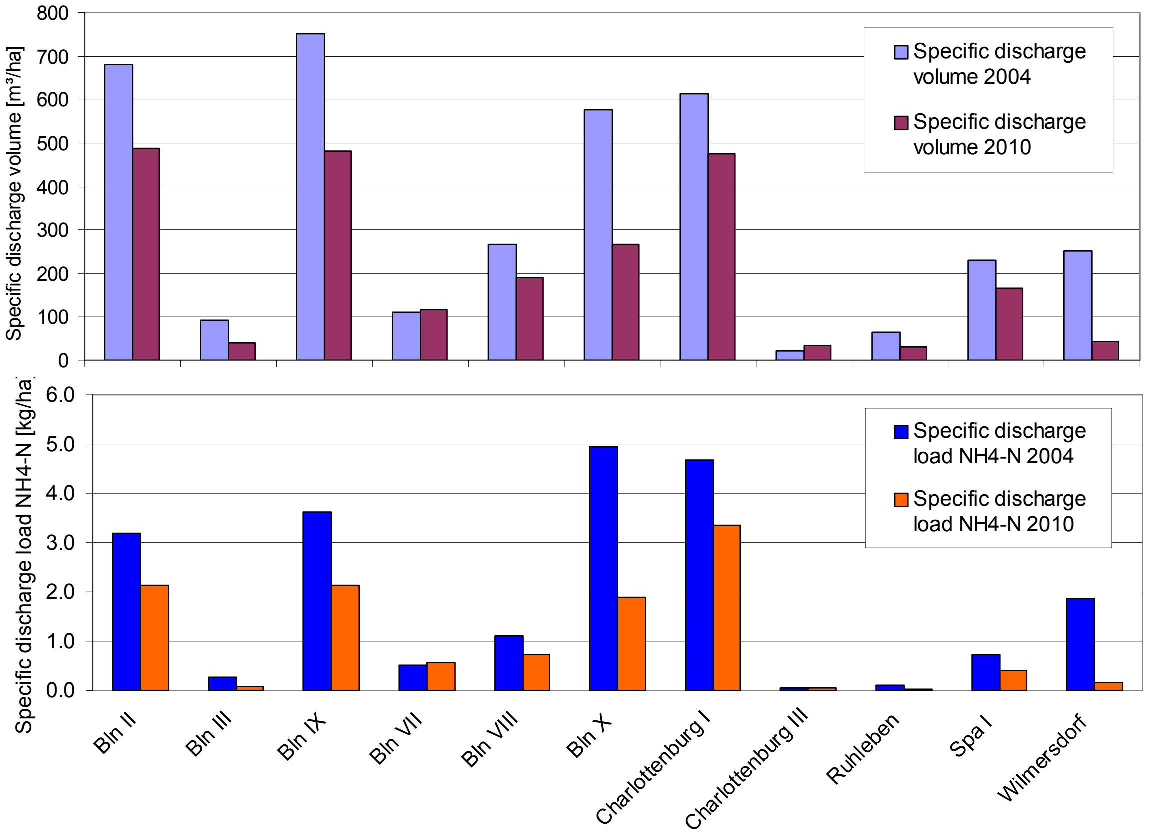


Figure 4.20 Simulated improvement of combined sewer overflows from 2004 to 2010 concerning specific discharge volumes and NH_4-N loads

4.3.3.3 Evaluation of the global control concept

As described above, two different variants of the global control concept have been studied and compared with a local control of the pump stations. Hereafter, the results are stated. The used model components and data are:

- Network: *Ruhleben_2010*
- Rtc: *local* versus *global_a* versus *global_b*
- Rain input: *N12*

Storage utilisation

The first criterion for the evaluation of the global control concept is the uniform utilisation of storage capacities throughout the system. It is one of the general objectives of rtc.

The rain-duration-height diagram can give an estimation of those rain events that can be stored in the system if the overall capacity is utilised optimally (Weyand, 1999). Hence, it shows which rain events lead to combined sewer overflow even if the system is controlled optimally. The diagram only gives a rough estimation due to the following reasons:

- Rainfall runoff volume is considered as a uniform impact on the system. Rainfall and runoff peaks at individual catchments are neglected.
- Non-uniform runoff behaviour (runoff formation and concentration) of the different catchments is neglected.
- Storage capacity is considered as uniformly distributed over the system.

However, the rain-duration-height diagram can be used to assess the storage potential of the drainage system for a given rain series. Figure 4.21 shows the diagram for the above-described rainfall series 2004-2005 and the properties of the Ruhleben catchment. The summation of 1 mm of initial losses, the specific storage volume of 2.85 mm (available for rainwater storage) and the rainwater capacity of the wwtp of 0.23 mm/h give a critical rainwater line. Any rain event that is located above this line will definitely cause overflows. Under these simplified assumptions 18 rain events of this period (36 %) have definitely been uncontrollable.

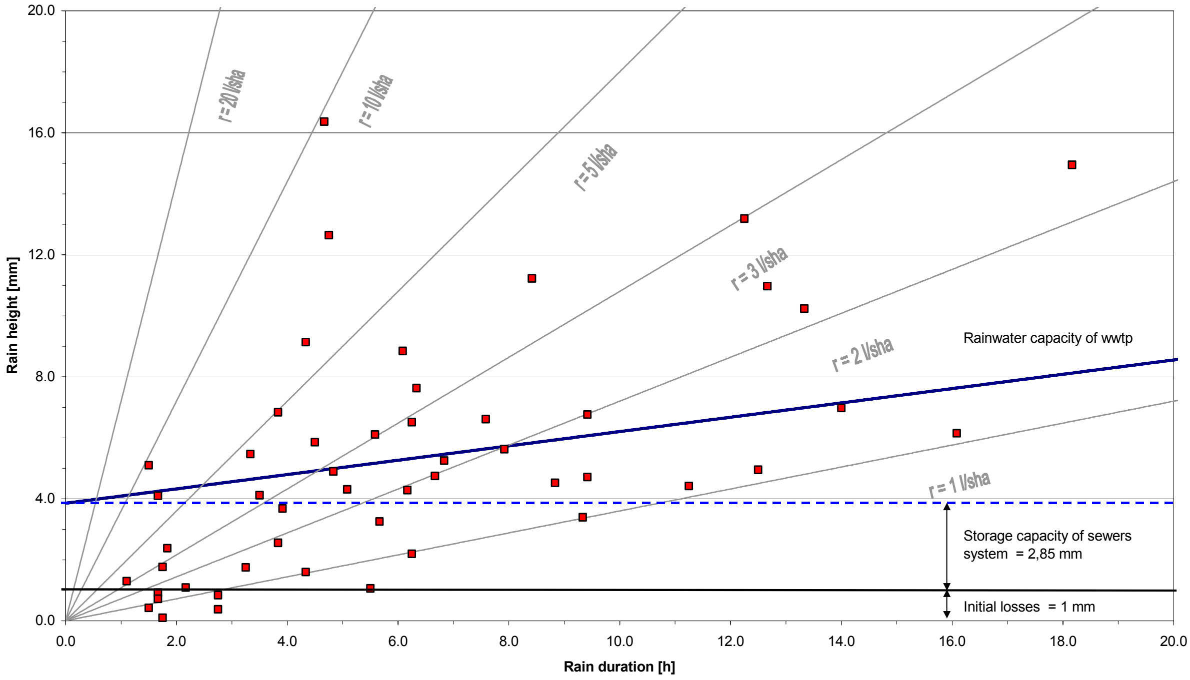


Figure 4.21 Rain-duration-height diagram based on the rain events July 2004 - June 2005 and the properties of catchment Ruhleben. Additionally, for orientation different rain yield factors (l/(s*ha)) are illustrated.

According to chapter 4.3.1 the uniform utilisation of storage capacities can be expressed by means of the standard deviation of the single storage utilisations (of the different subcatchments) from the average utilisation (throughout the total system).

Figure 4.22 shows the utilisation of the different storage capacities under global control (global_b) for the rain event from 29.08.2003. It can be observed that at some catchments combined sewer overflows cannot be avoided (utilisation exceeds 100 %, e.g. Bln VIII and Bln IX) although the overall storage utilisation is below 100 % and at some catchments capacities are still free (e.g. Bln VII, Heiligensee and

Spandau II). This situation can be explained by the very unequal relation between available storage volume and rain impact for the individual catchments.

On average, the standard deviation of the single storage utilisations from the average utilisation is around 14 %. That shows that it is possible to achieve a uniform utilisation of storage capacities by means of the control algorithm.

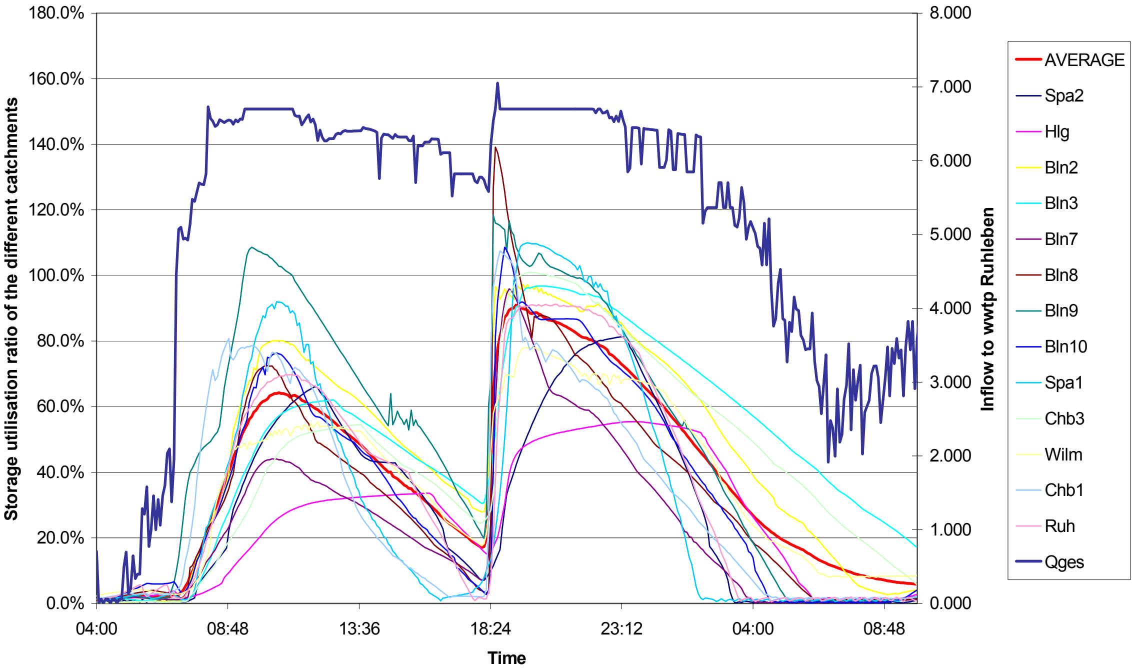


Figure 4.22 Utilisation of the subcatchment's storage capacities under global control (global_b) for the rain event from chapter 4.3.1 (29.08.2003)

Combined sewer overflows

The effect of the rtc strategy on discharges from combined sewer overflows plays a prominent role since they present a highly dynamic impact on the water body. The simulations show that on average during periods of cso 2.5 t COD/h enter the receiving water (scenario *local*). Compared to that load the continuous impact from the wwtp effluent is only 0.4 t COD/h. The resultant concentrations are illustrated in figure 4.23.

Moreover, due to the high fraction of biodegradable organic substrate the impact from combined sewer overflows is of special relevance. In contrary to the refractory COD from wwtp effluents, 60 % of the COD from combined sewer overflows are biodegradable leading to extreme oxygen depletion within the receiving water (Seggelke, 2002).

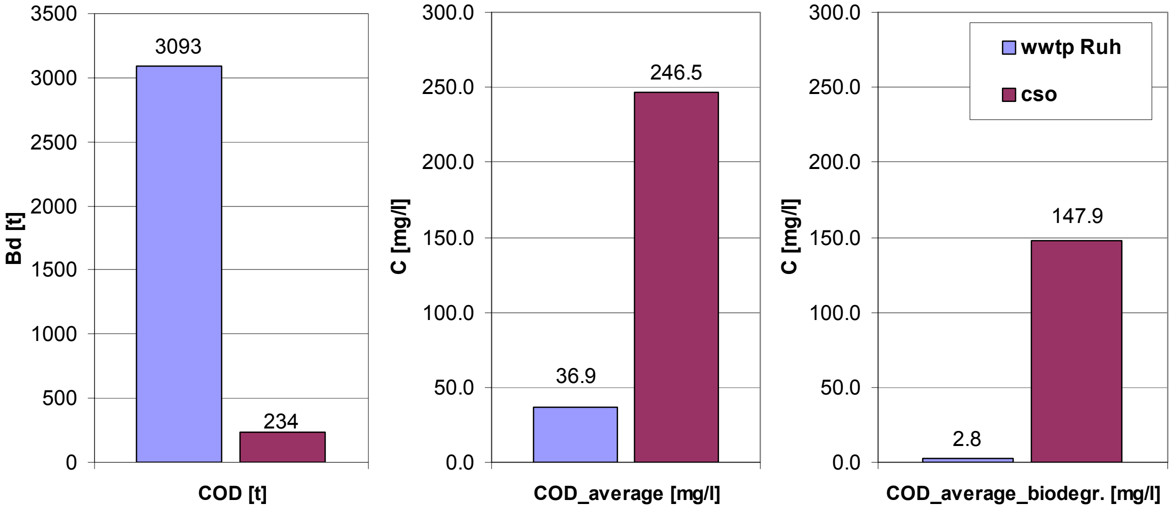


Figure 4.23 Simulated COD loads and accordant average concentrations from combined sewer overflows versus wwtp effluents for the period July 2004 - June 2005

The analysis of the entire period July 2004 – June 2005 shows that the control concept *global_b* and even more the control concept *global_a* lead to a reduction of combined sewer overflows compared to a *local* control (see Figure 4.24).
By applying concept *global_b* the reduction ranges between 8 % for volume and 22 % for NH_4-N load. Due to the higher total delivery at scenario *global_a* the improvements are more significant. Here, the reduction ranges between 19 % for volume and 32 % for NH_4-N load.

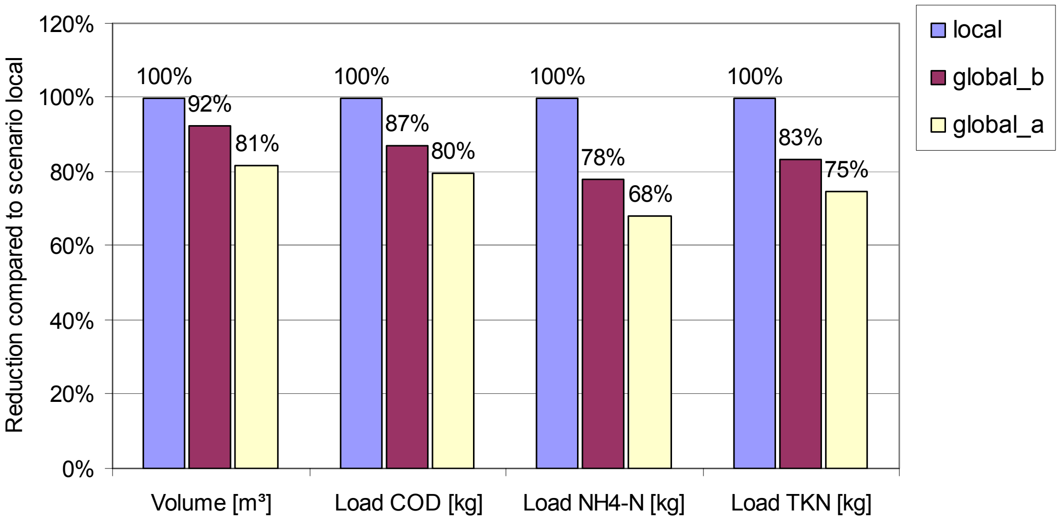


Figure 4.24 Comparison of total discharge volumes and loads (COD, NH_4-N and TKN) for scenario *local*, *global_b*, *global_a*

In general, the reduction rate of the pollutant loads is higher than that of volume. This phenomenon can be explained by the difference in pollutant concentrations during discharge for the different scenarios. Besides the avoidance of discharge, a reduction in discharge concentrations is achieved through global control. Due to an

optimum utilisation of storage capacities a higher portion of rainwater is stored in the sewers before overflow happens. Consequently, a higher dilution of wastewater and lower concentrations of combined water entering the rivers can be observed (4.6 mg NH_4-N/l for scenario *global_a* compared to 5.5 mg NH_4-N/l for scenario *local*).
Compared to COD, the NH_4-N concentrations of surface runoff are very low in relation to that of wastewater (see table 4.8). Hence, the above-described effect has a much stronger influence on the improvement concerning ammonium than on that concerning COD. The TKN runoff concentrations and consequently the TKN improvement can be classified in between.

	Wastewater	**Surface runoff**	**Relation**
COD [mg/l]	996	106	9.4
TKN [mg/l]	80	2.5	32.0
NH4-N [mg/l]	57	1.5	38.0

Table 4.8 Relation between wastewater and surface runoff concentrations for parameters COD, TKN and NH_4-N

As illustrated in figure 4.25 the improvement of the cso situation is more or less uniformly distributed over the entire system. Only at catchment Wilmersdorf scenario *global_b* leads to a significant increase of discharge. Also for scenario *global_a* a slight increase can be found. This circumstance can be ascribed to the low maximum capacity of the Wilmersdorf pump station in relation to the pumpage under *local* control. In comparison to the average over-capacity of 31 % this station is only able to exceed the *local* control value by 17 %. Obviously, it will be necessary to adjust the control algorithm to remedy this imbalance in discharge behaviour.

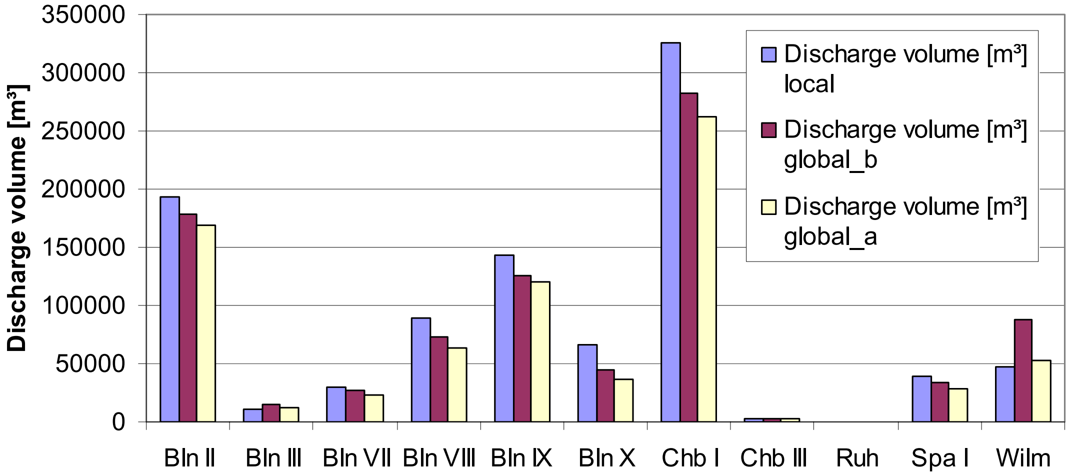


Figure 4.25 Comparison of discharge volumes at the different catchments for scenario *local*, *global_b*, *global_a*

In contrary to the regionally uniform distribution of improvements, there is a focus of improvement concerning the type of discharge assets. Figure 4.26 shows the distribution of discharges between storm water tanks and combined sewer overflows (2:1) illustrating the dominance of storm water tanks. One can see that major improvements are achieved at reservoirs; reductions at sewer overflows are marginal.

In Berlin the level for the filling of a storm water tank (whether by gravity or by a pump) is always below the lowest cso crest. This constructional situation (realised throughout the entire combined sewer system) is derived from the general conception for the Berlin storm water tanks, which aims at a filling of the tanks before discharge over combined sewer overflows happens. Consequently, discharge events are dominated by tank overflows. A reduction and temporal shortening of these events as realised by the global control will firstly and chiefly affect the situation of the storage tanks.

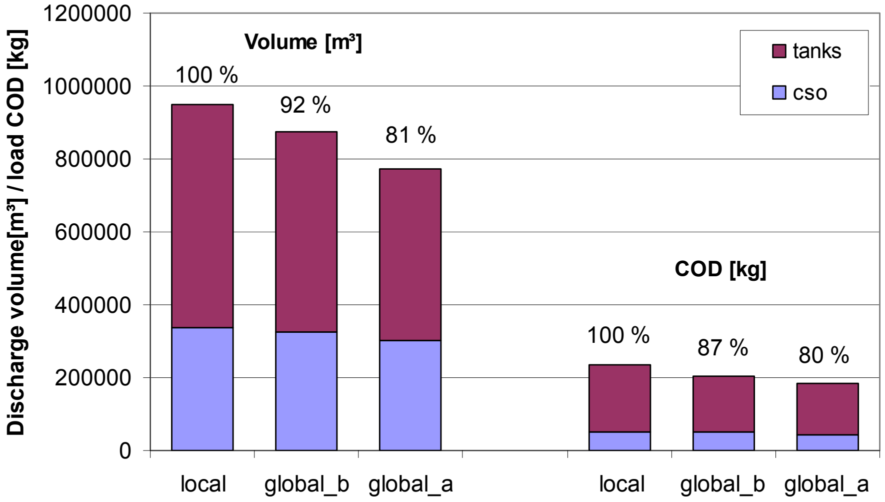


Figure 4.26 Comparison of discharge volumes and COD loads for scenario *local*, *global_b*, *global_a* divided into contributions from storm water tanks and combined sewer overflows

A commonly known characteristic of real-time control is that the effectiveness of rtc measures decreases with increasing intensity of rain impact on the system. Figure 4.27 illustrates this system behaviour.

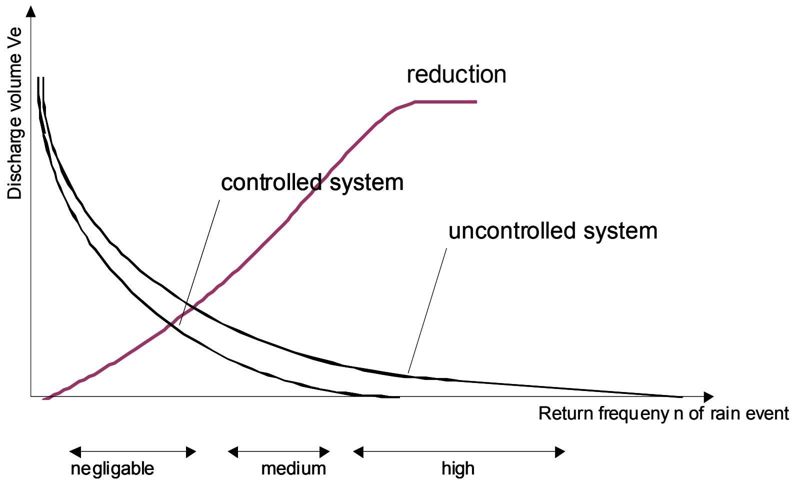


Figure 4.27 Characteristic scope of effectiveness of real-time control, following (DWA, 2005)

The same characteristic can be found for the discharge events of the simulated time series July 2004 – June 2005. Figure 4.28 shows the reduction of discharge volume by applying global control (scenario *global_b*) in relation to the discharge volume under *local* control for all rain events. The dots in magenta reflect those events where overflow happens far upstream and uninfluenced from the pump station at hydraulic bottlenecks. Although being very small in volume, those events cannot be controlled. Table 4.9 gives an overview of the combined sewer overflows where these events occur.

The yellow dots show those discharge events that can be ascribed to locally extreme rain peaks leading to uncontrollable situations in the accordant sewer network. The remaining blue dots show the scope of effectiveness of the applied global control strategy illustrating decreasing benefit with increasing intensity of impact on the system.

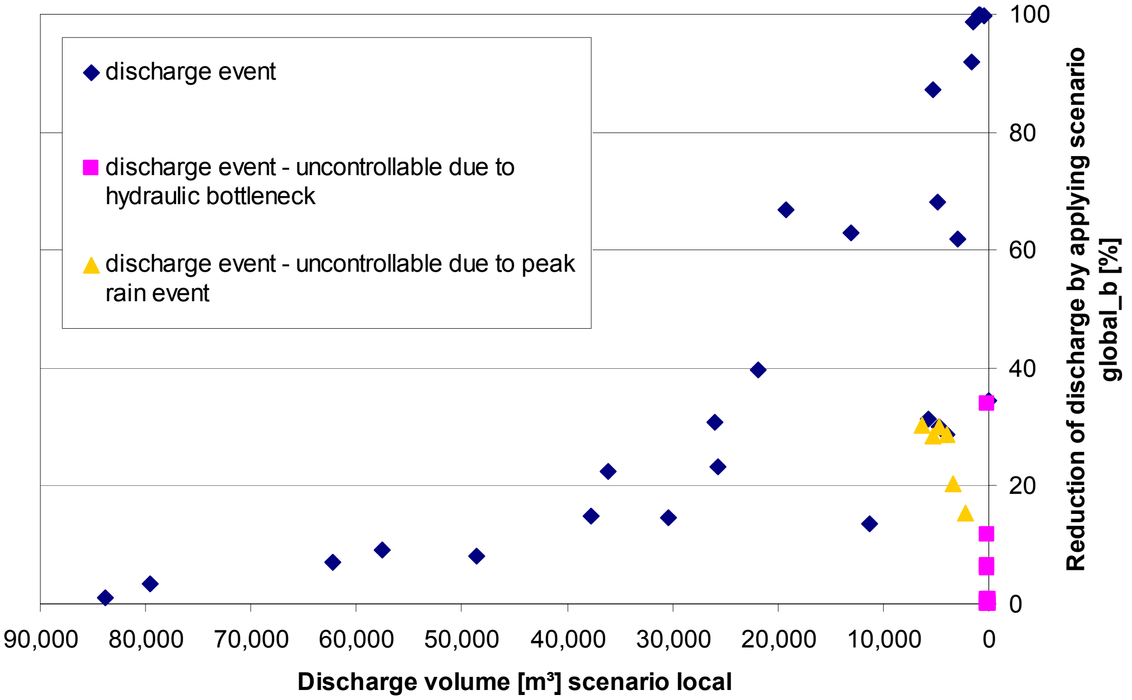


Figure 4.28 Illustration of the effectiveness of the applied rtc concept

Catchment	CSO	Comment
Bln II	RUE 11	Weir crest at 32.67 mAD, above influence of pump station (32.10 mAD). Discharge due to hydraulic bottleneck.
Spandau I	RUE 7	Weir crest at 31.49 mAD, above influence of pump station (30.54 mAD). Discharge due to hydraulic bottleneck.
Spandau I	RUE 25	Weir crest at 32.32 mAD, above influence of pump station (30.54 mAD). Discharge due to hydraulic bottleneck.
Charlottenburg I	RUE 6	Cso at subcatchment Charlottenburg Ia, out of influence from pump station. Discharge due to hydraulic bottleneck.
Charlottenburg I	RUE 12	Weir crest at 31.77 mAD, above influence of pump station (30.84 mAD). Discharge due to hydraulic bottleneck.
Charlottenburg I	RUE 36	Weir crest at 32.00 mAD, above influence of pump station (30.84 mAD). Discharge due to hydraulic bottleneck.
Charlottenburg I	RUE 37	Weir crest at 31.88 mAD, above influence of pump station (30.84 mAD). Discharge due to hydraulic bottleneck.

Table 4.9 Combined sewer overflows that cannot be controlled by the pump station regime

To illustrate the impact on the different Berlin watercourses the overflows have been aggregated corresponding to the discharge location. In summary it can be said that the reduction in volume and pollutant load caused by the application of global management strategies has a remarkable effect on the watercourses Spree, Panke, Hohenzollernkanal and Havel (an overview is illustrated in appendix 10). A slight increase of cso volume and cod load into the canalised Landwehrkanal can be registered for the *global_b* strategy compared to the *local* strategy. No load reduction for NH_4-N and TKN regarding the discharges into this watercourse can be achieved by scenario *global_b*. This circumstance can be explained by the unfavorable performance at catchment Wilmersdorf that has been illustrated before (see figure 4.25).

Regarding scenario *local* river Spree receives the main impact from cso in terms of both, volume and load. For this watercourse a *global* strategy has the most beneficial effect. This results from the high rate of enhancement of the maximum delivery of all regarding pump stations under global control in relation to the maximum flow for the *local* scenario. The mean increase of the maximum pumpage from the four catchment areas, which discharge into the Spree, is 50%. Whereas the mean increase of the maximum flow rate of the four catchment areas associated to the Landwehrkanal reaches an amount of only 20%. This low advance arises from the hydraulic limitation of the pressure mains, where those pump stations are connected in a row. To achieve further improvements concerning cso reduction at the Landwehrkanal by a global management, the capacity of those pressure mains needs to be expanded.

Figure 4.29 shows in extracts the distribution of TKN discharges for the studied scenarios. The parameter TKN has a high relevance for the receiving water because it covers the nitrogen fractions ammonium (NH_4) and organic nitrogen. In the water body the organic compounds are hydrolysed to ammonium. Depending on pH and temperature of the environment ammonium in turn can convert to ammoniac (dissociation), which is fish-toxic. Furthermore, the oxidation of ammonium in the water body leads to oxygen depletion.

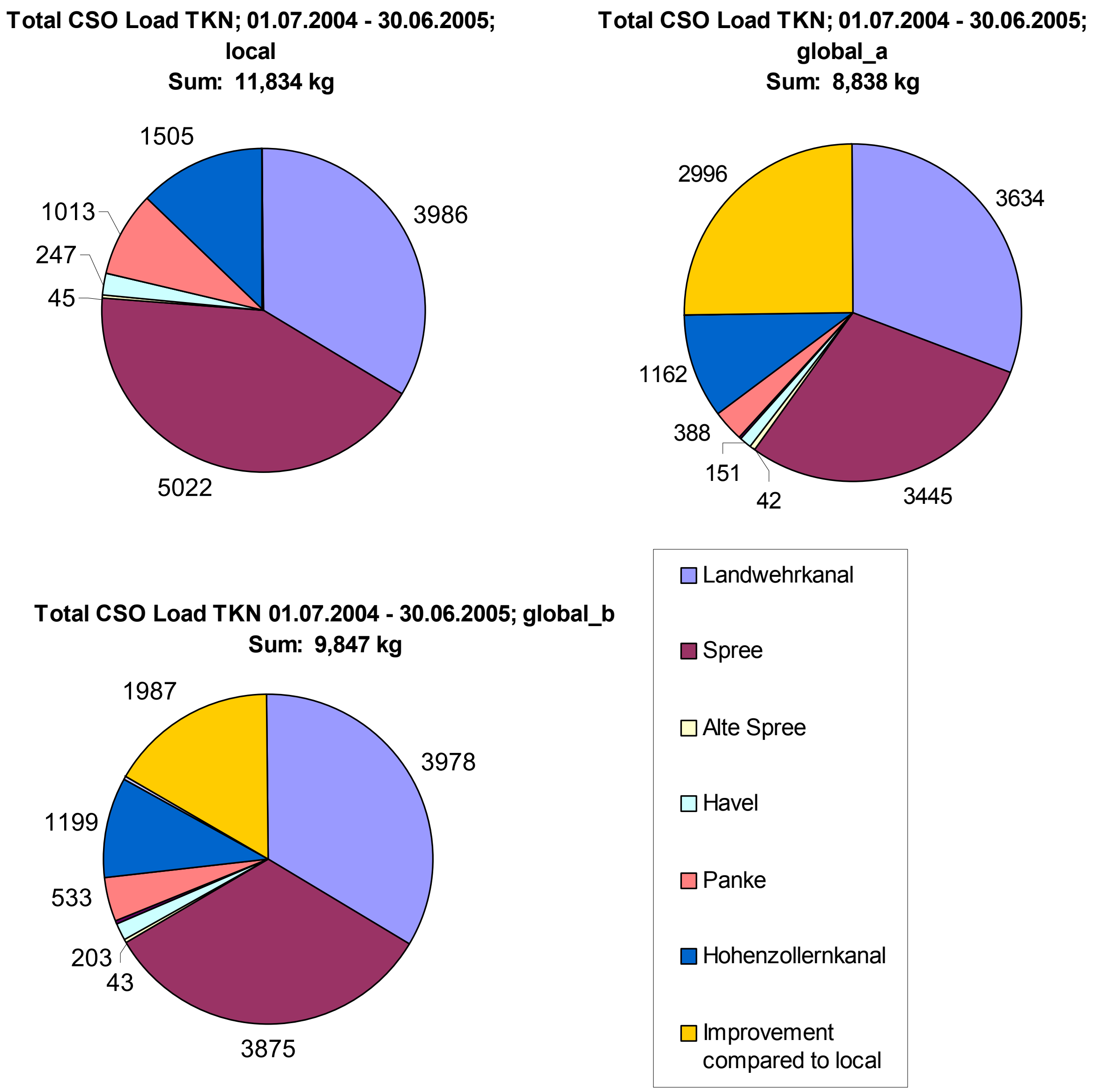


Figure 4.29 Simulated distribution of TKN discharges onto the Berlin watercourses for scenarios *local*, *global_a* and *global_b*

The reduction of emissions into the Panke by 47 % and Hohenzollernkanal by 20 % originates from the raise of the maximum pumpage around 63 % (Berlin X) and 32 % (Berlin IX). The high benefit of the global management strategy at Berlin X derives also from the poor storage capacity, which leads to a high emission rate for scenario *local*. Synonymously, the high magnitude of maximum delivery of pump station Berlin X under global control (see table 4.4) leads to a remarkable compensation.

If the pumpage during global control exceeds the maximum rate defined at the local scenario, there has to be an available sufficient storage capacity at other pump stations to equalise the entire storage utilisation. Table 4.5 lists the available storage volumes of the catchment areas considered at the global control algorithm related to the impervious area.

Pump station	Max storage level [mAD]	Storage volume [m³]	A_{imp} [ha]	Specific storage volume [m³/ha]
Chb I	30.70	10450	720	14,5
Chb III	30.63	17610	216	81,5
Ruh	29.75	1790	38	47,5
Bln VIII	30.80	7836	387	20,2
Bln IX	31.75	11210	312	35,9
Bln X	38.35	4410	290	15,2
Spa I	30.75	6970	160	43,4
Spa II	28.82	2140	20	104,9
Hlg	30.39	3650	8	430,9
BlnII	32.75 (BlnII), 32.80 (BlnVI)	22360	483	46,3
Bln III	32.35	21670	297	73,0
Wilm	32.54	31601	1001	31,6
Bln VII	31,75	7930	241	32,9

Table 4.10 Storage volumes (absolute and specific) considered at the global control algorithm.

The success of a *global* management regarding the emissions into the mentioned watercourses derives mainly from the increase of maximum pumpage in relation to the *local* automatic. A notable benefit to the watercourse can be estimated, if the specific storage volume is low and the increase in pumpage is more than 50% compared to the maximum rate of the *local* scenario. The results of scenario *global_b* show one third less reduction in load versus scenario *global_a*, which underlines again the relevance of the enhancement of the cumulated maximum pumpage.

Besides the reduction of discharge volumes and loads an improvement of the discharge hydrographs through global control can be observed, too. The global control has an influence on flood wave propagation and the runoff peak of discharge events.

Flood wave propagation is defined as the tangent gradient of the increasing wave front as illustrated in figure 4.30. A flat wave will lead to less drift at the riverbed and consequently will have a positive effect on the biocoenosis.

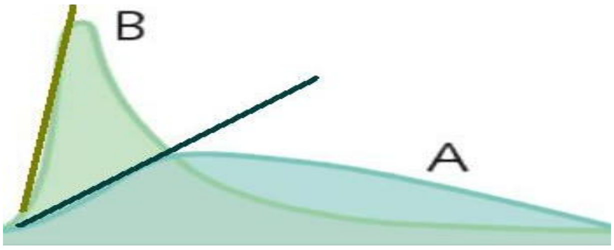


Figure 4.30 Definition of flood wave propagation

Figure 4.31 shows a comparison of aggregated discharge hydrographs for the rain event from 20.08.2004. On the left hand side the aggregation of discharges under *local* control is illustrated. Each color represents the discharge from one overflow device. The sum of the hydrographs gives the total impact on the receiving water. The maximum flow of the second peak reaches 1000 m³/10 min. The same curve can be found in red at the figure on the right hand side. In contrast, the blue lines represent the aggregated discharges under global control (scenarios *global_a* and *global_b*). It can be observed that the peak runoff has been reduced from 1000 m³/10 min to 600 m³/10 min (reduction by 40 %). Furthermore, the flood wave propagation, as defined above, has been improved. This change of runoff characteristics can be found for several cso events when applying global control. It can be assumed that the effect is a reduction of stress on the aquatic fauna.

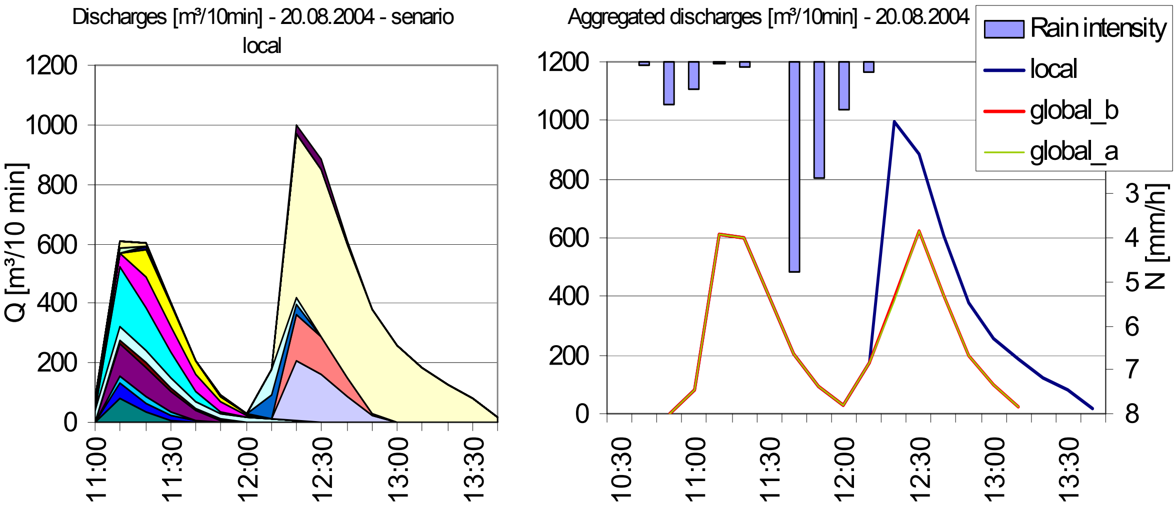


Figure 4.31 Aggregation of discharge hydrographs for rain event 20.08.2004 applying local and global control

Total emissions

A look on the total emissions from combined sewer overflows and wwtp shows that concerning the quantities the load from the plant is highly dominant. Around 93 % of the yearly COD load and 99 % of the yearly N_{tot} load have their origin at the wwtp. The COD and N_{tot} load from combined sewer overflows represent only 7 % and 1%, respectively. That is not astonishing since most of the time (during 90-95 %) there are dry weather conditions and consequently during that time wwtp effluents are the only impact on the receiving water. Furthermore, the global control concept only works during rain situation and does not have an influence on dry weather effluents. Congruously, the influence of global control on yearly total emissions is marginal as illustrated in figure 4.32.

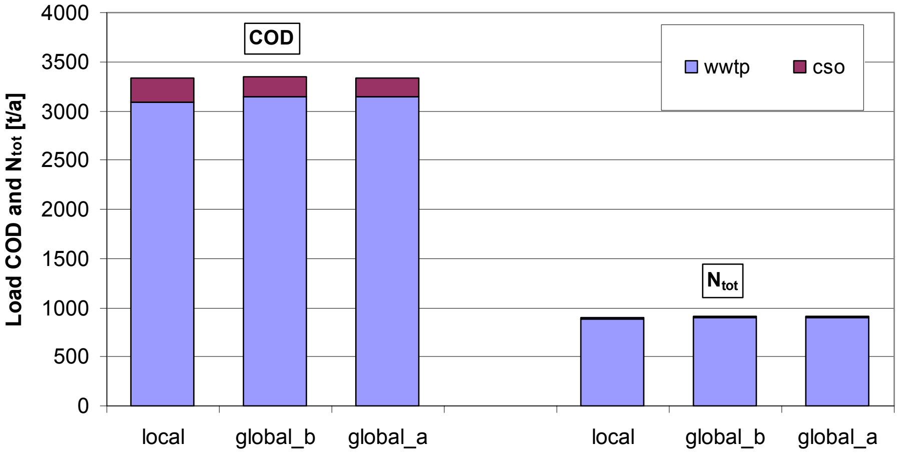


Figure 4.32 Total emissions from combined sewer overflows and wwtp for the simulated period July 2004 – June 2005

When focusing on those periods with maximum discharges the impact from combined sewer overflows becomes obvious. Figure 4.33 shows the average COD discharge from wwtp and cso for the 5 maximal 2h-intervals of the simulated year. Over these intervals the portion of combined sewer overflows in total COD emissions is around 85 %.

Scenario *global_b* leads to a reduction of COD emissions by 3 %. This reduction is realised mainly at the wwtp whereas the improvement of combined sewer overflows is insignificant. This can be explained by the reduction of the maximally allowed inflow to wwtp Ruhleben from 7650 l/s to 6700 l/s under *global_b*-control leading to a reduction of effluent load.

Scenario *global_a* leads to a reduction of COD emissions by 5 % compared to scenario *local*. This improvement can be realised although the load emitted by the wwtp is increased due to longer periods of maximum charging (7650 l/s). However, the reduction in cso load that is associated with the increased delivery is higher and leads to the improvement in total.

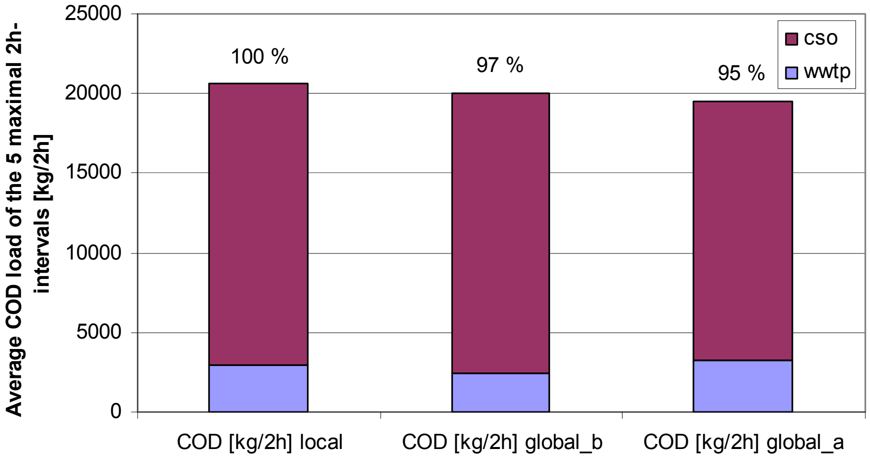


Figure 4.33 Comparison of average discharges of the 5 maximal 2h-intervals of the simulated period July 2004 – June 2005 distinguished between wwtp and cso

Also when looking at single events the portion of combined sewer overflows in the impact on the receiving water becomes obvious. A comparison of the scenarios has been carried out for the rain event from 29.09.2004. An average rain height of 13.7 mm has been measured and the spatial distribution of rainfall was very uniform as illustrated in figure 4.34.

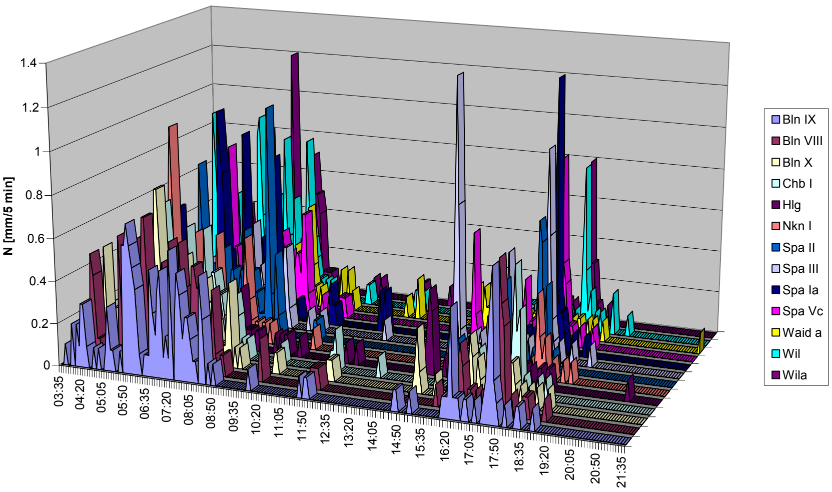


Figure 4.34 Illustration of the rain event from 29.09.2004 showing the spatial distribution of rainfall

Figure 4.35 shows the emissions from sewer overflows and wwtp compared for the three scenarios. The contribution from cso is around 40 % for COD and around 12 % for N_{tot}. The reduction of the loads from sewer overflows for scenario *global_b* is 9 %, for scenario *global_a* is 23 % (both, COD and N_{tot}). These figures correspond to the reductions over the entire simulated period (see figure 4.24).

Concerning total COD emissions, scenarios *global_b* and *global_a* achieve a reduction of 4 % and 6 %, respectively. Concerning total N_{tot} emissions, no improvement at all could be achieved since the influence from cso reductions is too small and is being cancelled by the increase in wwtp emissions.

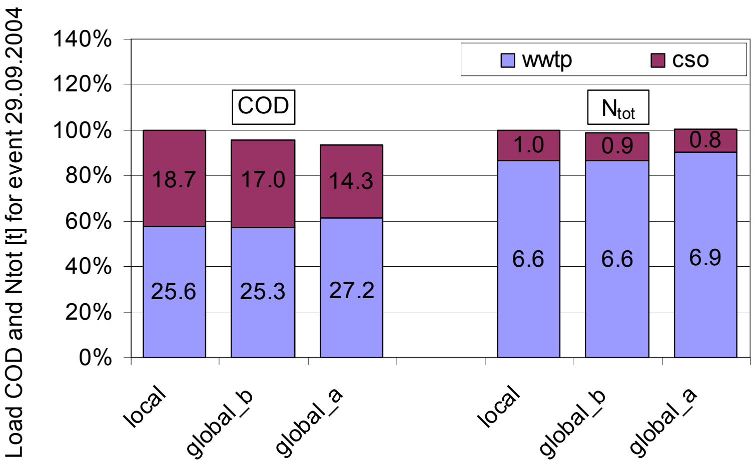


Figure 4.35 Total emissions from cso and wwtp for the rain event from 29.09.2004

For the same event (29.09.2004) figure 4.36 shows the influence of the different control strategies on the inflow to wwtp Ruhleben. As illustrated by the red line by applying *global_b*-control the defined hydraulic capacity of the plant of 6700 l/s is not exceeded. The combined water that is stored in the networks is delivered in delay after the end of the rain. The pollutograph below points out the associated reduction of the NH_4-N load peak at 08:00 h.

In contrary to scenarios *global_b* and *local*, *global_a* leads to a maximum delivery of 7650 l/s over a long period associated with a significant load peak at 08:00 h.

A ranking of the 2h-intervals of wwtp effluent load shows the above-mentioned influence of the control strategies for the entire simulated year. Figure 4.37 presents the effluent COD and N_{tot} load of the 100 maximal 2h-intervals. It is obvious that the strict adherence to the plants capacity of 6700 l/s by scenario *global_b* is necessary to achieve a sufficient effluent quality. The overloading of the plant by scenarios *local* and *global_a* leads to excessive peak loads in the effluent.

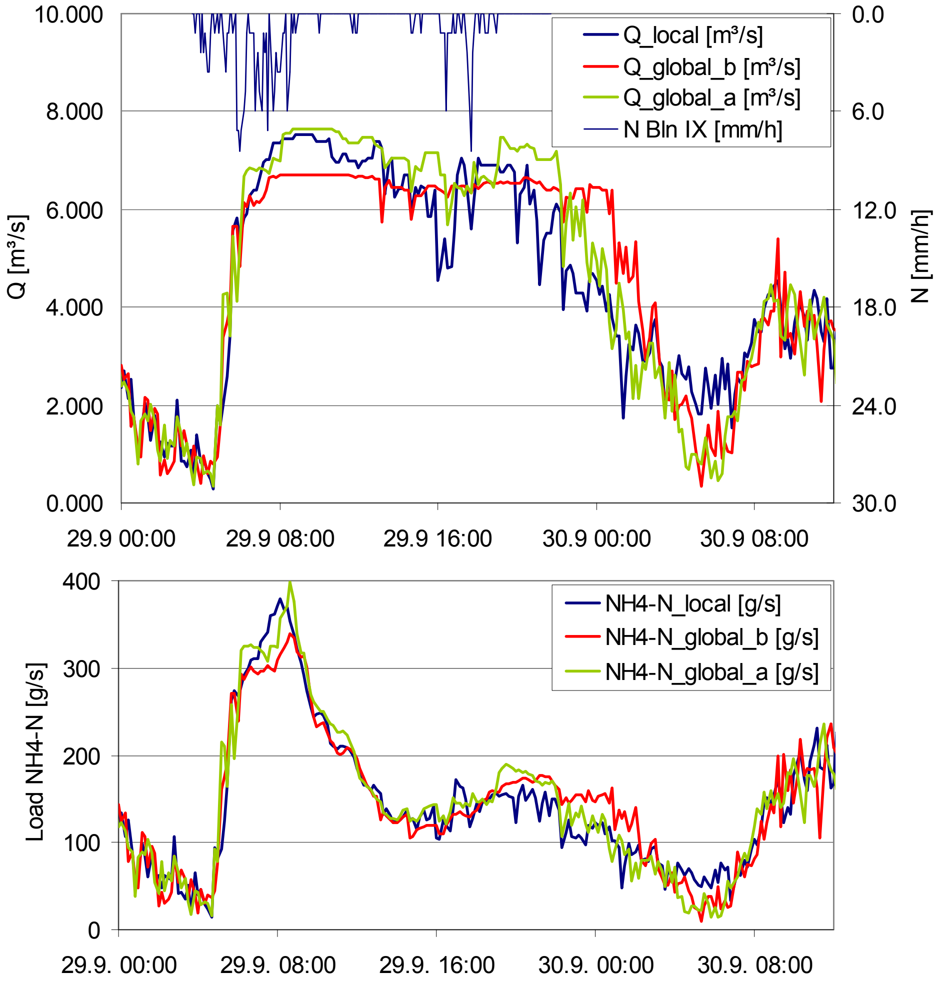


Figure 4.36 Inflow hydrographs and NH_4-N pollutagraphs to wwtp Ruhleben during the rain event from 29.09.2004 illustrating the influence of the different control strategies *local*, *global_b* and *global_a*

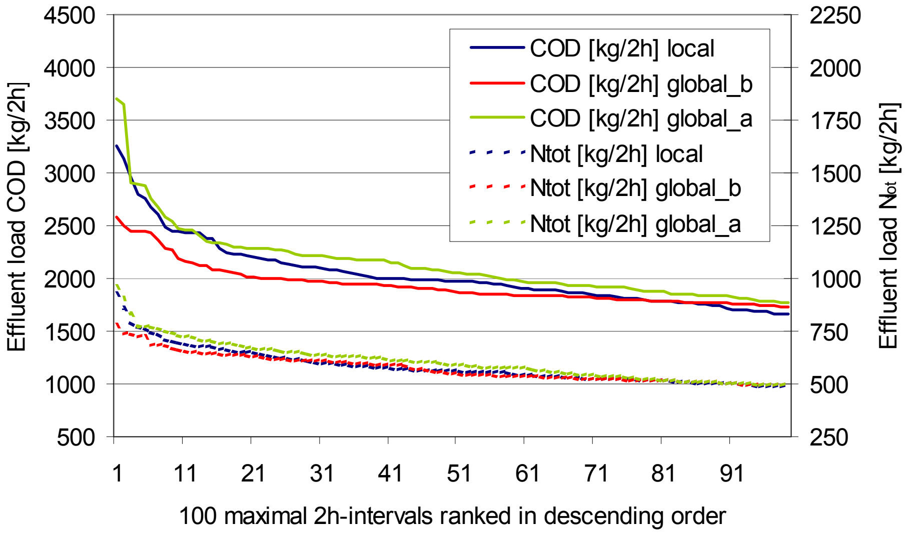


Figure 4.37 Ranking of the 2h-intervals of wwtp effluent load (COD and N_{tot})

4.3.3.4 Summary of the results concerning global control

The assessment of the Berlin drainage system that was carried out at chapter 4.1 arrives at the conclusion that there is a high potential for the control of the total system. The positive rating can partly be ascribed to the high storage volume that can be activated within the trunk sewers and the high number of pump stations that are used as actuators. However, this potential is already used by locally controlling the pump stations and backing up wastewater in the collectors. The potential of a global control of sewage pump stations arises from the non-uniform distribution of rainfall and the non-uniform distribution of storage volumes over the system. Those conditions usually lead to a non-uniform utilisation of storage capacities and further on to sewer overflows that cannot be balanced by local control.

The effects and the benefit from a global pump station control in comparison to local control have been given in chapter 4.3.3.3. Below, these results will be summarized and referred to the current operation regime of the Berlin pump stations.

A look on the total emissions shows that concerning the quantities the load from the wwtp is highly dominant. Around 93 % of the yearly COD load and 99 % of the yearly N_{tot} load have their origin at the wwtp. The COD and N_{tot} load from combined sewer overflows represent only 7 % and 1%, respectively, since most of the time (under dry weather conditions) wwtp effluents are the only impact on the receiving water. Furthermore, the global control concept only works during rain situation and does not have an influence on dry weather effluents. Consequently, the influence of global control on yearly total emissions is marginal.

Nevertheless, it could be shown that global control (scenario *global_b*) can avoid peak load situations at the inflow to the wwtp and consequently reduce peak loads in the effluent.

This corresponds with operational experiences. Keller (2005) notes that during rain situations an increased charging of the wwtp above capacity (6700 l/s) may lead to an exceeding of the official threshold limit values. Due to this boundary condition, in reality the inflow to wwtp Ruhleben is adjusted manually by a coordination of the delivery of the different pump stations.

The simulations of the wwtp didn't show an exceeding but an approach to the threshold limit values under high hydraulic charging of the plant. Sludge washout from the secondary clarifier cannot be represented reliably by the model approach used. The resulting increase in pollutant discharge may be underestimated.

Due to the quantitative dominance of emissions from wwtp effluents, the influence of the studied global control variants on yearly total emissions is insignificant.
However, the control concepts have a significant influence on the emissions from combined sewer overflows. The reduction of sewer overflows plays a prominent role since they present a highly dynamic impact on the water body. The simulations show that on average during periods of cso 2.5 t COD/h enter the receiving water (scenario *local*). Compared to that load the continuous impact from the wwtp effluent is only 0.4 t COD/h. Moreover, due to the high fraction of biodegradable organic substrate the impact from combined sewer overflows is of special relevance. In contrary to the refractory COD from wwtp effluents, 60 % of the COD from combined sewer overflows are biodegradable leading to extreme oxygen depletion within the receiving water (Seggelke, 2002).

It could be shown that under current conditions at the wwtp (rain weather capacity of wwtp Ruhleben = 6700 l/s) a local control (= local automation) of the pump stations as represented by scenario *local* (Q_{max} = 7650 l/s) has an adverse effect on the performance of the sewage system. In contrary to an optimum coordination of the pump stations (as represented by scenario *global_b*) this leads to an overloading of the wwtp and an increase of emissions from combined sewer overflows by 9 % (volume), 15 % (COD) and 20 % (TKN) (see figure 4.24).
Due to that reason the current operation provides for manual interventions in case of rain events to coordinate the delivery of the pump stations. This necessity will persist under the LISA automation.

Assuming a future upgrade of wwtp Ruhleben and an increase in rain weather capacity up to 7650 l/s, global pump station control (scenario *global_a*) will result in cso emissions that are 19 % (volume), 20 % (COD) and 25 % (TKN) below that under *local* control (see figure 4.24).

Due to the availability of the necessary data given by the existing scada system of BWB and due to the controllability (variable speed drives) of the majority of used pumps the studied control concept could be implemented without any further constructional investment. Nevertheless, the algorithm had to be adapted to operational and technical boundary conditions. Those pump stations that won't be equipped with variable speed drives would be integrated in a modified way (during the scenario analysis all pumps have been regarded as variable speed pumps). Furthermore, a detailed practical planning in terms of control engineering had to be carried out.
The main prerequisite for an implementation of the introduced control concept is the technical ability of the pump stations to increase delivery beyond the value of 2 * $Q_{d,16}$. Simultaneously, an authorisation is necessary to introduce a flexible regulation of the pump station's rain weather delivery off the value of 2 * $Q_{d,16}$ as demanded nowadays by the Berlin water authority.

5 Simulation of the “local pump automatic“ for catchment of wastewater treatment plant Schönerlinde

5.1 New pump automatic (Neue Pumpen Automatik)

In the framework of the LISA project (BWB) a stepwise implementation of the new pump automatic (**N**eue **P**umpen **A**utomatik, NPA) is carried out. Firstly, the pumps are equipped with variable speed drives. The idea is to control the pumps continuously to keep a constant level in the pump well. Hence, the pump delivery is equal to the inflow to the pump station until its maximum capacity is reached.

For the assessment of the impact of the NPA control on the wwtp the applicability of the ISM model was tested. Therefore, the inflow to wwtp Schönerlinde for one rain event has been simulated.

The used model simulates the pump stations Bln V, Bln XI, Marzahn I, Malchow, Karow and Niederschönhausen with NPA. The residual pump stations are controlled automatically according to the old step regime (fixed pumps of different capacities are switched on or off depending on the water level within the pump well).

5.2 Buildup of the model for wwtp Schönerlinde

The model for wwtp Schönerlinde covers 4 combined sewer catchments (Bln IV, Bln V, Bln XI, Bln XII) and 7 separate sewer catchments (Buchholz, Heinersdorf, Karow, Niederschönhausen, Rosenthal, Malchow, Marzahn I). The small catchments Hohenschönhausen, Buch II and Pankow have not been regarded due to the irrelevance of their quantities. Characteristic figures are given in table 5.1.
For all catchments the dry weather calibration has been adapted to current measurements of the pumped quantities of 2004.

Catchment	System type	Contributing Area	Impervious/ Misconnected Area	Population	Average dry weather flow
		[ha]	[ha]		[l/s]
Bln IV	combined	726	566	96880	224.90
Bln V	combined	675	507	88964	171.30
Bln XI	combined/separate	1515	449	91052	156.50
Bln XII	combined	418	345	62693	127.80
Buchholz	separate	556	12	17581	21.50
Heinersdorf	separate	233	9	3857	12.00
Karow	separate	828	14	26878	45.00
Niederschönhausen	separate	1131	23	81826	115.60
Rosenthal	separate	401	9	14584	21.20
Malchow	separate	474	6	57434	61.90
Marzahn I	separate	1516	18	118123	157.80
total		8473	1958	659872	1115.50

Table 5.1 Characteristic figures of the catchments of wwtp Schönerlinde

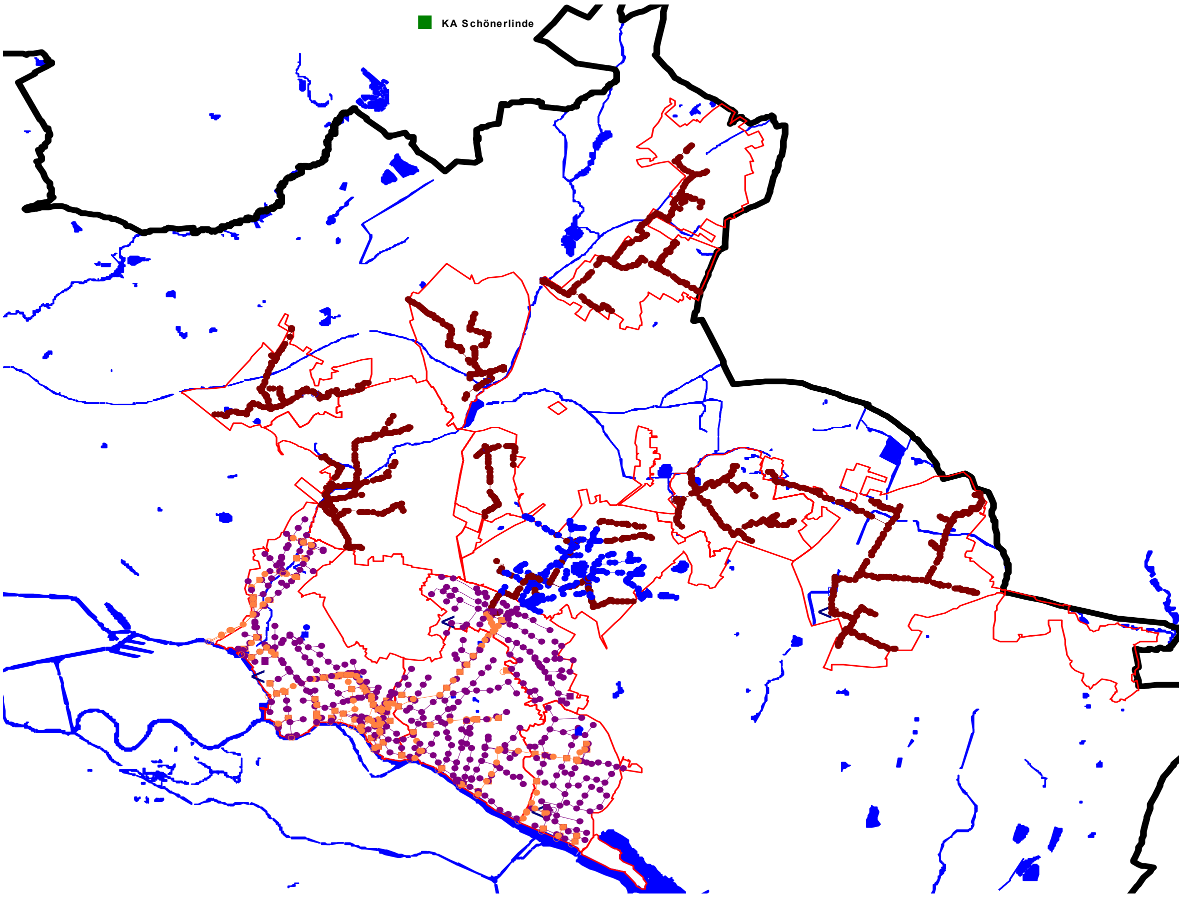


Figure 5.1 InfoWorks model of treatment plant Schönerlinde

5.3 Choice of rain event

In coordination with the department for sewage disposal (BWB-AE) a rain day (23.10.2005) has been chosen to simulate the inflow to wwtp Schönerlinde. The day had two rain events. At catchment Bln X the first event (beginning at 06:30 h and having a duration of 3 hours) had a total height of 8.1 mm. The second one at 16:30 h had a total height of 2.7 mm. For the simulation data from 5 rain gauges have been used.

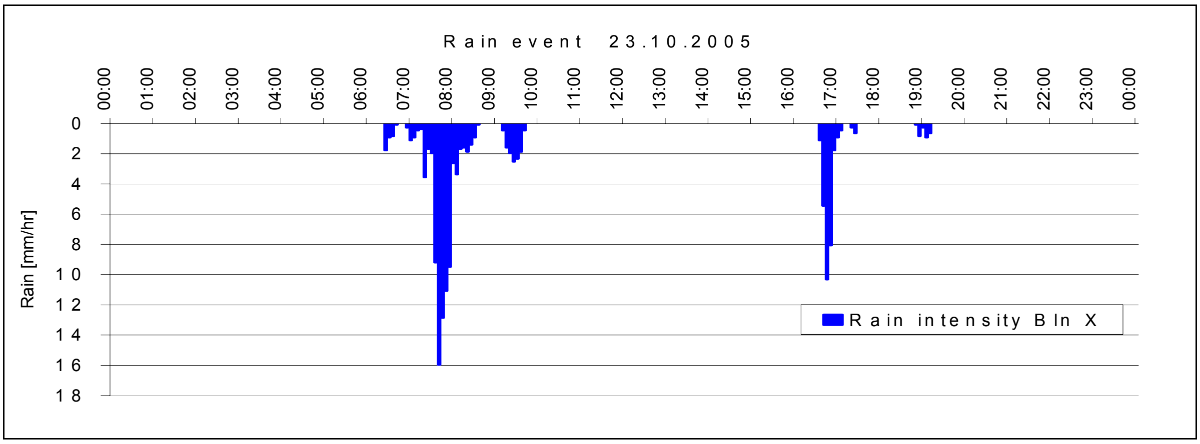
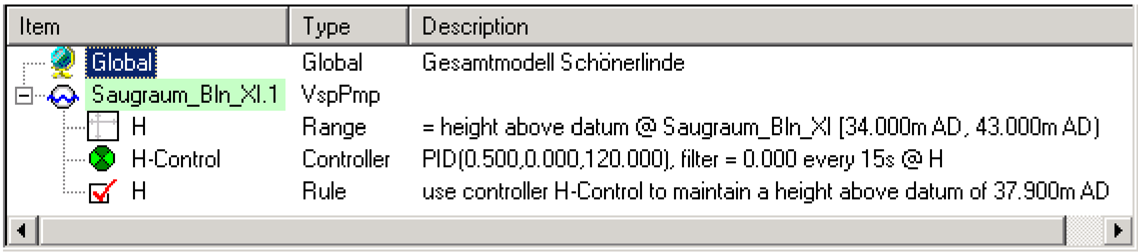


Figure 5.2 Rain intensity in mm/hr for event 23.10.2005

5.4 Results

The NPA control of the pump stations could be simulated well on the basis of the InfoWorks rtc module. A pd (proportional, differential) controller has been used to regulate the flow (p=0.5, d=120, see Table 5.2). The level in the pump well is kept to the set point (e.g. 37.90 mAD at Bln XI) until the maximum capacity of the pump is reached. Consequently, the water level rises above the set point if the inflow exceeds the pump capacity.



Item	Type	Description
Global	Global	Gesamtmodell Schönerlinde
Saugraum_Bln_XI.1	VspPmp	
H	Range	= height above datum @ Saugraum_Bln_XI [34.000m AD, 43.000m AD]
H-Control	Controller	PID(0.500,0.000,120.000), filter = 0.000 every 15s @ H
H	Rule	use controller H-Control to maintain a height above datum of 37.900m AD

Table 5.2 Rtc file for the simulation of the new pump automatic (NPA) of pump station Bln XI

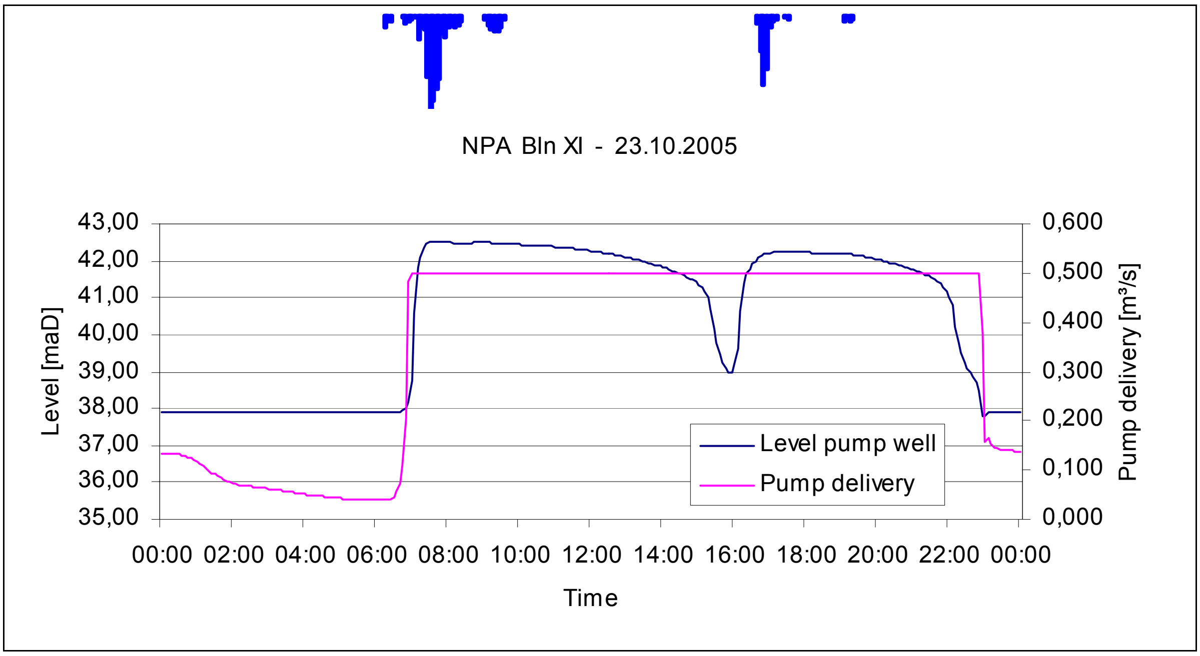


Figure 5.3 Level at pump well Bln XI for event 23.10.2005

The simulated total inflow to the wwtp corresponds satisfactorily with the measured one from 23.10.2005. Improvements of the simulation could be possible by applying a more detailed step regime. Further deviations between simulation and reality result from the insufficient number of rain gauges that have been available for 23.10.2005.

Between 08:30 h and 12:30 h the delivery of pump stations Bln IV und Bln V had to be reduced due to an exceeding of critical pressure values and partly, sewage was delivered to wwtp Ruhleben. Hence, during this period the real inflow to wwtp Schönerlinde falls above the simulated one.

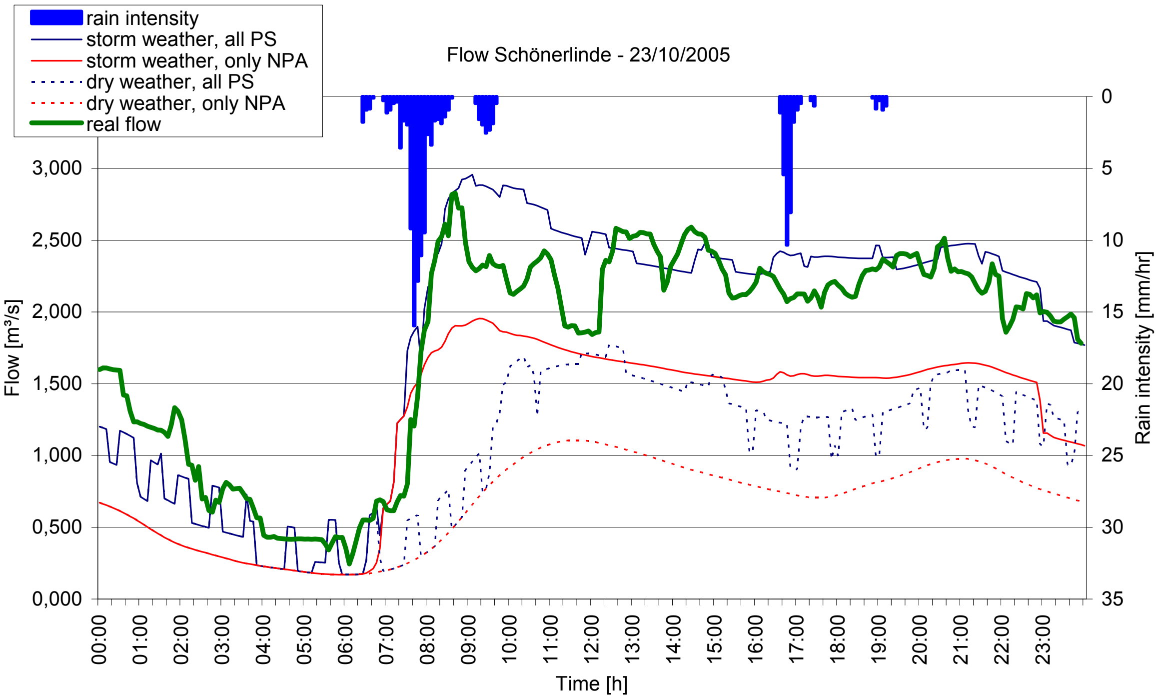


Figure 5.4 Storm weather flow at treatment plant Schönerlinde

6 Summary and Outlook

6.1 Summary

The development of the integrated control of sewage network and wastewater treatment plant has progressed during the last decade. Nevertheless, an operational implementation of the concepts for huge, complex systems has hardly been realised. That was an obvious reason to initiate the project "Integrated Sewage Management (ISM)". The ISM project aims at the development of strategies for an integrated management of the Berlin sewage system consisting of sewer networks (both, combined and separate system), pump stations, pressure mains and wwtp.

The initial agreement between Berliner Wasserbetriebe (BWB) and Veolia Water to establish the project was declared in April 2000. The parties jointly agreed on the way to incorporate the project within the structures of the Berlin Centre of Competence for Water (KWB). Based on general studies and on modelling the definition and design of an operation policy for the Berlin sewage system should be derived. With the beginning of 2003 the project was integrated as a flagship project in the KWB; this contract ended in December 2005.

After a state of the art study of existing tools and methods a survey of the existing sewage system has been prepared. 3.5 million inhabitants and an area of around 900 km^2 are connected to the system. The total length of collectors is around 9000 km. Around three quarters of the area of Berlin is drained via a separate system, whereas in the inner city, around a quarter of the total area drains into the combined system. The wastewater is pumped by 147 pump stations and over 1000 km of pressurised mains to six wastewater treatment plants for mechanical and biological treatment. On average, a total of approximately 620000 cubic metres of wastewater are delivered and treated per day.

On the basis of these data an integrated numerical model of the Berlin sewage system was built up. Those catchments have been chosen that have a significant quantity of wastewater and are connected to the three main wastewater treatment plants of Berlin (Ruhleben, Waßmannsdorf and Schönerlinde). Elaborate calibrations were performed for 18 combined and 29 separate sewer systems.
To enable an evaluation of total emissions it was necessary to incorporate not only catchment area (wastewater collection, rainfall-runoff-process, pollution accumulation and washoff) and collection system (flow, pollutant transport, storage, combined sewer overflows) but also the wwtp (biological conversion processes, clarification). Exemplarily, that has been done for the catchment of wwtp Ruhleben.
Furthermore, the Berlin specific transport of wastewater through pressure mains had to be considered. In case of a rain event the increase of pumpage immediately leads to an increased inflow and load at the wwtp. During the period of high pumpage the inflow load will stay high until the lower concentrated combined water will reach the plant (after hours). Both, advective pollutant transport and the limiting pressure situation had to be taken into account. Concerning the interaction of the subsystems, the pumps play the prominent role. The pumps influence both, the flow through the pressure pipes and the storage of combined water within the main

collectors. In contrast, the interface between pressure main and wwtp is unidirectional and as long as there is no integrated control there will be no feedback from the plant and no need for a parallel simulation.

Those processes that were of particular importance for the control concepts or had a significant influence on the criteria (objectives) had to be simulated adequately. Hence, for the Berlin model the main attention was paid to an accurate reproduction of in-pipe storage activation and the transport of wastewater through the pressure pipes. A sufficient set of data was available to model the system structure. For process parameter estimation the necessary information was taken from the operational SCADA system. Some gaps in the data could be closed by additional measurement campaigns (Bln VII, 2001; Bln X, 2002; Heiligensee, 2003).

To take into account reverse flow and the activation of in-pipe storage a dynamic flow routing model had to be incorporated. The model had to be capable of simulating pollutant transport and carrying out long-term simulations. Furthermore, a module for real-time control was indispensable.
The dynamic flow routing model InfoWorks CS of Wallingford Software Limited was chosen due to its user-friendliness (window navigation, GIS) and comprehensiveness (pollutant load calculation, long-time simulation, spatial rainfall distribution, rtc module).
The network has been built up in a skeletonised form, nevertheless accounting for the total available storage capacity. Storm water tanks and combined sewer overflows as well as actuators for real-time control have been considered in detail.

To accurately simulate the transport of wastewater through pressure mains, for this subsystem it was necessary to turn away from the dynamic flow routing model. The simulations of pressure conditions that were based on the Preissmann slot led to retention effects within the pressure mains and thus, to unreasonable results. On the other hand a conceptual approach on the basis of completely stirred tank reactors would not have been able to reproduce the pressure conditions that were of high importance for the evaluation of operational scenarios.
A suitable approach to the simulation of the Berlin pressure mains finally was found to be based on EPANET 2 of the U.S. Environmental Protection Agency. Flow continuity and headloss equations are solved under steady state conditions using the so-called “Gradient Method”. The governing equations for the quality solver are based on the principles of conservation of mass simulating advective transport within the pipes and complete and instantaneous mixing at the pipe junctions. Biological conversion processes within the pressurised pipes are neglected.
The network data have been adopted from the SIR-3S model used by BWB, department AE. Redundant pipes have not been modelled. The statuses of the valves (open/close) and reductions of pipe diameters due to incrustations have been set according to the information and assumptions given by BWB, department AE.

The software SIMBA® 5 of ifak System GmbH has been used to simulate the dynamic treatment processes. For the activated sludge conversion part the Activated Sludge Model No. 1 (ASM 1) has been used. To simulate primary clarification a modified version of the model of Otterpohl et al. has been applied

taking into account the relation between particulate COD and total COD. For the simulation of the final clarification the 10-layer-model of Otterpohl and Freund has been used.
A static calibration of the model has been conducted based on the set of data from the standard sampling procedure carried out at the plant (24-h composite samples every second day).

The three models have been coupled in sequence on the basis of simple input and output files.
Further on, in the framework of three sub studies the ISM model has been applied to operational questions.

1. New pump automatic (NPA)
The applicability of the ISM model for the assessment of the impact of the NPA control on the wwtp was tested. NPA stands for "new pump automatic (**N**eue **P**umpen **A**utomatik)" and signifies a control concept that is implemented in the framework of the LISA project (BWB). Sewage pumps are equipped with variable speed drives and are controlled continuously to keep a constant level in the pump well. Hence, the pump delivery is equal to the inflow to the pump station until its maximum capacity is reached.
For the assessment the inflow to wwtp Schönerlinde for one rain event has been simulated. The NPA control of the pump stations could be simulated well on the basis of the InfoWorks rtc module. A pd (proportional, differential) controller has been used to regulate the flow. The simulated total inflow to the wwtp corresponded satisfactorily with the measured one.

2. Level dependant pump control (PGF)
A level dependant real-time control (**P**egel**g**esteuerte **F**örderstromregelung) for sewage pump stations has been introduced. The idea was to build an easy function that allowed continuously varying the pumpage and implicitly managing available inline storage capacities. The objective was to smooth the delivery towards the treatment plant to avoid peak loads. Furthermore, adverse effects that are linked to inline storage activation like deposition of sediments, formation of hydrogen sulphide and the increased risk of cso activity should be minimised.
An evaluation of the control concept has been carried out on the basis of simulations with a spectrum of synthetic rain events of constant intensity. The evaluation based on two indicators, the reduction of peak pumpage and the reduction of the standard deviation of the delivery hydrograph compared to a step regime.

The simulation results showed that an improvement of the flow characteristic towards the wwtp is hardly possible if there is not a high retention capacity within the sewer networks. For catchments with low or medium inline storage capacities no significant reduction of the standard deviation could be achieved. A reduction of the peak flow was not possible at all.
For a catchment with high inline storage capacities (67.6 m³/ha A_{imp}) a significant reduction of the standard deviation was possible. Furthermore, a reduction of the peak pumpage could be achieved. However, a significant improvement was possible only for low intensity rain events ($n \geq 5\ a^{-1}$).

Recapitulatory, the evaluation showed that it is possible to manage available inline storage volume by applying the control function. But only if there is an adequate retention volume of around 60.0 m³/ha A_{imp} or more a significant improvement of the flow characteristic towards the wwtp is possible. Consequently, in Berlin only two catchments have the potential for the introduced control concept.

3. Global pump station control

The assessment of the Berlin drainage system that was carried out arrived at the conclusion that there is a high potential for the control of the total system. The positive rating can partly be ascribed to the high storage volume that can be activated within the trunk sewers and the high number of pump stations that are used as actuators. However, this potential is already used by locally controlling the pump stations and storing sewage in the collectors. The potential of a global control of sewage pump stations arises from the non-uniform distribution of rainfall and the non-uniform distribution of storage volumes over the system. Those conditions usually lead to a non-uniform utilisation of storage capacities and further on to sewer overflows that cannot be balanced by local control.

The effects and the benefit from global pump station control in comparison to local control have been studied on the basis of the integrated model. Here, main emphasis was placed on the analysis of the catchment area of wastewater treatment plant Ruhleben. This catchment area is composed of 13 combined sewer systems and 3 separate sewer systems.

The studied control concept aims at a uniform utilisation of storage volumes throughout the drainage system by controlling the pump stations with respect to measurement of water levels. The developed algorithm is based on the imagination that the total storage volume of each of the subsystems can be considered as a tank or a reservoir. Assuming hydrostatic water level propagation within the collectors, the fill level of the virtual reservoir can be derived by the currently measured water level at the accordant pump station and the storage characteristic of the sewers. In addition the fill level of storm water tanks, if existing, are taken into account, translated into the accordant volume and added to the in-pipe storage volume.

For the evaluation of the rtc algorithm also in-pipe storage capacities of the wastewater sewers (separate system) have been taken into account where available and consequently activated during rainfall. In the course of an implementation this concept of sanitary sewer storage surely has to be coordinated with the sewer operator.

A look on the simulated total emissions showed that concerning quantities the load from the wwtp is highly dominant. Around 93 % of the yearly COD load and 99 % of the yearly N_{tot} load have their origin at the wwtp. The COD and N_{tot} load from combined sewer overflows represent only 7 % and 1%, respectively, since most of the time (under dry weather conditions) wwtp effluents are the only impact on the receiving water. Furthermore, the global control concept only works during rain situation and does not have an influence on dry weather effluents. Consequently, the influence of global control on yearly total emissions is marginal.

Nevertheless, it could be shown that global control can avoid peak load situations at the inflow to the wwtp and consequently reduce peak loads in the effluent. This

corresponds with operational experiences; during rain situations an increased charging of the wwtp above capacity (6700 l/s) may lead to an exceeding of the official threshold limit values. Due to this boundary condition, in reality the inflow to wwtp Ruhleben is adjusted manually by a coordination of the delivery of the different pump stations.
The simulations of the wwtp didn't show an exceeding but an approach to the threshold limit values under high hydraulic charging of the plant. Sludge washout from the secondary clarifier cannot be represented reliably by the model approach used. CFD (computational fluid dynamics) simulations, which are beyond the scope of the ISM project, would be necessary. The resulting increase in pollutant discharge may be underestimated.

Due to the quantitative dominance of emissions from wwtp effluents, the influence of the studied global control variants on yearly total emissions was insignificant.
However, the control concepts had a significant influence on the emissions from combined sewer overflows. The reduction of sewer overflows plays a prominent role since they present a highly dynamic impact on the water body. The simulations showed that on average during periods of cso 2.5 t COD/h enter the receiving water. Compared to that load the continuous impact from the wwtp effluent was only 0.4 t COD/h. Moreover, due to the high fraction of biodegradable organic substrate the impact from combined sewer overflows is of special relevance. In contrary to the refractory COD from wwtp effluents, 60 % of the COD from combined sewer overflows are biodegradable leading to extreme oxygen depletion within the receiving water.

It could be shown that under current conditions at the wwtp (rain weather capacity of wwtp Ruhleben = 6700 l/s) a local control (= local automation) of the pump stations has an adverse effect on the performance of the sewage system. In contrary to an optimum coordination of the pump stations this leads to an overloading of the wwtp and an increase of emissions from combined sewer overflows by 9 % (volume), 15 % (COD) and 20 % (TKN).
Due to that reason the current operation provides for manual interventions in case of rain events to coordinate the delivery of the pump stations. This necessity will persist under the LISA automation.

Assuming a future upgrade of wwtp Ruhleben and an increase in rain weather capacity up to 7650 l/s, global pump station control will result in cso emissions that are 19 % (volume), 20 % (COD) and 25 % (TKN) below that under local control (= local automation).

6.2 Outlook

The major deliverable of the ISM project is the model for the Berlin collection system (18 combined and 29 separate sewer systems that are connected to the three main wastewater treatment plants Ruhleben, Waßmannsdorf and Schönerlinde).
The further application and maintenance of the sewer model will take place at BWB, department NA-G. The scope of studies that will be supported by the model covers operational planning as well as general, conceptual and investment planning (storage optimisation, problem of parasite water).

Concerning the implementation of the global control concept that has been developed in the framework of the ISM project first tests shall be carried out in 2006 and 2007. Therefore, the follow-up project EVA (Entscheidungshilfesystem zur Verbundsteuerung von Abwasserpumpwerken / Decision support system for global control of sewage pump stations) was planned at KWB to enable support and a further cooperation between KWB and BWB.

Due to the availability of the necessary data (given by the existing scada system of BWB) and due to the controllability (variable speed drives) of the majority of used pumps the studied control concept can be implemented without any further constructional investment. Nevertheless, the algorithm has to be adapted to the operational and technical boundary conditions and a detailed practical planning in terms of control engineering has to be carried out.

The main prerequisite for an implementation of the introduced control concept is the technical ability of the pump stations to increase delivery beyond the value of 2 * $Q_{d,16}$. Simultaneously, an authorisation is necessary to introduce a flexible regulation of the pump station’s rain weather delivery off the value of 2 * $Q_{d,16}$ as demanded nowadays by the Berlin water authority. Therefore, a close coordination with the water authority will be essential.

In the frame of the ISM project the total system and the accordant processes have been analysed consistently with a view on technical and ecological aspects. Questions of integrated system management have been discussed. The outcomes of the ISM project contribute to an integrated management of the Berlin sewage system.

New aspects of integrated modelling of huge, complex systems drained by sewage pump stations have been studied and further developed. Through this, the basis for future operational applications has been set. At the same time, the ISM model has been used to study and evaluate the potential of a global pump station control. In the future, it will be necessary to find the optimum way of implementing global control under operational boundary conditions. In this connection, there are still aspects that have to be evaluated concerning their benefit, like e.g. operational online-simulation, rainfall-forecast based on radar data and the integrated control of treatment plant and collection system.

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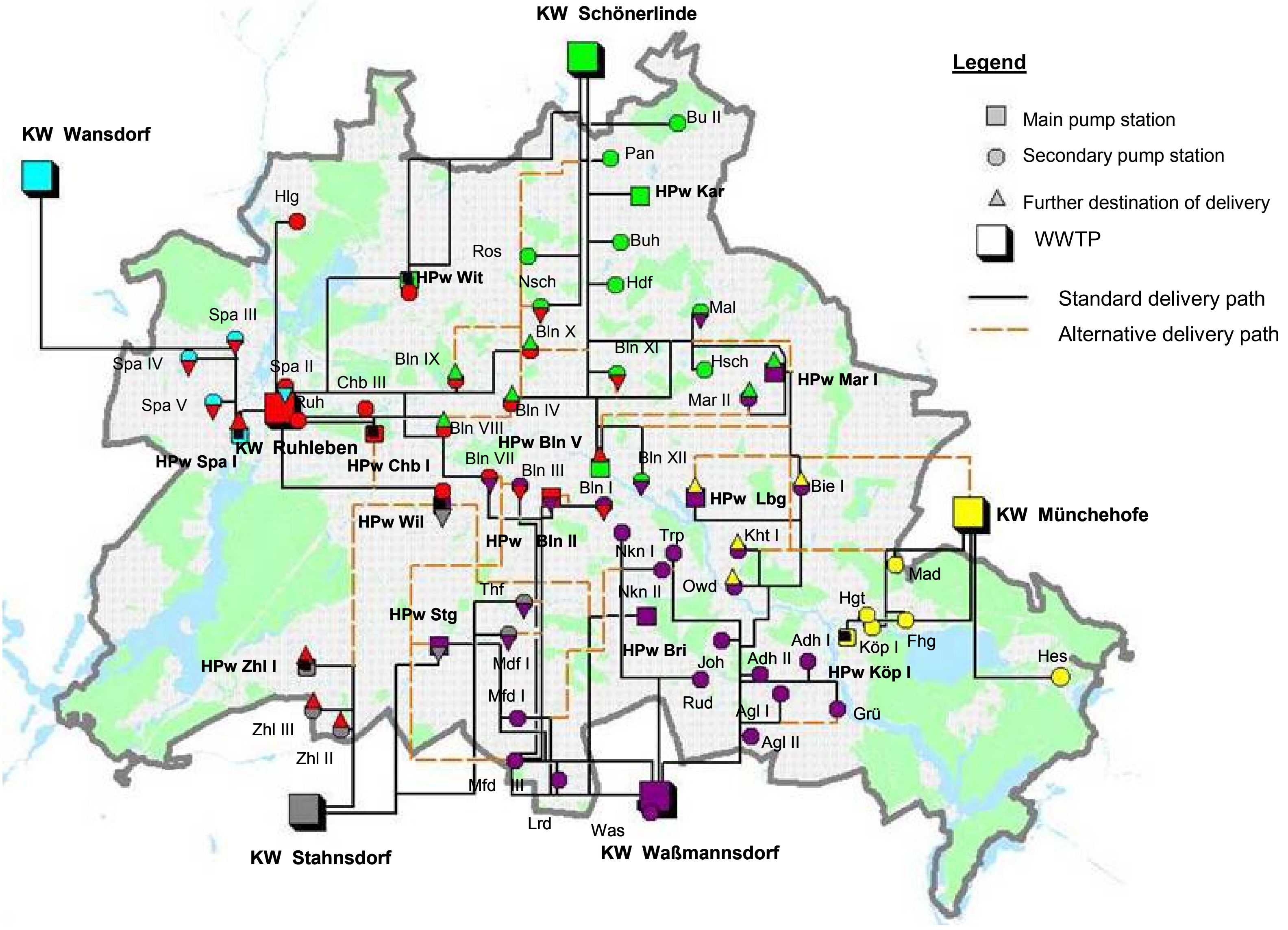
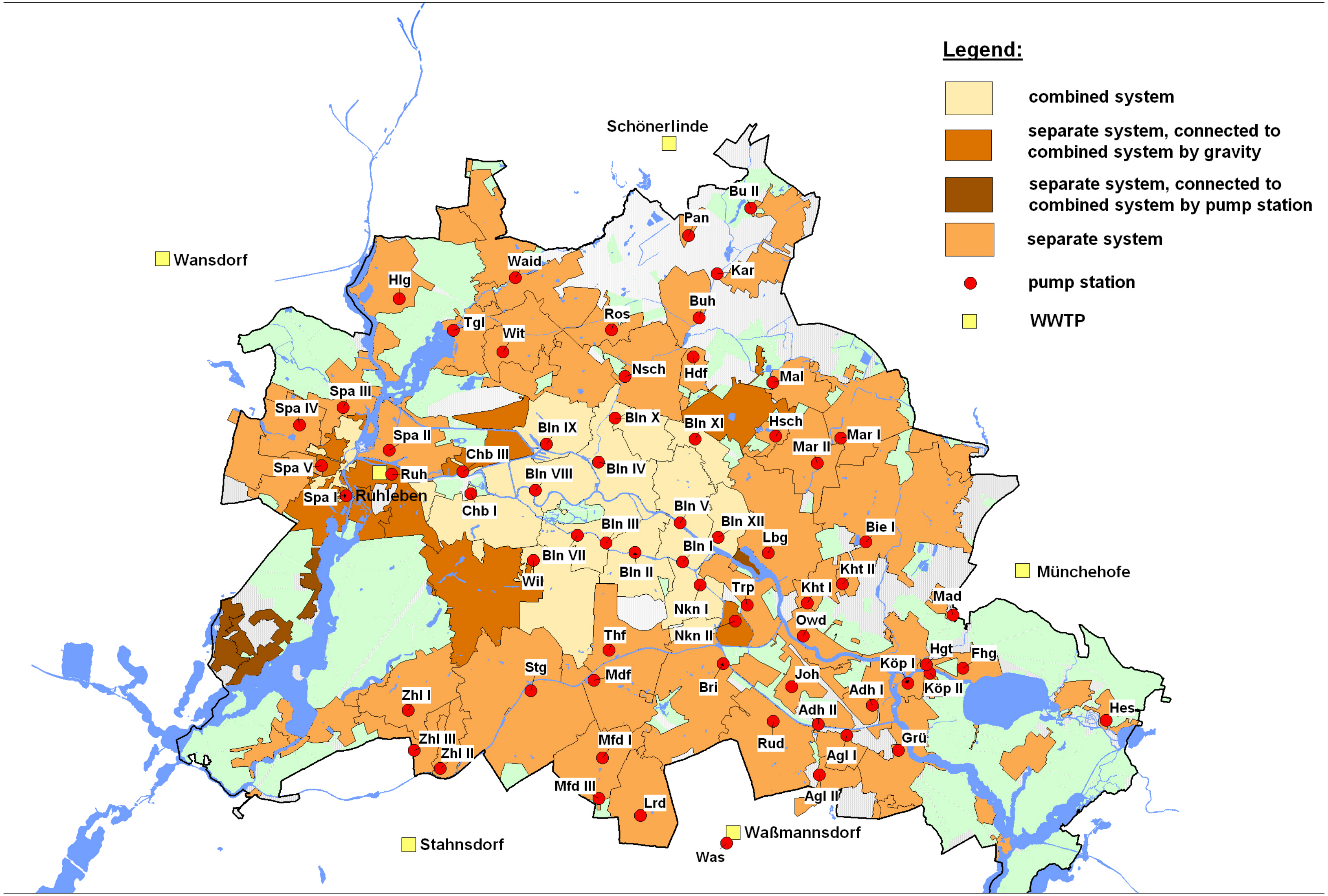
Appendix

1. Schematic illustration of the Berlin system of pump stations, pressure mains and wwtps
2. Sewage system of Berlin
3. Statistical data of the Berlin catchments in the combined sewer system
4. Overview of InfoWorks landuse Ids
5. Modeled catchments of the Berlin drainage system and their allocation to the three major wwtps
6. Overview of criteria for the evaluation of the control potential of the Berlin combined sewer systems according to DWA-M 180
7. InfoWorks rtc code for global control
8. Global rtc algorithm InfoWorks - explanation of variables and parameters
9. Thiessen polygons of catchment Ruhleben
10. Aggregated cso impact on the different Berlin watercourses
11. ISM publications

Appendix 1 – Schematic illustration of the Berlin system of pump stations, pressure mains and wwtps



Appendix 2 – Sewage system of Berlin



Appendix 3 - Statistical data of the Berlin catchments in the combined sewer system (2005)

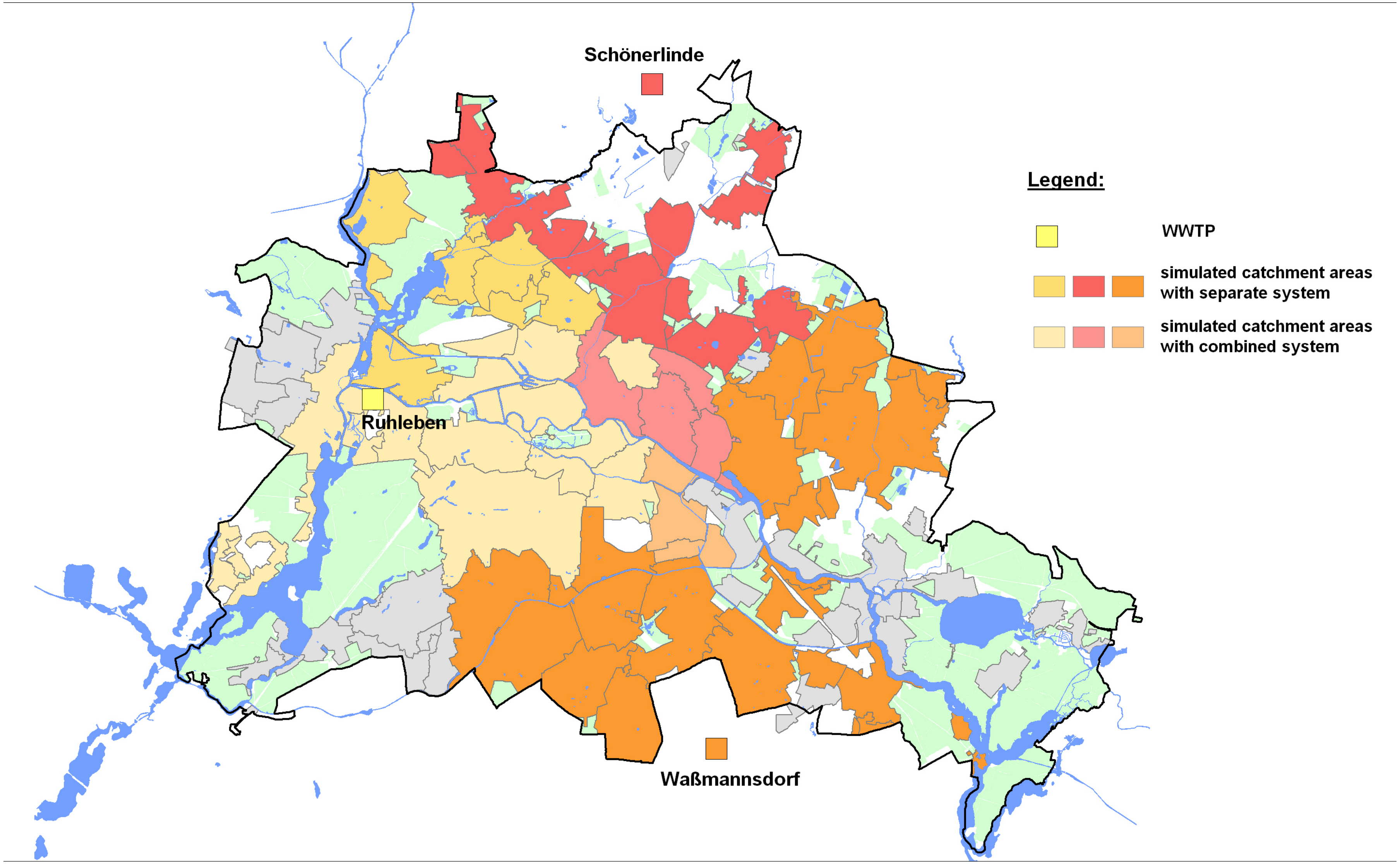
Pump station	Total area	Area of combined sewerage	Area of separate sewerage	Canalised area of combined sewerage (R/C)	Canalised impervious area of combined sewerage (R/C)	Ratio of imperviousness combined sewerage	Length combined sewerage	Total population 1999	Population combined sewerage 1999	Population separate sewerage 1999	Average daily dry weather flow	Average infiltration	Specific inflitration	Number of cso	Number of stormwater retention facilities	Storage volume	Specific storage volume	In-pipe storage volume	Specific in-pipe storage volume	Total storage volume	Total specific srtorage volume	Receiving water
	A_E	$A_{E,Mi}$	$A_{E,Tr}$	$A_{E,Mi,k}$	$A_{E,Mi,k,b}$	$\gamma_{E,Mi,k}$	$L_{K,Mi}$	EZ	EZ_{Mi}	EZ_{Tr}	$Q_{T,d,aM}$	$Q_{F,aM}$	q_F			V_R	$V_{S,R}$	V_k	$V_{S,k}$	V	V_S	
	ha	ha	ha	ha	ha	-	km	E	E	E	m3/d	l/s	l/(s*ha)			m³	m³/ha	m³	m³/ha	m³	m³/ha	
APW Kreuzberg - Bln I Paul-Lincke-Ufer	334	334	0	300	244	0.81	61.9	55125	55125	0	9832	13	0.04	32	1 RÜB Paul-Lincke-Ufer	2170	9	5000	20	7170	29	Spree Landwehrkanal
HPW Kreuzberg - Bln II Gitschiner Straße	749	717	32	623	483	0.78	132.1	95498	95498	0	16224	23	0.04	73	1 RÜB (Bln II) Gitschiner Str. 1 RÜB (Bln VI) Urbanstr.	6000	12	8580	18	14580	30	Spree Landwehrkanal
APW Kreuzberg - Bln III Schöneberger Straße	452	452	0	400	303	0.76	89.3	17289	17289	0	8763	54	0.14	46	1 SK Ebertstraße	2190	7	12560	41	14750	49	Spree Landwehrkanal Kupfergraben
APW Mitte - Bln IV Scharnhorststraße	967	963	4	726	566	0.78	190.0	107054	106007	1047	20426	40	0.06	101	none	0	0	2900	5	2900	5	Berlin-Spandauer Schiffahrtskanal Panke Spree
HPW Friedrichshain - Bln V Holzmarktstraße	806	806	0	675	507	0.75	163.3	87492	87492	0	14986	33	0.05	19	1 SK Straße der Pariser Kommune	6200	12	14330	28	20530	40	Spree
APW Tiergarten - Bln VII Genthiner Straße	414	414	0	311	242	0.78	63.9	41111	41111	0	11220	32	0.10	14	1 RÜB Lützowplatz	1000	4	11760	49	12760	53	Landwehrkanal
APW Tiergarten - Bln VIII Alt-Moabit	721	690	31	516	388	0.75	103.0	76186	76183	3	13436	38	0.07	19	1 RÜB Alt-Moabit	1500	4	9770	25	11270	29	Berlin-Spandauer Schiffahrtskanal Spree Charlottenburger Verbindungskanal
APW Wedding - Bln IX Seestraße	769	769	0	478	312	0.65	91.9	70444	70444	0	12972	11	0.02	5	1 local rtc Seestr./Afrikanische Str. 1 RÜB Seestr.	5600	18	5880	19	11480	37	Westhafen
APW Wedding - Bln X Bellermannstraße	458	458	0	359	290	0.81	90.0	68249	68249	0	10069	8	0.02	21	1 RÜB Bellermannstr.	1500	5	1620	6	3120	11	Panke Spree (together with cso from another catchment)
APW Prenzlauer Berg - Bln XI Erich-Weinert-Straße	1318	416	902	371	275	0.74	83.3	94499	45968	48531	13835	7.2	0.02	5	none	0	0	5340	19	5340	19	Panke Spree (together with cso from another catchment)
APW Friedrichshain - Bln XII Rudolfstraße	606	451	155	405	336	0.83	90.5	92045	57484	34561	11821	1	0.00	18	1 SK Straße der Pariser Kommune	6200	18	5180	15	11380	34	Spree
APW Neukölln I Wildenbruchstraße	574	574	0	486	394	0.81	127.4	103907	103907	0	17344	25.5	0.05	26	1 RÜB Wildenbruchstr.	3600	9	7970	20	11570	29	Landwehrkanal Neuköllner Schiffahrtskanal
APW Neukölln II Dammweg	420	168	252	140	117	0.84	35.5	31678	18662	13016	7500	17.7	0.13	5	none	0	0	2740	23	2740	23	Neuköllner Schiffahrtskanal
HPW Spandau I Betckestraße	2134	224 R in C: 30	1910	549	170	0.31	38.5	93784	33630	60154	12455	1.8	0.00	23	none	0	0	5900	35	5900	35	Havel
HPW Wilmersdorf Hohenzollerndamm	3120	1277 R in C: 339	1843	1502	996	0.66	219.7	263423	157856	105567	43435	42	0.03	24	1 RÜB Lützowplatz 1 SK Lützowplatz	6460	6	5990	6	12450	13	Landwehrkanal
HPW Charlottenburg I Sophie-Charlotte-Straße	1309	1309	0	1079	806	0.75	201.4	122931	122931	0	25276	42.8	0.04	68	1 RÜB Mollwitzstraße	3000	4	8610	11	11610	14	Spree Landwehrkanal
APW Charlottenburg III Nonnendamm	891	172 R in C: 148	719	216	152	0.70	25.5	33081	14024	19057	7600	5.1	0.02	12	1 RKB Saatwinkler Damm	0	0	14600	96	14600	96	Spree Westhafenkanal
APW Ruhleben Freiheit	708	53	655	53	31	0.58	12.0	14250	6202	8048	4437	5.2	0.10	3	none	0	0	1980	64	1980	64	Spree Ruhlebener Altarm

SK: Stauraumkanal = sewer with storage capacity and overflow
RÜB: Regenüberlaufbecken = combined water tank with overflow
RKB: Regenklärbecken = storm water tank

Appendix 4 - Overview of InfoWorks landuse Ids

Catchment	Landuse ID	Wastewater Profile	Trade Profile	Runoff Surface 1	Runoff Surface2	Runoff Surface 3	Runoff Surface 4
				impervious	pervious	impervious	impervious
Mischsystem							
Bln 1	Bln1	1	1,2,3	1	21		
Bln 2	Bln2	2		2	21	97	
Bln 3	Bln3	3		3	21	93	
Bln 4	Bln4	4		4	21		
Bln 5	Bln5	5		5	21		
Bln 7	Bln7	7, 96, 95, 94		7	21		
Bln 8	Bln8	8	8	8	21		
Bln 9	Bln9	9		9	21		
Bln 10	Bln10	10, 99		10	21	99	98
Bln 11	Bln11	11		11	21		
Bln 12	Bln12	12		12	21		
Wilm	Wilm	13		13	21		
Chb 1	Chb1	14		14	21		
Chb 3	Chb3	15	15	15	21	93	
Ruh	Ruh	16	16	16	21	96	
Spa 1	Spa1	17		17	21	92	
Nkn 1	Nkn1	18		18	21		
Nkn 2	Nkn2	19		19	21		
Trennsystem							
Wit	Wit	20		20	21		
Rei_I	Rei1	22		22	21		
Rei_II	Rei2	23		23	21		
Tgl	Tgl	24		24	21		
Waid	Waid	25		25	21		
Hlg	Hlg	26		26	21		
Spa_II	Spa2	27		27	21		
Kar	Kar	28		28	21		
Ros	Ros	29		29	21		
Nsch	Nsch	30		30	21		
Hdf	Hdf	31		31	21		
Buh	Buh	32		32	21		
Mar_I	Mar1	33		33	21		
Mar_II	Mar2	34		34	21		
Mal	Mal	35		35	21		
Lbg	Lbg	36		36	21		
Bie_I	Bie1	37		37	21		
Kht_I	Kht1	38		38	21		
Bri	Bri	39		39	21		
Rud	Rud	40		40	21		
Altgl_I	Altgl1	41		41	21		
Grü	Grü	42		42	21		
Joh	Joh	43		43	21		
Stg	Stg	44		44	21		
Mdf	Mdf	45		45	21		
Lrd	Lrd	46		46	21		
Mfd_I	Mfd1	47		47	21		
Thf	Thf	48		48	21		

Appendix 5 – Modeled catchments of the Berlin drainage system and their allocation to the three major wwtps



Appendix 6 - Overview of criteria for the evaluation of the control potential of the Berlin combined sewer systems according to DWA-M 180

			Catchment			Wastewater production		Sewer system								Operational system behaviour			Receiving water			Wwtp	
Pump station	Category[1]	Total score	Average surface slope [%]	Catchment area [m]	Difference between current and planned development of the area	Area with increased pollution of surface runoff	Variability in time and space of wastewater production	Number of existing control devices	Slope of trunk sewers [%]	Loops in the sewer system	Number of existing storage tanks	Number of discharge devices	Total storage volume [m³]	Specific storage volume [m³/ha]	Number of collectors to wwtp	Local flood areas	Number of non-uniformly used tanks	Non-uniform discharge behaviour	Local differences in hydraulic capacity	Local differences of load capacity	Sensitivity of the receiving water body	Admissible combined water inflow	Sensitivity of wwtp to hydraulic or pollutant peaks
APW Kreuzberg - Bln I Paul-Linke-Ufer	2	30	0,21	2000	none	none	high	none	0,14	none	1 RÜB	32	5940	24	2	none	none	medium	none	medium	very sensitive	$> f_{S,QM} \cdot Q_{S,aM} + Q_{F,aM}$	less sensitive
			2	1	0	0	2	0	4	0	2	4	4	2	1	0	0	2	0	2	2	1	1
HPW Kreuzberg - Bln II Gitschiner Straße	2	31	0,68	2500	none	none	medium	2	0,38	none	2 RÜB	73	9600	20	3	none	2	insignificant	none	medium	very sensitive	$> f_{S,QM} \cdot Q_{S,aM} + Q_{F,aM}$	less sensitive
			1	1	0	0	1	2	2	0	2	4	4	2	2	0	4	0	0	2	2	1	1
APW Kreuzberg - Bln III Schöneberger Straße	2	32	0,37	2800	none	none	none	1	0,19	none	1 SK	46	14993	49	1	none	none	medium	medium	medium	very sensitive	$> f_{S,QM} \cdot Q_{S,aM} + Q_{F,aM}$	less sensitive
			1	1	0	0	0	2	4	0	2	4	4	4	0	0	0	2	2	2	2	1	1
APW Mitte - Bln IV Scharnhorststraße	2	28	0,42	3800	small	none	medium	1	0,30	none	none	101	2640	5	1	none	none	medium	significant	significant	very sensitive	$> f_{S,QM} \cdot Q_{S,aM} + Q_{F,aM}$	less sensitive
			1	1	1	0	1	2	2	0	0	4	2	0	0	0	0	2	4	4	2	1	1
HPW Friedrichshain - Bln V Holzmarktstraße	2	26	0,54	4000	small	none	none	none	0,36	none	1 SK	19	20530	40	2	none	none	significant	none	none	very sensitive	$> f_{S,QM} \cdot Q_{S,aM} + Q_{F,aM}$	less sensitive
			1	1	1	0	0	0	2	0	2	4	4	2	1	0	0	4	0	0	2	1	1
APW Tiergarten - Bln VII Genthiner Straße	2	29	0,32	2500	none	none	medium	1	0,13	none	1 RÜB	14	12950	54	1	none	none	medium	none	none	very sensitive	$> f_{S,QM} \cdot Q_{S,aM} + Q_{F,aM}$	less sensitive
			1	1	0	0	1	2	4	0	2	4	4	4	0	0	0	2	0	0	2	1	1
APW Tiergarten - Bln VIII Alt-Moabit	2	33	0,79	3900	none	none	medium	none	0,17	none	1 RÜB	19	11450	30	2	1	none	significant	medium	medium	very sensitive	$> f_{S,QM} \cdot Q_{S,aM} + Q_{F,aM}$	less sensitive
			1	1	0	0	1	0	4	0	2	4	4	2	1	1	0	4	2	2	2	1	1
APW Wedding - Bln IX Seestraße	2	28	0,43	2600	none	none	none	3	0,26	1	1 local control of combined sewer	5	9650	31	1	none	none	significant	none	none	very sensitive	$> f_{S,QM} \cdot Q_{S,aM} + Q_{F,aM}$	less sensitive
			1	1	0	0	0	4	2	2	2	2	4	2	0	0	0	4	0	0	2	1	1
APW Wedding - Bln X Bellermannstraße	1	24	0,8	3500	none	none	none	none	0,46	none	1 RÜB	21	3120	11	1	none	none	insignificant	significant	significant	very sensitive	$> f_{S,QM} \cdot Q_{S,aM} + Q_{F,aM}$	less sensitive
			1	1	0	0	0	0	2	0	2	4	2	0	0	0	0	0	4	4	2	1	1
APW Prenzlauer Berg - Bln XI Erich-Weinert-Straße	1	19	0,62	2400	none	none	high	none	0,45	none	1 SK	5	5350	19	2	none	none	medium	none	none	very sensitive	$> f_{S,QM} \cdot Q_{S,aM} + Q_{F,aM}$	less sensitive
			1	1	0	0	2	0	2	0	0	2	4	0	1	0	0	2	0	0	2	1	1
APW Friedrichshain - Bln XII Rudolfstraße	2	28	0,50	3200	none	none	high	2	0,30	3	none	18	11440	34	1	none	none	medium	none	none	very sensitive	$> f_{S,QM} \cdot Q_{S,aM} + Q_{F,aM}$	less sensitive
			1	1	0	0	2	2	2	4	0	4	4	2	0	0	0	2	0	0	2	1	1
APW Neukölln I Wildenbruchstraße	1	24	0,49	2500	none	none	high	none	0,48	1	1 RÜB	26	11720	30	1	none	none	insignificant	none	none	very sensitive	$> f_{S,QM} \cdot Q_{S,aM} + Q_{F,aM}$	less sensitive
			1	1	0	0	2	0	2	2	2	4	4	2	0	0	0	0	0	0	2	1	1
APW Neukölln II Dammweg	1	17	0,84	2000	none	1	none	none	0,29	none	none	5	2900	25	1	none	none	medium	none	none	very sensitive	$> f_{S,QM} \cdot Q_{S,aM} + Q_{F,aM}$	less sensitive
			1	1	0	1	0	0	2	0	0	2	2	2	0	0	0	2	0	0	2	1	1
HPW Spandau I Betckestraße	2	31	0,35	3800	none	none	high	4	0,33	1	none	23	5980	35	2	none	none	significant	none	none	very sensitive	$> f_{S,QM} \cdot Q_{S,aM} + Q_{F,aM}$	less sensitive
			1	1	0	0	2	4	2	2	0	4	4	2	1	0	0	4	0	0	2	1	1
HPW Wilmersdorf Hohenzollerndamm	2	31	0,38	6000	small	none	high	none	0,25	4	1 RÜB	24	7150	7	1	1	none	significant	none	none	very sensitive	$> f_{S,QM} \cdot Q_{S,aM} + Q_{F,aM}$	less sensitive
			1	2	1	0	2	0	2	4	2	4	4	0	0	1	0	4	0	0	2	1	1
HPW Charlottenburg I Sophie-Charlotte-Straße	2	27	0,74	4000	none	1	high	1	0,5	none	1 RÜB	68	11860	15	1	none	none	significant	none	none	very sensitive	$> f_{S,QM} \cdot Q_{S,aM} + Q_{F,aM}$	less sensitive
			1	1	0	1	2	2	2	0	2	4	4	0	0	0	0	4	0	0	2	1	1
APW Charlottenburg III Nonnendamm	2	32	0,38	4200	none	1	medium	1	0,11	none	1 RKB	12	14710	97	1	none	none	insignificant	none	significant	very sensitive	$< f_{S,QM} \cdot Q_{S,aM} + Q_{F,aM}$	less sensitive
			1	1	0	1	2	2	4	0	2	4	4	4	0	0	0	0	0	4	2	0	1
APW Ruhleben Freiheit	1	23	0,92	2400	none	none	high	none	0,87	none	none	3	2020	65	2	1	none	insignificant	medium	significant	very sensitive	$< f_{S,QM} \cdot Q_{S,aM} + Q_{F,aM}$	less sensitive
			1	1	0	0	2	0	0	0	0	2	2	4	1	1	0	0	2	4	2	0	1
Total combined sewer system	3	56	0.54	6000	small	2	high	34	0.33	several	14	514	102360	15	> 3	several	13	significant	significant	significant	very sensitive	$> f_{S,QM} \cdot Q_{S,aM} + Q_{F,aM}$	less sensitive
			1	2	1	1	2	4	2	4	4	4	4	2	3	2	4	4	4	4	2	1	1

[1] Category according to DWA-M 180:
Category 1 (0 - 24 points): probably not suitable for rtc
Category 2 (25 - 35 points): probably suitable for rtc
Category 3 (> 35 points): very suitable for rtc

SK: Stauraumkanal = sewer with storage capacity and overflow
RÜB: Regenüberlaufbecken = combined water tank with overflow
RKB: Regenklärbecken = storm water tank

Appendix 7 – InfoWorks rtc code for global control

```
         1 EZG Ruh_02092000
   COMMENT
   COMMENT Abfrage des Systemzustandes: globale/lokale Steuerung
   COMMENT
     RANGE   Hcon_Hlg     Z "saugraum Hlg"     0.0        25.1000
     RANGE  Hcon_Bln8     Z "saugraum_Bln8"     0.0        29.3000
     RANGE  Hcon_Bln9     Z "saugraum_Bln9"     0.0        30.0000
     RANGE Hcon_Bln10     Z   25214002     0.0        36.5000
     LOGIC Con_glob_1    OR   Hcon_Hlg  Hcon_Bln8  Hcon_Bln9 Hcon_Bln10
     RANGE  Hcon_Chb1     Z "Saugraum_Chb1"     0.0        29.2000
     RANGE  Hcon_Chb3     Z "Saugraum_Chb3"     0.0        26.6000
     RANGE   Hcon_Ruh     Z "Saugraum_Ruh"     0.0        25.6000
     RANGE  Hcon_Spa1     Z "Saugraum_HPW_Spa1"     0.0        28.3000
     LOGIC Con_glob_2    OR  Hcon_Chb1  Hcon_Chb3   Hcon_Ruh  Hcon_Spa1
     RANGE  Hcon_Spa2     Z   22342008     0.0       27.5000
     RANGE  Hcon_Bln7     Z   16235319     0.0        30.5000
     RANGE  Hcon_Bln3     Z   15211002     0.0        30.6000
     RANGE   Hcon_Wil     Z   14264009     0.0        28.0000
     LOGIC Con_glob_3    OR  Hcon_Spa2  Hcon_Bln7  Hcon_Bln3   Hcon_Wil
     RANGE  Hcon_Bln2     Z   15206005     0.0        30.5000
     LOGIC Con_global    OR Con_glob_1 Con_glob_2 Con_glob_3  Hcon_Bln2
     LOGIC  Con_lokal   NOT Con_global
   COMMENT
   COMMENT Berechnung der einzelnen Speicherauslastungen
   COMMENT
   COMMENT Hlg
     RANGE     H_NHlg     Z "saugraum Hlg"     0.0        20.5400
40.0000
     TABLE      V_Hlg     H_NHlg         LINEAR
TABLEENTRY                               20.540          0.100
TABLEENTRY                               25.160          6.000
TABLEENTRY                               25.520          9.600
TABLEENTRY                               27.010         39.700
TABLEENTRY                               28.820         64.900
TABLEENTRY                               30.090         89.600
TABLEENTRY                               30.390        100.000
TABLEENTRY                               40.000        100.000
  VARIABLE  V_Hlg_abs     *          V_Hlg       36.50000
   COMMENT Bln8
     RANGE    H_NBln8     Z "saugraum_Bln8"     0.0        22.0000
40.0000
     TABLE    V_NBln8    H_NBln8         LINEAR
TABLEENTRY                               22.000          0.100
TABLEENTRY                               29.480        470.000
TABLEENTRY                               29.730        780.000
TABLEENTRY                               30.150       1900.000
TABLEENTRY                               30.500       3800.000
TABLEENTRY                               30.800       6370.000
TABLEENTRY                               35.000       6370.000
     RANGE    H_BBln8     Z   rub_Bln8     0.0        30.4300
36.0000
     TABLE    V_BBln8    H_BBln8         LINEAR
TABLEENTRY                               30.430          0.100
TABLEENTRY                               31.240          8.000
TABLEENTRY                               33.430       1466.000
```

```
TABLEENTRY                               35.000       1466.000
  VARIABLE  V_N+BBln8     +        V_NBln8        V_BBln8
  VARIABLE     V_Bln8     /      V_N+BBln8       78.36000
   COMMENT Bln9
     RANGE    H_NBln9     Z "saugraum_Bln9"     0.0        24.4000
40.0000
     TABLE    V_NBln9    H_NBln9         LINEAR
TABLEENTRY                               24.400          0.100
TABLEENTRY                               28.740        210.000
TABLEENTRY                               29.730        330.000
TABLEENTRY                               30.060        730.000
TABLEENTRY                               30.480       1830.000
TABLEENTRY                               30.990       4200.000
TABLEENTRY                               31.750       9050.000
TABLEENTRY                               40.000       9050.000
     RANGE    H_BBln9     Z  23256rueb     0.0        29.1000
35.0000
     TABLE    V_BBln9    H_BBln9         LINEAR
TABLEENTRY                               29.100          0.100
TABLEENTRY                               31.800       2160.000
TABLEENTRY                               40.000       2160.000
  VARIABLE  V_N+BBln9     +        V_NBln9        V_BBln9
  VARIABLE     V_Bln9     /      V_N+BBln9      112.10000
   COMMENT Bln10
     RANGE   H_NBln10     Z   25214002     0.0        30.5000
40.0000
     TABLE   V_NBln10   H_NBln10         LINEAR
TABLEENTRY                               30.500          0.100
TABLEENTRY                               32.740         70.000
TABLEENTRY                               36.210        360.000
TABLEENTRY                               36.800        480.000
TABLEENTRY                               37.210        750.000
TABLEENTRY                               37.870       1640.000
TABLEENTRY                               38.350       2570.000
TABLEENTRY                               40.000       2570.000
     RANGE   H_BBln10     Z   25214952     0.0        38.0800
45.0000
     TABLE   V_BBln10   H_BBln10         LINEAR
TABLEENTRY                               38.080          0.100
TABLEENTRY                               40.470       1510.000
TABLEENTRY                               45.000       1510.000
     RANGE   H_SBln10     Z   25214910     0.0        36.9000
45.0000
     TABLE   V_SBln10   H_SBln10         LINEAR
TABLEENTRY                               36.900          0.100
TABLEENTRY                               37.330         10.000
TABLEENTRY                               37.560         30.000
TABLEENTRY                               37.820         70.000
TABLEENTRY                               37.880        100.000
TABLEENTRY                               37.890        190.000
TABLEENTRY                               38.340        330.000
TABLEENTRY                               40.000        330.000
  VARIABLE V_N+BBln10     +       V_NBln10       V_BBln10
  VARIABLE V_N+SBln10     +     V_N+BBln10       V_SBln10
  VARIABLE    V_Bln10     /     V_N+SBln10       44.10000
   COMMENT Chb1
     RANGE    H_NChb1     Z "Saugraum_Chb1"     0.0        27.0000
35.0000
     TABLE    V_NChb1    H_NChb1         LINEAR
```

```
TABLEENTRY                              27.000         0.100
TABLEENTRY                              28.800       370.000
TABLEENTRY                              29.180       650.000
TABLEENTRY                              29.520      1180.000
TABLEENTRY                              30.000      2660.000
TABLEENTRY                              30.300      4300.000
TABLEENTRY                              30.350      4990.000
TABLEENTRY                              30.700      7670.000
TABLEENTRY                              35.000      7670.000
     RANGE   H_B1Chb1     Z   19293004     0.0        30.2400
35.0000
     TABLE   V_B1Chb1   H_B1Chb1        LINEAR
TABLEENTRY                              30.240         0.100
TABLEENTRY                              30.740        89.000
TABLEENTRY                              32.380       961.000
TABLEENTRY                              35.000       961.000
     RANGE   H_B2Chb1     Z   19293006     0.0        30.2000
35.0000
     TABLE   V_B2Chb1   H_B2Chb1        LINEAR
TABLEENTRY                              30.200         0.100
TABLEENTRY                              30.700        89.000
TABLEENTRY                              32.380       981.000
TABLEENTRY                              35.000       981.000
     RANGE   H_B3Chb1     Z   19293008     0.0        30.6900
35.0000
     TABLE   V_B3Chb1   H_B3Chb1        LINEAR
TABLEENTRY                              30.690         0.100
TABLEENTRY                              31.150        82.000
TABLEENTRY                              32.570       837.000
TABLEENTRY                              35.000       837.000
  VARIABLE V_N+B1Chb1     +        V_NChb1       V_B1Chb1
  VARIABLE V_N+B2Chb1     +     V_N+B1Chb1       V_B2Chb1
  VARIABLE  V_N+BChb1     +     V_N+B2Chb1       V_B3Chb1
  VARIABLE     V_Chb1     /      V_N+BChb1      104.49000
   COMMENT Chb3
     RANGE    H_NChb3     Z "Saugraum_Chb3"     0.0        23.8500
35.0000
     TABLE     V_Chb3    H_NChb3        LINEAR
TABLEENTRY                              23.850         0.100
TABLEENTRY                              26.230         0.700
TABLEENTRY                              26.740         3.700
TABLEENTRY                              27.340        11.100
TABLEENTRY                              28.490        32.500
TABLEENTRY                              29.150        42.400
TABLEENTRY                              29.820        63.900
TABLEENTRY                              30.630       100.000
TABLEENTRY                              35.000       100.000
  VARIABLE V_Chb3_abs     *         V_Chb3      176.10000
   COMMENT Ruh
     RANGE     H_NRuh     Z "Saugraum_Ruh"     0.0        22.3500
35.0000
     TABLE      V_Ruh     H_NRuh        LINEAR
TABLEENTRY                              22.350         0.100
TABLEENTRY                              23.960         2.200
TABLEENTRY                              25.700         8.400
TABLEENTRY                              26.480        15.100
TABLEENTRY                              27.800        44.100
TABLEENTRY                              29.750       100.000
TABLEENTRY                              35.000       100.000
```

```
  VARIABLE  V_Ruh_abs     *          V_Ruh       17.90000
   COMMENT Spa1
     RANGE    H_NSpa1     Z "Saugraum_HPW_Spa1"     0.0        24.7000
40.0000
     TABLE     V_Spa1    H_NSpa1         LINEAR
TABLEENTRY                               24.700          0.100
TABLEENTRY                               28.270          3.300
TABLEENTRY                               28.610          5.900
TABLEENTRY                               29.000         14.200
TABLEENTRY                               30.000         54.500
TABLEENTRY                               30.750        100.000
TABLEENTRY                               40.000        100.000
  VARIABLE V_Spa1_abs     *         V_Spa1       69.70000
   COMMENT Spa2
     RANGE    H_NSpa2     Z   22342008     0.0        26.1200
35.0000
     TABLE     V_Spa2    H_NSpa2         LINEAR
TABLEENTRY                               26.120          0.100
TABLEENTRY                               27.570          1.900
TABLEENTRY                               28.100         17.300
TABLEENTRY                               28.110         22.000
TABLEENTRY                               28.590         70.100
TABLEENTRY                               28.820        100.000
TABLEENTRY                               35.000        100.000
  VARIABLE V_Spa2_abs     *         V_Spa2       21.40000
   COMMENT Bln1
     RANGE    H_NBln7     Z   16235319     0.0        24.2500
35.0000
     TABLE    V_NBln7    H_NBln7         LINEAR
TABLEENTRY                               24.250          0.100
TABLEENTRY                               30.540        300.000
TABLEENTRY                               30.590        440.000
TABLEENTRY                               30.860       1060.000
TABLEENTRY                               31.200       2470.000
TABLEENTRY                               31.530       4760.000
TABLEENTRY                               31.750       6930.000
TABLEENTRY                               35.000       6930.000
     RANGE H_BLutzow1     Z   16244950     0.0        31.7800
40.0000
     TABLE V_BLutzow1 H_BLutzow1         LINEAR
TABLEENTRY                               31.780          0.100
TABLEENTRY                               33.930       1000.000
TABLEENTRY                               40.000       1000.000
  VARIABLE  V_N+BBln7     +        V_NBln7     V_BLutzow1
  VARIABLE     V_Bln7     /      V_N+BBln7       79.30000
   COMMENT Bln3
     RANGE    H_NBln3     Z   15211002     0.0        24.5700
35.0000
     TABLE    V_NBln3    H_NBln3         LINEAR
TABLEENTRY                               24.570          0.100
TABLEENTRY                               30.460        330.000
TABLEENTRY                               30.750        640.000
TABLEENTRY                               30.920       1120.000
TABLEENTRY                               31.290       3090.000
TABLEENTRY                               31.610       6220.000
TABLEENTRY                               31.840       9650.000
TABLEENTRY                               32.350      19480.000
TABLEENTRY                               35.000      19480.000
```

```
     RANGE  H_SRKBln3     Z   18224005     0.0        23.0400
35.0000
     TABLE  V_SRKBln3  H_SRKBln3         LINEAR
TABLEENTRY                               23.040          0.100
TABLEENTRY                               23.540         30.000
TABLEENTRY                               24.210        200.000
TABLEENTRY                               26.100       1200.000
TABLEENTRY                               26.940       1360.000
TABLEENTRY                               30.910       1550.000
TABLEENTRY                               31.260       1690.000
TABLEENTRY                               32.200       2190.000
TABLEENTRY                               35.000       2190.000
  VARIABLE V_N+SKBln3     +        V_NBln3      V_SRKBln3
  VARIABLE     V_Bln3     /      V_N+SKBln3      216.70000
   COMMENT Wil
     RANGE     H_NWil     Z   14264009     0.0        20.1200
35.0000
     TABLE     V_NWil     H_NWil         LINEAR
TABLEENTRY                               20.120          0.100
TABLEENTRY                               28.180        850.000
TABLEENTRY                               29.690       1800.000
TABLEENTRY                               31.450       4590.000
TABLEENTRY                               32.040       8800.000
TABLEENTRY                               32.440      14200.000
TABLEENTRY                               40.000      14200.000
     RANGE     H_BWil     Z  14264rueb     0.0        23.0000
35.0000
     TABLE     V_BWil     H_BWil         LINEAR
TABLEENTRY                               23.000          0.100
TABLEENTRY                               23.850          8.500
TABLEENTRY                               32.850       3675.000
TABLEENTRY                               35.000       3675.000
     RANGE H_BLutzow2     Z   16246T02     0.0        32.0200
40.0000
     TABLE V_BLutzow2 H_BLutzow2         LINEAR
TABLEENTRY                               32.020          0.100
TABLEENTRY                               33.930        978.000
TABLEENTRY                               35.000        978.000
     RANGE H_BLutzow3     Z   16246T01     0.0        32.0200
40.0000
     TABLE V_BLutzow3 H_BLutzow3         LINEAR
TABLEENTRY                               32.020          0.100
TABLEENTRY                               33.930        978.000
TABLEENTRY                               40.000        978.000
     RANGE  H_SRKWilm     Z   16246701     0.0        29.6000
40.0000
     TABLE  V_SRKWilm  H_SRKWilm         LINEAR
TABLEENTRY                               29.650          0.100
TABLEENTRY                               30.500         50.000
TABLEENTRY                               30.660        390.000
TABLEENTRY                               31.080       2400.000
TABLEENTRY                               31.940       7360.000
TABLEENTRY                               32.550      10160.000
TABLEENTRY                               40.000      10160.000
  VARIABLE   V_N+BWil     +         V_NWil         V_BWil
  VARIABLE  V_BLutzow     +      V_BLutzow2     V_BLutzow3
  VARIABLE   V_Lutzow     +       V_BLutzow      V_SRKWilm
  VARIABLE V_N+B+SWil     +        V_N+BWil       V_Lutzow
  VARIABLE      V_Wil     /      V_N+B+SWil      299.91000
```

```
   COMMENT Bln2
     RANGE    H_NBln2     Z   15206002     0.0        30.4100
35.0000
     TABLE    V_NBln2    H_NBln2         LINEAR
TABLEENTRY                               30.410          0.100
TABLEENTRY                               30.900         60.000
TABLEENTRY                               31.300        420.000
TABLEENTRY                               31.600       1070.000
TABLEENTRY                               31.900       2190.000
TABLEENTRY                               32.250       4360.000
TABLEENTRY                               32.600       7750.000
TABLEENTRY                               40.000       7750.000
     RANGE    H_BBln2     Z   15206951     0.0        27.8500
40.0000
     TABLE    V_BBln2    H_BBln2         LINEAR
TABLEENTRY                               27.850          0.100
TABLEENTRY                               29.600         11.000
TABLEENTRY                               29.710         67.000
TABLEENTRY                               32.300       2679.000
TABLEENTRY                               40.000       2679.000
     RANGE    H_NBln6     Z   fromBln6     0.0        25.9600
35.0000
     TABLE    V_NBln6    H_NBln6         LINEAR
TABLEENTRY                               25.960          0.100
TABLEENTRY                               30.280        120.000
TABLEENTRY                               30.900        360.000
TABLEENTRY                               31.200        620.000
TABLEENTRY                               31.600       1320.000
TABLEENTRY                               32.000       2860.000
TABLEENTRY                               32.650       6850.000
TABLEENTRY                               40.000       6850.000
     RANGE    H_BBln6     Z   14193952     0.0        25.4500
40.0000
     TABLE    V_BBln6    H_BBln6         LINEAR
TABLEENTRY                               25.450          0.100
TABLEENTRY                               29.620        164.000
TABLEENTRY                               29.800        271.000
TABLEENTRY                               32.440       3297.000
TABLEENTRY                               40.000       3297.000
  VARIABLE  V_N+BBln2     +        V_NBln2        V_BBln2
  VARIABLE  V_N+BBln6     +        V_NBln6        V_BBln6
  VARIABLE V_N+BBln26     +      V_N+BBln2      V_N+BBln6
  VARIABLE     V_Bln2     /     V_N+BBln26      205.76000
   COMMENT
   COMMENT Berechnung der mittleren Gesamtspeicherauslastung
   COMMENT
  VARIABLE  V_summe_1     +      V_Hlg_abs      V_N+BBln8
  VARIABLE  V_summe_2     +      V_summe_1      V_N+BBln9
  VARIABLE  V_summe_3     +      V_summe_2     V_N+SBln10
  VARIABLE  V_summe_4     +      V_summe_3      V_N+BChb1
  VARIABLE  V_summe_5     +      V_summe_4     V_Chb3_abs
  VARIABLE  V_summe_6     +      V_summe_5      V_Ruh_abs
  VARIABLE  V_summe_7     +      V_summe_6     V_Spa1_abs
  VARIABLE  V_summe_8     +      V_summe_7     V_Spa2_abs
  VARIABLE  V_summe_9     +      V_summe_8      V_N+BBln7
  VARIABLE V_summe_10     +      V_summe_9     V_N+SKBln3
  VARIABLE V_summe_11     +     V_summe_10     V_N+B+SWil
  VARIABLE V_summe_12     +     V_summe_11     V_N+BBln26
  VARIABLE    V_mittel    /     V_summe_12     1462.32000
```

```
   COMMENT
  VARIABLE Vmittelalt     *     Vmittelalt        1.00000
  VARIABLE  dV_mittel     -       V_mittel     Vmittelalt
  VARIABLE Vmittelalt     =       V_mittel
     TABLE    dV_mi>0  dV_mittel         LINEAR
TABLEENTRY                             -100.000          0.000
TABLEENTRY                                0.000          0.000
TABLEENTRY                                0.001          1.000
TABLEENTRY                              100.000          1.000
   COMMENT
   COMMENT Berechnung der neuen Förderleistung
   COMMENT
   COMMENT Hlg
     RANGE   Qakt_Hlg     Q "saugraum Hlg.1"     0.0
  VARIABLE     dV_Hlg     -          V_Hlg       V_mittel
     TABLE    dQ_Hlg1     dV_Hlg         LINEAR
TABLEENTRY                             -100.000         -0.025
TABLEENTRY                               -0.001         -0.001
TABLEENTRY                                0.000          0.000
TABLEENTRY                                0.001          0.050
TABLEENTRY                              100.000          0.600
     TABLE    dQ_Hlg2     dV_Hlg         LINEAR
TABLEENTRY                             -100.000          0.000
TABLEENTRY                                0.000          0.000
TABLEENTRY                                0.001          0.050
TABLEENTRY                              100.000          0.600
  VARIABLE     dQ_Hlg    IF        dV_mi>0        dQ_Hlg1        dQ_Hlg2
  VARIABLE    Qn1_Hlg     +       Qakt_Hlg         dQ_Hlg        dQ_Hlg2
     TABLE Qn1_Hlg>mi    Qn1_Hlg         LINEAR
TABLEENTRY                               -1.000          0.000
TABLEENTRY                                0.035          0.000
TABLEENTRY                                0.036          1.000
TABLEENTRY                               10.000          1.000
  VARIABLE    Qn2_Hlg    IF     Qn1_Hlg>mi        Qn1_Hlg        0.03600
     RANGE  H_Hlg>Hma     Z "saugraum Hlg"     0.0        30.3900
  VARIABLE    Qn3_Hlg    IF      H_Hlg>Hma        0.15000        Qn2_Hlg
   COMMENT Bln8
     RANGE  Qakt_Bln8     Q "saugraum_Bln8.1"     0.0
  VARIABLE    dV_Bln8     -         V_Bln8       V_mittel
     TABLE   dQ_Bln81    dV_Bln8         LINEAR
TABLEENTRY                             -100.000         -0.025
TABLEENTRY                               -0.001         -0.001
TABLEENTRY                                0.000          0.000
TABLEENTRY                                0.001          0.050
TABLEENTRY                              100.000          0.600
     TABLE   dQ_Bln82    dV_Bln8         LINEAR
TABLEENTRY                             -100.000          0.000
TABLEENTRY                                0.000          0.000
TABLEENTRY                                0.001          0.050
TABLEENTRY                              100.000          0.600
  VARIABLE    dQ_Bln8    IF        dV_mi>0       dQ_Bln81       dQ_Bln82
  VARIABLE   Qn1_Bln8     +      Qakt_Bln8        dQ_Bln8       dQ_Bln82
     TABLE  Qn1_B8>mi   Qn1_Bln8         LINEAR
TABLEENTRY                               -1.000          0.000
TABLEENTRY                                0.153          0.000
TABLEENTRY                                0.154          1.000
TABLEENTRY                               10.000          1.000
  VARIABLE   Qn2_Bln8    IF      Qn1_B8>mi       Qn1_Bln8        0.15400
     RANGE   H_B8>Hma     Z "saugraum_Bln8"     0.0        30.8000
```

```
  VARIABLE   Qn3_Bln8    IF       H_B8>Hma        1.00000        Qn2_Bln8
   COMMENT Bln9
     RANGE  Qakt_Bln9     Q "saugraum_Bln9.1"     0.0
  VARIABLE    dV_Bln9     -          V_Bln9       V_mittel
     TABLE   dQ_Bln91    dV_Bln9         LINEAR
TABLEENTRY                             -100.000        -0.025
TABLEENTRY                               -0.001        -0.001
TABLEENTRY                                0.000         0.000
TABLEENTRY                                0.001         0.050
TABLEENTRY                              100.000         0.600
     TABLE   dQ_Bln92    dV_Bln9         LINEAR
TABLEENTRY                             -100.000         0.000
TABLEENTRY                                0.000         0.000
TABLEENTRY                                0.001         0.050
TABLEENTRY                              100.000         0.600
  VARIABLE    dQ_Bln9    IF        dV_mi>0      dQ_Bln91       dQ_Bln92
  VARIABLE   Qn1_Bln9     +      Qakt_Bln9        dQ_Bln9
     TABLE  Qn1_B9>mi   Qn1_Bln9         LINEAR
TABLEENTRY                               -1.000         0.000
TABLEENTRY                                0.151         0.000
TABLEENTRY                                0.152         1.000
TABLEENTRY                               10.000         1.000
  VARIABLE   Qn2_Bln9    IF      Qn1_B9>mi      Qn1_Bln9         0.15200
     RANGE   H_B9>Hma     Z "saugraum_Bln9"     0.0        31.7500
  VARIABLE   Qn3_Bln9    IF       H_B9>Hma        0.60000        Qn2_Bln9
   COMMENT Bln10
     RANGE Qakt_Bln10     Q 25214002.1     0.0
  VARIABLE   dV_Bln10     -         V_Bln10       V_mittel
     TABLE  dQ_Bln101   dV_Bln10         LINEAR
TABLEENTRY                             -100.000        -0.025
TABLEENTRY                               -0.001        -0.001
TABLEENTRY                                0.000         0.000
TABLEENTRY                                0.001         0.050
TABLEENTRY                              100.000         0.600
     TABLE  dQ_Bln102   dV_Bln10         LINEAR
TABLEENTRY                             -100.000         0.000
TABLEENTRY                                0.000         0.000
TABLEENTRY                                0.001         0.050
TABLEENTRY                              100.000         0.600
  VARIABLE   dQ_Bln10    IF        dV_mi>0     dQ_Bln101      dQ_Bln102
  VARIABLE  Qn1_Bln10     +     Qakt_Bln10       dQ_Bln10
     TABLE Qn1_B10>mi  Qn1_Bln10         LINEAR
TABLEENTRY                               -1.000         0.000
TABLEENTRY                                0.121         0.000
TABLEENTRY                                0.122         1.000
TABLEENTRY                               10.000         1.000
  VARIABLE  Qn2_Bln10    IF     Qn1_B10>mi     Qn1_Bln10         0.12200
     RANGE  H_B10>Hma     Z   25214002     0.0        38.3500
  VARIABLE  Qn3_Bln10    IF      H_B10>Hma        0.60000       Qn2_Bln10
   COMMENT Chb1
     RANGE  Qakt_Chb1     Q "Saugraum_Chb1.5"     0.0
  VARIABLE    dV_Chb1     -          V_Chb1       V_mittel
     TABLE   dQ_Chb11    dV_Chb1         LINEAR
TABLEENTRY                             -100.000        -0.025
TABLEENTRY                               -0.001        -0.001
TABLEENTRY                                0.000         0.000
TABLEENTRY                                0.001         0.050
TABLEENTRY                              100.000         0.600
     TABLE   dQ_Chb12    dV_Chb1         LINEAR
```

```
TABLEENTRY                             -100.000          0.000
TABLEENTRY                                0.000          0.000
TABLEENTRY                                0.001          0.050
TABLEENTRY                              100.000          0.600
  VARIABLE    dQ_Chb1    IF        dV_mi>0       dQ_Chb11       dQ_Chb12
  VARIABLE   Qn1_Chb1     +      Qakt_Chb1        dQ_Chb1
     TABLE Qn1_Ch1>mi   Qn1_Chb1         LINEAR
TABLEENTRY                               -1.000          0.000
TABLEENTRY                                0.299          0.000
TABLEENTRY                                0.300          1.000
TABLEENTRY                               10.000          1.000
  VARIABLE   Qn2_Chb1    IF     Qn1_Ch1>mi       Qn1_Chb1        0.30000
     RANGE  H_Ch1>Hma     Z "Saugraum_Chb1"     0.0        30.7000
  VARIABLE   Qn3_Chb1    IF      H_Ch1>Hma        1.10000       Qn2_Chb1
   COMMENT Chb3
     RANGE   Qakt_Chb3    Q "Saugraum_Chb3.1"     0.0
  VARIABLE    dV_Chb3     -         V_Chb3       V_mittel
     TABLE   dQ_Chb31    dV_Chb3         LINEAR
TABLEENTRY                             -100.000         -0.025
TABLEENTRY                               -0.001         -0.001
TABLEENTRY                                0.000          0.000
TABLEENTRY                                0.001          0.050
TABLEENTRY                              100.000          0.600
     TABLE   dQ_Chb32    dV_Chb3         LINEAR
TABLEENTRY                             -100.000          0.000
TABLEENTRY                                0.000          0.000
TABLEENTRY                                0.001          0.050
TABLEENTRY                              100.000          0.600
  VARIABLE    dQ_Chb3    IF        dV_mi>0       dQ_Chb31       dQ_Chb32
  VARIABLE   Qn1_Chb3     +      Qakt_Chb3        dQ_Chb3
     TABLE Qn1_Ch3>mi   Qn1_Chb3         LINEAR
TABLEENTRY                               -1.000          0.000
TABLEENTRY                                0.082          0.000
TABLEENTRY                                0.083          1.000
TABLEENTRY                               10.000          1.000
  VARIABLE   Qn2_Chb3    IF     Qn1_Ch3>mi       Qn1_Chb3        0.08300
     RANGE  H_Ch3>Hma     Z "Saugraum_Chb3"     0.0        30.6300
  VARIABLE   Qn3_Chb3    IF      H_Ch3>Hma        0.40000       Qn2_Chb3
   COMMENT Ruh
     RANGE   Qakt_Ruh     Q "Saugraum_Ruh.1"     0.0
  VARIABLE     dV_Ruh     -          V_Ruh       V_mittel
     TABLE    dQ_Ruh1     dV_Ruh         LINEAR
TABLEENTRY                             -100.000         -0.025
TABLEENTRY                               -0.001         -0.001
TABLEENTRY                                0.000          0.000
TABLEENTRY                                0.001          0.050
TABLEENTRY                              100.000          0.600
     TABLE    dQ_Ruh2     dV_Ruh         LINEAR
TABLEENTRY                             -100.000          0.000
TABLEENTRY                                0.000          0.000
TABLEENTRY                                0.001          0.050
TABLEENTRY                              100.000          0.600
  VARIABLE     dQ_Ruh    IF        dV_mi>0        dQ_Ruh1        dQ_Ruh2
  VARIABLE    Qn1_Ruh     +       Qakt_Ruh         dQ_Ruh
     TABLE Qn1_Ruh>mi    Qn1_Ruh         LINEAR
TABLEENTRY                               -1.000          0.000
TABLEENTRY                                0.075          0.000
TABLEENTRY                                0.076          1.000
TABLEENTRY                               10.000          1.000
```

```
  VARIABLE    Qn2_Ruh    IF     Qn1_Ruh>mi        Qn1_Ruh        0.07600
     RANGE  H_Ruh>Hma     Z "Saugraum_Ruh"     0.0        29.7500
  VARIABLE    Qn3_Ruh    IF      H_Ruh>Hma        0.50000        Qn2_Ruh
   COMMENT Spa1
     RANGE  Qakt_Spa1     Q "Saugraum_HPW_Spa1.1"     0.0
  VARIABLE    dV_Spa1     -         V_Spa1       V_mittel
     TABLE   dQ_Spa11    dV_Spa1         LINEAR
TABLEENTRY                             -100.000         -0.025
TABLEENTRY                               -0.001         -0.001
TABLEENTRY                                0.000          0.000
TABLEENTRY                                0.001          0.050
TABLEENTRY                              100.000          0.600
     TABLE   dQ_Spa12    dV_Spa1         LINEAR
TABLEENTRY                             -100.000          0.000
TABLEENTRY                                0.000          0.000
TABLEENTRY                                0.001          0.050
TABLEENTRY                              100.000          0.600
  VARIABLE    dQ_Spa1    IF        dV_mi>0       dQ_Spa11       dQ_Spa12
  VARIABLE   Qn1_Spa1     +      Qakt_Spa1        dQ_Spa1
     TABLE Qn1_Sp1>mi   Qn1_Spa1         LINEAR
TABLEENTRY                               -1.000          0.000
TABLEENTRY                                0.161          0.000
TABLEENTRY                                0.162          1.000
TABLEENTRY                               10.000          1.000
  VARIABLE   Qn2_Spa1    IF     Qn1_Sp1>mi       Qn1_Spa1        0.16200
     RANGE  H_Sp1>Hma     Z "Saugraum_HPW_Spa1"     0.0        30.7500
  VARIABLE   Qn3_Spa1    IF      H_Sp1>Hma        1.00000       Qn2_Spa1
   COMMENT Spa2
     RANGE  Qakt_Spa2     Q 22342008.1     0.0
  VARIABLE    dV_Spa2     -         V_Spa2       V_mittel
     TABLE   dQ_Spa21    dV_Spa2         LINEAR
TABLEENTRY                             -100.000         -0.025
TABLEENTRY                               -0.001         -0.001
TABLEENTRY                                0.000          0.000
TABLEENTRY                                0.001          0.050
TABLEENTRY                              100.000          0.600
     TABLE   dQ_Spa22    dV_Spa2         LINEAR
TABLEENTRY                             -100.000          0.000
TABLEENTRY                                0.000          0.000
TABLEENTRY                                0.001          0.050
TABLEENTRY                              100.000          0.600
  VARIABLE    dQ_Spa2    IF        dV_mi>0       dQ_Spa21       dQ_Spa22
  VARIABLE   Qn1_Spa2     +      Qakt_Spa2        dQ_Spa2
     TABLE Qn1_Sp2>mi   Qn1_Spa2         LINEAR
TABLEENTRY                               -1.000          0.000
TABLEENTRY                                0.078          0.000
TABLEENTRY                                0.079          1.000
TABLEENTRY                               10.000          1.000
  VARIABLE   Qn2_Spa2    IF     Qn1_Sp2>mi       Qn1_Spa2        0.07900
     RANGE  H_Sp2>Hma     Z   22342008     0.0        28.8200
  VARIABLE   Qn3_Spa2    IF      H_Sp2>Hma        0.25000       Qn2_Spa2
   COMMENT Bln1
     RANGE  Qakt_Bln7     Q 16235319.1     0.0
  VARIABLE    dV_Bln7     -         V_Bln7       V_mittel
     TABLE   dQ_Bln71    dV_Bln7         LINEAR
TABLEENTRY                             -100.000         -0.025
TABLEENTRY                               -0.001         -0.001
TABLEENTRY                                0.000          0.000
TABLEENTRY                                0.001          0.050
```

```
TABLEENTRY                              100.000          0.600
     TABLE   dQ_Bln72    dV_Bln7         LINEAR
TABLEENTRY                             -100.000          0.000
TABLEENTRY                                0.000          0.000
TABLEENTRY                                0.001          0.050
TABLEENTRY                              100.000          0.600
  VARIABLE    dQ_Bln7    IF        dV_mi>0       dQ_Bln71       dQ_Bln72
  VARIABLE   Qn1_Bln7     +      Qakt_Bln7        dQ_Bln7
     TABLE  Qn1_B7>mi   Qn1_Bln7         LINEAR
TABLEENTRY                               -1.000          0.000
TABLEENTRY                                0.138          0.000
TABLEENTRY                                0.139          1.000
TABLEENTRY                               10.000          1.000
  VARIABLE   Qn2_Bln7    IF      Qn1_B7>mi       Qn1_Bln7        0.13900
     RANGE   H_B7>Hma     Z   16235319     0.0        31.7500
  VARIABLE   Qn3_Bln7    IF       H_B7>Hma        0.50000       Qn2_Bln7
   COMMENT Bln3
     RANGE  Qakt_Bln3     Q 15211002.1     0.0
  VARIABLE    dV_Bln3     -          V_Bln3      V_mittel
     TABLE   dQ_Bln31    dV_Bln3         LINEAR
TABLEENTRY                             -100.000         -0.025
TABLEENTRY                               -0.001         -0.001
TABLEENTRY                                0.000          0.000
TABLEENTRY                                0.001          0.050
TABLEENTRY                              100.000          0.600
     TABLE   dQ_Bln32    dV_Bln3         LINEAR
TABLEENTRY                             -100.000          0.000
TABLEENTRY                                0.000          0.000
TABLEENTRY                                0.001          0.050
TABLEENTRY                              100.000          0.600
  VARIABLE    dQ_Bln3    IF        dV_mi>0       dQ_Bln31       dQ_Bln32
  VARIABLE   Qn1_Bln3     +      Qakt_Bln3        dQ_Bln3
     TABLE  Qn1_B3>mi   Qn1_Bln3         LINEAR
TABLEENTRY                               -1.000          0.000
TABLEENTRY                                0.132          0.000
TABLEENTRY                                0.133          1.000
TABLEENTRY                               10.000          1.000
  VARIABLE   Qn2_Bln3    IF      Qn1_B3>mi       Qn1_Bln3        0.13300
     RANGE   H_B3>Hma     Z   15211002     0.0        32.3500
  VARIABLE   Qn3_Bln3    IF       H_B3>Hma        0.50000       Qn2_Bln3
   COMMENT Wil
     RANGE   Qakt_Wil     Q 14264009.1     0.0
  VARIABLE     dV_Wil     -           V_Wil      V_mittel
     TABLE    dQ_Wil1     dV_Wil         LINEAR
TABLEENTRY                             -100.000         -0.010
TABLEENTRY                               -0.001         -0.001
TABLEENTRY                                0.000          0.000
TABLEENTRY                                0.001          0.050
TABLEENTRY                              100.000          0.800
     TABLE    dQ_Wil2     dV_Wil         LINEAR
TABLEENTRY                             -100.000          0.000
TABLEENTRY                                0.000          0.000
TABLEENTRY                                0.001          0.050
TABLEENTRY                              100.000          0.600
  VARIABLE     dQ_Wil    IF        dV_mi>0        dQ_Wil1        dQ_Wil2
  VARIABLE    Qn1_Wil     +       Qakt_Wil         dQ_Wil
     TABLE Qn1_Wil>mi    Qn1_Wil         LINEAR
TABLEENTRY                               -1.000          0.000
TABLEENTRY                                0.514          0.000
```

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TABLEENTRY                                0.515          1.000
TABLEENTRY                               10.000          1.000
  VARIABLE    Qn2_Wil    IF     Qn1_Wil>mi        Qn1_Wil        0.51500
     RANGE  H_Wil>Hma     Z   14264009     0.0        32.4400
  VARIABLE    Qn3_Wil    IF      H_Wil>Hma        1.70000        Qn2_Wil
   COMMENT Bln2
     RANGE  Qakt_Bln2     Q 15206005.1     0.0
  VARIABLE    dV_Bln2     -         V_Bln2       V_mittel
     TABLE   dQ_Bln21    dV_Bln2         LINEAR
TABLEENTRY                             -100.000         -0.025
TABLEENTRY                               -0.001         -0.001
TABLEENTRY                                0.000          0.000
TABLEENTRY                                0.001          0.050
TABLEENTRY                              100.000          0.600
     TABLE   dQ_Bln22    dV_Bln2         LINEAR
TABLEENTRY                             -100.000          0.000
TABLEENTRY                                0.000          0.000
TABLEENTRY                                0.001          0.050
TABLEENTRY                              100.000          0.600
  VARIABLE    dQ_Bln2    IF       dV_mi>0       dQ_Bln21       dQ_Bln22
  VARIABLE   Qn1_Bln2     +      Qakt_Bln2        dQ_Bln2
     TABLE  Qn1_B2>mi   Qn1_Bln2         LINEAR
TABLEENTRY                               -1.000          0.000
TABLEENTRY                                0.190          0.000
TABLEENTRY                                0.191          1.000
TABLEENTRY                               10.000          1.000
  VARIABLE   Qn2_Bln2    IF      Qn1_B2>mi       Qn1_Bln2        0.19100
     RANGE   H_B2>Hma     Z   15206002     0.0        32.5500
     RANGE   H_B6>Hma     Z   fromBln6     0.0        32.6000
     LOGIC H_Bln2>Hma    OR   H_B2>Hma   H_B6>Hma
  VARIABLE   Qn3_Bln2    IF     H_Bln2>Hma        0.70000       Qn2_Bln2
   COMMENT Wit
     RANGE   Qakt_Wit     Q "Saugraum_Wit.1"     0.0
   COMMENT
   COMMENT Überprüfung auf zul. Qmax,ges
   COMMENT
  VARIABLE  Q_summe_1     +        Qn3_Hlg       Qn3_Bln8
  VARIABLE  Q_summe_2     +      Q_summe_1       Qn3_Bln9
  VARIABLE  Q_summe_3     +      Q_summe_2      Qn3_Bln10
  VARIABLE  Q_summe_4     +      Q_summe_3       Qn3_Chb1
  VARIABLE  Q_summe_5     +      Q_summe_4       Qn3_Chb3
  VARIABLE  Q_summe_6     +      Q_summe_5        Qn3_Ruh
  VARIABLE  Q_summe_7     +      Q_summe_6       Qn3_Spa1
  VARIABLE  Q_summe_8     +      Q_summe_7       Qn3_Spa2
  VARIABLE  Q_summe_9     +      Q_summe_8       Qn3_Bln7
  VARIABLE Q_summe_10     +      Q_summe_9       Qn3_Bln3
  VARIABLE Q_summe_11     +     Q_summe_10        Qn3_Wil
  VARIABLE Q_summe_12     +     Q_summe_11       Qn3_Bln2
  VARIABLE Q_summe_13     +     Q_summe_12       Qakt_Wit
  VARIABLE    Q_ratio     /       6.70000     Q_summe_13
     TABLE  Q_ratio<1    Q_ratio         LINEAR
TABLEENTRY                                0.000          1.000
TABLEENTRY                                0.999          1.000
TABLEENTRY                                1.000          0.000
TABLEENTRY                              100.000          0.000
  VARIABLE      Q_pot     -       6.70000       Qakt_Wit
  VARIABLE   Q_faktor     /         Q_pot     Q_summe_12
  VARIABLE    Qn4_Hlg     *       Qn3_Hlg       Q_faktor
  VARIABLE   Qn4_Bln8     *      Qn3_Bln8       Q_faktor
```

```
  VARIABLE   Qn4_Bln9     *       Qn3_Bln9       Q_faktor
  VARIABLE  Qn4_Bln10     *      Qn3_Bln10       Q_faktor
  VARIABLE   Qn4_Chb1     *       Qn3_Chb1       Q_faktor
  VARIABLE   Qn4_Chb3     *       Qn3_Chb3       Q_faktor
  VARIABLE    Qn4_Ruh     *        Qn3_Ruh       Q_faktor
  VARIABLE   Qn4_Spa1     *       Qn3_Spa1       Q_faktor
  VARIABLE   Qn4_Spa2     *       Qn3_Spa2       Q_faktor
  VARIABLE   Qn4_Bln7     *       Qn3_Bln7       Q_faktor
  VARIABLE   Qn4_Bln3     *       Qn3_Bln3       Q_faktor
  VARIABLE    Qn4_Wil     *        Qn3_Wil       Q_faktor
  VARIABLE   Qn4_Bln2     *       Qn3_Bln2       Q_faktor
  VARIABLE   Qend_Hlg    IF      Q_ratio<1        Qn4_Hlg        Qn3_Hlg
  VARIABLE  Qend_Bln8    IF      Q_ratio<1       Qn4_Bln8       Qn3_Bln8
  VARIABLE  Qend_Bln9    IF      Q_ratio<1       Qn4_Bln9       Qn3_Bln9
  VARIABLE Qend_Bln10    IF      Q_ratio<1      Qn4_Bln10      Qn3_Bln10
  VARIABLE  Qend_Chb1    IF      Q_ratio<1       Qn4_Chb1       Qn3_Chb1
  VARIABLE  Qend_Chb3    IF      Q_ratio<1       Qn4_Chb3       Qn3_Chb3
  VARIABLE   Qend_Ruh    IF      Q_ratio<1        Qn4_Ruh        Qn3_Ruh
  VARIABLE  Qend_Spa1    IF      Q_ratio<1       Qn4_Spa1       Qn3_Spa1
  VARIABLE  Qend_Spa2    IF      Q_ratio<1       Qn4_Spa2       Qn3_Spa2
  VARIABLE  Qend_Bln7    IF      Q_ratio<1       Qn4_Bln7       Qn3_Bln7
  VARIABLE  Qend_Bln3    IF      Q_ratio<1       Qn4_Bln3       Qn3_Bln3
  VARIABLE   Qend_Wil    IF      Q_ratio<1        Qn4_Wil        Qn3_Wil
  VARIABLE  Qend_Bln2    IF      Q_ratio<1       Qn4_Bln2       Qn3_Bln2
14264009.1                                     1
   COMMENT Bei globalen Bedingungen, setzen der koordinierten
Förderleistung
      RULE Con_global   POS                        Qend_Wil
   COMMENT Bei lokalen Bedingungen, lokale Steuerung
     RANGE          P0      Z   14264009     0.0        20.1000
21.8500
     RANGE          P1      Z   14264009     0.0        27.0000
27.4000
     RANGE          P2      Z   14264009     0.0        27.4000
27.6000
     RANGE          P3      Z   14264009     0.0        27.6000
27.8000
     RANGE          P4      Z   14264009     0.0        27.8000
28.0000
     RANGE      reg=P0   REG 14264009.1     0.0
0.0020
     RANGE      reg=P1   REG 14264009.1     0.0
0.3020
     RANGE      reg=P2   REG 14264009.1     0.0
0.6020
     RANGE      reg=P3   REG 14264009.1     0.0
0.9020
     LOGIC    LogicP0   AND         P0  Con_lokal
     LOGIC    LogicP1   AND         P1     reg=P0  Con_lokal
     LOGIC    LogicP2   AND         P2     reg=P1  Con_lokal
     LOGIC    LogicP3   AND         P3     reg=P2  Con_lokal
     LOGIC    LogicP4   AND         P4     reg=P3  Con_lokal
      RULE    LogicP0   POS    0.000
      RULE    LogicP1   POS    0.300
      RULE    LogicP2   POS    0.600
      RULE    LogicP3   POS    0.900
      RULE    LogicP4   POS    1.000
rub_Bln8.2                                     1
```

```
     RANGE         H1     Z "saugraum_Bln8"     0.0         0.0000
29.2000
     RANGE         H2     Z "saugraum_Bln8"     0.0        29.3000
      RULE         H1   POS    0.532
      RULE         H2   POS    0.000
"saugraum_Bln8.1"                                      1
   COMMENT Bei globalen Bedingungen, setzen der koordinierten
Förderleistung
      RULE Con_global   POS                      Qend_Bln8
   COMMENT Bei lokalen Bedingungen, lokale Steuerung
     RANGE         P0     Z "saugraum_Bln8"     0.0        22.0000
24.4000
     RANGE         P1     Z "saugraum_Bln8"     0.0        28.9500
29.1000
     RANGE         P2     Z "saugraum_Bln8"     0.0        29.1000
29.2000
     RANGE         P3     Z "saugraum_Bln8"     0.0        29.2000
29.3000
     RANGE     reg=P0   REG "saugraum_Bln8.1"     0.0
0.0020
     RANGE     reg=P1   REG "saugraum_Bln8.1"     0.0
0.1320
     RANGE     reg=P2   REG "saugraum_Bln8.1"     0.0
0.1820
     LOGIC    LogicP0   AND         P0  Con_lokal
     LOGIC    LogicP1   AND         P1     reg=P0  Con_lokal
     LOGIC    LogicP2   AND         P2     reg=P1  Con_lokal
     LOGIC    LogicP3   AND         P3     reg=P2  Con_lokal
      RULE    LogicP0   POS    0.000
      RULE    LogicP1   POS    0.130
      RULE    LogicP2   POS    0.180
      RULE    LogicP3   POS    0.350
18224005.3                                      1
     RANGE  Level_off     Z   18224305     0.0        32.3000
     RANGE   Level_on     Z   18224305     0.0
31.8000
      RULE   Level_on    ON    0.000
      RULE  Level_off   OFF    0.000
15211002.1                                      1
   COMMENT Bei globalen Bedingungen, setzen der koordinierten
Förderleistung
      RULE Con_global   POS                      Qend_Bln3
   COMMENT Bei lokalen Bedingungen, lokale Steuerung
     RANGE         P0     Z   15211002     0.0        24.5500
27.5000
     RANGE         P1     Z   15211002     0.0        30.0000
30.1500
     RANGE         P2     Z   15211002     0.0        30.1500
30.3000
     RANGE         P3     Z   15211002     0.0        30.3000
30.6000
     RANGE     reg=P0   REG 15211002.1     0.0
0.0020
     RANGE     reg=P1   REG 15211002.1     0.0
0.1380
     RANGE     reg=P2   REG 15211002.1     0.0
0.1870
     LOGIC    LogicP0   AND         P0  Con_lokal
     LOGIC    LogicP1   AND         P1     reg=P0  Con_lokal
```

```
     LOGIC    LogicP2   AND         P2     reg=P1  Con_lokal
     LOGIC    LogicP3   AND         P3     reg=P2  Con_lokal
      RULE    LogicP0   POS    0.000
      RULE    LogicP1   POS    0.136
      RULE    LogicP2   POS    0.185
      RULE    LogicP3   POS    0.250
 weir_us.1                                      1
     RANGE   hWSensor     Z    weir_us     0.0
     RANGE    qSensor     Q  weir_ds.1    20.0
     RANGE   hPS<31.0     Z "23256pszulauf"     0.0
31.0000
     RANGE   hPS>31.0     Z "23256pszulauf"     0.0        31.0000
     RANGE   hW<30.65     Z    weir_us     0.0
30.6500
     RANGE 30.65-32.2     Z    weir_us     0.0        30.6500
32.2000
     RANGE    hW>32.2     Z    weir_us     0.0        32.2000
     RANGE      Q>300     Q  weir_ds.1    20.0         0.3100
     RANGE      Q<300     Q  weir_ds.1    20.0
0.2900
     LOGIC     Logic1   AND 30.65-32.2   hPS>31.0
     LOGIC     Logic2   AND 30.65-32.2   hPS<31.0
     LOGIC     Logic3   AND    hW>32.2      Q>300
     LOGIC     Logic4   AND    hW>32.2      Q<300
CONTROLLER   hControl   PID   hWSensor    60    0.000   -1.000    0.000
0.000
CONTROLLER qControler   PID    qSensor    60    0.000    0.500    0.000
0.000
      RULE   hW<30.65   POS   30.240 qControler
      RULE     Logic1  CTRL    0.300 qControler
      RULE     Logic2   POS   30.240   hControl
      RULE     Logic3  CTRL   32.300   hControl
      RULE     Logic4  CTRL    0.300 qControler
"22252schieberoben.1"                                      1
     RANGE     h<31.2     Z   22252901     0.0
31.2000
     RANGE     h>31.4     Z   22252901     0.0        31.4000
      RULE     h<31.2   POS    0.266
      RULE     h>31.4   POS    0.000
22252303.2                                      1
     RANGE     h<32.0     Z   22252303     0.0
32.0000
     RANGE     h>32.0     Z   22252303     0.0        32.0000
CONTROLLER   hControl   PID     h>32.0    60    0.000   -2.000    0.000
0.000
      RULE     h<32.0   POS   32.200   hControl
      RULE     h>32.0  CTRL   32.200   hControl
23256001.1                                      1
     RANGE     h<31.8     Z   23256001     0.0
31.8000
     RANGE     h>31.8     Z   23256001     0.0        31.8000
CONTROLLER   hControl   PID     h>31.8    60    0.000   -2.000    0.000
0.000
      RULE     h<31.8   POS   32.000
      RULE     h>31.8  CTRL   32.000   hControl
"23256rueb.2"                                      1
     RANGE     h<28.8     Z "saugraum_Bln9"     0.0
28.7000
     RANGE     h>28.8     Z "saugraum_Bln9"     0.0        28.9000
```

```
      RULE     h<28.8   POS    1.000
      RULE     h>28.8   POS    0.000
"saugraum_Bln9.1"                                     1
   COMMENT Bei globalen Bedingungen, setzen der koordinierten
Förderleistung
      RULE Con_global   POS                      Qend_Bln9
   COMMENT Bei lokalen Bedingungen, lokale Steuerung
     RANGE         P0     Z "saugraum_Bln9"     0.0        24.4000
25.7500
     RANGE         P1     Z "saugraum_Bln9"     0.0        29.2000
29.4000
     RANGE         P2     Z "saugraum_Bln9"     0.0        29.4000
29.8000
     RANGE         P3     Z "saugraum_Bln9"     0.0        29.8000
30.0000
     RANGE     reg=P0   REG "saugraum_Bln9.1"     0.0
0.0020
     RANGE     reg=P1   REG "saugraum_Bln9.1"     0.0
0.1020
     RANGE     reg=P2   REG "saugraum_Bln9.1"     0.0
0.2120
     LOGIC    LogicP0   AND         P0  Con_lokal
     LOGIC    LogicP1   AND         P1     reg=P0  Con_lokal
     LOGIC    LogicP2   AND         P2     reg=P1  Con_lokal
     LOGIC    LogicP3   AND         P3     reg=P2  Con_lokal
      RULE    LogicP0   POS    0.000
      RULE    LogicP1   POS    0.100
      RULE    LogicP2   POS    0.210
      RULE    LogicP3   POS    0.320
"saugraum Hlg.1"                                     1
   COMMENT Bei globalen Bedingungen, setzen der koordinierten
Förderleistung
      RULE Con_global   POS                      Qend_Hlg
   COMMENT Bei lokalen Bedingungen, lokale Steuerung
     RANGE         P0     Z "saugraum Hlg"     0.0        20.5400
22.0000
     RANGE         P1     Z "saugraum Hlg"     0.0        24.6000
24.9000
     RANGE         P2     Z "saugraum Hlg"     0.0        24.9000
25.1000
     RANGE     reg=P0   REG "saugraum Hlg.1"     0.0
0.0020
     RANGE     reg=P1   REG "saugraum Hlg.1"     0.0
0.0520
     LOGIC    LogicP0   AND         P0  Con_lokal
     LOGIC    LogicP1   AND         P1     reg=P0  Con_lokal
     LOGIC    LogicP2   AND         P2     reg=P1  Con_lokal
      RULE    LogicP0   POS    0.000
      RULE    LogicP1   POS    0.050
      RULE    LogicP2   POS    0.100
25214952.1                                     1
     RANGE        auf     Z   25214002     0.0
36.7000
     RANGE         zu     Z   25214002     0.0        36.9000
      RULE        auf   POS    0.200
      RULE         zu   POS    0.000
25214002.1                                     1
   COMMENT Bei globalen Bedingungen, setzen der koordinierten
Förderleistung
```

```
      RULE Con_global   POS                     Qend_Bln10
   COMMENT Bei lokalen Bedingungen, lokale Steuerung
     RANGE         P0     Z   25214002     0.0        30.5000
31.3000
     RANGE         P1     Z   25214002     0.0        35.6000
35.9000
     RANGE         P2     Z   25214002     0.0        35.9000
36.0500
     RANGE         P3     Z   25214002     0.0        36.0500
36.5000
     RANGE     reg=P0   REG 25214002.1     0.0
0.0020
     RANGE     reg=P1   REG 25214002.1     0.0
0.1020
     RANGE     reg=P2   REG 25214002.1     0.0
0.2220
     LOGIC    LogicP0   AND         P0  Con_lokal
     LOGIC    LogicP1   AND         P1     reg=P0  Con_lokal
     LOGIC    LogicP2   AND         P2     reg=P1  Con_lokal
     LOGIC    LogicP3   AND         P3     reg=P2  Con_lokal
      RULE    LogicP0   POS    0.000
      RULE    LogicP1   POS    0.100
      RULE    LogicP2   POS    0.220
      RULE    LogicP3   POS    0.300
"Saugraum_Ruh.1"                                      1
   COMMENT Bei globalen Bedingungen, setzen der koordinierten
Förderleistung
      RULE Con_global   POS                       Qend_Ruh
   COMMENT Bei lokalen Bedingungen, lokale Steuerung
     RANGE         P0     Z "Saugraum_Ruh"     0.0        22.3500
23.8000
     RANGE         P1     Z "Saugraum_Ruh"     0.0        25.0000
25.3000
     RANGE         P2     Z "Saugraum_Ruh"     0.0        25.3000
25.6000
     RANGE     reg=P0   REG "Saugraum_Ruh.1"     0.0
0.0020
     RANGE     reg=P1   REG "Saugraum_Ruh.1"     0.0
0.1520
     LOGIC    LogicP0   AND         P0  Con_lokal
     LOGIC    LogicP1   AND         P1     reg=P0  Con_lokal
     LOGIC    LogicP2   AND         P2     reg=P1  Con_lokal
      RULE    LogicP0   POS    0.000
      RULE    LogicP1   POS    0.150
      RULE    LogicP2   POS    0.200
"Zulaufbauwerk_Ruh.3"                                      1
     RANGE    H<29.80     Z "Zulaufbauwerk_Ruh"     0.0
29.8000
     RANGE    H>30.44     Z "Zulaufbauwerk_Ruh"     0.0        30.4400
      RULE    H<29.80   POS    0.000
      RULE    H>30.44   POS    0.711
22342008.1                                      1
   COMMENT Bei globalen Bedingungen, setzen der koordinierten
Förderleistung
      RULE Con_global   POS                      Qend_Spa2
   COMMENT Bei lokalen Bedingungen, lokale Steuerung
     RANGE         P0     Z   22342008     0.0        26.1000
26.4000
```

```
     RANGE          P1      Z   22342008     0.0        27.0000
27.3000
     RANGE          P2      Z   22342008     0.0        27.3000
27.5000
     RANGE      reg=P0   REG 22342008.1     0.0
0.0020
     RANGE      reg=P1   REG 22342008.1     0.0
0.0620
     LOGIC    LogicP0    AND         P0  Con_lokal
     LOGIC    LogicP1    AND         P1     reg=P0  Con_lokal
     LOGIC    LogicP2    AND         P2     reg=P1  Con_lokal
      RULE    LogicP0    POS    0.000
      RULE    LogicP1    POS    0.060
      RULE    LogicP2    POS    0.150
"Saugraum_Tgl.1"                                      1
     RANGE          P0      Z "Saugraum_Tgl"     0.0        26.5400
27.3000
     RANGE          P1      Z "Saugraum_Tgl"     0.0        29.0000
29.1500
     RANGE          P2      Z "Saugraum_Tgl"     0.0        29.1500
29.4500
     RANGE          P3      Z "Saugraum_Tgl"     0.0        29.4500
     RANGE      reg=P0   REG "Saugraum_Tgl.1"     0.0
0.0020
     RANGE      reg=P1   REG "Saugraum_Tgl.1"     0.0
0.1020
     LOGIC    LogicP1    AND         P1     reg=P0
     LOGIC    LogicP2    AND         P2     reg=P1
      RULE         P0    POS    0.000
      RULE    LogicP1    POS    0.100
      RULE    LogicP2    POS    0.180
      RULE         P3    POS    0.220
"Saugraum_Rei_I.1"                                      1
     RANGE          P0      Z "Saugraum_Rei_I"     0.0        30.5000
31.4000
     RANGE          P1      Z "Saugraum_Rei_I"     0.0        33.8000
34.3000
     RANGE          P2      Z "Saugraum_Rei_I"     0.0        34.3000
34.5000
     RANGE          P3      Z "Saugraum_Rei_I"     0.0        34.5000
     RANGE      reg=P0   REG "Saugraum_Rei_I.1"     0.0
0.0020
     RANGE      reg=P1   REG "Saugraum_Rei_I.1"     0.0
0.1220
     LOGIC    LogicP1    AND         P1     reg=P0
     LOGIC    LogicP2    AND         P2     reg=P1
      RULE         P0    POS    0.000
      RULE    LogicP1    POS    0.120
      RULE    LogicP2    POS    0.240
      RULE         P3    POS    0.340
"Saugraum_Waid.1"                                      1
     RANGE          P0      Z "Saugraum_Waid"     0.0        27.6000
28.8000
     RANGE          P1      Z "Saugraum_Waid"     0.0        30.9000
31.3000
     RANGE          P2      Z "Saugraum_Waid"     0.0        31.3000
31.5000
     RANGE          P3      Z "Saugraum_Waid"     0.0        31.5000
```

```
     RANGE     reg=P0   REG "Saugraum_Waid.1"     0.0
0.0020
     RANGE     reg=P1   REG "Saugraum_Waid.1"     0.0
0.1820
     LOGIC    LogicP1   AND         P1     reg=P0
     LOGIC    LogicP2   AND         P2     reg=P1
      RULE         P0   POS    0.000
      RULE    LogicP1   POS    0.180
      RULE    LogicP2   POS    0.300
      RULE         P3   POS    0.400
"Saugraum_Wit.1"                                  1
     RANGE         P0     Z "Saugraum_Wit"     0.0        28.6000
30.0000
     RANGE         P1     Z "Saugraum_Wit"     0.0        31.6000
32.0000
     RANGE         P2     Z "Saugraum_Wit"     0.0        32.0000
32.7000
     RANGE         P3     Z "Saugraum_Wit"     0.0        32.7000
     RANGE     reg=P0   REG "Saugraum_Wit.1"     0.0
0.0020
     RANGE     reg=P1   REG "Saugraum_Wit.1"     0.0
0.5020
     LOGIC    LogicP1   AND         P1     reg=P0
     LOGIC    LogicP2   AND         P2     reg=P1
      RULE         P0   POS    0.000
      RULE    LogicP1   POS    0.500
      RULE    LogicP2   POS    0.600
      RULE         P3   POS    0.950
"Saugraum_HPW_Spa1.1"                                  1
   COMMENT Bei globalen Bedingungen, setzen der koordinierten
Förderleistung
      RULE Con_global   POS                      Qend_Spa1
   COMMENT Bei lokalen Bedingungen, lokale Steuerung
     RANGE         P0     Z "Saugraum_HPW_Spa1"     0.0        24.7000
26.3000
     RANGE         P1     Z "Saugraum_HPW_Spa1"     0.0        27.9000
28.1000
     RANGE         P2     Z "Saugraum_HPW_Spa1"     0.0        28.1000
28.3000
     RANGE     reg=P0   REG "Saugraum_HPW_Spa1.1"     0.0
0.0020
     RANGE     reg=P1   REG "Saugraum_HPW_Spa1.1"     0.0
0.1720
     LOGIC    LogicP0   AND         P0  Con_lokal
     LOGIC    LogicP1   AND         P1     reg=P0  Con_lokal
     LOGIC    LogicP2   AND         P2     reg=P1  Con_lokal
      RULE    LogicP0   POS    0.000
      RULE    LogicP1   POS    0.170
      RULE    LogicP2   POS    0.300
"Saugraum_Chb3.1"                                  1
   COMMENT Bei globalen Bedingungen, setzen der koordinierten
Förderleistung
      RULE Con_global   POS                      Qend_Chb3
   COMMENT Bei lokalen Bedingungen, lokale Steuerung
     RANGE         P0     Z "Saugraum_Chb3"     0.0        23.8450
25.1000
     RANGE         P1     Z "Saugraum_Chb3"     0.0        26.2000
26.4000
```

```
     RANGE         P2     Z "Saugraum_Chb3"     0.0        26.4000
26.6000
     RANGE     reg=P0   REG "Saugraum_Chb3.1"     0.0
0.0020
     RANGE     reg=P1   REG "Saugraum_Chb3.1"     0.0
0.1020
     LOGIC    LogicP0   AND         P0  Con_lokal
     LOGIC    LogicP1   AND         P1     reg=P0  Con_lokal
     LOGIC    LogicP2   AND         P2     reg=P1  Con_lokal
      RULE    LogicP0   POS    0.000
      RULE    LogicP1   POS    0.100
      RULE    LogicP2   POS    0.150
"Saugraum_Chb1.5"                                      1
   COMMENT Bei globalen Bedingungen, setzen der koordinierten
Förderleistung
      RULE Con_global   POS                      Qend_Chb1
   COMMENT Bei lokalen Bedingungen, lokale Steuerung
     RANGE         P0     Z "Saugraum_Chb1"     0.0        27.0000
28.5000
     RANGE         P1     Z "Saugraum_Chb1"     0.0        28.8000
29.0000
     RANGE         P2     Z "Saugraum_Chb1"     0.0        29.0000
29.2000
     RANGE     reg=P0   REG "Saugraum_Chb1.5"     0.0
0.0020
     RANGE     reg=P1   REG "Saugraum_Chb1.5"     0.0
0.3520
     LOGIC    LogicP0   AND         P0  Con_lokal
     LOGIC    LogicP1   AND         P1     reg=P0  Con_lokal
     LOGIC    LogicP2   AND         P2     reg=P1  Con_lokal
      RULE    LogicP0   POS    0.000
      RULE    LogicP1   POS    0.350
      RULE    LogicP2   POS    0.550
19293004.1                                      1
     RANGE        auf     Z "Saugraum_Chb1"     0.0
28.8000
     RANGE         zu     Z "Saugraum_Chb1"     0.0        29.0000
      RULE        auf   POS    0.200
      RULE         zu   POS    0.000
19293006.1                                      1
     RANGE        auf     Z "Saugraum_Chb1"     0.0
28.7000
     RANGE         zu     Z "Saugraum_Chb1"     0.0        28.9000
      RULE        auf   POS    0.200
      RULE         zu   POS    0.000
19293008.1                                      1
     RANGE        auf     Z "Saugraum_Chb1"     0.0
28.6000
     RANGE         zu     Z "Saugraum_Chb1"     0.0        28.8000
      RULE        auf   POS    0.200
      RULE         zu   POS    0.000
25214910.2                                      1
     RANGE        auf     Z   25214002     0.0
36.5000
     RANGE         zu     Z   25214002     0.0        36.7000
      RULE        auf   POS    0.400
      RULE         zu   POS    0.000
"14264rueb.2"                                      1
```

```
     RANGE         ON     Z   14264009     0.0
27.7000
     RANGE        OFF     Z   14264009     0.0        28.0000
      RULE         ON    ON    0.000
      RULE        OFF   OFF    0.000
15206005.1                                     1
   COMMENT Bei globalen Bedingungen, setzen der koordinierten
Förderleistung
      RULE Con_global   POS                     Qend_Bln2
   COMMENT Bei lokalen Bedingungen, lokale Steuerung
     RANGE         P0     Z   15206005     0.0
25.3000
     RANGE         P1     Z   15206005     0.0        30.3000
30.4000
     RANGE         P2     Z   15206005     0.0        30.4000
30.4500
     RANGE         P3     Z   15206005     0.0        30.4500
30.5000
     RANGE     reg=P0   REG 15206005.1     0.0        -0.0010
0.0010
     RANGE     reg=P1   REG 15206005.1     0.0         0.1690
0.1710
     RANGE     reg=P2   REG 15206005.1     0.0         0.2340
0.2360
     LOGIC    LogicP0   AND         P0  Con_lokal
     LOGIC    LogicP1   AND         P1     reg=P0  Con_lokal
     LOGIC    LogicP2   AND         P2     reg=P1  Con_lokal
     LOGIC    LogicP3   AND         P3     reg=P2  Con_lokal
      RULE    LogicP0   POS    0.000
      RULE    LogicP1   POS    0.170
      RULE    LogicP2   POS    0.235
      RULE    LogicP3   POS    0.370
"RuebZulaufBln2.3"                                     1
     RANGE         Zu     Z   15206005     0.0        28.0000
     RANGE        Auf     Z   15206005     0.0
27.5000
      RULE         Zu   POS    0.000
      RULE        Auf   POS    0.300
15206951.2                                     1
     RANGE         Zu     Z   15206005     0.0        28.0000
     RANGE        Auf     Z   15206005     0.0
27.5000
      RULE         Zu   POS    0.000
      RULE        Auf   POS    0.600
14193952.1             0.500             0.500  1
     RANGE Stammkanal     Z   14195003     0.0
31.1000
     RANGE  PegelRueb     Z   14193952     0.0        26.1000
32.1000
     LOGIC    PumpeAn   AND  PegelRueb Stammkanal
     LOGIC   PumpeAus  NAND Stammkanal  PegelRueb
      RULE    PumpeAn    ON    0.600
      RULE   PumpeAus   OFF    0.000
14193951.2                                     1
     RANGE  PegelRueb     Z   14193952     0.0
27.3000
     RANGE  Pegelfall    DZ   14193952     0.0                     -
0.0010
     LOGIC  SchiebAUF   AND  PegelRueb  Pegelfall
```

```
     LOGIC   SchiebZU  NAND  PegelRueb  Pegelfall
      RULE  SchiebAUF   POS    0.400
      RULE   SchiebZU   POS    0.000
"ruebzulschieb2.1"                                      1
     RANGE Hrb2<32.25     Z   15206951     0.0
32.2490
     RANGE Hrb2>32.25     Z   15206951     0.0        32.2500
     RANGE  Hru<32.65     Z   15206305     0.0
32.6490
     RANGE  Hru>32.75     Z   15206305     0.0        32.7500
     LOGIC     Logic1   AND Hrb2>32.25  Hru<32.65
     LOGIC     Logic2   AND Hrb2>32.25  Hru>32.75
      RULE Hrb2<32.25   POS    2.000
      RULE     Logic1   POS    0.000
      RULE     Logic2   POS    2.000
"ZulSchiebBln6.1"                                      1
     RANGE Hrb6<32.39     Z   14193952     0.0
32.3890
     RANGE Hrb6>32.39     Z   14193952     0.0        32.3900
     RANGE  Hru<31.65     Z   14195003     0.0
31.6490
     RANGE  Hru<32.70     Z   14195003     0.0        31.6500
32.6990
     RANGE  Hru>32.80     Z   14195003     0.0        32.8000
     LOGIC     Logic0   AND Hrb6>32.39  Hru<31.65
     LOGIC     Logic1   AND Hrb6>32.39  Hru<32.70
     LOGIC     Logic2   AND Hrb6>32.39  Hru>32.80
      RULE Hrb6<32.39   POS    2.000
      RULE     Logic0   POS    2.000
      RULE     Logic1   POS    0.000
      RULE     Logic2   POS    2.000
fromBln6.1                                      1
     RANGE  Hsr<32.05     Z   15206005     0.0
32.0490
     RANGE  Hsr>32.05     Z   15206005     0.0        32.0500
     RANGE      Qpump     Q 15206005.1     0.0         0.0000
1.0000
     RANGE   Qzu,bln6     Q "schieber_süd.1"     2.5         0.0000
2.0000
      RULE  Hsr<32.05   POS    0.850
  VARIABLE   Qzu,soll     *       0.50000          Qpump
CONTROLLER  Control_Q   PID   Qzu,bln6    60    0.000   -1.000    0.001
60.000
      RULE  Hsr>32.05  CTRL           Control_Q   Qzu,soll
15206002.1                                      1
     RANGE  Hsr<32.10     Z   15206005     0.0
32.0990
     RANGE  Hsr>32.10     Z   15206005     0.0        32.1000
33.0000
      RULE  Hsr<32.10   POS    1.410
CONTROLLER ControlHsr   PID  Hsr>32.10    60    0.000   -1.000    0.001
60.000
      RULE  Hsr>32.10  CTRL   32.200 ControlHsr
16244307.2                                      1
     RANGE     h<31.8     Z   16235009     0.0
31.8000
     RANGE     h>32.1     Z   16235009     0.0        32.1000
      RULE     h<31.8   OFF    0.000
      RULE     h>32.1    ON    0.000
```

```
16235319.1                                      1
   COMMENT Bei globalen Bedingungen, setzen der koordinierten
Förderleistung
      RULE Con_global   POS                      Qend_Bln7
   COMMENT Bei lokalen Bedingungen, lokale Steuerung
     RANGE         P0     Z   16235319     0.0        24.2500
25.8000
     RANGE         P1     Z   16235319     0.0        30.1500
30.3000
     RANGE         P2     Z   16235319     0.0        30.3000
30.4500
     RANGE         P3     Z   16235319     0.0        30.4500
30.5000
     RANGE     reg=P0   REG 16235319.1     0.0        -0.0010
0.0010
     RANGE     reg=P1   REG 16235319.1     0.0         0.0990
0.1010
     RANGE     reg=P2   REG 16235319.1     0.0         0.1690
0.1710
     LOGIC    LogicP0   AND         P0  Con_lokal
     LOGIC    LogicP1   AND         P1     reg=P0  Con_lokal
     LOGIC    LogicP2   AND         P2     reg=P1  Con_lokal
     LOGIC    LogicP3   AND         P3     reg=P2  Con_lokal
      RULE    LogicP0   POS    0.000
      RULE    LogicP1   POS    0.100
      RULE    LogicP2   POS    0.170
      RULE    LogicP3   POS    0.320
16246T01.2                                      1
     RANGE     H>31.6     Z   16244307     0.0        31.6000
     RANGE     H<31.6     Z   16244307     0.0
31.5000
      RULE     H>31.6   POS    0.000
      RULE     H<31.6   POS    0.800
16246T02.2                                      1
     RANGE     H>31.5     Z   16244307     0.0        31.5000
     RANGE     H<31.5     Z   16244307     0.0
31.4000
      RULE     H>31.5   POS    0.000
      RULE     H<31.5   POS    0.800
16244950.2                                      1
     RANGE     H>31.4     Z   16244307     0.0        31.4000
     RANGE     H<31.4     Z   16244307     0.0
31.3000
      RULE     H>31.4   POS    0.000
      RULE     H<31.4   POS    0.800
14243902.2                                      1
     RANGE     H>32.5     Z   14243002     0.0        32.5000
     RANGE     H<32.2     Z   14243002     0.0
32.2000
     RANGE Hekanal>31     Z   14243902     0.0        31.0000
     LOGIC      Logic   AND     H<32.2 Hekanal>31
      RULE     H>32.5   OFF    0.000
      RULE      Logic    ON    0.000
TERMINATOR
```

Appendix 8 - Global rtc algorithm InfoWorks - explanation of variables and parameters

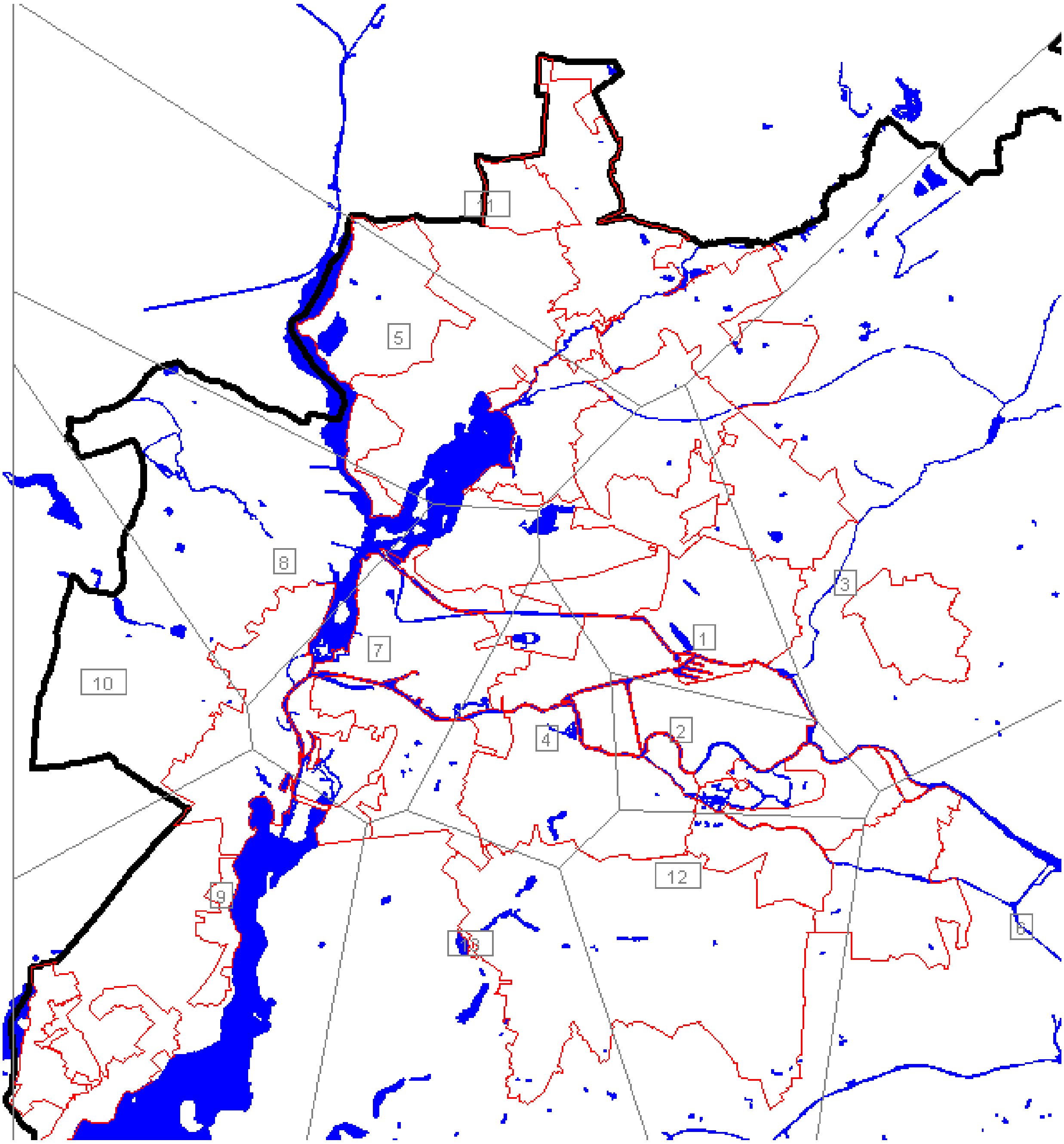
Globaler Teil

Variable	Typ	Befehl	Beschreibung	Sensitiver Parameter
Abfrage des Systemzustandes: globale/lokale Steuerung				
Hcon_xxx	Range	height aD	Abfrage, ob Wasserstand am Pumpwerk xxx über TW-Marke	Höhe des max. TW Pegels
Con_glob_y (y=1->n)	Logic	OR	Abfrage, ob ein Hcon_xxx wahr ist, also RW-Bedingungen herrschen	
Con_global	Logic	OR	Kombination der Con_glob_y: wenn wahr -> Zustand: Global	
Con_lokal	Logic	NOT	Abfrage, ob Con_global nicht wahr ist -> Zustand: Lokal	
Berechnung der einzelnen Speicherauslastungen				
H_Nxxx	Range	height aD	Abfrage des aktuellen Wasserstandes am Pumpwerk xxx	
V_Nxxx	Table	Linear	Ableitung der aktuellen Speicherauslastung im Kanalnetz xxx von H_Nxxx	Höhe des Zielwasserstandes entspr. 100% Auslastung
H_Bxxx	Range	height aD	Abfrage des aktuellen Wasserstandes im Becken xxx	
V_Bxxx	Table	Linear	Ableitung der aktuellen Speicherauslastung im Becken xxx von H_Bxxx	
V_N+Bxxx	Variable	+	Addition der Volumina aus Netz (V_Nxxx) und Becken (V_Bxxx) für das Teileinzugsgebiet xxx	Wichtung der Speicheranteile aus Netz und Becken
V_xxx	Variable	/	Berechnung der normierten Speicherauslastung für das Teileinzugsgebiet xxx	
V_xxx_abs	Variable	*	Berechnung der absoluten Speicherauslastung für das Teileinzugsgebiet xxx, wenn nicht schon durch V_N+Bxxx gegeben	
Berechnung der mittleren Gesamtspeicherauslastung				
V_summe_y (y=1->n)	Variable	+	Addition der genormten Speicherauslastungen der Teileinzugsgebiete V_xxx	Wichtung der Speichervolumina der Teileinzugsgebiete für Berücksichtigung unterschiedlicher Gewässersituationen
V_mittel	Variable	/	Berechnung der mittleren Gesamtspeicherauslastung	
dV_mittel	Variable	-	Berechnung der Veränderung der mittleren Gesamtspeicherauslastung aus V_mittel und V_mittelalt (=vorheriger Zeitschritt)	
V_mittelalt	Variable	=	Neusetzen von V_mittelalt	
dV_mi>0	Table	Linear	Überprüfung ob dV_mittel größer Null ist, um bei allg. sinkender Speicherauslastung ein schnelles Leerfördern der Netze zu ermöglichen	
Berechnung der neuen Förderleistung				
Qakt_xxx	Range	flow	Abfrage der aktuellen Förderleistung am Pumpwerk xxx	
dV_xxx	Variable	-	Berechnung der Abweichung der Speicherauslastung V_xxx von der mittleren Gesamtspeicherauslastung V_mittel	
dQ_xxx1	Table	Linear	Ableitung der Förderveränderung von der Abweichung dV_xxx (für dV_mi>0)	Verhältnis zwischen dV und dQ
dQ_xxx2	Table	Linear	Ableitung der Förderveränderung von der Abweichung dV_xxx (für dV_mi<=0)	Verhältnis zwischen dV und dQ
dQ_xxx	Table	Linear	Festlegung der Förderveränderung in Abhängigkeit von dv_mi>0	
Qn1_xxx	Variable	+	Berechnung der neuen Förderleistung aus Qakt_xxx und dQ_xxx	
Abfrage, ob neue Förderleitung größer als Qmin=Qt24 ist				
Qn1_xxx>mi	Table	Linear	Zuweisung von 1 (wahr) und 0 (falsch) entsprechend Qn1_xxx größergleich oder kleiner Qmin (m)	Variation der zulässigen Mindestförderleistung Qmin
Qn2_xxx	Variable	IF	Wenn Förderleistung > Qmin, dann Qn1_xxx beibehalten, sonst auf Qmin setzen	
Abfrage, ob Ziel-Wasserstand errreicht ist				
H_xxx>Hma	Range	height aD	Abfrage, ob Wasserstand am Pumpwerk xxx über Zielwasserstand	
Qn3_xxx	Variable	IF	Wenn Zielwasserstand erreicht ist, Förderleistung von Pumpwerk xxx auf Qmax setzen, sonst Qn2_xxx beibehalten	Variation der maximalen Förderleistung an den Pumpwerken
Abfrage, ob neue Gesamtförderleitung größer als Qmax,gesamt ist				
Q_summe_y (y=1->n)	Variable	+	Addition der einzelnen aktuellen Förderleistungen Qn3_xxx	
Q_ratio	Variable	/	Division von Qmax,ges durch Qsumme, als Indikator für die Überschreitung der zulässigen Gesamtförderung	Variation der zul. Gesamtförderleistung
Q_ratio<1	Table	Linear	Zuweisung von 1 (wahr) und 0 (falsch) entsprechend Q_ratio kleiner oder größergleich 1	
Q_pot	Variable	-	Reduktion von Qmax,ges um Qakt_Wit zur Ermittlung der für die übrigen Pw max möglichen Fördermenge	
Q_faktor	Variable	/	Division von Q_pot durch Q_summe_(ohne Wit), zur Ermittlung des Reduktionsfaktors	
Qn4_xxx	Variable	*	Multiplikation von Qn3_xxx mit Q_faktor zur Reduzierung der Gesamtförderleistung auf Qmax,ges	
Qend_xxx	Variable	IF	Zuweisung von Qn4_xxx, wenn Q_ratio<1, sonst beibehalten von Qn3_xxx	

Lokaler Teil

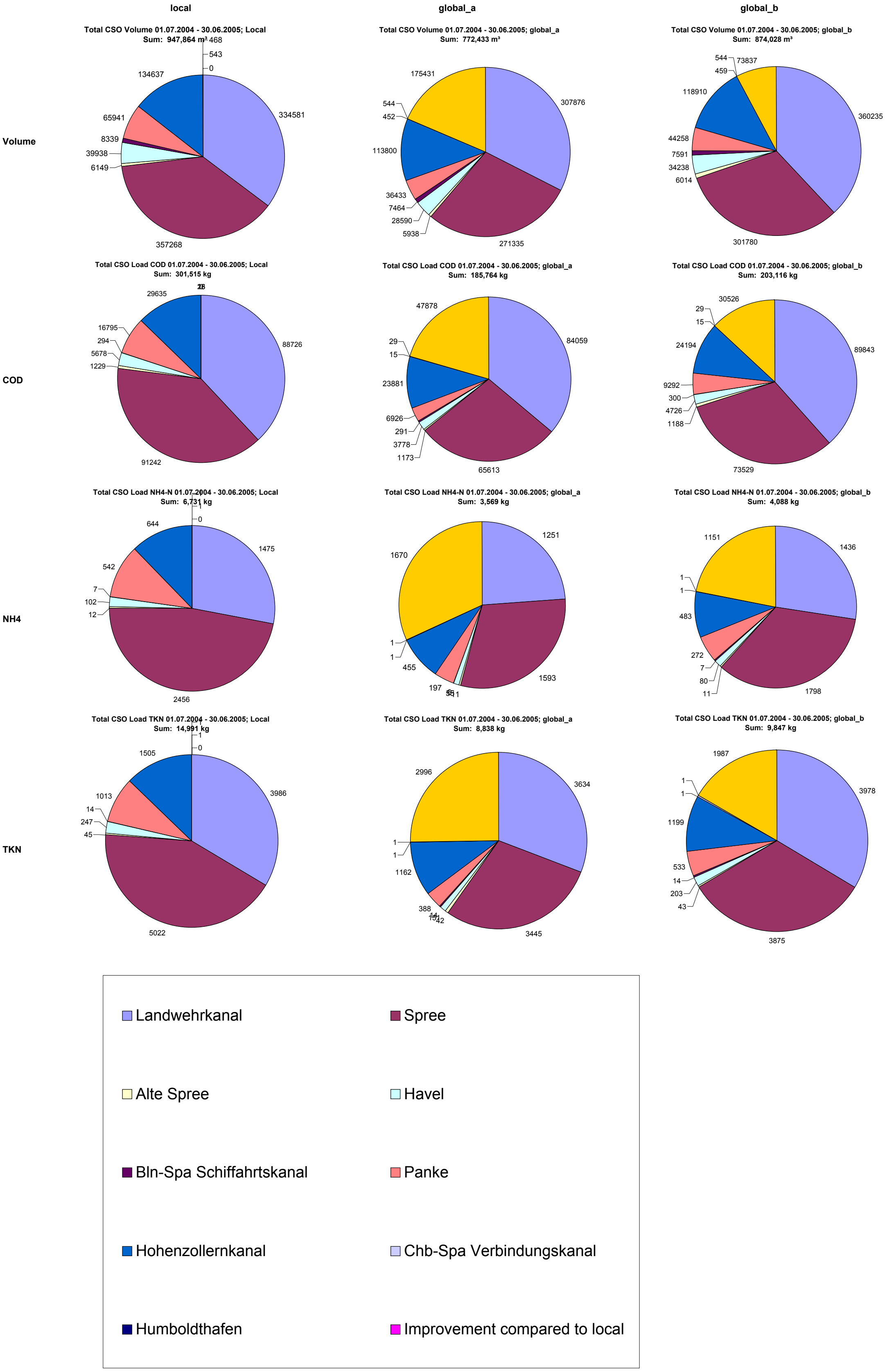
Variable	Typ	Befehl	Beschreibung	Sensitiver Parameter
Bei globalen Bedingungen setzen der koordinierten Förderleistung				
Con_global	Rule	POS, Variable	Setze Pumpe xxx auf Förderleistung Qend_xxx	
Lokale Steuerung				
Py (y=0->n)	Range	height aD	Abfrage des Wasserstandes am Pumpwerk zur lokalen Steuerung	
reg=Py (y=0->n-1)	Range	Flow	Abfrage der aktuellen Förderleistung	
Logic_Py (y=0->n)	Logic	AND	Verknüpfung von Wasserstandsabfrage Py, Föderleistungsabfrage reg=Py und lokaler Bedingung Con_lokal	
Logic_Py (y=0->n)	Rule	POS, Fixed	Setze Pumpe xxx auf Förderleistung nach Sägezahnregime	

Appendix 9 – Thiessen polygons of catchment Ruhleben



Catchment area of wwtp Ruhleben. Red lines indicating the boundaries of the sub catchments. Numbers 1-13 indicating the location of rain gauges and grey lines giving the accordant Thiessen polygons.

Appendix 10 - Aggregated cso impact on the different Berlin watercourses



Appendix 11 – ISM publications

Water Science & Technology, (52) 12, 2005, S. 181-187
Kai Schroeder, Erika Pawlowsky-Reusing
Current State And Development Of The Real-Time Control Of The Berlin Sewage System

Arbeitkreis der Betriebsleiter süddeutscher Großstädte, sowie Berlin, Wien und Zürich. 11. November 2005 in Berlin
Erika Pawlowsky-Reusing
ISM - Integrated Sewage Management (Integrierte Abwassersteuerung in Berlin)

Vorlesung im Rahmen der Veranstaltung “Ausgewählte Kapitel des Bauingenieurwesens – Wasserwirtschaft“ an der TFH Berlin, 8. November 2005
Erika Pawlowsky-Reusing
Lokale und globale Abflusssteuerung des Berliner Abwassersystems

Vorlesung im Rahmen der Veranstaltung “Ausgewählte Kapitel des Bauingenieurwesens – Wasserwirtschaft“ an der TFH Berlin, 8. November 2005
Kai Schroeder
Grundlagen der Abflusssteuerung

International User Conference Wallingford Software, 14.-15. September 2005, Howbery Park, Oxfordshire, England
Holger Huß, Kai Schroeder
Case study of global pump station control for the combined sewerage of Berlin

10th International Conference on Urban Drainage 2005, Kopenhagen, Dänemark
Kai Schroeder, René Mannel, Erika Pawlowsky-Reusing, Johannes Broll
Integrated Simulation of the Berlin Sewage System and Evaluation of a global Real-time Control Concept

IDS Water Europe – Online Conference 2005
Kai Schroeder, Francis Luck
Assessment of Global Pump Station Control Strategies on the Basis of Numerical Modelling

1. Berliner Wasserwerkstatt, 19. Oktober 2004, Berlin
Kai Schroeder
Bewertung von Strategien der Abflusssteuerung mittels Kanalnetzsimulation

Water & Wastewater International, 10/2004, S. 32-33
Kai Schroeder, Erika Pawlowsky-Reusing
Integrated sewage management to reduce pollution load in Berlin

wwt – Wasserwirtschaft Wassertechnik, 7-8/2004, S. 19-2
Kai Schroeder, Erika Pawlowsky-Reusing

Integriertes Abwassermanagement – Strategien für eine integrierte Bewirtschaftung des Berliner Abwassersystems und Nutzen von lokalen und globalen Steuerungskonzepten (Integrated sewage management - strategies for an integrated management of the Berlin sewage system and advantages of local and global control concepts)

4th IWA World Water Congress and Exhibition, 19.-24. September 2004, Marrakech, Maroc
Kai Schroeder, Erika Pawlowsky-Reusing
Current State And Development Of The Real-Time Control Of The Berlin Sewage System

Urban Drainage Modelling – UDM’04, 15.-17. September 2004, Dresden, Germany
Kai Schroeder, Johannes Broll, Erika Pawlowsky-Reusing
Model-based evaluation of a level dependant real-time control for sewage pump stations

Novatech 2004 - 5ème conférence internationale sur les techniques
et stratégies durables pour la gestion des eaux urbaines par temps
de pluie, 6-10 juin 2004, Lyon, France
Kai Schroeder
Integrated Sewage Management – Development of a global Real Time Control for three interconnected Subcatchments of the Berlin Drainage System

11. SIMBA-Anwendertreffen, 4-5 mai 2004, Tangermünde
René Mannel
Pegelbasierte Förderstromregelung - eine Möglichkeit zur gezielten Bewirtschaftung des Kanals (Level-based pumpage control - a possibility for the systematic control of the sewer inline storage)

5. Hannoversche Software-Tage für die Wasserwirtschaft, 30/31 mars 2004, Hannover
Kai Schroeder
Simulationsgestützte Entwicklung von Strategien der Verbundsteuerung am Beispiel des Berliner Entwässerungssystems (Simulation-based development of strategies for a global real-time control of the Berlin drainage system)

ATV-DVWK and VDI/VDE symposium "Mess- und Regelungstechnik in abwassertechnischen Anlagen"
25./26. November 2003, Wuppertal
Kai Schroeder, Erika Pawlowsky-Reusing
Zustand und Entwicklung der Steuerung des Berliner Entwässerungssystems (Poster)
(State and development of the control of the Berlin drainage system)

ATV-DVWK and VDI/VDE symposium "Mess- und Regelungstechnik in abwassertechnischen Anlagen"
25./26. November 2003, Wuppertal

René Manell, Erika Pawlowsky-Reusing
Erfahrungen mit neuronalen Netzen für Simulationen des Kanalnetzes
(Experiences with artificial neural networks for the simulation of sewer networks)

Congress Wasser Berlin 2003, Berlin
Kai Schroeder, Lionel Gommery, Laurent Phan, Erika Pawlowsky-Reusing, Dieter Jacobi
Integriertes Abwasser Management – Aufbau eines integrierten Modells zur Optimierung des Berliner Abwasser Systems
(Integrated Sewage Management - Setup of an integrated model for the optimization of the Berlin Sewage System)

16th European Junior Scientist Workshop 2002, Catania
Kai Schroeder
Integrated Sewage Management – Setup of an integrated strategy for the control of the Berlin sewage system

3rd International Conference on Sewer Processes and Networks 2002, Paris
Kai Schroeder, Lionel Gommery
Integrated Sewage Management - Setup of networked models for analysis and improvement of the Berlin sewage system (Poster)